TUGAS AKHIR - SF 141501

ALGORITMA DEUTSCH-JOZSA PADA KUANTUM KOMPUTER SISTEM NMR (*Nuclear Magnetic Resonance)* 4 QUBIT

Bayu Dwi Hatmoko
NRP 1112 100 060

Dosen Pembimbing
Agus Purwanto, D.Sc

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FINAL PROJECT - SF 141501

DEUTSCH-JOZSA ALGORITHM IN QANTUM COMPUTER WITH NMR (Nuclear Magnetic Resonance) 4 QUBITS SYSTEM

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Surabaya 2017

ALGORTIMA DEUSCH JOZSA PADA KOMPUTER KUANTUM SISTEM NMR (*Nuclear Magnetic Resonance) 4 QUBIT*

TUGAS AKHIR
Diajukan Untuk Memenuhi Salah Satu Syarat
Memperoleh Gelar Sarjana Sains
pada
Bidang Fisika Teori
Program Studi S-1 Jurusan Fisika
Fakultas Matematika dan Ilmu Pengetahuan Alam
Institut Teknologi Sepuluh Nopember

Oleh:
BAYU DWI HATMOKO
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Disetujui oleh Pembimbing Tugas Akhir
Surabaya, Januari 2017

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KEMENTERIAN RISET, TEKNOLOGI DAN PENDIDIKAN TINGGI
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM
JURUSAN FISIKA

ALGORITMA DEUTSCH-JOZSA PADA KOMPUTER KUANTUM SISTEM NMR *(Nuclear Magnetic Resonance)* 4 QUBIT

Nama : Bayu Dwi Hatmoko
NRP : 1112100060
Jurusan : Fisika, FMIPA-ITS
Pembimbing : Agus Purwanto, D.Sc

Abstrak

Gagasan tentang komputer kuantum dikenalkan oleh Yuri Marin pada tahun 1980, kemudian disusul ilmuan Paul Benioff pada tahun 1981 dan disusul lagi oleh Richard feynman pada tahun 1982, komputer kuantum sendiri merupakan teknologi masa depan komputasi yang dapat menggantikan komputer saat ini. Komputer merupakan piranti yang dapat menghitung berdasarkan logika analitis yang dimiliki oleh rangkaian-rangkaian transistor logika. Menurut hukum Moore jumlah transistor pada mikroprosesor terus meningkat dua kali lipat setiap dua tahun. Berdasarkan hal itu para ahli memperkirakan akan menemukan sirkuit pada mikroprosesor yang diukur pada skala atom, dari sinilah kemudian munculah gagasan yang memanfaatkan kuantitas atom dan molekul untuk melakukan pengolahan data dan memori, yang kemudian disebut sebagai komputer kuantum. Kemudian Deutsc membuat rancangan algoritma kuantum yaitu algoritma Deutsch pada sistem dua qubit. (Deustch, 1985).Komputer kuantum saat ini masih dalam prototype 10 qubit, namun dalam Tugas akhir ini akan di bahas secara matematis untuk NMR 4 qubit.

Kata kunci : *Algoritma Deutsch-Jozsa, Kuantum Komputer, NMR, qubit*

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DEUTSCH-JOZSA ALGORITHM IN QUANTUM COMPUTER WITH NMR (Nuclear Magnetic Resonance) 4 QUBITS SYSTEM

Name	**: Bayu Dwi Hatmoko**
NRP	**: 1112100060**
Major	**: Physics, FMIPA-ITS**
Advisor	**: Agus Purwanto, D.Sc**

Abstrak

The idea of a quantum computer introduced by Yuri Marin in 1980, scientist Paul Benioff followed in 1981 and was followed again by Richard Feynman in 1982, quantum computer is the future of computing technology that can replace today's computers. The computer is a tool that can calculate based on the analytical logic used by transistor logic circuits. According to Moore's law continues the number of transistors on a microprocessor has doubled every two years. Based on that scientist predict will find circuits on a microprocessor measured on the atomic scale, from here then comes the idea of utilizing the quantity of atoms and molecules to perform memory and data processing, which is then referred to as quantum computers. Then Deutsch make an Algorithm that is Deutsch quantum algorithm which is an algorithm on a two qubit system. (Deustch, 1985). A quantum computer is still in the prototype 10 qubits, but the final project will be discussed mathematically for NMR four qubits.

Keywords **:** Deutsch-Jozsa algorithm, NMR, Quantum Computers , qubit

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KATA PENGANTAR

Alhamdulillah, beribu-ribu katapun tak akan mampu mewakili rasa syukur penulis atas selesainya laporan tugas akhir ini. Dengan menyebut nama Allah SWT yang Maha Pengasih lagi Maha Penyayang, penulis panjatkan puja dan puji syukur atas kehadirat-Nya, yang telah melimpahkan rahmat, hidayah, dan inayah-Nya sehingga penulis dapat menyelesaikan laporan tugas akhir yang berjudul:

"**Algoritma Deutsch-Jozsa pada NMR (Nuclear Magnetic Resonance) 4 Qubit**".

Laporan tugas akhir ini penulis persembahkan kepada mayarakat Indonesia sebagai implementai kebermanfaatan bagi bangsa Indoneia dalam bidang yang penulis dalami, yaitu fisika bidang teori. Penulisan laporan tugas akhir ini telah penulis susun dengan maksimal dan mendapat bantuan dari berbagai pihak sehingga dapat memperlancar pembuatan laporan tugas akhir ini. Untuk itu penulis menyampaikan banyak terima kasih kepada semua pihak yang telah berkontribusi, baik dukungan moril, materiil dan pengertiannya dalam pembuatan laporan tugas akhir ini:

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penulis dapat menyelesaikan Tugas Akhir ini dengan baik, dan beliau adalah ayah saya di jurusan Fisika FMIPA ITS.

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Surabaya, Januari 2017

Penulis

DAFTAR ISI

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DAFTAR GAMBAR

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BAB I
PENDAHULUAN

1.1 Latar Belakang

Gagasan tentang komputer kuantum dikenalkan oleh Yuri Marin pada tahun 1980, kemudian disusul ilmuan Paul Benioff pada tahun 1981 dan disusul lagi oleh Richard feynman pada tahun 1982, komputer kuantum sendiri merupakan teknologi masa depan komputasi yang dapat menggantikan komputer saat ini. Komputer merupakan piranti yang dapat menghitung berdasarkan logika analitis yang dimiliki oleh rangkaian-rangkaian transistor logika. Menurut hukum Moore jumlah transistor pada mikroprosesor terus meningkat dua kali lipat setiap dua tahun. Berdasarkan hal itu para ahli memperkirakan akan menemukan sirkuit pada mikroprosesor yang diukur pada skala atom, dari sinilah kemudian munculah gagasan yang memenafaatkan kuantitas atom dan molekul untuk melakukan pengolahan data dan memori, yang kemudian disebut sebagai komputer kuantum. Kemudian pada tahun 1985, David Deutsch menyatakan bahwa setiap komputer secara umum dapat meniru setiap sistem, sehingga permodelan komputasi yang lebih umum sangat diharapkan untuk menggambarkan komputer umum. Akhirnya Deutsch mengambil sistem-sistem fisika yaitu permasalahan fisika kuantum untuk membuat permodelan komputer kuantum yang diharapkan mampu menyelesaikan persoalan-persoalan komputasi secara efisien dimana belum memiliki penyelesaian yang efisien di komputer klasik. Kemudian Deutsc membuat rancangan algoritma kuantum yaitu algoritma Deutsch pada sistem dua qubit. (Deustch, 1985).

NMR (Nuclear Magnetic Resonance) merupakan sistem kantum dua keadaan yang mampu menerapkan algoritma Deutsch, algorima Deutsch-Jozsa dan beberapa algoritma kuntum yang laian. NMR memiliki teori yang paling mapan dari realisasi fisis yang berkaitan dengan komputer kuantum. Qubit pada realisasi sistem ini merupakan inti yang berspin 1/2. Molekul yang berisi beberapa inti disebut sebagai "Quantum Register" dimana sistem NMR dibuat dari jumlah molekul makroskopik dalam keadaan kesetimbangan termal. Komputer kuantum saat ini masih dalam prototype 10 qubit, namun dalam jurnal-jurnal belum menerangkan perhitungan matematis secara terperinci. Sehubungan dengan hal tersebut, maka ada peluang yang besar untuk mengkaji lebih mendalam dari perhitungan matematis yang lebih terperinci untuk sistem kuantum NMR ini.

1.2 Perumusan Masalah

Dalam tugas akhir ini permasalahan yang akan dibahas adalah bagaimana pengaplikasian algoritma Deutsch-Josza 4 qubit secara matematis.

1.3 Batasan Masalah

Pada tugas akhir ini permasalahan hanya dibatasi pada sistem fisis NMR.

1.4 Tujuan

Dalam Tugas Akhir ini bertujuan untuk menganalisa grafik hasil penerapan Algoritma Deutsch-Josza pada Kuantum komputer sistem NMR 4 qubit.

BAB II
TINTJAUAN PUSTAKA

2.1 Komputer Klasik

2.1.1 Bilangan Biner

Bilangan biner adalah bilangna yang berbasis 2 keadaan yaitu 0 dan 1, maka dengan demikian apabila dipandang sebagai bilangan desimal, bilangan biner adalah bilangan yang berbasis 2^n, jadi untuk mengkonversikan bilangan biner ke bilangan desimal atau sebaliknya maka dapat dibuat jumlahan deret,sebagai berikut:

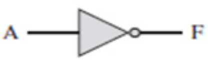
Misalkan kita memiliki angka biner 100110
Tabel 2.1 Bilangan biner

Basis	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Biner					1	0	0	1	1	0
Desimal					32	0	0	4	2	0

maka bilangan biner 100110 merupakan representasi bilangan desimal 38, begitu seterusnya, apabila kita meninjau alat pengukur jarak odometer yang berbasis lima digit maka kita dapatkan

2.1.2 Gerbang Klasik

Komputer bekerja berdasarkan gerbang-gerbang logika yang telah disusun sedemikian rupa dalam transistor-transistor logika, berikut adalah gerbang-gerbang logika dalam komputer klasik:
Tabel 2.2 Gerbang Komputer klasik

AND		$F = A \bullet B$ or $F = AB$	A B | F 0 0 | 0 0 1 | 0 1 0 | 0 1 1 | 1
OR		$F = A + B$	A B | F 0 0 | 0 0 1 | 1 1 0 | 1 1 1 | 1
NOT		$F = \overline{A}$ or $F = A'$	A | F 0 | 1 1 | 0
NAND		$F = \overline{AB}$	A B | F 0 0 | 1 0 1 | 1 1 0 | 1 1 1 | 0
NOR		$F = \overline{A + B}$	A B | F 0 0 | 1 0 1 | 0 1 0 | 0 1 1 | 0
XOR		$F = A \oplus B$	A B | F 0 0 | 0 0 1 | 1 1 0 | 1 1 1 | 0

2.2 Komputer kuantum

2.2.1 Qubit

Didalam logika komputer klasik dikenal istilah ketukan, ketukan ini berkaitan dengan kemampuan hitung komputer, ketukan dalam proses perhitungan ini disebut sebagai bit, untuk saat ini komputer klasik sudah mencapai 64 bit artinya dalam satu kali hitung komputer dapat menghitung 64 masukan yang berbeda. Namun bit dalam istilah komputer kuantum disebut sebagai qubit (quantum bit) yang dinyatakan dalam basis keadaan berikut:

$$|0\rangle \equiv |+\rangle \equiv \begin{bmatrix} 1 \\ 0 \end{bmatrix} \tag{1}$$

untukkeadaan spin up, sedangkanuntukkeadaan spin down dinyatakan dengan ket berikut:

$$|1\rangle \equiv |-\rangle \equiv \begin{bmatrix} 0 \\ 1 \end{bmatrix} \tag{2}$$

dan untuk keadaan yang menyatakan solusi secara lengkap (mengkombinasikan kedua keadaan spin up dan spin down) dinyatakan sebagai berikut:

$$|\psi\rangle = \alpha|+\rangle + \beta|-\rangle \tag{3}$$

dimana koefisien alfa dan beta merupakan koefisien kompleks yang memenuhi orthonormalitas berikut:

$$\langle\psi|\psi\rangle = |\alpha|^2 + |\beta|^2 = 1 \tag{4}$$

sedangkan $|+\rangle$ dan $|-\rangle$ merupakan vektor basis orthonormal dari keadaan $|\psi\rangle$

2.2.2 Gerbang Kuantum

Dalam komputer klasik untuk meproses suatu data maka diperlukan gerbang-gerbang logika seperti gerbang AND, OR, NOT dan lain sebagaianya, begitu juga dalam komputer kuantum, komputer kuantum memiliki gerbang logika yang disebut sebagai gerbang kuantum. Gerbang kuantum ini digunakan untuk memproses data kuantum agar dapat membuat informasi yang utuh. Apabila gerbang kuantum dikenai operator uniter maka gerbang kuantum tersebut berevolusi sesuai persamaan berikut:

$$|\psi\rangle \rightarrow |\psi'\rangle = U|\psi\rangle \tag{5}$$

berdasarkan jumlah qubitnya gerbang kuantum dibagi menjadi 2 yaitu gerbang qubit tunggal dan gerbang 2 qubit, berikut adalah uraian dari masing-masing gerbang:

2.2.2.1 Gerbang Qubit Tunggal

Ada beberapa gerbang logika dalam gerbang qubit tunggal yaitu sebagai berikut: gerbang Z, gerbang NOT dan operator Hadamard. Berikut adalah penjelasan dari masing-masing gerbang:

Gerbang Z
Gerbang Z bekerja dalam logika persamaan berikut:

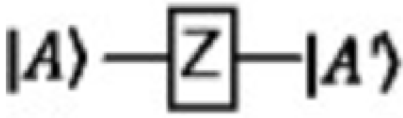
$$\begin{aligned} Z|+\rangle &= |+\rangle \\ Z|-\rangle &= -|-\rangle \end{aligned} \tag{6}$$

dikarenakan $|psi\rangle = \alpha|+\rangle + \beta|-\rangle$, maka

$$\begin{aligned} Z|\psi\rangle &= \alpha Z|+\rangle + \beta Z|-\rangle \\ &= \alpha|\psi\rangle - \beta|-\rangle \end{aligned} \tag{7}$$

maka dengan demikian operator Z merupakan operator uniter yaitu sebagai berikut:

$$Z = \begin{bmatrix} \langle +|Z|+\rangle & \langle +|Z|-\rangle \\ \langle -|Z|+\rangle & \langle -|Z|-\rangle \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \tag{8}$$



Gambar 2.1 Gerbang Z

Gerbang NOT
Gerbang logika NOT memiliki simbol X, yang bekerja sesuai dengan persamaan:

$$X|+\rangle = |-\rangle$$
$$X|-\rangle = |+\rangle \tag{9}$$

dikarenakan $|\psi\rangle = \alpha|+\rangle + \beta|-\rangle$, maka

$$X|\psi\rangle = \alpha X|+\rangle + \beta X|-\rangle$$
$$= \alpha|-\rangle - \beta|+\rangle \tag{10}$$

maka dengan demikian operator X merupakan operator uniter yaitu sebagai berikut:

$$X = \begin{bmatrix} \langle+|X|+\rangle & \langle+|X|-\rangle \\ \langle-|X|+\rangle & \langle-|X|-\rangle \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \tag{11}$$

Operator Hadamard
Operator Hadamard memiliki simbol H yang bekerja sesuai dengan persamaan berikut:

Gambar 2.2 Gerbang hadamard

$$H|+\rangle = \frac{1}{\sqrt{2}}(|+\rangle + |-\rangle)$$
$$H|-\rangle = \frac{1}{\sqrt{2}}(|+\rangle - |-\rangle) \tag{12}$$

dikarenakan $|\psi\rangle = \alpha|+\rangle + \beta|-\rangle$, maka

$$\begin{aligned} H|\psi\rangle &= \alpha H|+\rangle + \beta H|-\rangle \\ &= \alpha[\frac{1}{\sqrt{2}}(|+\rangle + |-\rangle)] + \beta[\frac{1}{\sqrt{2}}(|+\rangle - |-\rangle)] \\ &= \frac{1}{\sqrt{2}}[\alpha + \beta]|+\rangle - \frac{1}{\sqrt{2}}\beta[\alpha - \beta]|-\rangle \end{aligned} \tag{13}$$

maka dengan demikan operator H merupakan operator uniter yaitu sebagai berikut:

$$X = \begin{bmatrix} \langle +|H|+\rangle & \langle +|H|-\rangle \\ \langle -|H|+\rangle & \langle -|XH-\rangle \end{bmatrix} = \frac{1}{\sqrt{2}}\begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \tag{14}$$

2.2.2.2 Gerbang 2 Qubit

Ada beberapa operator yang bekerja pada sistem kuantum 2 qubit salah satunya adalah SWAP (exchange) dan operator CNOT. Berikut adalah penjelasan dari masing-masing gerbang:

Operator SWAP

Operator SWAP berfungsi untuk menukarkan keadaan qubit ke-0 dengan keadaan qubit ke-1 dengan memenuhi persamaan berikut:

$$S|xy\rangle = |yx\rangle \tag{15}$$

maka didapatkan keadaan lengkapnya sebagai berikut:

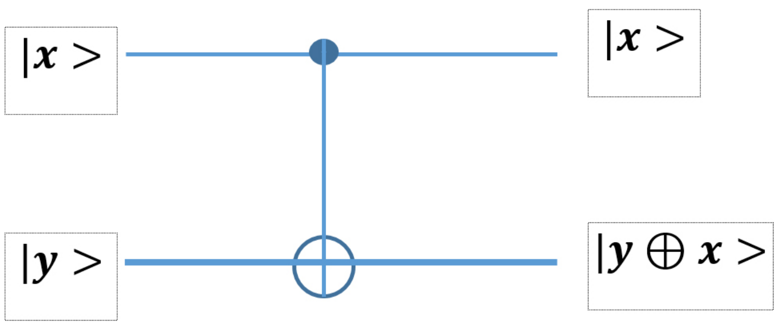
$$\begin{aligned} S|00\rangle &= |00\rangle \\ S|01\rangle &= |01\rangle \\ S|10\rangle &= |10\rangle \\ S|11\rangle &= |11\rangle \end{aligned} \tag{16}$$

yang memiliki operator uniter berikut

$$S = \begin{bmatrix} \langle 00|S|00\rangle & \langle 00|S|01\rangle & \langle 00|S|10\rangle & \langle 00|S|11\rangle \\ \langle 01|S|00\rangle & \langle 01|S|01\rangle & \langle 01|S|10\rangle & \langle 01|S|11\rangle \\ \langle 10|S|00\rangle & \langle 10|S|01\rangle & \langle 10|S|10\rangle & \langle 10|S|11\rangle \\ \langle 11|S|00\rangle & \langle 11|S|01\rangle & \langle 11|S|10\rangle & \langle 11|S|11\rangle \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{17}$$

Operator CNOT (Controlled NOT)
Berikut adalah diagram operator CNOT:



Gambar 2.3 Gerbang UCNOT

Operator CNOT disimbolkan dengna huruf C, yang bekerja sesuai dengan persamaan berikut:

$$C_{10}|xy\rangle = |xy \oplus x\rangle \tag{18}$$

$$\begin{aligned} C_{10}|00\rangle &= |00\rangle \\ C_{10}|01\rangle &= |01\rangle \\ C_{10}|10\rangle &= |10\rangle \\ C_{10}|11\rangle &= |11\rangle \end{aligned}$$

$$C_{01}|xy\rangle = |xy \oplus x\rangle \tag{19}$$

$$\begin{aligned} C_{01}|00\rangle &= |00\rangle \\ C_{01}|01\rangle &= |11\rangle \\ C_{01}|10\rangle &= |10\rangle \\ C_{01}|11\rangle &= |01\rangle \end{aligned}$$

sehingga didapatkan operator uniternya sebagain berikut:

$$C_{10} = \begin{bmatrix} \langle 00|C_{10}|00\rangle & \langle 00|C_{10}|01\rangle & \langle 00|C_{10}|10\rangle & \langle 00|C_{10}|11\rangle \\ \langle 01|C_{10}|00\rangle & \langle 01|C_{10}|01\rangle & \langle 01|C_{10}|10\rangle & \langle 01|C_{10}|11\rangle \\ \langle 10|C_{10}|00\rangle & \langle 10|C_{10}|01\rangle & \langle 10|C_{10}|10\rangle & \langle 10|C_{10}|11\rangle \\ \langle 11|C_{10}|00\rangle & \langle 11|C_{10}|01\rangle & \langle 11|C_{10}|10\rangle & \langle 11|C_{10}|11\rangle \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{bmatrix} \tag{20}$$

$$C_{01} = \begin{bmatrix} \langle 00|C_{01}|00\rangle & \langle 00|C_{01}|01\rangle & \langle 00|C_{01}|10\rangle & \langle 00|C_{01}|11\rangle \\ \langle 01|C_{01}|00\rangle & \langle 01|C_{01}|01\rangle & \langle 01|C_{01}|10\rangle & \langle 01|C_{01}|11\rangle \\ \langle 10|C_{01}|00\rangle & \langle 10|C_{01}|01\rangle & \langle 10|C_{01}|10\rangle & \langle 10|C_{01}|11\rangle \\ \langle 11|C_{01}|00\rangle & \langle 11|C_{01}|01\rangle & \langle 11|C_{01}|10\rangle & \langle 11|C_{01}|11\rangle \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \tag{21}$$

2.3 Sitem Dua Keadaan

Komputer klasik menggunakan komponen terpadu (IC) yang terdiri dari ribuan transistor yang berfungsi sebagai saklar logika dengan dua keadaan, yaitu saklar terbuka atau saklar tertutup, maka dengan demikian komputer klasik memang sudah dirancang untuk bekerja dalam prinsip dua keadaan. Didalam memori komputer terdapat magnetik yang berisi ribuan register yang bekerja atas dasar dua keadaan yaitu fluks magnetik yang searah dengan jarum jam memiliki register (0) dan yang berlawanan dengan arah jarum jam memiliki register (1), sedangkan saklar elektronik yang bekerja dalam komputer juga berdasarkan dua keadaan yaitu saklar terbuka (0) dan saklar tertutup (1). Setiap sistem kuantum dua keadaan disebut sebagai qubit. Berikut adalah penerapan fisis dari qubit yang telah berhasil :

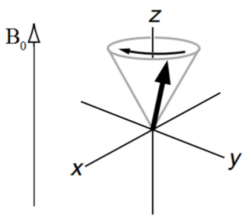
Tabel 2.3 Realiasi Fisis Kuantum Komputer

No	Sistem Fisis	Sistem dua keadaan	keadaan	
			$\|0\rangle$	$\|1\rangle$
1	NMR	spin inti atom	up	down
2	trapped ion, atom netral dalam potensial optik, rongga QED dengan atom-atom	keadaan ion atau atom	Keadaan dasar	Keadaan terkesitasi
3	elektron	spin elektron	up	down
		Banyak elektron	Tidak ada elektron	ada elektron Tunggal
4	keadaan koheren cahaya	squeezed light	amplitude squeezed light	phase squeezed light
5	kisi optik	spin atom	up	down
6	josephson junction	Qubit bermuatan superkonduktor	Tidak bermuatan	bermuatan
		Qubit fluks superkonduktor	Arus searah jarum jam	Arus berlawanan arah jarum jam
		Qubit fase superkonduktor	Keadaan dasar	Keadaan eksitasi pertama
7	Pasangan kuantum dot bermuatan tunggal	Lokalisasi elektron	Elektron disebelah kiri dot	Elektron disebelah kanan dot
8	quantum dot	dot spin	down	up
9	foton	Pengkodean polarisasi	horizontal	vertikal
		Jumlah foton	vakum	Keadaan tunggal
		time-bin encoding	Lebih cepat	Lebih lambat

2.4 NMR (Nuclear Magnetic Resonance)

2.4.1 Presesi Larmor di dalam Medan Magnet Konstan

Apabila ada momen magnetik yang ditempatkan dalam ruang dimana terdapat medan magnet luar yang konstan yang telah ditentukan sebagai arahsumbu-z, susuai dengan gambar 2.1 yaitu sebagai berikut:



Gambar 2.4 Presesi Larmor

maka momen magnetik tersebut akan mengalami interaksi dengan medan magnet luar sehingga mengalami presesi larmor. Dimana besarnya medan magnet luar sebesar:

$$\bar{B} = B_0\hat{k} \tag{22}$$

Energi interaksi momen magnetik dengan medan luar dinyatakan oleh hamiltonian sebagai berikut:

$$H = -\bar{\mu} \cdot \bar{B} = -(\mu_0 \sigma_z \bar{k}) = -\mu_0 \sigma_0 B_0 \tag{23}$$

dimana σ_z merupakan matriks Pauli. Berikut adalah matriks Pauli:

$$\sigma_x = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \tag{24}$$

apabila ditentukan bahwa

$$-\mu_0 \cdot B_0 = \frac{\hbar\omega_0}{2} \tag{25}$$

maka hamiltoniannya dapat dinyatakan sebagai barikut:

$$H = \frac{\hbar\omega_0}{2}\sigma_z \tag{26}$$

kemudian apabila hamiltonian bekerja pada vektor keadaan $|\pm\rangle$

$$H|\pm\rangle = \frac{\hbar\omega_0}{2}\sigma_z|\pm\rangle = \pm\frac{\hbar\omega_0}{2}|\pm\rangle \tag{27}$$

maka didapatkan bahwa medan luar yang konstan menyebabkan adanya dua tingkat energi pada sistem dengan kondisi awal dari vektor keadaan dinyatakan sebagai berikut:

$$|\psi(0)\rangle = \alpha|+\rangle + \beta|-\rangle \tag{28}$$

dengan α dan β merupakan koefisien kompleks yang memenuhi kaidah $|\alpha|^2 + |\beta|^2 = 1$ yang berevolusi terhadap waktu menjadi :

$$|\psi(t)\rangle = \alpha e^{\frac{-i\omega_0 t}{2}}|+\rangle + \beta e^{\frac{i\omega_0 t}{2}}|-\rangle \tag{29}$$

maka didapatkan nilai ekspektasi momen magnetik sebagai berikut:

$$\langle\mu\rangle = \mu_0\langle\psi(t)|(\sigma_x\hat{i} + \sigma_y\hat{j} + \sigma_z\hat{k})|\psi(t)\rangle \tag{30}$$

dimana $\bar{\sigma} = \sigma_x\hat{i} + \sigma_y\hat{j} + \sigma_z\hat{k}$, maka didapatkan

$$\langle\bar{\mu}\rangle = \mu_0\langle\psi(t)|\sigma_x\hat{i} + \sigma_y\hat{j} + \sigma_z\hat{k}|\psi(t)\rangle \tag{31}$$

maka nilai ekspektasi momen magnetik setiap sumbu adalah sebagai berikut:

$$\begin{aligned}\langle\bar{\mu}_0\rangle &= \mu_0\langle\psi(t)|\sigma_x|\psi(t)\rangle \\ &= \mu_0(\langle+|\alpha^* e^{\frac{-i\omega_0 t}{2}} + \langle-|\beta^* e^{\frac{i\omega_0 t}{2}})\sigma_x(\alpha^* e^{\frac{i\omega_0 t}{2}}|+\rangle + \beta^* e^{\frac{-i\omega_0 t}{2}}|-\rangle)\end{aligned}$$

mengingat bahwa $\sigma_x|\pm\rangle = |\mp\rangle$, maka didapatkan bahwa

$$= \mu_0(\langle +|\alpha^* e^{\frac{-i\omega_0 t}{2}} + \langle -|\beta^* e^{\frac{i\omega_0 t}{2}})(\alpha^* e^{\frac{i\omega_0 t}{2}}|-\rangle + \beta^* e^{\frac{-i\omega_0 t}{2}}|+\rangle)$$
$$= \mu_0(\alpha^*\alpha\langle +|-\rangle + \alpha^*\beta e^{-i\omega_0 t}\langle +|+\rangle + \beta^*\alpha e^{i\omega_0 t}\langle -|-\rangle + \beta^*\beta\langle -|+\rangle)$$
$$= \mu_0(\alpha^*\beta e^{-i\omega_0 t} + \beta^*\alpha e^{i\omega_0 t}$$

kemudian kita misalkan bahwa $\alpha = r_0 ei\theta_0, \beta = r_1 ei\theta_1, \psi = \theta_1 = \theta_2$, maka didapatkan

$$\langle\bar{\mu}_x\rangle = 2\mu_0 r_0 r_1 \cos(\omega_0 t + \psi) \tag{32}$$

kemudian komponen ekspektasi nilai momen magnetik terhadap sumbu-y adalah sebagai berikut:

$$\langle\bar{\mu}_y\rangle = \mu_0\langle\psi(t)|\sigma_y|\psi(t)\rangle$$
$$= \mu_0(\langle +|\alpha^* e^{\frac{-i\omega_0 t}{2}} + \langle -|\beta^* e^{\frac{i\omega_0 t}{2}})\sigma_y(\alpha^* e^{\frac{i\omega_0 t}{2}}|+\rangle + \beta^* e^{\frac{-i\omega_0 t}{2}}|-\rangle)$$

mengingat bahwa $\sigma_y|\pm\rangle = \pm i|\mp\rangle$, maka didapatkan bahwa

$$= i\mu_0(\langle +|\alpha^* e^{\frac{-i\omega_0 t}{2}} + \langle -|\beta^* e^{\frac{i\omega_0 t}{2}})(\alpha^* e^{\frac{i\omega_0 t}{2}}|-\rangle - \beta^* e^{\frac{-i\omega_0 t}{2}}|+\rangle)$$
$$= i\mu_0(\alpha^*\alpha\langle +|-\rangle - \alpha^*\beta e^{-i\omega_0 t}\langle +|+\rangle + \beta^*\alpha e^{i\omega_0 t}\langle -|-\rangle - \beta^*\beta\langle -|+\rangle)$$
$$= i\mu_0(-\alpha^*\beta e^{-i\omega_0 t} + \beta^*\alpha e^{i\omega_0 t}$$

kemudian kita misalkan bahwa $\alpha = r_0 e^{i\theta_0}, \beta = r_1 e^{i\theta_1}, \psi = \theta_1 = \theta_2$, maka didapatkan

$$\langle\bar{\mu}_x\rangle = -2\mu_0 r_0 r_1 \sin(\omega_0 t + \psi) \tag{33}$$

kemudian komponen ekspektasi nilai momen magnetik terhadap sumbu-z adalah sebagai berikut:

$$\langle\bar{\mu}_z\rangle = \mu_0\langle\psi(t)|\sigma_z|\psi(t)\rangle$$

$$= \mu_0(\langle+|\alpha^* e^{\frac{-i\omega_0 t}{2}} + \langle-|\beta^* e^{\frac{i\omega_0 t}{2}})\sigma_z(\alpha^* e^{\frac{i\omega_0 t}{2}}|+\rangle + \beta^* e^{\frac{-i\omega_0 t}{2}}|-\rangle)$$

mengingat bahwa $\sigma_z|\pm\rangle = \pm|\pm\rangle$, maka didapatkan bahwa

$$\begin{aligned}
&= \mu_0(\langle+|\alpha^* e^{\frac{-i\omega_0 t}{2}} + \langle-|\beta^* e^{\frac{i\omega_0 t}{2}})(\alpha^* e^{\frac{i\omega_0 t}{2}}|+\rangle - \beta^* e^{\frac{-i\omega_0 t}{2}}|-\rangle) \\
&= \mu_0(\alpha^*\alpha\langle+|+\rangle + \beta^*\beta\langle-|-\rangle) \\
&= \mu_0(|\alpha|^2 + |\beta|^2)
\end{aligned}$$

maka didapatkan

$$\langle\bar{\mu}_z\rangle = \mu_0(|\alpha|^2 + |\beta|^2) \tag{34}$$

2.4.2 Teknik Rabi

Apabila sistem momen magnetik dipengaruhi oleh medan magnet bergantung waktu yang tegak lurus dengan medan magnet statis, katakanlah medan magnet yang bergantung waktu adalah sebidang dengan bidang-xy, yang besarnya :

$$\bar{B}_1 = B_1 \cos\omega t\ \hat{i} + B_1 \sin\omega t\ \hat{j} \tag{35}$$

maka besar medan magnet total adalah sebagai berikut:

$$\bar{B}_1 = B_1 \cos\omega t\ \hat{i} + B_1 \sin\omega t\ \hat{j} + B_0\hat{k} \tag{36}$$

dengan demikian hamiltonian interaksinya adalah sebagai berikut:

$$\begin{aligned}
&H = \bar{\mu}\cdot\bar{B} \\
&H = \bar{\mu}_0(\sigma_x\hat{i} + \sigma_y\hat{j} + \sigma_z\hat{k})\cdot(B_1\cos\omega t\ \hat{i} + B_1\sin\omega t\ \hat{j} + B_0\hat{k})
\end{aligned}$$

maka didapatkan:

$$H = -\mu_0 B_1 \cos\omega t\ \sigma_x - B_1\mu_0 \sin\omega t\ \sigma_y - \mu_0 B_0 \sigma_z \tag{37}$$

dalam keadaan sembarang setiap keadaan diberikan oleh bentuk umum

$$|\psi(t)\rangle = \alpha(t)|+\rangle + \beta(t)|-\rangle \tag{38}$$

persamaan schrodinger untuk keadaan tersebut adalah

$$i\hbar\frac{d}{dt}|\psi(t)\rangle = H|\psi(t)\rangle \tag{39}$$

maka dapat kita selesaikan terlebih dahulu secara terpisah yaitu ruas kiri diselesaikan dulu kemudian ruas kanan kita selesaikan, berikut adalah penyelesaian ruas kiri:

$$i\hbar\frac{d}{dt}|\psi(t)\rangle = i\hbar\,\dot{\alpha}(t)|+\rangle + i\hbar\,\dot{\beta}(t)|-\rangle \tag{40}$$

dan berikut dalah penyelesaian ruas kanannya

$$\begin{aligned}
H|\psi(t)\rangle &= (-\mu_0 B_1\ \cos\omega t\ \sigma_x - B_1\mu_0\ \sin\omega t\ \sigma_y - \mu_0 B_0\sigma_z)(\alpha(t)|+\rangle + \beta(t)|-\rangle)\\
&= -\mu_0 B_1\ \cos\omega t\ \sigma_x(\alpha(t)|+\rangle + \beta(t)|-\rangle)\\
&\quad -B_1\mu_0\ \sin\omega t\ \sigma_y(\alpha(t)|+\rangle + \beta(t)|-\rangle) - \mu_0 B_0\sigma_z(\alpha(t)|+\rangle + \beta(t)|-\rangle)\\
&= -\mu_0 B_1\ \cos\omega t\ (\alpha(t)|+\rangle + \beta(t)|-\rangle)\\
&\quad - iB_1\mu_0\ \sin\omega t\ (\alpha(t)|+\rangle - \beta(t)|-\rangle) - \mu_0 B_0(\alpha(t)|+\rangle - \beta(t)|-\rangle)\\
&= (-\mu_0 B_1\ \cos\omega t\ \alpha(t) - iB_1\mu_0\ \sin\omega t\ \alpha(t) + \mu_0 B_0)|-\rangle\\
&\quad + (-\mu_0 B_1\ \cos\omega t\ \beta(t) + iB_1\mu_0\ \sin\omega t\ \beta(t) - \mu_0 B_0)|+\rangle
\end{aligned}$$

$$= -\mu_0(B_1\alpha(t)e^{i\omega t} - B_0)|-\rangle - \mu_0(B_1(t)e^{-i\omega t} + B_0)|+\rangle \tag{41}$$

maka ketika kita samakan antara persamaan 2.19 (ruas kiri) dengan 2.20 (ruas kanan) maka didapatkan bahwa koefisien masing-masing keadaan.

untuk keadaan $|+\rangle$

$$\begin{aligned} i\hbar\dot{\alpha}(t) &= -\mu_0(B_1\beta(t)e^{-i\omega t} + \mu_0 B_0\alpha(t)) \\ i\dot{\alpha}(t) &= \tfrac{-\mu_0 B_1}{\hbar}\beta(t)e^{-i\omega t} - \tfrac{\mu_0 B_0}{\hbar}\alpha(t) \end{aligned}$$

kita ingat kembali persamaan 2.4, maka kita dapatkan bahwa

$$i\dot{\alpha}(t) = \frac{\omega_1}{2}\beta(t)e^{-i\omega t} - \frac{\omega_0}{2}\alpha(t) \tag{42}$$

untuk keadaan $|-\rangle$

$$\begin{aligned} i\hbar\dot{\beta}(t) &= -\mu_0(\beta_1\alpha(t)e^{-\omega t} + \mu_0 B_0\beta(t)) \\ i\dot{\beta}(t) &= \tfrac{-\mu_0 B_1}{\hbar}\alpha(t)e^{-i\omega t} - \tfrac{-\mu_0 B_0}{\hbar}\beta(t) \end{aligned}$$

kita ingat kembali persamaan 2.4, maka kita dapatkan bahwa

$$i\beta(t) = \frac{\omega_1}{2}\alpha(t)e^{-i\omega t} - \frac{\omega_0}{2}\beta(t) \tag{43}$$

untuk mempermudah perhitungan maka dilakukan perubahan koefisien kompleks yaitu sebagai berikut:

$$\begin{aligned} \dot{\alpha}(t) &= \dot{\alpha}(t)e^{\frac{i\omega t}{2}} \\ \dot{\beta}(t) &= \dot{\beta}(t)e^{\frac{-i\omega t}{2}} \end{aligned}$$

maka apabila kita turunkan koefisien tersebut satu kali terhadap waktu diperoleh

$$\dot{\alpha}(t) = \dot{\alpha}(t)e^{\frac{i\omega t}{2}} + \frac{i\omega}{2}\alpha(t)e^{\frac{i\omega t}{2}}$$

$$\dot{\beta}(t) = \dot{\beta}(t)e^{\frac{-i\omega t}{2}} - \frac{i\omega}{2}\beta(t)e^{\frac{-i\omega t}{2}} \tag{44}$$

kemudian kita subtitusikan persamaan 2.21 dan 2.22 ke persamaan 2.23, maka didapatkan hasil sebagai berikut:

$$\begin{aligned}\dot{\alpha}(t) &= \frac{\omega_1}{2i}\beta(t) + \frac{\omega_0 - \omega}{2i}\alpha(t) \\ \dot{\beta}(t) &= \frac{\omega_1}{2i}\alpha(t) - \frac{\omega_0 - \omega}{2i}\beta(t) \end{aligned} \tag{45}$$

maka kita dapatkan hamiltonian dalam bentuk matriks yaitu sebagai berikut:

$$\begin{aligned} H|\psi(t)\rangle &= i\hbar\frac{d}{dt}|\psi(t)\rangle \\ &= i\hbar\begin{bmatrix}\dot{\alpha}(t) \\ \dot{\beta}(t)\end{bmatrix} \\ &= i\hbar\begin{bmatrix}\frac{\omega_1}{2i}\beta(t) + \frac{\omega_0-\omega}{2i}\alpha(t) \\ \frac{\omega_1}{2i}\alpha(t) - \frac{\omega_0-\omega}{2i}\beta(t)\end{bmatrix} \\ &= \frac{i\hbar}{2i}\begin{bmatrix}\omega_0 - \omega & \omega_1 \\ \omega_1 & -(\omega_0 - \omega)\end{bmatrix}\begin{bmatrix}\alpha(t) \\ \beta(t)\end{bmatrix} \end{aligned}$$

sehingga diperoleh bentuk hamiltonian sebagai berikut:

$$\begin{aligned} H &= \frac{\hbar}{2}\begin{bmatrix}\omega_0 - \omega & \omega_1 \\ \omega_1 & -(\omega_0 - \omega)\end{bmatrix} \\ &= \frac{\hbar}{2}\begin{bmatrix}\omega_0 - \omega & 0 \\ 0 & -(\omega_0 - \omega)\end{bmatrix} + \frac{\hbar}{2}\begin{bmatrix}0 & \omega_1 \\ \omega_1 & 0\end{bmatrix} \end{aligned}$$

sehingga diperoleh

$$H = \frac{\hbar}{2}(\omega_0 - \omega)\ \sigma_z + \frac{\hbar}{2}\omega_1\sigma_x \tag{46}$$

kemudian kita turunkan koefisien kompleks α dan β satu kali lagi terhadap waktu maka kita dapatkan

$$\ddot{\alpha}(t) = -\frac{\omega_1}{2i}\beta(t) + \frac{\omega_0 - \omega}{2i}\dot{\alpha}(t)$$

$$\ddot{\beta}(t) = \frac{\omega_1}{2i}\alpha(t) - \frac{\omega_0 - \omega}{2i}\dot{\beta}(t) \tag{47}$$

kemudian apabila kita subtitusikan persamaan 2.24 ke persamaan 2.26 maka kita dapatkan

$$\ddot{\alpha}(t) = -\frac{1}{4}[(\omega_0 - \omega)^2 + \omega_1^2]\alpha(t)$$

$$\ddot{\beta}(t) = -\frac{1}{4}[(\omega_0 - \omega)^2 + \omega_1^2]\beta(t) \tag{48}$$

kita definisikan bahwa $\omega^2 = [(\omega_0 - \omega)^2 + \omega_1^2]$, maka diperoleh

$$\ddot{\alpha}(t) + (\frac{\omega}{2})^2\alpha(t) = 0$$

$$\ddot{\beta}(t) + (\frac{\omega}{2})^2\beta(t) = 0 \tag{49}$$

sebagaimana kita tahu bahwa solusi dari persamaan 2.28 merupakan kombinasi *sin* dan *cos*, yaitu sebagai berikut:

$$\alpha(t) = A_1 \sin\frac{\omega t}{2} + A_2 \sin\frac{\omega t}{2}$$

$$\beta(t) = A_3 \sin\frac{\omega t}{2} + A_4 \sin\frac{\omega t}{2} \tag{50}$$

dimana A_1, A_2, A_3, A_4 merupakan konstanta, misalkan dalam keadaan spin up memiliki kondisi sebagai berikut:

$$\alpha(0) = 1 \text{ dan } \beta(0) = 0$$

maka kita dapatkan

$$\alpha(0) = A_1 \sin\frac{0.t}{2} + A_2 \cos\frac{0.t}{2}$$

$$1 = A_1 \sin 0 + A_2 \cos 0$$

$$1 = A_2$$

dan

$$\beta(0) = A_3 \sin\frac{0.t}{2} + A_4 \cos\frac{0.t}{2}$$
$$1 = A_3 \sin 0 + A_4 \cos 0$$
$$1 = A_4$$

sehingga persamaan 2.29 menjadi berikut

$$\alpha(t) = A_1 \sin\frac{\omega t}{2} + \cos\frac{\omega t}{2}$$

$$\beta(t) = A_3 \sin\frac{\omega t}{2} \tag{51}$$

untuk mendapatkan A_1 dan A_3 maka dipakai syarat orthonormalitas yaitu sebagai berikut:

$$1 = \langle\psi(t)|\psi(t)\rangle$$
$$1 = (\langle+|\alpha^*(t)e^{-i\frac{\omega_0 t}{2}} + \langle-|\beta^*(t)e^{i\frac{\omega_0 t}{2}})(\alpha(t)e^{-i\frac{\omega_0 t}{2}}|+\rangle + \beta(t)e^{i\frac{\omega_0 t}{2}}|-\rangle)$$
$$1 = \alpha^*(t)\alpha(t) + \beta*(t)\beta(t)$$
$$1 = ({A_1}^* \sin\frac{\omega t}{2} + \cos\frac{\omega t}{2})(A_1 \sin\frac{\Omega t}{2} + \cos\frac{\Omega t}{2}) + {A_3}^* A_3 \sin^2\frac{\Omega t}{2}$$
$$1 = (|A_1|^2 + |A_3|^2)sin^2\frac{\Omega t}{2} + \cos^2\frac{\Omega t}{2} + (A_1 + {A_1}^*)\sin\frac{\Omega t}{2}\cos\frac{\Omega t}{2}$$

maka dapat kita selesaikan terlebih dahulu yang bagian tidak konstan harus dibuat nol, yaitu sebagai berikut:

$$(A_1 + {A_1}^*)\sin\frac{\Omega t}{2}\cos\frac{\Omega t}{2} = 0 A_1 + {A_1}^* \quad = 0$$

sehingga

$${A_1}^* = -A_1$$

hal ini dapat terpenuhi jika A_1 merupakan perkalian bilangan imajiner dengan bagian imajiner suatu bilangan kompleks yang bagian rielnya berinilai nol (imaginer murni).

$$A_1 = iA_5 \tag{52}$$

Kemudian yang bagian konstan dapat kita selesaikan, yaitu sebagai berikut

$$1 = (|A_1|^2 + |A_3|^2)sin^2\frac{\Omega t}{2} + \cos^2\frac{\Omega t}{2}$$

maka kita dapat menggunakan kaidah $\sin^2\theta + \cos^2 = 1$, maka dengan nilai dari

$$|A_1|^2 + |A_3|^2 = 1 \tag{53}$$

persamaan 2.32 dapat dinyatakan dalam bentuk $(\frac{\omega-\omega_0}{\Omega})^2 + (\frac{\omega_1}{\Omega})^2$ dan dipenuhi oleh A_1 dan A_3 yaitu

$$\begin{aligned} A_1 &= i\frac{\omega - \omega_0}{\Omega} \\ A_3 &= -i\frac{\omega_1}{\Omega} \end{aligned} \tag{54}$$

berdasarkan persamaan 2.31 dengan 2.32 maka didapatkan keadaan awal spin adalah sebagai berikut:

$$\begin{aligned} \alpha(t) &= i\frac{\omega - \omega_0}{\Omega}\sin\frac{\Omega t}{2} + \cos\frac{\Omega t}{t} \\ \beta(t) &= -i\frac{\omega_1}{\Omega}\sin\frac{\Omega t}{2} \end{aligned} \tag{55}$$

maka dengan demikian diperoleh set lengkap keadaan adalah sebagai berikut:

$$\begin{aligned} |\psi\rangle = i\frac{\omega - \omega_0}{\Omega}\sin\frac{\Omega t}{2} + \cos\frac{\Omega t}{t}\,|0\rangle \\ - i\frac{\omega_1}{\Omega}\sin\frac{\Omega t}{2}\,|1\rangle \end{aligned} \tag{56}$$

apabila kita ingin mengukur spin dari keadaan negatif $|-\rangle \equiv |1\rangle$ maka

$$\langle 1|\psi\rangle = -i\frac{\omega_1}{\Omega}\sin\frac{\Omega t}{2} \tag{57}$$

dan apabila dihitung probabilitas spin flip dari keadaan up ke keadaan down maka diperoleh :

$$\begin{aligned} P_{+\to-} &= |\langle 1|\psi\rangle|^2 \\ &= \left(\frac{\omega_1}{\Omega}\right)^2 \sin^2\frac{\Omega t}{2} \end{aligned} \tag{58}$$

berdasarkan pers. (58) maka dapat diambil suatu keadaan khusus yaitu sebagai berikut:

1. apabila $|\omega_0 - \omega_1| >> \omega$ maka didapatkan spin flip dari keadaan up ke keadaan down memiliki probabilitas yang kecil, artinya sebagian besar masih tetap pada keadaan semula. (gambar a)

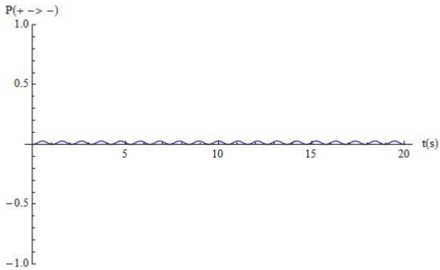
2. apabila $\omega = \omega_0$ maka pada waktu tertentu nilai probabilitas spin flip dari keadaan up ke keadaan down dapat bernilai 1, berikut adalah fungsi waktu untuk spin flip keadaan up ke keadaan down

$$t_n = \frac{(2n+1)\pi}{\omega_1} \tag{59}$$

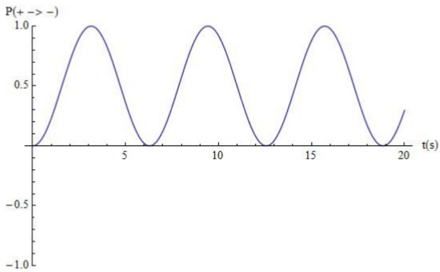
   dengan n=0,1,2,.. (gambar b)

3. apabila $|\omega_o - \omega_1| \approx \omega$ maka spin flip dari keadaan up ke keadaan down memiliki probabilitas kurang dari 0.5 (gamabr c)

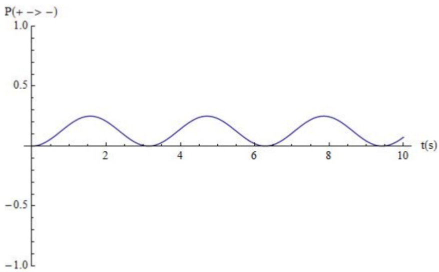
berikut adalah grafik probabilitas spin flip dari keadaan up ke keadaan down dari kondisi-kondisi diatas:



Gambar 2.4a Probabilitas untuk $|\omega_0 - \omega_1| >> \omega$



Gambar 2.4b Probabilitas untuk $\omega = \omega_0$



Gambar 2.4c Probabilitas untuk $|\omega_o - \omega_1| \approx \omega$

BAB III

ALGORITMA DEUTSCH DAN DUETSCH JOSZA

sebelum membahas tentang algoritma Deutsch dan Algoritma Deutsch-Josza diperlukan untuk membahas terlebih dahulu tentang register, yaitu sebagai berikut:

3.1 Register

3.1.1 Register Qubit Tunggal

Pada algortima Deutsch register yang diperlukan adalah register qubit tunggal dikarenakan Algortima Deutsch berfungsi untuk memetakan input qubit tunggal ke output qubit tunggal. Maka registernya adalah sebagai berikut: $|0\rangle$ dan $|1\rangle$ sedangkan set lengkap dari keadaan adalah sebagai berikut:

$$|\psi\rangle = a\,|0\rangle + b\,|1\rangle \tag{60}$$

3.1.2 Register Qubit Jamak

Sebelum membahas tentang register pada qubit jamak maka diperlukan terlbeih dahulu pemahaman tentang keadaan terbelit dan paralelisme kuantum. **Keadaan terbelit dan Paralelisme Kuantum**

Keadaan Terbelit

keadaan terbelit kuantum adalah fungsi keadaan yang tidak dapat di pisah menjadi perkalian direct product:

$$|\psi\rangle \neq |\psi_1\rangle \otimes |\psi_2\rangle \tag{61}$$

contoh

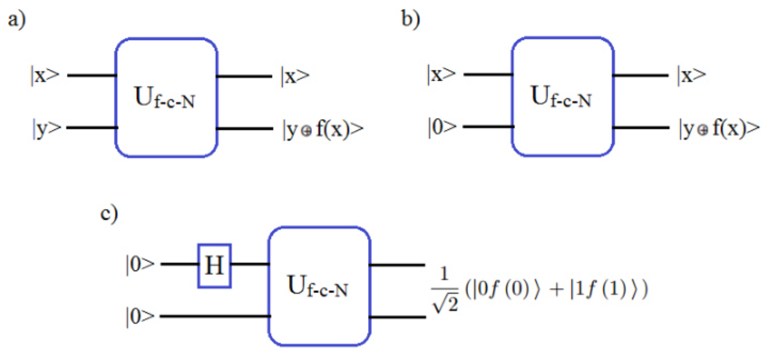
$$|\psi\rangle = \frac{1}{\sqrt{2}}\left[|00\rangle + |11\rangle\right] \tag{62}$$

Paralelisme Kuantum

Diberikan suatu fungsi f(x) yang membangun suatu sirkuit kuantum U_{f-c-N} yang bekerja sesuai dengan persamaan berikut:

$$|xy\rangle \rightarrow |xy \oplus f(x)\rangle \tag{63}$$

berikut adalah beberapa contoh keadaan paralelisme kuantum:



Gambar 3.1 Paralelisme Kuantum

berdasarkan gambar diagram diatas maka dapat diketahui bahwa sirkuit memiliki masukan $|x\rangle$ dan $|y\rangle$ dan memiliki keluaran $|xy \oplus f(x)\rangle$ (gambar a), untuk (gambar b) masukan $|y\rangle = |0\rangle$ maka sirkuit akan meiliki keluaran $|xf(x)\rangle$ sedangkan pada (gambar c) sirkuit memiliki kedua masukan $|0\rangle$ namun salah satunya melewati gerbang hadamar sehingga keluaran sirkuit adalah $\frac{1}{\sqrt{2}}(|0f(0)\rangle + |1f(1)\rangle)$

3.1.2a Register 2 Qubit

dalam register 2 qubit masukan merupakan superposisi keadaan yaitu berupa direct product:

$$|00\rangle = |0\rangle \otimes |0\rangle = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} \tag{64}$$

sedangakn dalam 2 qubit berikut adalah kemungkinan keadaan yang terjadi $|00\rangle, |01\rangle, |10\rangle, |11\rangle$, secara lengkap dapat dituliskan dalam bentuk

$$|\psi\rangle = a_0|00\rangle + a_1|01\rangle + a_3|10\rangle + a_4|11\rangle \tag{65}$$

3.1.2b Register 3 Qubit

Register 3 qubit masukan keadaan berupa $|000\rangle, |0001\rangle, ..., |111\rangle$ maka secara lengkap set keadaan dapat dituliskan sebagai berikut:

$$\begin{aligned} |\psi\rangle = a_0|000\rangle + a_1|001\rangle + a_2|010\rangle + a_3|011\rangle \\ + a_4|100\rangle + a_5|101\rangle + a_6|110\rangle + a_7|111\rangle \end{aligned} \tag{66}$$

3.1.2c Register 4 Qubit

Register 4 qubit juga terdiri dari 4 direct produc t dari keadaan yaitu sebagai berikut $|0000\rangle, |0001\rangle, ..., |1111\rangle$ dengan demikian set lengkap dari fungsi keadaan untuk 4 qubit dapat ditulis sebagai berikut:

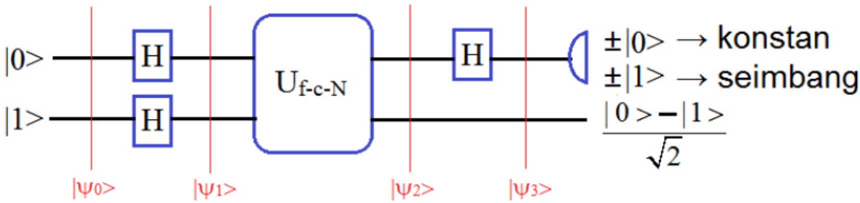
$$\begin{aligned} |\psi\rangle = a_0|0000\rangle + a_1|0001\rangle + a_2|0010\rangle + a_3|0011\rangle \\ + a_4|0100\rangle + a_5|0101\rangle + a_6|0110\rangle + a_7|0111\rangle \\ + a_8|1000\rangle + a_9|1001\rangle + a_{10}|1010\rangle + a_{11}|1011\rangle \\ + a_{12}|1100\rangle + a_{13}|1101\rangle + a_{14}|1110\rangle + a_{15}|1111\rangle \end{aligned} \tag{67}$$

3.2 Alogaritma Deutsch

Algoritma Deutsch merupakan algoritma kuantum yang pertama yang mana algoritma ini jauh lebih efisien daripada algoritma pada perhitungan klasik, Untuk memudahkan pemahaman maka kita misalakan $f : (0,1) \to (0,1)$ adalah fungsi biner maka fungsi tersebut hanya memiliki 4 kemungkinan yaitu :

$$\begin{aligned} f_1 &: 0 \to 0, 1 \to 0 \\ f_2 &: 0 \to 1, 1 \to 1 \\ f_3 &: 0 \to 0, 1 \to 1 \\ f_4 &: 0 \to 0, 1 \to 0 \end{aligned} \tag{68}$$

fungsi f_1 dan f_2 merupakan fungsi tetapan sedangkan f_3 dan f_4 merupakan fungsi setimbang. maka perlu dilakukan dua evaluasi untuk mengetahui bahwa fungsi f merupakan fungsi klasik atau fungsi setimbang.



Gambar 3.2 Skema Algoritma Deutsch

Algoritma kuantum yang paling sederhana untuk mengevaluasi fungsi f adalah algoritma Deutsch, sehingga dapat menentukan fungsi f merupakan tetapan atau setimbang, Evaluasi dapat dimulai dengan memasukkan qubit $|01\rangle$ Katakanlah $|\psi_{in} = |01\rangle$ merupakan keadaan masukan yang dikenai dengan operator Hadamard menghasilkan keadaan yang lain katakanlah $|\psi_1\rangle$ Maka Nilainya adalah

$$\begin{aligned}
|\psi_1\rangle &= H \otimes H|01\rangle \\
&= H|0\rangle \otimes H|1\rangle \\
&= \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)\frac{1}{\sqrt{2}}(|0\rangle + |1\rangle) \\
&= \frac{1}{2}(|00\rangle - |01\rangle + |10\rangle - |11\rangle)
\end{aligned} \tag{69}$$

kemudian kita dapat menerapkan operasi f pada keadaan $|\psi_1\rangle$ dalam suku operator uniter U_f

$$U_f|xy\rangle = |xy \otimes f(x)\rangle \tag{70}$$

maka operasi mendapatkan hasil

$$\begin{aligned}
|\psi_2\rangle &= U_f|\psi_1\rangle \\
&= \frac{1}{2}U_f(|00\rangle - |01\rangle + |10\rangle - |11\rangle)
\end{aligned}$$

$$|\psi_2\rangle = \frac{1}{2}(|0\rangle|f(0)\rangle - |0\rangle|f(0)\rangle + |1\rangle + |1\rangle|f(1)\rangle - |1\rangle - f(1)\rangle) \tag{71}$$

dimana $-f(x)$ bukan merupakan $f(x)$

selanjutnya kita terapkan gerbang hadamard pada qubit perrtama dan gerbang identitas pada qubit kedua

$$
\begin{aligned}
|\psi_3\rangle &= H \otimes I\,|\psi_2\rangle \\
&= \frac{1}{2} H \otimes I(|0\rangle\,|f(0)\rangle - |0\rangle\,|f(1)\rangle + |1\rangle\,|f(1)\rangle - |1\rangle\,|-f(1)\rangle \\
&= \frac{1}{2}\left(H\,|0\rangle \otimes I\,|f(0)\rangle - H\,|0\rangle \otimes I\,|-f(0)\rangle\right) \\
&+ \frac{1}{2}\left(H\,|1\rangle \otimes I\,|f(1)\rangle - H\,|1\rangle \otimes I\,|-f(1)\rangle\right) \\
&= \frac{1}{2\sqrt{2}}\left[(|0\rangle + |1\rangle)\,|f(0)\rangle - (|0\rangle + |1\rangle)\,|-f(0)\rangle\right] \\
&+ \frac{1}{2}\left[(|0\rangle - |1\rangle)\,|f(1)\rangle + (|0\rangle - |1\rangle)\,|-f(1)\rangle\right] \\
&= \frac{\sqrt{2}}{4}\left[(|0\rangle + |1\rangle)\,(|f(0)\rangle - |-f(0)\rangle)\right] \\
&+ \frac{1}{2}\left[(|0\rangle - |1\rangle)\,(|f(1)\rangle - |-f(1)\rangle)\right]
\end{aligned}
\tag{72}
$$

$|\psi_3\rangle$ merupakan output yang dapat mengetahui fungsi f itu konstan atau setimbang.
misalkan $f(0) = f(1)$ maka f konstan, sehingga:

$$
\begin{aligned}
|\psi_3\rangle &= \frac{\sqrt{2}}{4}\left[(|0\rangle + |1\rangle)\,(|f(0)\rangle - |-f(0)\rangle)\right] \\
&+ \frac{\sqrt{2}}{4}\left[(|0\rangle - |1\rangle)\,(|f(1)\rangle - |-f(1)\rangle)\right] \\
&= \frac{\sqrt{2}}{4}\,(|0\rangle + |1\rangle + |0\rangle - |1\rangle)\,(|f(0)\rangle - |-f(0)\rangle) \\
&= \frac{\sqrt{2}}{4} 2\,|0\rangle\,(|f(0)\rangle - |-f(0)\rangle) \\
&= \frac{1}{\sqrt{2}}\,|0\rangle\,(|f(0)\rangle - |-f(0)\rangle)
\end{aligned}
\tag{73}
$$

sedangkan untuk f merupakan fungsi setimbang dimana $f(0) = -f(1)$ dapat diuraikan sebagai berikut:

$$\begin{aligned}
|\psi_3\rangle &= \frac{\sqrt{2}}{4}\left[(|0\rangle + |1\rangle)(|f(0)\rangle - |-f(0)\rangle)\right] \\
&+ \frac{\sqrt{2}}{4}\left[(|0\rangle - |1\rangle)(|f(1)\rangle - |-f(1)\rangle)\right] \\
&= \frac{\sqrt{2}}{4}(|0\rangle + |1\rangle - (|0\rangle - |1\rangle))(|f(0)\rangle - |-f(0)\rangle) \\
&= \frac{\sqrt{2}}{4}2|1\rangle(|f(0)\rangle - |-f(0)\rangle) \\
&= \frac{\sqrt{2}}{2}|1\rangle(|f(0)\rangle - |-f(0)\rangle)
\end{aligned} \tag{74}$$

berikut adalah rincian luaran untuk setiap f: untuk $f_1(0) = 0$

$$\begin{aligned}
|\psi_{out}\rangle &= \frac{1}{\sqrt{2}}|0\rangle(|0\rangle - |1\rangle) \\
&= \frac{1}{\sqrt{2}}(|00\rangle - |01\rangle)
\end{aligned} \tag{75}$$

untuk $f_2(0) = 1$

$$\begin{aligned}
|\psi_{out}\rangle &= \frac{1}{\sqrt{2}}|1\rangle(|0\rangle - |0\rangle) \\
&= -\frac{1}{\sqrt{2}}(|00\rangle - |01\rangle)
\end{aligned} \tag{76}$$

maka didapatkan bahwa $f_2 = -f_1$ kemudian untuk fungsi yang setimbang didapatkan rincian sebagai berikut: untuk $f_3(0) = 0$

$$\begin{aligned}
|\psi_{out}\rangle &= \frac{1}{\sqrt{2}}|1\rangle(|0\rangle - |1\rangle) \\
&= \frac{1}{\sqrt{2}}(|10\rangle - |11\rangle)
\end{aligned} \tag{77}$$

untuk $f_4(0) = 1$

$$\begin{aligned} |\psi_{out}\rangle &= \frac{1}{\sqrt{2}} |1\rangle (|1\rangle - |0\rangle) \\ &= -\frac{1}{\sqrt{2}} (|10\rangle - |11\rangle) \end{aligned} \quad (78)$$

maka didapatkan bahwa $f_4 = -f_3$.

3.3 Algoritma Deutsch Josza pada sistem 2 qubit

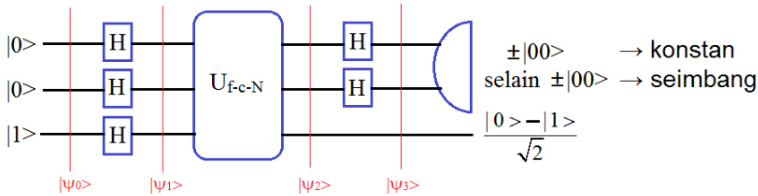
algoritma Deutsch-josza merupakan perluasan daripada algoritma Deutsch, yaitu dengan masukan n-qubit untuk memetakanpada qubit tungal. misalkan kita memiliki suatiu kotak hitam untuk 2 qubit maka kita mendapat masukan:

$$|\psi\rangle = |x_1 x_0\rangle = |00\rangle + |01\rangle + |10\rangle + |11\rangle$$

dari masukan tersebut dapat dibuta tabel kemungkinan untuk fungsi-fungsi konstan dan setimbang yakni sebagai berikut:

fungsi	$\|00\rangle$	$\|01\rangle$	$\|10\rangle$	$\|11\rangle$
f_{k0}	0	0	0	0
f_{k1}	1	1	1	1
f_{s1}	1	1	0	0
f_{s2}	1	0	1	0
f_{s3}	1	0	0	1
f_{s4}	0	1	1	0
f_{s5}	0	1	0	1
f_{s6}	0	0	1	1

berikut adalah diagram algoritma Deutsch-Josza 2 qubit :



Gambar 3.3 Algoritma Deutsch-Josza 2 qubit

kemudian kemungkinan-kemungkinan fungsi konstan dan setimbang diatas di evaluasi sebagai berikut: maka kita definisikan terlebih dahulu untuk masukan, dengan syarat bahwa dalam algoritma Deutsc-jozsa diberikan qubit tambahan dengan keadaan $|1\rangle$ maka dengan demikian didapatkan :

$$|\psi_{in}\rangle = |0\rangle \otimes |0\rangle \otimes |1\rangle = |001\rangle \tag{79}$$

kemudian diaplikasikan transformasi walsh-Hadamard didapatkan:

$$\begin{aligned} |\psi_1\rangle &= H \otimes H \otimes H\, |\psi_{in}\rangle \\ &= H\,|0\rangle \otimes H\,|0\rangle \otimes H\,|1\rangle \\ &= \frac{1}{2^{\frac{3}{2}}} \left(|0\rangle + |1\rangle\right)\left(|0\rangle + |1\rangle\right)\left(|0\rangle - |1\rangle\right) \\ &= \frac{1}{2^{\frac{3}{2}}} \left[|000\rangle - |001\rangle + |010\rangle - |011\rangle\right] \\ &+ \frac{1}{2^{\frac{3}{2}}} \left[|100\rangle - |101\rangle + |110\rangle - |111\rangle\right] \end{aligned} \tag{80}$$

kemudian diterapakan u_f pada $|\psi_1\rangle$ daan didapatkan:

$$\begin{aligned}
|\psi_2\rangle &= U_f\,|\psi_1\rangle \\
&= \frac{1}{2^{\frac{3}{2}}}\left[U\,|000\rangle - U\,|001\rangle + U\,|010\rangle - U\,|011\rangle\right] \\
&+ \frac{1}{2^{\frac{3}{2}}}\left[U\,|100\rangle - U\,|101\rangle + U\,|110\rangle - U\,|111\rangle\right] \\
&= \frac{1}{2^{\frac{3}{2}}}\left(|000 \oplus f(00)\rangle - |001 \oplus f(00)\rangle\right) \\
&+ \frac{1}{2^{\frac{3}{2}}}\left(|010 \oplus f(01)\rangle - |011 \oplus f(01)\rangle\right) \\
&+ \frac{1}{2^{\frac{3}{2}}}\left(|100 \oplus f(10)\rangle - |101 \oplus f(10)\rangle\right) \\
&+ \frac{1}{2^{\frac{3}{2}}}\left(|110 \oplus f(11)\rangle - |111 \oplus f(11)\rangle\right) \\
&= \frac{1}{2^{\frac{3}{2}}}\,|00\rangle\left(|0 \oplus f(00)\rangle - |1 \oplus f(00)\rangle\right) \\
&+ \frac{1}{2^{\frac{3}{2}}}\,|01\rangle\left(|0 \oplus f(01)\rangle - |1 \oplus f(01)\rangle\right) \\
&+ \frac{1}{2^{\frac{3}{2}}}\,|10\rangle\left(|0 \oplus f(10)\rangle - |1 \oplus f(10)\rangle\right) \\
&+ \frac{1}{2^{\frac{3}{2}}}\,|11\rangle\left(|0 \oplus f(11)\rangle - |1 \oplus f(11)\rangle\right) \\
&= \frac{1}{2^{\frac{3}{2}}}\,|00\rangle\left(|f(00)\rangle - |-f(00)\rangle\right) \\
&+ \frac{1}{2^{\frac{3}{2}}}\,|01\rangle\left(|f(01)\rangle - |-f(01)\rangle\right) \\
&+ \frac{1}{2^{\frac{3}{2}}}\,|10\rangle\left(|f(10)\rangle - |-f(10)\rangle\right) \\
&+ \frac{1}{2^{\frac{3}{2}}}\,|11\rangle\left(|f(11)\rangle - |-f(11)\rangle\right)
\end{aligned} \tag{81}$$

kemudian diterapkan kembali transformasi walsh hadamard maka diperoleh:

$$
\begin{aligned}
|\psi_3\rangle &= (H \otimes H \otimes I)\,|\psi_2\rangle \\
&= \frac{1}{2^{\frac{3}{2}}} H\,|0\rangle \otimes H\,|0\rangle \otimes I\,(|f(00)\rangle - |-f(00)\rangle) \\
&+ \frac{1}{2^{\frac{3}{2}}} H\,|0\rangle \otimes H\,|1\rangle \otimes I\,(|f(01)\rangle - |-f(01)\rangle) \\
&+ \frac{1}{2^{\frac{3}{2}}} H\,|1\rangle \otimes H\,|0\rangle \otimes I\,(|f(10)\rangle - |-f(10)\rangle) \\
&+ \frac{1}{2^{\frac{3}{2}}}\,|1\rangle \otimes H\,|1\rangle \otimes I\,(|f(11)\rangle - |-f(11)\rangle) \\
&= \frac{1}{2^{\frac{3}{2}}}\,(|0\rangle + |1\rangle)\,(|0\rangle + |1\rangle)\,(|f(00)\rangle - |-f(00)\rangle) \\
&+ \frac{1}{2^{\frac{3}{2}}}\,(|0\rangle + |1\rangle)\,(|0\rangle - |1\rangle)\,(|f(01)\rangle - |-f(01)\rangle) \\
&+ \frac{1}{2^{\frac{3}{2}}}\,(|0\rangle - |1\rangle)\,(|0\rangle + |1\rangle)\,(|f(10)\rangle - |-f(10)\rangle) \\
&+ \frac{1}{2^{\frac{3}{2}}}\,(|0\rangle - |1\rangle)\,(|0\rangle - |1\rangle)\,(|f(11)\rangle - |-f(11)\rangle) \\
&= \frac{1}{2^{\frac{5}{2}}}\,(|00\rangle + |01\rangle + |10\rangle + |11\rangle)\,(|f(00)\rangle - |-f(00)\rangle) \\
&+ \frac{1}{2^{\frac{5}{2}}}\,(|00\rangle - |01\rangle + |10\rangle - |11\rangle)\,(|f(01)\rangle - |-f(01)\rangle) \\
&+ \frac{1}{2^{\frac{5}{2}}}\,(|00\rangle + |01\rangle - |10\rangle - |11\rangle)\,(|f(10)\rangle - |-f(10)\rangle) \\
&+ \frac{1}{2^{\frac{5}{2}}}\,(|00\rangle - |01\rangle - |10\rangle + |11\rangle)\,(|f(11)\rangle - |-f(11)\rangle)
\end{aligned}
$$

$$
\begin{aligned}
&= \frac{1}{2^{\frac{5}{2}}}\left(|00\rangle\left[|f(00)\rangle - |{-f(00)}\rangle + |f(01)\rangle - |{-f(01)}\rangle\right]\right) \\
&+ \frac{1}{2^{\frac{5}{2}}}\left(|00\rangle\left[|f(10)\rangle - |{-f(10)}\rangle + |f(11)\rangle - |{-f(11)}\rangle\right]\right) \\
&+ \frac{1}{2^{\frac{5}{2}}}\left(|01\rangle\left[|f(00)\rangle - |{-f(00)}\rangle - |f(01)\rangle + |{-f(01)}\rangle\right]\right) \\
&+ \frac{1}{2^{\frac{5}{2}}}\left(|01\rangle\left[|f(10)\rangle - |{-f(10)}\rangle - |f(11)\rangle + |{-f(11)}\rangle\right]\right) \\
&+ \frac{1}{2^{\frac{5}{2}}}\left(|10\rangle\left[|f(00)\rangle - |{-f(00)}\rangle + |f(01)\rangle - |{-f(01)}\rangle\right]\right) \\
&- \frac{1}{2^{\frac{5}{2}}}\left(|10\rangle\left[|f(10)\rangle + |{-f(10)}\rangle - |f(11)\rangle + |{-f(11)}\rangle\right]\right) \\
&+ \frac{1}{2^{\frac{5}{2}}}\left(|11\rangle\left[|f(00)\rangle - |{-f(00)}\rangle - |f(01)\rangle + |{-f(01)}\rangle\right]\right) \\
&- \frac{1}{2^{\frac{5}{2}}}\left(|10\rangle\left[|f(10)\rangle + |{-f(10)}\rangle + |f(11)\rangle - |{-f(11)}\rangle\right]\right)
\end{aligned}
\tag{82}
$$

kemudian dievaluasi untuk setiap fungsi konstan dan setimbangnya.
untuk fungsi setimbang maka kita dapat mengambil bahwa $f(00) = f(01) = f(10) = f(11)$ maka dengan demikian didapatkan persamaan $|\psi_3\rangle$ untuk fungsi setimbang sebagai

berikut:

$$
\begin{aligned}
|\psi_3\rangle = \frac{1}{2^{\frac{5}{2}}} \left(|00\rangle \left[|f(00)\rangle - |-f(00)\rangle + |f(00)\rangle - |-f(00)\rangle\right]\right) \\
\frac{1}{2^{\frac{5}{2}}} \left(|00\rangle \left[+|f(00)\rangle - |-f(00)\rangle + |f(00)\rangle - |-f(00)\rangle\right]\right) \\
+ \frac{1}{2^{\frac{5}{2}}} \left(|01\rangle \left[|f(00)\rangle - |-f(00)\rangle - |f(00)\rangle + |-f(00)\rangle\right]\right) \\
+ \frac{1}{2^{\frac{5}{2}}} \left(|01\rangle \left[|f(00)\rangle - |-f(00)\rangle - |f(00)\rangle + |-f(00)\rangle\right]\right) \\
+ \frac{1}{2^{\frac{5}{2}}} \left(|10\rangle \left[|f(00)\rangle - |-f(00)\rangle + |f(00)\rangle - |-f(00)\rangle\right]\right) \\
- \frac{1}{2^{\frac{5}{2}}} \left(|10\rangle \left[|f(00)\rangle + |-f(00)\rangle - |f(00)\rangle + |-f(00)\rangle\right]\right) \\
+ \frac{1}{2^{\frac{5}{2}}} \left(|11\rangle \left[|f(00)\rangle - |-f(00)\rangle - |f(00)\rangle + |-f(00)\rangle\right]\right) \\
- \frac{1}{2^{\frac{5}{2}}} \left(|11\rangle \left[|f(00)\rangle + |-f(00)\rangle + |f(00)\rangle - |-f(00)\rangle\right]\right) \\
= \frac{1}{2^{\frac{5}{2}}} 4 \left(|00\rangle \left[|f(00)\rangle - |-f(00)\rangle\right] + |01\rangle .0 + |10\rangle .0 + |11\rangle .0\right) \\
= \frac{1}{\sqrt{2}} \left(|00\rangle \left[|f(00)\rangle - |-f(00)\rangle\right]\right)
\end{aligned}
\tag{83}
$$

untuk fungsi konstan $f_1(00) = 0$, kita dapatkan

$$
\begin{aligned}
|\psi_3\rangle &= \frac{1}{\sqrt{2}} |00\rangle \left[|0\rangle - |1\rangle\right] \\
&= \frac{1}{\sqrt{2}} \left[|000\rangle - |001\rangle\right]
\end{aligned}
\tag{84}
$$

sedangkan untuk fungsi setimbang $f_2(00) = 1$ maka didapatkan:

$$\begin{aligned} |\psi_3\rangle &= \frac{1}{\sqrt{2}} |00\rangle [|1\rangle - |0\rangle] \\ &= -\frac{1}{\sqrt{2}} [|000\rangle - |001\rangle] \end{aligned} \tag{85}$$

maka dengan demikian didapatkan bahwa $|\psi_{out2}\rangle = - |\psi_{out1}\rangle$.

untuk fungsi setimbang, diambil contoh evaluasi untuk $f_8 dan f_{11}$, yaitu sebagai berikut:
untuk f_8 diketahui dari tabel bahwa $f_8(00 = f_8(10) = 1$ dan $f_8(01) = f_8(11)$, maka dengan demikian didapatkan:

$$\begin{aligned} |\psi_3\rangle = &\frac{1}{2^{\frac{5}{2}}} (|00\rangle [|1\rangle - |0\rangle + |0\rangle - |1\rangle + |1\rangle - |0\rangle + |0\rangle - |-1\rangle]) \\ &+ \frac{1}{2^{\frac{5}{2}}} (|01\rangle [|1\rangle - |0\rangle - |0\rangle + |1\rangle + |1\rangle - |0\rangle - |0\rangle + |1\rangle]) \\ &+ \frac{1}{2^{\frac{5}{2}}} (|10\rangle [|1\rangle - |0\rangle + |0\rangle - |1\rangle - |1\rangle + |0\rangle - |0\rangle + |1\rangle]) \\ &+ \frac{1}{2^{\frac{5}{2}}} (|11\rangle [|1\rangle - |0\rangle - |0\rangle + |1\rangle - |1\rangle + |0\rangle + |0\rangle - |1\rangle]) \\ &= \frac{1}{2^{\frac{5}{2}}} 4 |01\rangle (|1\rangle - |0\rangle) \\ &= \frac{1}{\sqrt{2}} (|011\rangle - |010\rangle) \end{aligned} \tag{86}$$

sedangkan untuk fugnsi setimbang f_{11} diketahui bahwa $f_{11}(00) = f_{11}(10) = 0$ dan $f_{11}(01) = f_{11}(11) = 1$, sehingga didapatkan sebagai berikut:

$$
\begin{aligned}
|\psi_3\rangle = & \frac{1}{2^{\frac{5}{2}}}\left(|00\rangle\left[|0\rangle - |1\rangle + |1\rangle - |0\rangle + |0\rangle - |1\rangle + |1\rangle - |0\rangle\right]\right) \\
& + \frac{1}{2^{\frac{5}{2}}}\left(|01\rangle\left[|0\rangle - |1\rangle - |1\rangle + |0\rangle + |0\rangle - |1\rangle - |1\rangle + |0\rangle\right]\right) \\
& + \frac{1}{2^{\frac{5}{2}}}\left(|10\rangle\left[|0\rangle - |1\rangle + |1\rangle - |0\rangle - |0\rangle + |1\rangle - |1\rangle + |0\rangle\right]\right) \\
& + \frac{1}{2^{\frac{5}{2}}}\left(|11\rangle\left[|0\rangle - |1\rangle - |1\rangle + |0\rangle - |0\rangle + |1\rangle + |1\rangle - |0\rangle\right]\right) \\
& = \frac{1}{2^{\frac{5}{2}}} 4\,|01\rangle\left(|0\rangle - |1\rangle\right) \\
& = -\frac{1}{\sqrt{2}}\left(|011\rangle - |010\rangle\right)
\end{aligned} \tag{87}
$$

maka dengan demikian diperoleh bahwa $|\psi_{out11}\rangle = -|\psi_{out8}\rangle$. untuk selanjutnya juga dilakukan evaluasi terhadap fungsi-fungsi setimbang yang lain dan di dapatkan bahwa

$$
|\psi_{out}\rangle = \{ \begin{array}{lll}
|00\rangle\left[\frac{|0\rangle-|1\rangle}{\sqrt{2}}\right] & untuk f_{k0} & konstan0 \\
-|00\rangle\left[\frac{|0\rangle-|1\rangle}{\sqrt{2}}\right] & untuk f_{k1} & konstan1 \\
-|10\rangle\left[\frac{|0\rangle-|1\rangle}{\sqrt{2}}\right] & untuk f_{s1} & setimbang \\
-|01\rangle\left[\frac{|0\rangle-|1\rangle}{\sqrt{2}}\right] & untuk f_{s2} & setimbang \\
-|11\rangle\left[\frac{|0\rangle-|1\rangle}{\sqrt{2}}\right] & untuk f_{s3} & setimbang \\
|11\rangle\left[\frac{|0\rangle-|1\rangle}{\sqrt{2}}\right] & untuk f_{s4} & setimbang \\
|01\rangle\left[\frac{|0\rangle-|1\rangle}{\sqrt{2}}\right] & untuk f_{s5} & setimbang \\
|10\rangle\left[\frac{|0\rangle-|1\rangle}{\sqrt{2}}\right] & untuk f_{s6} & setimbang
\end{array} \tag{88}
$$

3.4 Algoritma Deutsch-Jozsa pada sistem 3 qubit

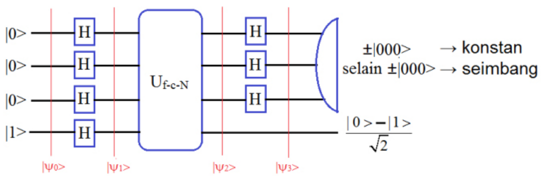
inti daripada algoritma Deutsch-jozsa adalah memetakan qubit banyak ke qubit tunggal. Dalama sisttem 3 qubit kotak hitam memiliki masukan keadaan:

$$|\psi\rangle = |x_2x_1x_0\rangle = |000\rangle + |001\rangle + |010\rangle + |011\rangle + |100\rangle + |101\rangle + |110\rangle + |111\rangle \quad (89)$$

berdasarkan masukan tersebut maka dapat dibuat tabel kemungkinan-kemungkinan fungsi konstan dan setimbang dalam sistem 3 qubit yaitu sebagai berikut:
Tabel 3.2 Kemungkinan Fungsi-Fungsi Kotak Hitam Pada sistem 3 qubit

$\|x_2x_1x_0\rangle$	f_{k0}	f_{k0}	f_{k1}	f_{s2}	f_{s3}	f_{s4}	f_{s5}	f_{s6}	f_{s7}	f_{s8}	f_{s9}
$\|000\rangle$	0	1	0	0	0	0	0	0	0	0	0
$\|001\rangle$	0	1	0	1	1	1	1	0	0	0	0
$\|010\rangle$	0	1	1	1	0	0	1	0	1	0	1
$\|011\rangle$	0	1	1	0	1	1	0	1	0	1	0
$\|100\rangle$	0	1	1	1	0	1	1	1	1	0	1
$\|101\rangle$	0	1	1	0	1	0	0	1	1	1	0
$\|110\rangle$	0	1	0	0	1	0	1	0	1	1	1
$\|111\rangle$	0	1	0	1	0	1	0	1	0	1	1

berikut adalah diagram algoritma Deutsch-Josza 3 qubit :



Gambar 3.4 Algoritma Deutsch-Josza 3 qubit

misalkan qubit masukan memiliki keadaan

$$|\psi_{in}\rangle = |0\rangle \otimes |0\rangle \otimes |0\rangle \otimes |1\rangle = |0001\rangle \tag{90}$$

dari qubit masukan tersebut diaplikasikan transformasi Walsh-Hadamard dan didapatkan :

$$\begin{aligned}
|\psi_1\rangle &= (H \otimes H \otimes H \otimes H) |\psi_{in}\rangle \\
&= H|0\rangle \otimes H|0\rangle \otimes H|0\rangle \otimes H|1\rangle \\
&= \frac{1}{4}\left[(|0\rangle + |1\rangle)(|0\rangle + |1\rangle)(|0\rangle + |1\rangle)(|0\rangle - |1\rangle)\right] \\
&= \frac{1}{4}\left[|0000\rangle - |0001\rangle + |0010\rangle - |0011\rangle\right] \\
&+ \frac{1}{4}\left[|0100\rangle - |0101\rangle + |0110\rangle - |0111\rangle\right] \\
&+ \frac{1}{4}\left[|1000\rangle - |1001\rangle + |1010\rangle - |1011\rangle\right] \\
&+ \frac{1}{4}\left[|1100\rangle - |1101\rangle + |1110\rangle - |1111\rangle\right]
\end{aligned} \tag{91}$$

kemudian diaplikasikan operator u_f pada $|\psi_1\rangle$ sehingga didapatkan:

$$\begin{aligned}
|\psi_2\rangle &= \frac{1}{4}\left[U|0000\rangle - U|0001\rangle + U|0010\rangle - U|0011\rangle\right] \\
&+ \frac{1}{4}\left[U|0100\rangle - U|0101\rangle + U|0110\rangle - U|0111\rangle\right] \\
&+ \frac{1}{4}\left[U|1000\rangle - U|1001\rangle + U|1010\rangle - U|1011\rangle\right] \\
&+ \frac{1}{4}\left[U|1100\rangle - U|1101\rangle + U|1110\rangle - U|1111\rangle\right]
\end{aligned}$$

$$= \frac{1}{4}\left[|0000 \oplus f(000)\rangle - |0001 \oplus f(000)\rangle\right]$$
$$+ \frac{1}{4}\left[|0010 \oplus f(001)\rangle - |0011 \oplus f(001)\rangle\right]$$
$$+ \frac{1}{4}\left[|0100 \oplus f(010)\rangle - |0101 \oplus f(101)\rangle\right]$$
$$+ \frac{1}{4}\left[|0110 \oplus f(011)\rangle - |0111 \oplus f(011)\rangle\right]$$
$$+ \frac{1}{4}\left[|1000 \oplus f(100)\rangle - |1001 \oplus f(100)\rangle\right]$$
$$+ \frac{1}{4}\left[|1010 \oplus f(101)\rangle - |1011 \oplus f(101)\rangle\right]$$
$$+ \frac{1}{4}\left[|1100 \oplus f(110)\rangle - |1101 \oplus f(110)\rangle\right]$$
$$+ \frac{1}{4}\left[|1110 \oplus f(111)\rangle - |1111 \oplus f(111)\rangle\right]$$
$$= \frac{1}{4}\left[|000\rangle\left(|0 \oplus f(000)\rangle - |1 \oplus f(000)\rangle\right)\right]$$
$$+ \frac{1}{4}\left[|001\rangle\left(|0 \oplus f(001)\rangle - |1 \oplus f(001)\rangle\right)\right]$$
$$+ \frac{1}{4}\left[|010\rangle\left(|0 \oplus f(010)\rangle - |1 \oplus f(010)\rangle\right)\right]$$
$$+ \frac{1}{4}\left[|011\rangle\left(|0 \oplus f(011)\rangle - |1 \oplus f(011)\rangle\right)\right]$$
$$+ \frac{1}{4}\left[|100\rangle\left(|0 \oplus f(100)\rangle - |1 \oplus f(100)\rangle\right)\right]$$
$$+ \frac{1}{4}\left[|101\rangle\left(|0 \oplus f(101)\rangle - |1 \oplus f(101)\rangle\right)\right]$$
$$+ \frac{1}{4}\left[|110\rangle\left(|0 \oplus f(110)\rangle - |1 \oplus f(110)\rangle\right)\right]$$
$$+ \frac{1}{4}\left[|111\rangle\left(|0 \oplus f(111)\rangle - |1 \oplus f(111)\rangle\right)\right]$$

$$
\begin{aligned}
&= \frac{1}{4}\left[|000\rangle\left(|f(000)\rangle - |{-f(000)}\rangle\right)\right] \\
&+ \frac{1}{4}\left[|001\rangle\left(|f(001)\rangle - |{-f(001)}\rangle\right)\right] \\
&+ \frac{1}{4}\left[|010\rangle\left(|f(010)\rangle - |{-f(010)}\rangle\right)\right] \\
&+ \frac{1}{4}\left[|011\rangle\left(|f(011)\rangle - |{-f(011)}\rangle\right)\right] \\
&+ \frac{1}{4}\left[|100\rangle\left(|f(100)\rangle - |{-f(100)}\rangle\right)\right] \\
&+ \frac{1}{4}\left[|101\rangle\left(|f(101)\rangle - |{-f(101)}\rangle\right)\right] \\
&+ \frac{1}{4}\left[|110\rangle\left(|f(110)\rangle - |{-f(110)}\rangle\right)\right] \\
&+ \frac{1}{4}\left[|111\rangle\left(|f(111)\rangle - |{-f(111)}\rangle\right)\right]
\end{aligned}
\tag{92}
$$

kemudian diaplikasin transformasi walsh-hadamard lagi sehingga didapatkan$|\psi_3\rangle$, yaitu sebagai berikut:

$$
\begin{aligned}
|\psi_3\rangle &= (H \otimes H \otimes H \otimes I)\,|\psi_2\rangle \\
&= \frac{1}{4}\left[H\,|0\rangle \otimes H\,|0\rangle \otimes H\,|0\rangle \otimes I\,(|f(000)\rangle - |-f(000)\rangle)\right] \\
&+ \frac{1}{4}\left[H\,|0\rangle \otimes H\,|0\rangle \otimes H\,|1\rangle \otimes I\,(|f(001)\rangle - |-f(001)\rangle)\right] \\
&+ \frac{1}{4}\left[H\,|0\rangle \otimes H\,|1\rangle \otimes H\,|0\rangle \otimes I\,(|f(010)\rangle - |-f(010)\rangle)\right] \\
&+ \frac{1}{4}\left[H\,|0\rangle \otimes H\,|1\rangle \otimes H\,|1\rangle \otimes I\,(|f(011)\rangle - |-f(011)\rangle)\right] \\
&+ \frac{1}{4}\left[H\,|1\rangle \otimes H\,|0\rangle \otimes H\,|0\rangle \otimes I\,(|f(100)\rangle - |-f(100)\rangle)\right] \\
&+ \frac{1}{4}\left[H\,|1\rangle \otimes H\,|0\rangle \otimes H\,|1\rangle \otimes I\,(|f(101)\rangle - |-f(101)\rangle)\right] \\
&+ \frac{1}{4}\left[H\,|1\rangle \otimes H\,|1\rangle \otimes H\,|0\rangle \otimes I\,(|f(110)\rangle - |-f(110)\rangle)\right] \\
&+ \frac{1}{4}\left[H\,|1\rangle \otimes H\,|1\rangle \otimes H\,|1\rangle \otimes I\,(|f(111)\rangle - |-f(111)\rangle)\right]
\end{aligned}
$$

$$
\begin{aligned}
&= \frac{1}{2^{\frac{7}{2}}}\left[\left(|0\rangle + |1\rangle\right)\left(|0\rangle + |1\rangle\right)\left(|0\rangle + |1\rangle\right)\left(|f(000)\rangle - |-f(000)\rangle\right)\right] \\
&+ \frac{1}{2^{\frac{7}{2}}}\left[\left(|0\rangle + |1\rangle\right)\left(|0\rangle + |1\rangle\right)\left(|0\rangle - |1\rangle\right)\left(|f(001)\rangle - |-f(001)\rangle\right)\right] \\
&+ \frac{1}{2^{\frac{7}{2}}}\left[\left(|0\rangle + |1\rangle\right)\left(|0\rangle - |1\rangle\right)\left(|0\rangle + |1\rangle\right)\left(|f(010)\rangle - |-f(010)\rangle\right)\right] \\
&+ \frac{1}{2^{\frac{7}{2}}}\left[\left(|0\rangle + |1\rangle\right)\left(|0\rangle - |1\rangle\right)\left(|0\rangle - |1\rangle\right)\left(|f(011)\rangle - |-f(011)\rangle\right)\right] \\
&+ \frac{1}{2^{\frac{7}{2}}}\left[\left(|0\rangle - |1\rangle\right)\left(|0\rangle + |1\rangle\right)\left(|0\rangle + |1\rangle\right)\left(|f(100)\rangle - |-f(100)\rangle\right)\right] \\
&+ \frac{1}{2^{\frac{7}{2}}}\left[\left(|0\rangle - |1\rangle\right)\left(|0\rangle + |1\rangle\right)\left(|0\rangle - |1\rangle\right)\left(|f(101)\rangle - |-f(101)\rangle\right)\right] \\
&+ \frac{1}{2^{\frac{7}{2}}}\left[\left(|0\rangle - |1\rangle\right)\left(|0\rangle - |1\rangle\right)\left(|0\rangle + |1\rangle\right)\left(|f(110)\rangle - |-f(110)\rangle\right)\right] \\
&- \frac{1}{2^{\frac{7}{2}}}\left[\left(|0\rangle - |1\rangle\right)\left(|0\rangle - |1\rangle\right)\left(|0\rangle - |1\rangle\right)\left(|f(111)\rangle - |-f(111)\rangle\right)\right]
\end{aligned}
$$

$$
\begin{aligned}
&= \frac{1}{2^{\frac{7}{2}}}\left[\left(|000\rangle + |001\rangle + |010\rangle + |011\rangle + |100\rangle + |101\rangle + |110\rangle + |111\rangle\right)\left(|f(000)\rangle - |-f(000)\rangle\right)\right] \\
&+ \frac{1}{2^{\frac{7}{2}}}\left[\left(|000\rangle - |001\rangle + |010\rangle - |011\rangle + |100\rangle - |101\rangle + |110\rangle - |111\rangle\right)\left(|f(001)\rangle - |-f(001)\rangle\right)\right] \\
&+ \frac{1}{2^{\frac{7}{2}}}\left[\left(|000\rangle + |001\rangle - |010\rangle - |011\rangle + |100\rangle + |101\rangle - |110\rangle - |111\rangle\right)\left(|f(010)\rangle - |-f(010)\rangle\right)\right] \\
&+ \frac{1}{2^{\frac{7}{2}}}\left[\left(|000\rangle - |001\rangle - |010\rangle + |011\rangle + |100\rangle - |101\rangle - |110\rangle + |111\rangle\right)\left(|f(011)\rangle - |-f(011)\rangle\right)\right] \\
&+ \frac{1}{2^{\frac{7}{2}}}\left[\left(|000\rangle + |001\rangle + |010\rangle + |011\rangle - |100\rangle - |101\rangle - |110\rangle - |111\rangle\right)\left(|f(100)\rangle - |-f(100)\rangle\right)\right] \\
&+ \frac{1}{2^{\frac{7}{2}}}\left[\left(|000\rangle - |001\rangle + |010\rangle - |011\rangle - |100\rangle + |101\rangle - |110\rangle + |111\rangle\right)\left(|f(101)\rangle - |-f(101)\rangle\right)\right] \\
&+ \frac{1}{2^{\frac{7}{2}}}\left[\left(|000\rangle + |001\rangle - |010\rangle - |011\rangle - |100\rangle - |101\rangle + |110\rangle + |111\rangle\right)\left(|f(110)\rangle - |-f(110)\rangle\right)\right] \\
&+ \frac{1}{2^{\frac{7}{2}}}\left[\left(|000\rangle - |001\rangle - |010\rangle - |011\rangle - |100\rangle - |101\rangle - |110\rangle - |111\rangle\right)\left(|f(111)\rangle - |-f(111)\rangle\right)\right]
\end{aligned}
$$

$$= \frac{1}{2^{\frac{7}{2}}} \left[|000\rangle \left(|f(000)\rangle - |-f(000)\rangle + |f(001)\rangle - |-f(001)\rangle \right) \right]$$
$$+ \frac{1}{2^{\frac{7}{2}}} \left[|000\rangle \left(|f(010)\rangle - |-f(010)\rangle + |f(011)\rangle - |-f(011)\rangle \right) \right]$$
$$+ \frac{1}{2^{\frac{7}{2}}} \left[|000\rangle \left(|f(100)\rangle - |-f(100)\rangle + |f(101)\rangle - |-f(101)\rangle \right) \right]$$
$$+ \frac{1}{2^{\frac{7}{2}}} \left[|000\rangle \left(|f(110)\rangle - |-f(110)\rangle + |f(111)\rangle - |-f(111)\rangle \right) \right]$$
$$+ \frac{1}{2^{\frac{7}{2}}} \left[|001\rangle \left(|f(000)\rangle - |-f(000)\rangle - |f(001)\rangle + |-f(001)\rangle \right) \right]$$
$$+ \frac{1}{2^{\frac{7}{2}}} \left[|001\rangle \left(|f(010)\rangle - |-f(010)\rangle - |f(011)\rangle + |-f(011)\rangle \right) \right]$$
$$+ \frac{1}{2^{\frac{7}{2}}} \left[|001\rangle \left(|f(100)\rangle - |-f(100)\rangle - |f(101)\rangle + |-f(101)\rangle \right) \right]$$
$$+ \frac{1}{2^{\frac{7}{2}}} \left[|001\rangle \left(|f(110)\rangle - |-f(110)\rangle - |f(111)\rangle + |-f(111)\rangle \right) \right]$$
$$+ \frac{1}{2^{\frac{7}{2}}} \left[|010\rangle \left(|f(000)\rangle - |-f(000)\rangle + |f(001)\rangle - |-f(001)\rangle \right) \right]$$
$$+ \frac{1}{2^{\frac{7}{2}}} \left[|010\rangle \left(- |f(010)\rangle + |-f(010)\rangle - |f(011)\rangle + |-f(011)\rangle \right) \right]$$
$$+ \frac{1}{2^{\frac{7}{2}}} \left[|010\rangle \left(|f(100)\rangle - |-f(100)\rangle + |f(101)\rangle - |-f(101)\rangle \right) \right]$$
$$+ \frac{1}{2^{\frac{7}{2}}} \left[|010\rangle \left(- |f(110)\rangle + |-f(110)\rangle - |f(111)\rangle + |-f(111)\rangle \right) \right]$$
$$+ \frac{1}{2^{\frac{7}{2}}} \left[|011\rangle \left(|f(000)\rangle - |-f(000)\rangle - |f(001)\rangle + |-f(001)\rangle \right) \right]$$

$$+\frac{1}{2^{\frac{7}{2}}}\left[|011\rangle\left(-|f(010)\rangle+|-f(010)\rangle+|f(011)\rangle-|-f(011)\rangle\right)\right]$$
$$+\frac{1}{2^{\frac{7}{2}}}\left[|011\rangle\left(|f(100)\rangle-|-f(100)\rangle-|f(101)\rangle+|-f(101)\rangle\right)\right]$$
$$+\frac{1}{2^{\frac{7}{2}}}\left[|011\rangle\left(-|f(110)\rangle+|-f(110)\rangle+|f(111)\rangle-|-f(111)\rangle\right)\right]$$
$$+\frac{1}{2^{\frac{7}{2}}}\left[|100\rangle\left(|f(000)\rangle-|-f(000)\rangle+|f(001)\rangle-|-f(001)\rangle\right)\right]$$
$$+\frac{1}{2^{\frac{7}{2}}}\left[|100\rangle\left(|f(010)\rangle-|-f(010)\rangle+|f(011)\rangle-|-f(011)\rangle\right)\right]$$
$$+\frac{1}{2^{\frac{7}{2}}}\left[|100\rangle\left(-|f(100)\rangle+|-f(100)\rangle-|f(101)\rangle+|-f(101)\rangle\right)\right]$$
$$+\frac{1}{2^{\frac{7}{2}}}\left[|100\rangle\left(-|f(110)\rangle+|-f(110)\rangle-|f(111)\rangle+|-f(111)\rangle\right)\right]$$
$$+\frac{1}{2^{\frac{7}{2}}}\left[|101\rangle\left(|f(000)\rangle-|-f(000)\rangle-|f(001)\rangle+|-f(001)\rangle\right)\right]$$
$$+\frac{1}{2^{\frac{7}{2}}}\left[|101\rangle\left(|f(010)\rangle-|-f(010)\rangle-|f(011)\rangle+|-f(011)\rangle\right)\right]$$
$$+\frac{1}{2^{\frac{7}{2}}}\left[|101\rangle\left(-|f(100)\rangle+|-f(100)\rangle+|f(101)\rangle-|-f(101)\rangle\right)\right]$$
$$+\frac{1}{2^{\frac{7}{2}}}\left[|101\rangle\left(-|f(110)\rangle+|-f(110)\rangle+|f(111)\rangle-|-f(111)\rangle\right)\right]$$
$$+\frac{1}{2^{\frac{7}{2}}}\left[|110\rangle\left(|f(000)\rangle-|-f(000)\rangle+|f(001)\rangle-|-f(001)\rangle\right)\right]$$
$$+\frac{1}{2^{\frac{7}{2}}}\left[|110\rangle\left(-|f(010)\rangle+|-f(010)\rangle-|f(011)\rangle+|-f(011)\rangle\right)\right]$$
$$+\frac{1}{2^{\frac{7}{2}}}\left[|110\rangle\left(-|f(100)\rangle+|-f(100)\rangle-|f(101)\rangle+|-f(101)\rangle\right)\right]$$
$$+\frac{1}{2^{\frac{7}{2}}}\left[|110\rangle\left(|f(110)\rangle-|-f(110)\rangle+|f(111)\rangle-|-f(111)\rangle\right)\right]$$

$$
\begin{aligned}
&+ \frac{1}{2^{\frac{7}{2}}} \left[|111\rangle \left(|f(000)\rangle - |-f(000)\rangle - |f(001)\rangle + |-f(001)\rangle \right) \right] \\
&+ \frac{1}{2^{\frac{7}{2}}} \left[|111\rangle \left(- |f(010)\rangle + |-f(010)\rangle + |f(011)\rangle - |-f(011)\rangle \right) \right] \\
&+ \frac{1}{2^{\frac{7}{2}}} \left[|111\rangle \left(- |f(100)\rangle + |-f(100)\rangle + |f(101)\rangle - |-f(101)\rangle \right) \right] \\
&+ \frac{1}{2^{\frac{7}{2}}} \left[|111\rangle \left(|f(110)\rangle - |-f(110)\rangle - |f(111)\rangle + |-f(111)\rangle \right) \right]
\end{aligned}
$$

apabila f merupakan fungsi konstsan maka $f(000) = f(001) = f(010) = f(011) = f(100) = f(101) = f(110) = f(111)$ sehingga didapatkan:

$$
\begin{aligned}
|\psi_{out}\rangle &= \frac{1}{2^{\frac{7}{2}}} \left[|000\rangle .8 \left(|f(000)\rangle - |-f(000)\rangle \right) + |001\rangle .0 + |010\rangle .0 + |011\rangle \right. \\
&= \frac{1}{2^{\frac{7}{2}}} .2^3 \, |000\rangle \left[|f(000)\rangle - |-f(000)\rangle \right] \\
&= \frac{1}{\sqrt{2}} \, |000\rangle \left[|f(000)\rangle - |-f(000)\rangle \right]
\end{aligned}
$$

apabila f merupakan fungsi konstan $f_k0 = f(000) = 0$ maka didapatkan:

$$
|\psi_{out}\rangle = \frac{1}{\sqrt{2}} \, |000\rangle \left[|0\rangle - |1\rangle \right] \tag{94}
$$

dan apabila fungsi f merupakan fungsi konstan $f_{k1} = f(0000) = 1$ maka didapatkan :

$$
|\psi_{out}\rangle = -\frac{1}{\sqrt{2}} \, |000\rangle \left[|0\rangle - |1\rangle \right] \tag{95}
$$

maka dengan demikian didapatkan keluaran $|\psi_{out1}\rangle = - |\psi_{out0}\rangle$ kemudian apabila fungsi f merupakan fungsi yang setimbang kita misalkan untuk f_3 dimana $f_3(000) = f_3(001) = f_3(010) = f_3(011) = 0$ dan $f_3(100) = f_3(101) = f_3(110) = f_3(111) = 1$ maka :

$$
\begin{aligned}
|\psi_{out}\rangle = \frac{1}{2^{\frac{7}{2}}} & [|000\rangle (|0\rangle - |1\rangle + |0\rangle - |1\rangle + |0\rangle - |1\rangle + |0\rangle - |1\rangle + |0\rangle - |1\rangle + |0\rangle - |1\rangle + |0\rangle - |1\rangle + |0\rangle - |1\rangle)] \\
+ \frac{1}{2^{\frac{7}{2}}} & [|001\rangle (|0\rangle - |1\rangle - |0\rangle + |1\rangle + |0\rangle - |1\rangle - |0\rangle + |1\rangle + |0\rangle - |1\rangle - |0\rangle + |1\rangle + |0\rangle - |1\rangle - |0\rangle + |1\rangle)] \\
+ \frac{1}{2^{\frac{7}{2}}} & [|010\rangle (|0\rangle - |1\rangle + |0\rangle - |1\rangle - |0\rangle + |1\rangle - |0\rangle + |1\rangle + |0\rangle - |1\rangle + |0\rangle - |1\rangle - |0\rangle + |1\rangle - |0\rangle + |1\rangle)] \\
+ \frac{1}{2^{\frac{7}{2}}} & [|011\rangle (|0\rangle - |1\rangle - |0\rangle + |1\rangle - |0\rangle + |1\rangle + |0\rangle - |1\rangle + |0\rangle - |1\rangle - |0\rangle + |1\rangle - |0\rangle + |1\rangle + |0\rangle - |1\rangle)] \\
+ \frac{1}{2^{\frac{7}{2}}} & [|100\rangle (|0\rangle - |1\rangle + |0\rangle - |1\rangle + |0\rangle - |1\rangle + |0\rangle - |1\rangle - |0\rangle + |1\rangle - |0\rangle + |1\rangle - |0\rangle + |1\rangle - |0\rangle + |1\rangle)] \\
+ \frac{1}{2^{\frac{7}{2}}} & [|101\rangle (|0\rangle - |1\rangle - |0\rangle + |1\rangle + |0\rangle - |1\rangle - |0\rangle + |1\rangle - |0\rangle + |1\rangle + |0\rangle - |1\rangle - |0\rangle + |1\rangle + |0\rangle - |1\rangle)] \\
+ \frac{1}{2^{\frac{7}{2}}} & [|110\rangle (|0\rangle - |1\rangle + |0\rangle - |1\rangle - |0\rangle + |1\rangle - |0\rangle + |1\rangle - |0\rangle + |1\rangle - |0\rangle + |1\rangle + |0\rangle - |1\rangle + |0\rangle - |1\rangle)] \\
+ \frac{1}{2^{\frac{7}{2}}} & [|111\rangle (|0\rangle - |1\rangle - |0\rangle + |1\rangle - |0\rangle + |1\rangle + |0\rangle - |1\rangle - |0\rangle + |1\rangle + |0\rangle - |1\rangle + |0\rangle - |1\rangle - |0\rangle + |1\rangle)]
\end{aligned}
\tag{96}
$$

sehingga didapatkan

$$
|\psi_{out3}\rangle = \frac{1}{2^{\frac{7}{2}}}.2^3 \, |100\rangle \, [|0\rangle - |1\rangle] = \frac{1}{\sqrt{2}} \, |100\rangle \, [|0\rangle - |1\rangle] \tag{97}
$$

3.5 Algoritma Deutsch-Josza Pada sistem 4 qubit

Dalam aplikasi algoritma 4 qubit maka langkah yang harus kita cari pertama kali adalah kemungkinan -kemungkinan fungsi konstan dan fungsi setimbang, yaitu sebagai berikut: sebelumnya kita definisikan bahwa qubit masukan

$$|\psi\rangle = |x_3 x_2 x_1 x_0\rangle \tag{98}$$

maka dapat kita ambil beberapa kemungkinan untuk fungsi konstan dan fungsi setimbang yaitu sebagai berikut:

$$\begin{aligned}
f_{k0} &= 0 & (konstan0)\\
f_{k1} &= 1 & (konstan1)\\
f_{s0} &= x_3 & (setimbang0)\\
f_{s1} &= x_1 \oplus x_0 & (setimbang1)\\
f_{s2} &= x_2 \oplus x_1 \oplus x_1 & (setimbang2)\\
f_{s3} &= x_3 \oplus x_2 \oplus x_1 \oplus x_1 & (setimbang3)\\
f_{s4} &= x_2 x_1 \oplus x_0 & (setimbang4)
\end{aligned} \tag{99}$$

maka dapat kita buat tabel untuk contoh fungsi-fungsi kotak hitam di atas, yaitu sebagai berikut:

$\|x_3x_2x_1x_0\rangle$	f_{k0}	f_{k1}	f_{s0}	f_{s1}	f_{s2}	f_{s3}	f_{s4}
$\|0000\rangle$	0	1	0	0	0	0	0
$\|0001\rangle$	0	1	0	1	1	1	1
$\|0010\rangle$	0	1	0	1	1	1	0
$\|0011\rangle$	0	1	0	0	0	0	1
$\|0100\rangle$	0	1	0	0	1	1	0
$\|0101\rangle$	0	1	0	1	0	0	1
$\|0110\rangle$	0	1	0	1	0	0	1
$\|0111\rangle$	0	1	0	0	1	1	0
$\|1000\rangle$	0	1	1	0	0	1	0
$\|1001\rangle$	0	1	1	1	1	0	1
$\|1010\rangle$	0	1	1	1	1	0	0
$\|1011\rangle$	0	1	1	0	0	1	1
$\|1100\rangle$	0	1	1	0	1	0	0
$\|1101\rangle$	0	1	1	1	0	1	1
$\|1110\rangle$	0	1	1	1	0	1	1
$\|1111\rangle$	0	1	1	0	1	0	0
total kemungkinan	1	1	8	12	8	2	24

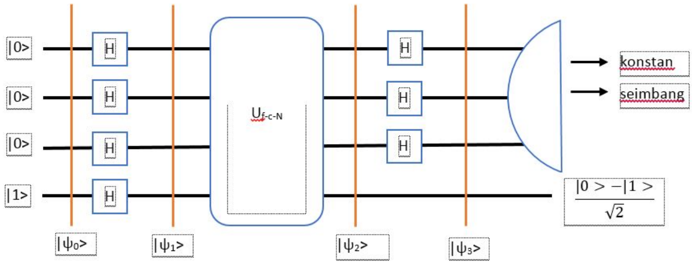
kemudian dikarenakan operator unitary memenuhi:

$$\begin{aligned} U_k &= U_f \otimes I \\ U_f &= (-1)^f(x)\,|\psi\rangle \end{aligned} \tag{100}$$

maka dengan demikian operator unitary untuk fungsi kotak hitam dapat di tuliskan sebagai berikut:

$$\begin{aligned} U_{k0} &= I \otimes I \otimes I \otimes I \\ U_{k1} &= -I \otimes I \otimes I \otimes I \\ U_{s0} &= I \otimes I \otimes I \otimes \sigma_z \\ U_{s1} &= I \otimes I \otimes \sigma_z \otimes \sigma_z \\ U_{s2} &= I \otimes \sigma_z \otimes \sigma_z \otimes \sigma_z \\ U_{s3} &= \sigma_z \otimes \sigma_z \otimes \sigma_z \otimes \sigma_z \\ U_{s4} &= I \otimes ([I \otimes \sigma_z] \oplus [\sigma_z \otimes \sigma_z]) \end{aligned} \tag{101}$$

berikut adalah diagram algoritma Deutsch-Josza 4 qubit :



Gambar 3.5 algoritma Deutsch-Josza 4 qubit

berdasarkan diagram diatas maka dapat diketahui bahwa fungsi keadaan input yaitu $|\psi_{in}\rangle = |00001\rangle$ kemudian diaplikasikan transformasi walsh-Hadamard pada fungsi keadaan input tersebut dihasilkan sebagai berikut:

$$
\begin{aligned}
|\psi_1\rangle &= H \otimes H \otimes H \otimes H \otimes H\,|00001\rangle \\
&= \left(\frac{1}{\sqrt{2}}\right)^5 (|0\rangle + |1\rangle)(|0\rangle + |1\rangle) \\
&\times (|0\rangle + |1\rangle)(|0\rangle + |1\rangle)(|0\rangle - |1\rangle) \\
&= \left(\frac{1}{\sqrt{2}}\right)^5 (|00000\rangle - |00001\rangle + |00010\rangle - |00011\rangle) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 (|00100\rangle - |00101\rangle + |00110\rangle - |00111\rangle) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 (|01000\rangle - |01001\rangle + |01010\rangle - |01011\rangle) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 (|01100\rangle - |01101\rangle + |01110\rangle - |01111\rangle) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 (|10000\rangle - |10001\rangle + |10010\rangle - |10011\rangle) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 (|10100\rangle - |10101\rangle + |10110\rangle - |10111\rangle) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 (|11000\rangle - |11001\rangle + |11010\rangle - |11011\rangle) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 (|11100\rangle - |11101\rangle + |11110\rangle - |11111\rangle)
\end{aligned}
\tag{102}
$$

kemudian diaplikasikan u_f pada $|\psi_1\rangle$ menurut persamaan $U_f : |xy\rangle \rightarrow |xy \oplus f(x)\rangle$ didapatkan $|\psi_2\rangle$ sebagai berikut:

$$\begin{aligned}
|\psi_2\rangle = &\left(\frac{1}{\sqrt{2}}\right)^5 (|00000 \oplus f(0000)\rangle - |00001 \oplus f(0000)\rangle) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 (|00010 \oplus f(0001)\rangle - |00011 \oplus f(0001)\rangle) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 (|00100 \oplus f(0010)\rangle - |00101 \oplus f(0010)\rangle) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 (|00110 \oplus f(0011)\rangle - |00111 \oplus f(0011)\rangle) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 (|01000 \oplus f(0100)\rangle - |01001 \oplus f(0100)\rangle) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 (|01010 \oplus f(0101)\rangle - |01011 \oplus f(0101)\rangle) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 (|01100 \oplus f(0110)\rangle - |01101 \oplus f(0110)\rangle) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 (|01110 \oplus f(0111)\rangle - |01111 \oplus f(0111)\rangle) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 (|10000 \oplus f(1000)\rangle - |10001 \oplus f(1000)\rangle) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 (|10010 \oplus f(1001)\rangle - |10011 \oplus f(1001)\rangle) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 (|10100 \oplus f(1010)\rangle - |10101 \oplus f(1010)\rangle) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 (|10110 \oplus f(1011)\rangle - |10111 \oplus f(1011)\rangle) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 (|11000 \oplus f(1100)\rangle - |11001 \oplus f(1100)\rangle) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 (|11010 \oplus f(1101)\rangle - |11011 \oplus f(1101)\rangle) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 (|11100 \oplus f(1110)\rangle - |11101 \oplus f(1110)\rangle) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 (|11110 \oplus f(1111)\rangle - |11111 \oplus f(1111)\rangle)
\end{aligned} \tag{103}$$

$$
\begin{aligned}
&= \left(\frac{1}{\sqrt{2}}\right)^5 |0000\rangle \left(|f(0000)\rangle - |-f(0000)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 |0001\rangle \left(|f(0001)\rangle - |-f(0001)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 |0010\rangle \left(|f(0010)\rangle - |-f(0010)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 |0011\rangle \left(|f(0011)\rangle - |-f(0011)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 |0100\rangle \left(|f(0100)\rangle - |-f(0100)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 |0101\rangle \left(|f(0101)\rangle - |-f(0101)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 |0110\rangle \left(|f(0110)\rangle - |-f(0110)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 |0111\rangle \left(|f(0111)\rangle - |-f(0111)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 |1000\rangle \left(|f(1000)\rangle - |-f(1000)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 |1001\rangle \left(|f(1001)\rangle - |-f(1001)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 |1010\rangle \left(|f(1010)\rangle - |-f(1010)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 |1011\rangle \left(|f(1011)\rangle - |-f(1011)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 |1100\rangle \left(|f(1100)\rangle - |-f(1100)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 |1101\rangle \left(|f(1101)\rangle - |-f(1101)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 |1110\rangle \left(|f(1110)\rangle - |-f(1110)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^5 |1111\rangle \left(|f(1111)\rangle - |-f(1111)\rangle\right)
\end{aligned} \tag{104}
$$

berdasarkan diagram diatas setelah mendapatkan $|\psi_2\rangle$ dioperasikan dengan transformasi Walsh-Hadamard lagi, diperoleh $|\psi_3\rangle$ yaitu sebagai berikut:

$$\begin{aligned} |\psi_3\rangle &= \left(\frac{1}{\sqrt{2}}\right)^4 H \otimes H \otimes H \otimes H \otimes I \, |\psi_2\rangle \\ &= A + B + C + D + E + F + G + H + I + J \\ &+ K + L + M + N + O + P \end{aligned} \tag{105}$$

dimana A=suku $|0000\rangle$, B=suku $|0001\rangle$, C=suku $|0010\rangle$, D=suku $|0011\rangle$, E=suku $|0100\rangle$, F=suku $|0101\rangle$, G=suku $|0110\rangle$, H=suku $|0111\rangle$, I=suku $|1000\rangle$, J=suku $|1001\rangle$, K=suku $|1010\rangle$, L=suku $|1011\rangle$, M=suku $|1100\rangle$, N=suku $|1101\rangle$, O=suku $|1110\rangle$, P=suku $|1111\rangle$ maka dapat diuraikan hasil operasi dari masing-masing suku yaitu sebagai berikut:

untuk A= suku $|0000\rangle$

$$
\begin{aligned}
&= \left(\frac{1}{\sqrt{2}}\right)^9 |0000\rangle \left(|f(0000)\rangle - |-f(0000)\rangle + |f(0001)\rangle - |-f(0001)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0000\rangle \left(|f(0010)\rangle - |-f(0010)\rangle + |f(0011)\rangle - |-f(0011)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0000\rangle \left(|f(0100)\rangle - |-f(0100)\rangle + |f(0101)\rangle - |-f(0101)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0000\rangle \left(|f(0110)\rangle - |-f(0110)\rangle + |f(0111)\rangle - |-f(0111)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0000\rangle \left(|f(1000)\rangle - |-f(1000)\rangle + |f(1001)\rangle - |-f(1001)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0000\rangle \left(|f(1010)\rangle - |-f(1010)\rangle + |f(1011)\rangle - |-f(1011)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0000\rangle \left(|f(1100)\rangle - |-f(1100)\rangle + |f(1101)\rangle - |-f(1101)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0000\rangle \left(|f(1110)\rangle - |-f(1110)\rangle + |f(1111)\rangle - |-f(1111)\rangle\right)
\end{aligned} \tag{106}
$$

untuk B= suku $|0001\rangle$

$$
\begin{aligned}
&= \left(\frac{1}{\sqrt{2}}\right)^9 |0000\rangle \left(|f(0001)\rangle - |-f(0000)\rangle - |f(0001)\rangle + |-f(0001)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0001\rangle \left(|f(0010)\rangle - |-f(0010)\rangle - |f(0011)\rangle + |-f(0011)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0001\rangle \left(|f(0100)\rangle - |-f(0100)\rangle - |f(0101)\rangle + |-f(0101)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0001\rangle \left(|f(0110)\rangle - |-f(0110)\rangle - |f(0111)\rangle + |-f(0111)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0001\rangle \left(|f(1000)\rangle - |-f(1000)\rangle - |f(1001)\rangle + |-f(1001)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0001\rangle \left(|f(1010)\rangle - |-f(1010)\rangle - |f(1011)\rangle + |-f(1011)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0001\rangle \left(|f(1100)\rangle - |-f(1100)\rangle - |f(1101)\rangle + |-f(1101)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0001\rangle \left(|f(1110)\rangle - |-f(1110)\rangle - |f(1111)\rangle + |-f(1111)\rangle\right)
\end{aligned}
\tag{107}
$$

untuk C= suku $|0010\rangle$

$$
\begin{aligned}
&= \left(\frac{1}{\sqrt{2}}\right)^9 |0000\rangle \left(|f(0000)\rangle - |-f(0000)\rangle + |f(0001)\rangle - |-f(0001)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0001\rangle \left(- |f(0010)\rangle + |-f(0010)\rangle - |f(0011)\rangle + |-f(0011)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0001\rangle \left(|f(0100)\rangle - |-f(0100)\rangle + |f(0101)\rangle - |-f(0101)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0001\rangle \left(- |f(0110)\rangle + |-f(0110)\rangle - |f(0111)\rangle + |-f(0111)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0001\rangle \left(|f(1000)\rangle - |-f(1000)\rangle + |f(1001)\rangle - |-f(1001)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0001\rangle \left(- |f(1010)\rangle + |-f(1010)\rangle - |f(1011)\rangle + |-f(1011)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0001\rangle \left(|f(1100)\rangle - |-f(1100)\rangle + |f(1101)\rangle - |-f(1101)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0001\rangle \left(- |f(1110)\rangle + |-f(1110)\rangle - |f(1111)\rangle + |-f(1111)\rangle\right)
\end{aligned} \tag{108}
$$

untuk D=suku $|0011\rangle$

$$
\begin{aligned}
&= \left(\frac{1}{\sqrt{2}}\right)^9 |0011\rangle \left(|f(0000)\rangle - |-f(0000)\rangle - |f(0001)\rangle + |-f(0001)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0011\rangle \left(- |f(0010)\rangle + |-f(0010)\rangle + |f(0011)\rangle - |-f(0011)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0011\rangle \left(|f(0100)\rangle - |-f(0100)\rangle - |f(0101)\rangle + |-f(0101)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0011\rangle \left(- |f(0110)\rangle + |-f(0110)\rangle + |f(0111)\rangle - |-f(0111)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0011\rangle \left(|f(1000)\rangle - |-f(1000)\rangle - |f(1001)\rangle + |-f(1001)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0011\rangle \left(- |f(1010)\rangle + |-f(1010)\rangle + |f(1011)\rangle - |-f(1011)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0011\rangle \left(|f(1100)\rangle - |-f(1100)\rangle - |f(1101)\rangle + |-f(1101)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0001\rangle \left(- |f(1110)\rangle + |-f(1110)\rangle + |f(1111)\rangle - |-f(1111)\rangle\right)
\end{aligned}
\tag{109}
$$

untuk E=suku $|0100\rangle$

$$
\begin{aligned}
&= \left(\frac{1}{\sqrt{2}}\right)^9 |0100\rangle \left(|f(0000)\rangle - |{-f(0000)}\rangle + |f(0001)\rangle - |{-f(0001)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0100\rangle \left(|f(0010)\rangle - |{-f(0010)}\rangle + |f(0011)\rangle - |{-f(0011)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0100\rangle \left(-|f(0100)\rangle + |{-f(0100)}\rangle - |f(0101)\rangle + |{-f(0101)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0100\rangle \left(-|f(0110)\rangle + |{-f(0110)}\rangle - |f(0111)\rangle + |{-f(0111)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0100\rangle \left(|f(1000)\rangle - |{-f(1000)}\rangle + |f(1001)\rangle - |{-f(1001)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0100\rangle \left(|f(1010)\rangle - |{-f(1010)}\rangle + |f(1011)\rangle - |{-f(1011)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0100\rangle \left(-|f(1100)\rangle + |{-f(1100)}\rangle - |f(1101)\rangle + |{-f(1101)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0100\rangle \left(-|f(1110)\rangle + |{-f(1110)}\rangle - |f(1111)\rangle + |{-f(1111)}\rangle\right)
\end{aligned} \tag{110}
$$

untuk F=suku $|0101\rangle$

$$
\begin{aligned}
&= \left(\frac{1}{\sqrt{2}}\right)^9 |0101\rangle \left(|f(0000)\rangle - |{-f(0000)}\rangle - |f(0001)\rangle + |{-f(0001)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0101\rangle \left(|f(0010)\rangle - |{-f(0010)}\rangle - |f(0011)\rangle + |{-f(0011)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0101\rangle \left(-|f(0100)\rangle + |{-f(0100)}\rangle + |f(0101)\rangle - |{-f(0101)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0101\rangle \left(-|f(0110)\rangle + |{-f(0110)}\rangle + |f(0111)\rangle - |{-f(0111)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0101\rangle \left(|f(1000)\rangle - |{-f(1000)}\rangle - |f(1001)\rangle + |{-f(1001)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0101\rangle \left(|f(1010)\rangle - |{-f(1010)}\rangle - |f(1011)\rangle + |{-f(1011)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0101\rangle \left(-|f(1100)\rangle + |{-f(1100)}\rangle + |f(1101)\rangle - |{-f(1101)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0101\rangle \left(-|f(1110)\rangle + |{-f(1110)}\rangle + |f(1111)\rangle - |{-f(1111)}\rangle\right)
\end{aligned}
\tag{111}
$$

untuk G=suku $|0110\rangle$

$$\begin{aligned}
&= \left(\frac{1}{\sqrt{2}}\right)^9 |0110\rangle \left(|f(0000)\rangle - |-f(0000)\rangle + |f(0001)\rangle - |-f(0001)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0110\rangle \left(-|f(0010)\rangle + |-f(0010)\rangle - |f(0011)\rangle + |-f(0011)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0110\rangle \left(-|f(0100)\rangle + |-f(0100)\rangle - |f(0101)\rangle + |-f(0101)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0110\rangle \left(|f(0110)\rangle - |-f(0110)\rangle + |f(0111)\rangle - |-f(0111)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0110\rangle \left(|f(1000)\rangle - |-f(1000)\rangle + |f(1001)\rangle - |-f(1001)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0110\rangle \left(-|f(1010)\rangle + |-f(1010)\rangle - |f(1011)\rangle + |-f(1011)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0110\rangle \left(-|f(1100)\rangle + |-f(1100)\rangle - |f(1101)\rangle + |-f(1101)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0110\rangle \left(|f(1110)\rangle - |-f(1110)\rangle + |f(1111)\rangle - |-f(1111)\rangle\right)
\end{aligned} \tag{112}$$

untuk H=suku $|0111\rangle$

$$\begin{aligned}
&= \left(\frac{1}{\sqrt{2}}\right)^9 |0111\rangle \left(|f(0000)\rangle - |{-f(0000)}\rangle - |f(0001)\rangle + |{-f(0001)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0111\rangle \left(-|f(0010)\rangle + |{-f(0010)}\rangle + |f(0011)\rangle - |{-f(0011)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0111\rangle \left(-|f(0100)\rangle + |{-f(0100)}\rangle + |f(0101)\rangle - |{-f(0101)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0111\rangle \left(|f(0110)\rangle - |{-f(0110)}\rangle - |f(0111)\rangle + |{-f(0111)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0111\rangle \left(|f(1000)\rangle - |{-f(1000)}\rangle - |f(1001)\rangle + |{-f(1001)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0111\rangle \left(-|f(1010)\rangle + |{-f(1010)}\rangle + |f(1011)\rangle - |{-f(1011)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0111\rangle \left(-|f(1100)\rangle + |{-f(1100)}\rangle + |f(1101)\rangle - |{-f(1101)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |0111\rangle \left(|f(1110)\rangle - |{-f(1110)}\rangle - |f(1111)\rangle + |{-f(1111)}\rangle\right)
\end{aligned} \tag{113}$$

untuk I=suku $|1000\rangle$

$$
\begin{aligned}
&= \left(\frac{1}{\sqrt{2}}\right)^9 |1000\rangle \left(|f(0000)\rangle - |-f(0000)\rangle + |f(0001)\rangle - |-f(0001)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1000\rangle \left(|f(0010)\rangle - |-f(0010)\rangle + |f(0011)\rangle - |-f(0011)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1000\rangle \left(|f(0100)\rangle - |-f(0100)\rangle + |f(0101)\rangle - |-f(0101)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1000\rangle \left(|f(0110)\rangle - |-f(0110)\rangle + |f(0111)\rangle - |-f(0111)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1000\rangle \left(-|f(1000)\rangle + |-f(1000)\rangle - |f(1001)\rangle + |-f(1001)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1000\rangle \left(-|f(1010)\rangle + |-f(1010)\rangle - |f(1011)\rangle + |-f(1011)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1000\rangle \left(-|f(1100)\rangle + |-f(1100)\rangle - |f(1101)\rangle + |-f(1101)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1000\rangle \left(-|f(1110)\rangle + |-f(1110)\rangle - |f(1111)\rangle + |-f(1111)\rangle\right)
\end{aligned} \tag{114}
$$

untuk J= suku $|1001\rangle$

$$\begin{aligned}
&= \left(\frac{1}{\sqrt{2}}\right)^9 |1001\rangle \left(|f(0000)\rangle - |{-f(0000)}\rangle - |f(0001)\rangle + |{-f(0001)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1001\rangle \left(|f(0010)\rangle - |{-f(0010)}\rangle - |f(0011)\rangle + |{-f(0011)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1001\rangle \left(|f(0100)\rangle - |{-f(0100)}\rangle - |f(0101)\rangle + |{-f(0101)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1001\rangle \left(|f(0110)\rangle - |{-f(0110)}\rangle - |f(0111)\rangle + |{-f(0111)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1001\rangle \left(- |f(1000)\rangle + |{-f(1000)}\rangle + |f(1001)\rangle - |{-f(1001)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1001\rangle \left(- |f(1010)\rangle + |{-f(1010)}\rangle + |f(1011)\rangle - |{-f(1011)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1001\rangle \left(- |f(1100)\rangle + |{-f(1100)}\rangle + |f(1101)\rangle - |{-f(1101)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1001\rangle \left(- |f(1110)\rangle + |{-f(1110)}\rangle + |f(1111)\rangle + |{-f(1111)}\rangle\right)
\end{aligned} \tag{115}$$

untuk K= suku $|1010\rangle$

$$\begin{aligned}
&= \left(\frac{1}{\sqrt{2}}\right)^{9} |1010\rangle \left(|f(0000)\rangle - |-f(0000)\rangle + |f(0001)\rangle - |-f(0001)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^{9} |1010\rangle \left(-|f(0010)\rangle + |-f(0010)\rangle - |f(0011)\rangle + |-f(0011)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^{9} |1010\rangle \left(|f(0100)\rangle - |-f(0100)\rangle + |f(0101)\rangle - |-f(0101)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^{9} |1010\rangle \left(-|f(0110)\rangle + |-f(0110)\rangle - |f(0111)\rangle + |-f(0111)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^{9} |1010\rangle \left(-|f(1000)\rangle + |-f(1000)\rangle - |f(1001)\rangle + |-f(1001)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^{9} |1010\rangle \left(|f(1010)\rangle - |-f(1010)\rangle + |f(1011)\rangle - |-f(1011)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^{9} |1010\rangle \left(-|f(1100)\rangle + |-f(1100)\rangle - |f(1101)\rangle + |-f(1101)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^{9} |1010\rangle \left(|f(1110)\rangle - |-f(1110)\rangle + |f(1111)\rangle - |-f(1111)\rangle\right)
\end{aligned} \tag{116}$$

untuk L= suku $|1011\rangle$

$$
\begin{aligned}
&= \left(\frac{1}{\sqrt{2}}\right)^{9} |1011\rangle \left(|f(0000)\rangle - |-f(0000)\rangle - |f(0001)\rangle + |-f(0001)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^{9} |1011\rangle \left(-|f(0010)\rangle + |-f(0010)\rangle + |f(0011)\rangle - |-f(0011)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^{9} |1011\rangle \left(|f(0100)\rangle - |-f(0100)\rangle - |f(0101)\rangle + |-f(0101)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^{9} |1011\rangle \left(-|f(0110)\rangle + |-f(0110)\rangle + |f(0111)\rangle - |-f(0111)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^{9} |1011\rangle \left(-|f(1000)\rangle + |-f(1000)\rangle + |f(1001)\rangle - |-f(1001)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^{9} |1011\rangle \left(|f(1010)\rangle - |-f(1010)\rangle - |f(1011)\rangle + |-f(1011)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^{9} |1011\rangle \left(-|f(1100)\rangle + |-f(1100)\rangle - |f(1101)\rangle + |-f(1101)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^{9} |1011\rangle \left(|f(1110)\rangle - |-f(1110)\rangle + |f(1111)\rangle - |-f(1111)\rangle\right)
\end{aligned}
\tag{117}
$$

untuk M= suku $|1100\rangle$

$$
\begin{aligned}
&= \left(\frac{1}{\sqrt{2}}\right)^9 |1100\rangle \left(|f(0000)\rangle - |-f(0000)\rangle + |f(0001)\rangle - |-f(0001)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1100\rangle \left(|f(0010)\rangle - |-f(0010)\rangle + |f(0011)\rangle - |-f(0011)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1100\rangle \left(-|f(0100)\rangle + |-f(0100)\rangle - |f(0101)\rangle + |-f(0101)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1100\rangle \left(-|f(0110)\rangle + |-f(0110)\rangle - |f(0111)\rangle + |-f(0111)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1100\rangle \left(-|f(1000)\rangle + |-f(1000)\rangle - |f(1001)\rangle + |-f(1001)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1100\rangle \left(-|f(1010)\rangle + |-f(1010)\rangle - |f(1011)\rangle + |-f(1011)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1100\rangle \left(|f(1100)\rangle - |-f(1100)\rangle + |f(1101)\rangle - |-f(1101)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1100\rangle \left(|f(1110)\rangle - |-f(1110)\rangle + |f(1111)\rangle - |-f(1111)\rangle\right)
\end{aligned}
\tag{118}
$$

untuk N= suku $|1101\rangle$

$$\begin{aligned}
&= \left(\frac{1}{\sqrt{2}}\right)^9 |1101\rangle \left(|f(0000)\rangle - |-f(0000)\rangle - |f(0001)\rangle + |-f(0001)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1101\rangle \left(|f(0010)\rangle - |-f(0010)\rangle - |f(0011)\rangle + |-f(0011)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1101\rangle \left(-|f(0100)\rangle + |-f(0100)\rangle + |f(0101)\rangle - |-f(0101)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1101\rangle \left(-|f(0110)\rangle + |-f(0110)\rangle + |f(0111)\rangle - |-f(0111)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1101\rangle \left(-|f(1000)\rangle + |-f(1000)\rangle + |f(1001)\rangle - |-f(1001)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1101\rangle \left(-|f(1010)\rangle + |-f(1010)\rangle + |f(1011)\rangle - |-f(1011)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1101\rangle \left(|f(1100)\rangle - |-f(1100)\rangle + |f(1101)\rangle - |-f(1101)\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1101\rangle \left(|f(1110)\rangle - |-f(1110)\rangle + |f(1111)\rangle - |-f(1111)\rangle\right)
\end{aligned} \tag{119}$$

untuk O=suku $|1110\rangle$

$$
\begin{aligned}
&= \left(\frac{1}{\sqrt{2}}\right)^9 |1110\rangle \left(|f(0000)\rangle - |{-f(0000)}\rangle + |f(0001)\rangle - |{-f(0001)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1110\rangle \left(- |f(0010)\rangle + |{-f(0010)}\rangle - |f(0011)\rangle + |{-f(0011)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1110\rangle \left(- |f(0100)\rangle + |{-f(0100)}\rangle - |f(0101)\rangle + |{-f(0101)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1110\rangle \left(|f(0110)\rangle - |{-f(0110)}\rangle + |f(0111)\rangle - |{-f(0111)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1110\rangle \left(- |f(1000)\rangle + |{-f(1000)}\rangle - |f(1001)\rangle + |{-f(1001)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1110\rangle \left(|f(1010)\rangle - |{-f(1010)}\rangle + |f(1011)\rangle - |{-f(1011)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1110\rangle \left(|f(1100)\rangle - |{-f(1100)}\rangle + |f(1101)\rangle - |{-f(1101)}\rangle\right) \\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1110\rangle \left(- |f(1110)\rangle + |{-f(1110)}\rangle - |f(1111)\rangle + |{-f(1111)}\rangle\right)
\end{aligned} \tag{120}
$$

untuk P= suku $|1111\rangle$

$$
\begin{aligned}
&= \left(\frac{1}{\sqrt{2}}\right)^9 |1111\rangle \left(|f(0000)\rangle - |{-f(0000)}\rangle - |f(0001)\rangle + |{-f(0001)}\rangle\right)\\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1111\rangle \left(- |f(0010)\rangle + |{-f(0010)}\rangle + |f(0011)\rangle - |{-f(0011)}\rangle\right)\\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1111\rangle \left(- |f(0100)\rangle + |{-f(0100)}\rangle + |f(0101)\rangle - |{-f(0101)}\rangle\right)\\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1111\rangle \left(|f(0110)\rangle - |{-f(0110)}\rangle - |f(0111)\rangle + |{-f(0111)}\rangle\right)\\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1111\rangle \left(- |f(1000)\rangle + |{-f(1000)}\rangle + |f(1001)\rangle - |{-f(1001)}\rangle\right)\\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1111\rangle \left(|f(1010)\rangle - |{-f(1010)}\rangle - |f(1011)\rangle + |{-f(1011)}\rangle\right)\\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1111\rangle \left(|f(1100)\rangle - |{-f(1100)}\rangle - |f(1101)\rangle + |{-f(1101)}\rangle\right)\\
&+ \left(\frac{1}{\sqrt{2}}\right)^9 |1111\rangle \left(- |f(1110)\rangle + |{-f(1110)}\rangle + |f(1111)\rangle - |{-f(1111)}\rangle\right)
\end{aligned} \tag{121}
$$

untuk fungsi konstan $f(0000) = f(0001) = f(0010) = f(0011) = f(0100) = f(0101) = f(0110) = f(0111) = f(1000) = f(1001) = f(1010) = f(1011) = f(1100) = f(1101) = f(1110) = f(1111) = 0$ didapatkan :

$$|\psi_{k0}\rangle = \frac{1}{\sqrt{2}} |0000\rangle \, [|0\rangle - |1\rangle] \tag{122}$$

untuk fungsi konstan $f(0000) = f(0001) = f(0010) = f(0011) = f(0100) = f(0101) = f(0110) = f(0111) = f(1000) = f(1001) = f(1010) = f(1011) = f(1100) = f(1101) = f(1110) = f(1111) = 1$ didapatkan :

$$|\psi_{k1}\rangle = -\frac{1}{\sqrt{2}} |0000\rangle \, [|0\rangle - |1\rangle] \tag{123}$$

untuk fungsi setimbang $f(0000) = f(0001) = f(0010) = f(0011) = f(0100) = f(0101) = f(0110) = 0$ dan $f(0111) = f(1000) = f(1001) = f(1010) = f(1011) = f(1100) = f(1101) = f(1110) = f(1111) = 1$ didapatkan

$$|\psi_{s0}\rangle = \frac{1}{\sqrt{2}} |1000\rangle \, [|0\rangle - |1\rangle] \tag{124}$$

untuk fungsi setimbang s_1 $f(0000) = 0, f(0001) = f(0010) = 1, f(0011) = f(0100) = 0, f(0101) = f(0110) = 1, f(0111) = f(1000) = 0, f(1001) = f(1010) = 1, f(1011) = f(1100) = 0, f(1101) = f(1110) = 1, f(1111) = 0$

$$|\psi_{s1}\rangle = \frac{1}{\sqrt{2}} |0011\rangle \, [|0\rangle - |1\rangle] \tag{125}$$

untuk fungsi setimbang s_2 $f(0000) = 0, f(0001) = f(0010) = 1, f(0011) = 0, f(0100) = 1, f(0101) = f(0110) = 0, f(0111) = 1, f(1000) = 0, f(1001) = f(1010) = 1, f(1011) = 0, f(1100) = 1, f(1101) = f(1110) = 1, f(1111) = 0$ didapatkan :

$$|\psi_{s2}\rangle = \frac{1}{\sqrt{2}} |0111\rangle \, [|0\rangle - |1\rangle] \tag{126}$$

untuk fungsi setimbang s_3 $f(0000) = f(0001) = f(0010) = f(0011) = f(0100) = f(0101) = f(0110) = f(0111) = f(1000) = f(1001) = f(1010) = f(1011) = f(1100) = f(1101) = f(1110) = f(1111) = 0$ didapatkan :

$$|\psi_{s3}\rangle = \frac{1}{\sqrt{2}} |1111\rangle \, |[|0\rangle - |1\rangle] \tag{127}$$

"Halaman ini sengaja dikosongkan"

BAB IV
SISTEM N-QUBIT

Sebelum membahas permasalahan dalam sistem N-qubit maka harus dibahas terlebih dahulu untuk sistem 1-qubit, 2 qubit, 3 qubit dan 4 qubit untuk mendapatkan pola dari pada masing-masing sistem, sehingga dapat diketahui apabila sistem memiliki pola atau hanya perluasan saja tanpa pola umum

4.1 Sistem 1, 2 dan 3 qubit

Pada sistem 1 qubit. Level energi dihasilkan oleh 1 partikel, dimana hamiltonian untuk presesi bebas qubit tunggal adalah:

$$\begin{aligned} H_0 &= -\hbar\gamma B_0 I_z \\ &= \hbar\omega_0 I_z \end{aligned} \tag{128}$$

dimana $\omega_0 = -\gamma B_0$ dan ω_0 merupakan frekuensi sudut larmor dan γ merupakan rasio giromagnetik. kemudian diambil $\hbar = 1$ sehingga didapatkan:

$$H_0 = \omega_0 I_z \tag{129}$$

untuk spin tunggal masukan keadaannya adalah:

$$|\psi\rangle = \alpha\,|0\rangle + \beta\,|1\rangle \tag{130}$$

maka dengan demikian kita dapat mengoperasikan hamiltonian pada keadaan tersebut dan diperoleh sebagai berikut:

$$\begin{aligned}
H_0 |\psi\rangle &= \omega_0 Iz (|0\rangle + |1\rangle) \\
&= \omega_0 (I_z |0\rangle + I_z |1\rangle) \\
&= \omega_0 \left(\frac{1}{2} \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \times \begin{pmatrix} 1 \\ 0 \end{pmatrix} + \frac{1}{2} \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \times \begin{pmatrix} 0 \\ 1 \end{pmatrix} \right) \\
&= \omega_0 \left[\frac{1}{2} \begin{pmatrix} 1 \\ 0 \end{pmatrix} - \frac{1}{2} \begin{pmatrix} 0 \\ 1 \end{pmatrix} \right] \\
&= \omega_0 \left(\frac{1}{2} |0\rangle - \frac{1}{2} |1\rangle \right) \\
&= \frac{1}{2} \omega_0 (|0\rangle - |1\rangle)
\end{aligned} \tag{131}$$

maka dengan demikian diperoleh dua nilai level energi yaitu sebagai berikut:

$$E_a = m\omega_0 = \{ \begin{array}{cccc} E_0 = \frac{1}{2}\omega_0 & untuk & a = |0\rangle \, dan & m = \frac{1}{2} \\ E_1 = -\frac{1}{2}\omega_0 & untuk & a = |1\rangle \, dan & m = -\frac{1}{2} \end{array} \tag{132}$$

Pada sistem NMR 2 qubit interaksi yang terjadi diasumsikan sebagai interaksi heisenberg yaitu interaksi yang diperanguri oleh atom tetangga yang terdekat sehingga hamiltonian sistem adalah sebagai brikut:

$$H = \omega_0 I \otimes I_z + \omega_1 I_z \otimes I + 2\pi J 10 I_z \otimes I_z \tag{133}$$

dimana ω_0 dan ω_1 merupakan frekuensi sudut larmor untuk qubit ke 0 dan qubit ke 1, sedangkan J_{10} merupakan kopling skalar yang melibatkan qubit-0 dan qubit-1. kemudian vektor keadaan untuk sistem 2 qubit adalah sebagai berikut:

$$|\psi\rangle = c_0 |00\rangle + c_1 |01\rangle + c_2 |10\rangle + c_3 |11\rangle \tag{134}$$

dengan c_0, c_1, c_2, c_3 meruapakan koefisien kompleks. apabila H bekerja pada vektor keadaan maka diperoleh:

$$\begin{aligned}
H|\psi\rangle &= (\omega_0 I \otimes I_z + \omega_1 I_z \otimes I + 2\pi J10 I_z \otimes I_z)|\psi\rangle \\
&= \omega_0 I \otimes I_z (c_0|00\rangle + c_1|01\rangle + c_2|10\rangle + c_3|11\rangle) \\
&+ \omega_1 I_z \otimes I (c_0|00\rangle + c_1|01\rangle + c_2|10\rangle + c_3|11\rangle) \\
&+ 2\pi J10 I_z \otimes I_z (c_0|00\rangle + c_1|01\rangle + c_2|10\rangle + c_3|11\rangle) \\
&= \omega_0 (c_0 I|0\rangle I_z|0\rangle + c_1 I|0\rangle I_z|1\rangle + c_2 I|1\rangle I_z|0\rangle + c_3 I|1\rangle I_z|1\rangle) \\
&+ \omega_1 (c_0 I_z|0\rangle I|0\rangle + c_1 I_z|0\rangle I|1\rangle + c_2 I_z|1\rangle I|0\rangle + c_3 I_z|1\rangle I|1\rangle) \\
&+ 2\pi J_{10} (c_0 I_z|0\rangle I_z|0\rangle + c_1 I_z|0\rangle I_z|1\rangle + c_2 I_z|1\rangle I_z|0\rangle) \\
&+ 2\pi J_{10} (c_3 I_z|1\rangle I_z|1\rangle)
\end{aligned}$$

$$
\begin{aligned}
&= \omega_0 \left(c_0 \left|0\right\rangle \frac{1}{2} \left|0\right\rangle + c_1 \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle + c_2 \left|1\right\rangle \frac{1}{2} \left|0\right\rangle \right) \\
&+ \omega_0 \left(c_3 \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \right) \\
&+ \omega_1 \left(c_0 \frac{1}{2} \left|0\right\rangle \left|0\right\rangle + c_1 \frac{1}{2} \left|0\right\rangle \left|1\right\rangle + c_2 \left(-\frac{1}{2}\right) \left|1\right\rangle \left|0\right\rangle \right) \\
&+ \omega_1 \left(c_3 \left(-\frac{1}{2}\right) \left|1\right\rangle \left|1\right\rangle \right) \\
&+ 2\pi J_{10} \left(c_0 \frac{1}{2} \left|0\right\rangle \frac{1}{2} \left|0\right\rangle + c_1 \frac{1}{2} \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle + c_2 \left(-\frac{1}{2}\right) \left|1\right\rangle \frac{1}{2} \left|0\right\rangle \right) \\
&+ 2\pi J_{10} \left(c_3 \left(-\frac{1}{2}\right) \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \right) \qquad (135) \\
&= \omega_0 \left[\frac{1}{2} C_0 \left|00\right\rangle - \frac{1}{2} C_1 \left|01\right\rangle + \frac{1}{2} C_2 \left|10\right\rangle - \frac{1}{2} C_3 \left|11\right\rangle \right] \\
&+ \omega_1 \left[\frac{1}{2} C_0 \left|00\right\rangle + \frac{1}{2} C_1 \left|01\right\rangle + -da C_2 \left|10\right\rangle - \frac{1}{2} C_3 \left|11\right\rangle \right] \\
&+ 2\pi J_{10} \left[\frac{1}{4} C_0 \left|00\right\rangle - \frac{1}{4} C_1 \left|01\right\rangle - \frac{1}{4} C_2 \left|10\right\rangle + \frac{1}{4} C_3 \left|11\right\rangle \right] \\
&= \frac{1}{2} \left(\omega_0 + \omega_1 + \pi J_{10}\right) c_0 \left|00\right\rangle + \frac{1}{2} \left(-\omega_0 - \omega_1 + \pi J_{10}\right) c_1 \left|01\right\rangle \\
&+ \frac{1}{2} \left(\omega_0 - \omega_1 - \pi J_{10}\right) c_2 \left|10\right\rangle + \frac{1}{2} \left(-\omega_0 - \omega_1 + \pi J_{10}\right) c_3 \left|11\right\rangle
\end{aligned}
$$

maka dengan demikian diperoleh bentuk

$$
H \left|\psi\right\rangle = E_{2,0} c_0 \left|00\right\rangle + E_{2,1} c_1 \left|01\right\rangle + E_{2,2} c_2 \left|10\right\rangle + E_{2,3} c_3 \left|11\right\rangle \qquad (136)
$$

sehingga dapat dibuat tabel level-level energi untuk sistem 2 qubit yaitu sebagai berikut:

n	$E_{2,n}$
0	$\frac{1}{2}(\omega_0 + \omega_1 + \pi J_{10})$
1	$\frac{1}{2}(-\omega_0 - \omega_1 + \pi J_{10})$
2	$\frac{1}{2}(\omega_0 - \omega_1 - \pi J_{10})$
3	$\frac{1}{2}(-\omega_0 - \omega_1 + \pi J_{10})$

Level Energi pada sistem 3 qubit ditentukan oleh energi 3 partikel dan interaksinya. untuk cataan bahwa interaksi yang terjadi adalah interaksi heisenberg yakni interaksi yang hanya dipengruhi oleh atom tetangga terdekat. Bentuk Hamiltonian utnuk sistem 3 qubit adalah sebagai betikut:

$$\begin{aligned} H = &\omega_0 I \otimes I \otimes I_z + \omega_1 I \otimes I_z \otimes I + \omega_2 I_z \otimes I \otimes I \\ &+ 2\pi J_{10} I \otimes I_z \otimes I_z + 2\pi j_{20} I_z \otimes I \otimes I_z + 2\pi j_{21} I_z \otimes I_z \otimes I \end{aligned} \tag{137}$$

sedangkan untuk vektor keadan 3 qubit adalah sebagai berikut:

$$\begin{aligned} |\psi\rangle = &c_0 |000\rangle + c_1 |001\rangle + c_2 |010\rangle + c_3 |011\rangle \\ &+ c_4 |100\rangle + c_5 |101\rangle + c_6 |110\rangle + c_7 |111\rangle \end{aligned} \tag{138}$$

dengan $c_1, c_2, ..., c_7$ merupakan koefisien kompleks. utnuk mendapatkan nilai level energi dari keadaan 3 qubit maka dioperasikan hamiltonian pada vektor keadaannya yaitu sebagai berikut:

$$
\begin{aligned}
H|\psi\rangle &= (\omega_0 I\otimes I\otimes I_z + \omega_1 I\otimes I_z\otimes I + \omega_2 I_z\otimes I\otimes I)|\psi\rangle \\
&+ (2\pi J_{10} I\otimes I_z\otimes I_z + 2\pi j_{20} I_z\otimes I\otimes I_z + 2\pi j_{21} I_z\otimes I_z\otimes I)|\psi\rangle \\
&= \omega_0 I\otimes I\otimes I_z (c_0|000\rangle + c_1|001\rangle + c_2|010\rangle + c_3|011\rangle) \\
&+ \omega_0 I\otimes I\otimes I_z (c_4|100\rangle + c_5|101\rangle + c_6|110\rangle + c_7|111\rangle) \\
&+ \omega_1 I\otimes I_z\otimes I (c_0|000\rangle + c_1|001\rangle + c_2|010\rangle + c_3|011\rangle) \\
&+ \omega_1 I\otimes I_z\otimes I (c_4|100\rangle + c_5|101\rangle + c_6|110\rangle + c_7|111\rangle) \\
&+ \omega_2 I_z\otimes I\otimes I (c_0|000\rangle + c_1|001\rangle + c_2|010\rangle + c_3|011\rangle) \\
&+ \omega_2 I_z\otimes I\otimes I (c_4|100\rangle + c_5|101\rangle + c_6|110\rangle + c_7|111\rangle) \\
&+ 2\pi J_{10} I\otimes I_z\otimes I_z (c_0|000\rangle + c_1|001\rangle + c_2|010\rangle + c_3|011\rangle) \\
&+ 2\pi J_{10} I\otimes I_z\otimes I_z (c_4|100\rangle + c_5|101\rangle + c_6|110\rangle + c_7|111\rangle) \\
&+ 2\pi j_{20} I_z\otimes I\otimes I_z (c_0|000\rangle + c_1|001\rangle + c_2|010\rangle + c_3|011\rangle) \\
&+ 2\pi j_{20} I_z\otimes I\otimes I_z (c_4|100\rangle + c_5|101\rangle + c_6|110\rangle + c_7|111\rangle) \\
&+ 2\pi j_{21} I_z\otimes I_z\otimes I (c_0|000\rangle + c_1|001\rangle + c_2|010\rangle + c_3|011\rangle) \\
&+ 2\pi j_{21} I_z\otimes I_z\otimes I (c_4|100\rangle + c_5|101\rangle + c_6|110\rangle + c_7|111\rangle) \\
&= \omega_0 (c_0 I|0\rangle I|0\rangle I_z|0\rangle + c_1 I|0\rangle I|0\rangle I_z|1\rangle + c_2 I|0\rangle I|1\rangle I_z|0\rangle) \\
&+ \omega_0 (c_3 I|0\rangle I|1\rangle I_z|1\rangle + c_4 I|1\rangle I|0\rangle I_z|0\rangle + c_5 I|1\rangle I|0\rangle I_z|1\rangle) \\
&+ \omega_0 (c_6 I|1\rangle I|1\rangle I_z|0\rangle + c_7 I|1\rangle I|1\rangle I_z|1\rangle) \\
&+ \omega_1 (c_0 I|0\rangle I_z|0\rangle I|0\rangle + c_1 I|0\rangle I_z|0\rangle I|1\rangle + c_2 I|0\rangle I_z|1\rangle I|0\rangle) \\
&+ \omega_1 (c_3 I|0\rangle I_z|1\rangle I|1\rangle + c_4 I|1\rangle I_z|0\rangle I|0\rangle + c_5 I|1\rangle I_z|0\rangle I|1\rangle) \\
&+ \omega_1 (c_6 I|1\rangle I_z|1\rangle I|0\rangle + c_7 I|1\rangle I_z|1\rangle I|1\rangle) \\
&+ \omega_2 (c_0 I_z|0\rangle I|0\rangle I|0\rangle + c_1 I_z|0\rangle I|0\rangle I|1\rangle + c_2 I_z|0\rangle I|1\rangle I|0\rangle) \\
&+ \omega_1 (c_3 I_z|0\rangle I|1\rangle I|1\rangle + c_4 I_z|1\rangle I|0\rangle I|0\rangle + c_5 I_z|1\rangle I|0\rangle I|1\rangle) \\
&+ \omega_1 (c_6 I_z|1\rangle I|1\rangle I|0\rangle + c_7 I_z|1\rangle I|1\rangle I|1\rangle) \\
&+ 2\pi J_{10} (c_0 I|0\rangle I_z|0\rangle I_z|0\rangle + c_1 I|0\rangle I_z|0\rangle I_z|1\rangle) \\
&+ 2\pi J_{10} (c_2 I|0\rangle I_z|1\rangle I_z|0\rangle + c_3 I|0\rangle I_z|1\rangle I_z|1\rangle) \\
&+ 2\pi J_{10} (c_4 I|1\rangle I_z|0\rangle I_z|0\rangle + c_5 I|1\rangle I_z|0\rangle I_z|1\rangle) \\
&+ 2\pi J_{10} (c_6 I|1\rangle I_z|1\rangle I_z|0\rangle + c_7 I|1\rangle I_z|1\rangle I_z|1\rangle)
\end{aligned}
$$

$$
\begin{aligned}
&+ 2\pi J_{20} \left(c_0 I_z \left|0\right\rangle I \left|0\right\rangle I_z \left|0\right\rangle + c_1 I_z \left|0\right\rangle I \left|0\right\rangle I_z \left|1\right\rangle + c_2 I_z \left|0\right\rangle I \left|1\right\rangle I_z \left|0\right\rangle\right)\\
&+ 2\pi J_{20} \left(c_3 I_z \left|0\right\rangle I \left|1\right\rangle I_z \left|1\right\rangle + c_4 I_z \left|1\right\rangle I \left|0\right\rangle I_z \left|0\right\rangle + c_5 I_z \left|1\right\rangle I \left|0\right\rangle I_z \left|1\right\rangle\right)\\
&+ 2\pi J_{20} \left(c_6 I_z \left|1\right\rangle I \left|1\right\rangle I_z \left|0\right\rangle + c_7 I_z \left|1\right\rangle I \left|1\right\rangle I_z \left|1\right\rangle\right)\\
&+ 2\pi J_{21} \left(c_0 I_z \left|0\right\rangle I_z \left|0\right\rangle I \left|0\right\rangle + c_1 I_z \left|0\right\rangle I_z \left|0\right\rangle I \left|1\right\rangle + c_2 I_z \left|0\right\rangle I_z \left|1\right\rangle I \left|0\right\rangle\right)\\
&+ 2\pi J_{21} \left(c_3 I_z \left|0\right\rangle I_z \left|1\right\rangle I_z \left|1\right\rangle + c_4 I_z \left|1\right\rangle I_z \left|0\right\rangle I \left|0\right\rangle + c_5 I_z \left|1\right\rangle I_z \left|0\right\rangle I \left|1\right\rangle\right)\\
&+ 2\pi J_{21} \left(c_6 I_z \left|1\right\rangle I_z \left|1\right\rangle I \left|0\right\rangle + c_7 I_z \left|1\right\rangle I_z \left|1\right\rangle I \left|1\right\rangle\right)\\
&= \omega_0 \left(c_0 \left|0\right\rangle \left|0\right\rangle \frac{1}{2} \left|0\right\rangle + c_1 \left|0\right\rangle \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle + c_2 \left|0\right\rangle \left|1\right\rangle \frac{1}{2} \left|0\right\rangle\right)\\
&+ \omega_0 \left(c_3 \left|0\right\rangle \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle + c_4 \left|1\right\rangle \left|0\right\rangle \frac{1}{2} \left|0\right\rangle + c_5 \left|1\right\rangle \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle\right)\\
&+ \omega_0 \left(c_6 \left|1\right\rangle \left|1\right\rangle \frac{1}{2} \left|0\right\rangle + c_7 \left|1\right\rangle \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle\right)\\
&+ \omega_1 \left(c_0 \left|0\right\rangle \frac{1}{2} \left|0\right\rangle \left|0\right\rangle + c_1 \left|0\right\rangle \frac{1}{2} \left|0\right\rangle \left|1\right\rangle + c_2 \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left|0\right\rangle\right)\\
&+ \omega_1 \left(c_3 \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left|1\right\rangle + c_4 \left|1\right\rangle \frac{1}{2} \left|0\right\rangle \left|0\right\rangle + c_5 \left|1\right\rangle \frac{1}{2} \left|0\right\rangle \left|1\right\rangle\right)\\
&+ \omega_1 \left(c_6 \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left|0\right\rangle + c_7 \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left|1\right\rangle\right)\\
&+ \omega_2 \left(c_0 \frac{1}{2} \left|0\right\rangle \left|0\right\rangle \left|0\right\rangle + c_1 \frac{1}{2} \left|0\right\rangle \left|0\right\rangle \left|1\right\rangle + c_2 \frac{1}{2} \left|0\right\rangle \left|1\right\rangle \left|0\right\rangle\right)\\
&+ \omega_2 \left(c_3 \frac{1}{2} \left|0\right\rangle \left|1\right\rangle \left|1\right\rangle + c_4 \left(-\frac{1}{2}\right) \left|1\right\rangle \left|0\right\rangle \left|0\right\rangle + c_5 \left(-\frac{1}{2}\right) \left|1\right\rangle \left|0\right\rangle \left|1\right\rangle\right)\\
&+ \omega_2 \left(c_6 \left(-\frac{1}{2}\right) \left|1\right\rangle \left|1\right\rangle \left|0\right\rangle + c_7 \left(-\frac{1}{2}\right) \left|1\right\rangle \left|1\right\rangle \left|1\right\rangle\right)\\
&+ 2\pi J_{10} \left(c_0 \left|0\right\rangle \frac{1}{2} \left|0\right\rangle \frac{1}{2} \left|0\right\rangle + c_1 \left|0\right\rangle \frac{1}{2} \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle + c_2 \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \frac{1}{2} \left|0\right\rangle\right)\\
&+ 2\pi J_{10} \left(c_3 \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle + c_4 \left|1\right\rangle \frac{1}{2} \left|0\right\rangle \frac{1}{2} \left|0\right\rangle + c_5 \left|1\right\rangle \frac{1}{2} \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle\right)\\
&+ 2\pi J_{10} \left(c_6 \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \frac{1}{2} \left|0\right\rangle + c_7 \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle\right)\\
&+ 2\pi J_{20} \left(c_0 \frac{1}{2} \left|0\right\rangle \left|0\right\rangle \frac{1}{2} \left|0\right\rangle + c_1 \frac{1}{2} \left|0\right\rangle \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle + c_2 \frac{1}{2} \left|0\right\rangle \left|1\right\rangle \frac{1}{2} \left|0\right\rangle\right)\\
&+ 2\pi J_{20} \left(c_3 \frac{1}{2} \left|0\right\rangle \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle + c_4 \left(-\frac{1}{2}\right) \left|1\right\rangle \left|0\right\rangle \frac{1}{2} \left|0\right\rangle + c_5 \left(-\frac{1}{2}\right) \left|1\right\rangle \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle\right)\\
&+ 2\pi J_{20} \left(c_6 \left(-\frac{1}{2}\right) \left|1\right\rangle \left|1\right\rangle \frac{1}{2} \left|0\right\rangle + c_7 \left(-\frac{1}{2}\right) \left|1\right\rangle \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle\right)\\
&+ 2\pi J_{21} \left(c_0 \frac{1}{2} \left|0\right\rangle \frac{1}{2} \left|0\right\rangle \left|0\right\rangle + c_1 \frac{1}{2} \left|0\right\rangle \frac{1}{2} \left|0\right\rangle \left|1\right\rangle + c_2 \frac{1}{2} \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left|0\right\rangle\right)\\
&+ 2\pi J_{21} \left(c_3 \frac{1}{2} \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left|1\right\rangle + c_4 \left(-\frac{1}{2}\right) \left|1\right\rangle \frac{1}{2} \left|0\right\rangle \left|0\right\rangle + c_5 \left(-\frac{1}{2}\right) \left|1\right\rangle \frac{1}{2} \left|0\right\rangle \left|1\right\rangle\right)\\
&+ 2\pi J_{21} \left(c_6 \left(-\frac{1}{2}\right) \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left|0\right\rangle + c_7 \left(-\frac{1}{2}\right) \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left|1\right\rangle\right)
\end{aligned}
$$

$$
\begin{aligned}
&= \frac{\omega_0}{2}\left(c_0\left|000\right\rangle - c_1\left|001\right\rangle + c_2\left|010\right\rangle - c_3\left|011\right\rangle\right)\\
&+ \frac{\omega_0}{2}\left(c_4\left|100\right\rangle - c_5\left|101\right\rangle + c_6\left|110\right\rangle - c_7\left|111\right\rangle\right)\\
&+ \frac{\omega_1}{2}\left(c_0\left|000\right\rangle + c_1\left|001\right\rangle - c_2\left|010\right\rangle - c_3\left|011\right\rangle\right)\\
&+ \frac{\omega_1}{2}\left(c_4\left|100\right\rangle + c_5\left|101\right\rangle - c_6\left|110\right\rangle - c_7\left|111\right\rangle\right)\\
&+ \frac{\omega_2}{2}\left(c_0\left|000\right\rangle + c_1\left|001\right\rangle + c_2\left|010\right\rangle + c_3\left|011\right\rangle\right)\\
&+ \frac{\omega_2}{2}\left(-c_4\left|100\right\rangle - c_5\left|101\right\rangle - c_6\left|110\right\rangle - c_7\left|111\right\rangle\right)\\
&+ \frac{\pi J_{10}}{2}\left(c_0\left|000\right\rangle - c_1\left|001\right\rangle - c_2\left|010\right\rangle + c_3\left|011\right\rangle\right)\\
&+ \frac{\pi J_{10}}{2}\left(c_4\left|100\right\rangle - c_5\left|101\right\rangle - c_6\left|110\right\rangle + c_7\left|111\right\rangle\right)\\
&+ \frac{\pi J_{20}}{2}\left(c_0\left|000\right\rangle - c_1\left|001\right\rangle + c_2\left|010\right\rangle - c_3\left|011\right\rangle\right)\\
&+ \frac{\pi J_{20}}{2}\left(-c_4\left|100\right\rangle + c_5\left|101\right\rangle - c_6\left|110\right\rangle + c_7\left|111\right\rangle\right)\\
&+ \frac{\pi J_{21}}{2}\left(c_0\left|000\right\rangle + c_1\left|001\right\rangle - c_2\left|010\right\rangle - c_3\left|011\right\rangle\right)\\
&+ \frac{\pi J_{21}}{2}\left(-c_4\left|100\right\rangle - c_5\left|101\right\rangle + c_6\left|110\right\rangle + c_7\left|111\right\rangle\right)\\
&= \frac{\omega_0 + \omega_1 + \omega_2 + \pi J_{10} + \pi J_{20} + \pi J_{21}}{2} c_0\left|000\right\rangle\\
&+ \frac{-\omega_0 + \omega_1 + \omega_2 - \pi J_{10} - \pi J_{20} + \pi J_{21}}{2} c_1\left|001\right\rangle\\
&+ \frac{\omega_0 - \omega_1 + \omega_2 - \pi J_{10} + \pi J_{20} - \pi J_{21}}{2} c_2\left|010\right\rangle\\
&+ \frac{-\omega_0 - \omega_1 + \omega_2 + \pi J_{10} - \pi J_{20} - \pi J_{21}}{2} c_3\left|011\right\rangle\\
&+ \frac{\omega_0 + \omega_1 - \omega_2 + \pi J_{10} - \pi J_{20} - \pi J_{21}}{2} c_4\left|100\right\rangle\\
&+ \frac{-\omega_0 + \omega_1 - \omega_2 - \pi J_{10} + \pi J_{20} - \pi J_{21}}{2} c_5\left|101\right\rangle\\
&+ \frac{\omega_0 - \omega_1 - \omega_2 - \pi J_{10} - \pi J_{20} + \pi J_{21}}{2} c_6\left|110\right\rangle\\
&+ \frac{-\omega_0 - \omega_1 - \omega_2 + \pi J_{10} + \pi J_{20} + \pi J_{21}}{2} c_7\left|111\right\rangle
\end{aligned} \tag{139}
$$

maka dengan demikian bentuk diatas sama dengan bentuk

$$
\begin{aligned}
H\left|\psi\right\rangle = {} & E_{3,0}c_0\left|000\right\rangle + E_{3,1}c_1\left|001\right\rangle + E_{3,2}c_2\left|010\right\rangle + E_{3,3}c_3\left|011\right\rangle\\
& + E_{3,4}c_4\left|100\right\rangle + E_{3,5}c_5\left|101\right\rangle + E_{3,6}c_6\left|110\right\rangle + E_{3,7}c_7\left|111\right\rangle
\end{aligned} \tag{140}
$$

sehingga dapat dibuat tabel level energi sebagai berikut:

n	$E_{3,n}$
0	$\frac{\omega_0+\omega_1+\omega_2+\pi J_{10}+\pi J_{20}+\pi J_{21}}{2}$
1	$\frac{-\omega_0+\omega_1+\omega_2-\pi J_{10}-\pi J_{20}+\pi J_{21}}{2}$
2	$\frac{\omega_0-\omega_1+\omega_2-\pi J_{10}+\pi J_{20}-\pi J_{21}}{2}$
3	$\frac{-\omega_0-\omega_1+\omega_2+\pi J_{10}-\pi J_{20}-\pi J_{21}}{2}$
4	$\frac{\omega_0+\omega_1-\omega_2+\pi J_{10}-\pi J_{20}-\pi J_{21}}{2}$
5	$\frac{-\omega_0+\omega_1-\omega_2-\pi J_{10}+\pi J_{20}-\pi J_{21}}{2}$
6	$\frac{\omega_0-\omega_1-\omega_2-\pi J_{10}-\pi J_{20}+\pi J_{21}}{2}$
7	$\frac{-\omega_0-\omega_1-\omega_2+\pi J_{10}+\pi J_{20}+\pi J_{21}}{2}$

4.2 Sistem 4 qubit

pada sistem 4 qubit, level energi dihasilkan dari interaksi 4 partikel, dimana bentuk hamiltonian dari sistem 4 qubit adalah sebagai beriktu:

$$\begin{aligned} H = {} & \omega_0 I \otimes I \otimes I \otimes I_z + \omega_1 I \otimes I \otimes I_z \otimes I + \omega_2 I \otimes I_z \otimes I \otimes I \\ & + \omega_3 I_z \otimes I \otimes I \otimes I + 2\pi J_{10} I \otimes I \otimes I_z \otimes I_z \\ & + 2\pi J_{20} I \otimes I_z \otimes I \otimes I_z 2\pi J_{30} I_z \otimes I \otimes \otimes I_z \\ & + 2\pi J_{21} I \otimes I_z \otimes I_z \otimes I + 2\pi J_{31} I_z \otimes I \otimes I_z \otimes I \\ & + 2\pi J_{32} I_z \otimes I_z \otimes I \otimes I \end{aligned} \tag{141}$$

sedangkan vektor keadaan untuk 4 qubit adalah sebagai berikut:

$$\begin{aligned} |\psi\rangle = {} & c_0 |0000\rangle + c_1 |0001\rangle + c_2 |0010\rangle \\ & + c_3 |0011\rangle + c_4 |0100\rangle + c_5 |0101\rangle \\ & + c_6 |0110\rangle + c_7 |0111\rangle + c_8 |1000\rangle + \\ & + c_9 |1001\rangle + c_{10} |1010\rangle + c_{11} |1011\rangle \\ & + c_{12} |1100\rangle + c_{13} |1101\rangle + c_{14} |1110\rangle \\ & + c_{15} |1111\rangle \end{aligned} \tag{142}$$

kemudian dilakukan operasi berikut:

$$
\begin{aligned}
H|\psi\rangle &= \omega_0 I \otimes I \otimes I \otimes I_z |\psi\rangle \\
&+ \omega_1 I \otimes I \otimes I_z \otimes I |\psi\rangle \\
&+ \omega_2 I \otimes I_z \otimes I \otimes I |\psi\rangle \\
&+ \omega_3 I_z \otimes I \otimes I \otimes I |\psi\rangle \\
&+ 2\pi J_{10} I \otimes I \otimes I_z \otimes I_z |\psi\rangle \\
&+ 2\pi J_{20} I \otimes I_z \otimes I \otimes I_z |\psi\rangle \\
&+ 2\pi J_{30} I_z \otimes I \otimes \otimes I_z |\psi\rangle \\
&+ 2\pi J_{21} I \otimes I_z \otimes I_z \otimes I |\psi\rangle \\
&+ 2\pi J_{31} I_z \otimes I \otimes I_z \otimes I |\psi\rangle \\
&+ 2\pi J_{32} I_z \otimes I_z \otimes I \otimes I |\psi\rangle \\
&= \omega_0 \left(c_0 I|0\rangle I|0\rangle I|0\rangle I_z|0\rangle + c_1 I|0\rangle I|0\rangle I|0\rangle I_z|1\rangle \right) \\
&+ \omega_0 \left(c_2 I|0\rangle I|0\rangle I|1\rangle I_z|0\rangle + c_3 I|0\rangle I|0\rangle I|1\rangle I_z|1\rangle \right) \\
&+ \omega_0 \left(c_4 I|0\rangle I|1\rangle I|0\rangle I_z|0\rangle + c_5 I|0\rangle I|1\rangle I|1\rangle I_z|1\rangle \right) \\
&+ \omega_0 \left(c_6 I|0\rangle I|1\rangle I|1\rangle I_z|1\rangle + c_7 I|1\rangle I|0\rangle I|0\rangle I_z|0\rangle \right) \\
&+ \omega_0 \left(c_8 I|1\rangle I|0\rangle I|0\rangle I_z|1\rangle + c_9 I|1\rangle I|0\rangle I|1\rangle I_z|0\rangle \right) \\
&+ \omega_0 \left(c_{10} I|1\rangle I|0\rangle I|1\rangle I_z|1\rangle + c_{11} I|1\rangle I|1\rangle I|0\rangle I_z|0\rangle \right) \\
&+ \omega_0 \left(c_{12} I|1\rangle I|1\rangle I|0\rangle I_z|1\rangle + c_{13} I|1\rangle I|1\rangle I|0\rangle I_z|1\rangle \right) \\
&+ \omega_0 \left(c_{14} I|1\rangle I|1\rangle I|1\rangle I_z|0\rangle + c_{15} I|1\rangle I|1\rangle I|1\rangle I_z|1\rangle \right) \\
&+ \omega_1 \left(c_0 I|0\rangle I|0\rangle I_z|0\rangle I|0\rangle + c_1 I|0\rangle I|0\rangle I_z|0\rangle I|1\rangle \right) \\
&+ \omega_1 \left(c_2 I|0\rangle I|0\rangle I_z|1\rangle I|0\rangle + c_3 I|0\rangle I|0\rangle I_z|1\rangle I|1\rangle \right) \\
&+ \omega_1 \left(c_4 I|0\rangle I|1\rangle I_z|0\rangle I|0\rangle + c_5 I|0\rangle I|1\rangle I_z|1\rangle I|1\rangle \right) \\
&+ \omega_1 \left(c_6 I|0\rangle I|1\rangle I_z|1\rangle I|1\rangle + c_7 I|1\rangle I|0\rangle I_z|0\rangle I|0\rangle \right) \\
&+ \omega_1 \left(c_8 I|1\rangle I|0\rangle I_z|0\rangle I|1\rangle + c_9 I|1\rangle I|0\rangle I_z|1\rangle I|0\rangle \right) \\
&+ \omega_1 \left(c_{10} I|1\rangle I|0\rangle I_z|1\rangle I|1\rangle + c_{11} I|1\rangle I|1\rangle I_z|0\rangle I|0\rangle \right) \\
&+ \omega_1 \left(c_{12} I|1\rangle I|1\rangle I_z|0\rangle I|1\rangle + c_{13} I|1\rangle I|1\rangle I_z|0\rangle I|1\rangle \right) \\
&+ \omega_1 \left(c_{14} I|1\rangle I|1\rangle I|1\rangle I|0\rangle + c_{15} I|1\rangle I|1\rangle I_z|1\rangle I|1\rangle \right)
\end{aligned}
$$

$$+\,\omega_2\left(c_0I\left|0\right\rangle I_z\left|0\right\rangle I\left|0\right\rangle I\left|0\right\rangle + c_1I\left|0\right\rangle I_z\left|0\right\rangle I\left|0\right\rangle I\left|1\right\rangle\right)$$
$$+\,\omega_2\left(c_2I\left|0\right\rangle I_z\left|0\right\rangle I\left|1\right\rangle I\left|0\right\rangle + c_3I\left|0\right\rangle I_z\left|0\right\rangle I\left|1\right\rangle I\left|1\right\rangle\right)$$
$$+\,\omega_2\left(c_4I\left|0\right\rangle I_z\left|1\right\rangle I\left|0\right\rangle I\left|0\right\rangle + c_5I\left|0\right\rangle I_z\left|1\right\rangle I\left|1\right\rangle I\left|1\right\rangle\right)$$
$$+\,\omega_2\left(c_6I\left|0\right\rangle I_z\left|1\right\rangle I\left|1\right\rangle I\left|1\right\rangle + c_7I\left|1\right\rangle I_z\left|0\right\rangle I\left|0\right\rangle I\left|0\right\rangle\right)$$
$$+\,\omega_2\left(c_8I\left|1\right\rangle I_z\left|0\right\rangle I\left|0\right\rangle I\left|1\right\rangle + c_9I\left|1\right\rangle I_z\left|0\right\rangle I\left|1\right\rangle I\left|0\right\rangle\right)$$
$$+\,\omega_2\left(c_{10}I\left|1\right\rangle I_z\left|0\right\rangle I\left|1\right\rangle I\left|1\right\rangle + c_{11}I\left|1\right\rangle I_z\left|1\right\rangle I\left|0\right\rangle I\left|0\right\rangle\right)$$
$$+\,\omega_2\left(c_{12}I\left|1\right\rangle I_z\left|1\right\rangle I\left|0\right\rangle I\left|1\right\rangle + c_{13}I\left|1\right\rangle I_z\left|1\right\rangle I\left|0\right\rangle I\left|1\right\rangle\right)$$
$$+\,\omega_2\left(c_{14}I\left|1\right\rangle I_z\left|1\right\rangle I\left|1\right\rangle I\left|0\right\rangle + c_{15}I\left|1\right\rangle I_z\left|1\right\rangle I\left|1\right\rangle I\left|1\right\rangle\right)$$
$$+\,\omega_3\left(c_0I_z\left|0\right\rangle I\left|0\right\rangle I\left|0\right\rangle I\left|0\right\rangle + c_1I_z\left|0\right\rangle I\left|0\right\rangle I\left|0\right\rangle I\left|1\right\rangle\right)$$
$$+\,\omega_3\left(c_2I_z\left|0\right\rangle I\left|0\right\rangle I\left|1\right\rangle I\left|0\right\rangle + c_3I_z\left|0\right\rangle I\left|0\right\rangle I\left|1\right\rangle I\left|1\right\rangle\right)$$
$$+\,\omega_3\left(c_4I_z\left|0\right\rangle I\left|1\right\rangle I\left|0\right\rangle I\left|0\right\rangle + c_5I_z\left|0\right\rangle I\left|1\right\rangle I\left|1\right\rangle I\left|1\right\rangle\right)$$
$$+\,\omega_3\left(c_6I_z\left|0\right\rangle I\left|1\right\rangle I\left|1\right\rangle I\left|1\right\rangle + c_7I_z\left|1\right\rangle I\left|0\right\rangle I\left|0\right\rangle I\left|0\right\rangle\right)$$
$$+\,\omega_3\left(c_8I_z\left|1\right\rangle I\left|0\right\rangle I\left|0\right\rangle I\left|1\right\rangle + c_9I_z\left|1\right\rangle I\left|0\right\rangle I\left|1\right\rangle I\left|0\right\rangle\right)$$
$$+\,\omega_3\left(c_{10}I_z\left|1\right\rangle I\left|0\right\rangle I\left|1\right\rangle I\left|1\right\rangle + c_{11}I_z\left|1\right\rangle I\left|1\right\rangle I\left|0\right\rangle I\left|0\right\rangle\right)$$
$$+\,\omega_1\left(c_{12}I_z\left|1\right\rangle I\left|1\right\rangle I\left|0\right\rangle I\left|1\right\rangle + c_{13}I_z\left|1\right\rangle I\left|1\right\rangle I\left|0\right\rangle I_z\left|1\right\rangle\right)$$
$$+\,\omega_3\left(c_{14}I_z\left|1\right\rangle I\left|1\right\rangle I\left|1\right\rangle I\left|0\right\rangle + c_{15}I_z\left|1\right\rangle I\left|1\right\rangle I\left|1\right\rangle I\left|1\right\rangle\right)$$
$$+\,2\pi J_{10}\left(c_0I\left|0\right\rangle I\left|0\right\rangle I_z\left|0\right\rangle I_z\left|0\right\rangle + c_1I\left|0\right\rangle I\left|0\right\rangle I_z\left|0\right\rangle I_z\left|1\right\rangle\right)$$
$$+\,2\pi J_{10}\left(c_2I\left|0\right\rangle I\left|0\right\rangle I_z\left|1\right\rangle I_z\left|0\right\rangle + c_3I\left|0\right\rangle I\left|0\right\rangle I_z\left|1\right\rangle I_z\left|1\right\rangle\right)$$
$$+\,2\pi J_{10}\left(c_4I\left|0\right\rangle I\left|1\right\rangle I_z\left|0\right\rangle I_z\left|0\right\rangle + c_5I\left|0\right\rangle I\left|1\right\rangle I_z\left|1\right\rangle I_z\left|1\right\rangle\right)$$
$$+\,2\pi J_{10}\left(c_6I\left|0\right\rangle I\left|1\right\rangle I_z\left|1\right\rangle I_z\left|1\right\rangle + c_7I\left|1\right\rangle I\left|0\right\rangle I_z\left|0\right\rangle I_z\left|0\right\rangle\right)$$
$$+\,2\pi J_{10}\left(c_8I\left|1\right\rangle I\left|0\right\rangle I_z\left|0\right\rangle I_z\left|1\right\rangle + c_9I\left|1\right\rangle I\left|0\right\rangle I_z\left|1\right\rangle I_z\left|0\right\rangle\right)$$
$$+\,2\pi J_{10}\left(c_{10}I\left|1\right\rangle I\left|0\right\rangle I_z\left|1\right\rangle I_z\left|1\right\rangle + c_{11}I\left|1\right\rangle I\left|1\right\rangle I_z\left|0\right\rangle I_z\left|0\right\rangle\right)$$
$$+\,2\pi J_{10}\left(c_{12}I\left|1\right\rangle I\left|1\right\rangle I_z\left|0\right\rangle I_z\left|1\right\rangle + c_{13}I\left|1\right\rangle I\left|1\right\rangle I_z\left|0\right\rangle I_z\left|1\right\rangle\right)$$
$$+\,2\pi J_{10}\left(c_{14}I\left|1\right\rangle I\left|1\right\rangle I_z\left|1\right\rangle I_z\left|0\right\rangle + c_{15}I\left|1\right\rangle I\left|1\right\rangle I\left|1\right\rangle I\left|1\right\rangle\right)$$

$$
\begin{aligned}
&+ 2\pi J_{20} \left(c_0 I \left|0\right\rangle I_z \left|0\right\rangle I \left|0\right\rangle I_z \left|0\right\rangle + c_1 I \left|0\right\rangle I_z \left|0\right\rangle I \left|0\right\rangle I_z \left|1\right\rangle\right) \\
&+ 2\pi J_{20} \left(c_2 I \left|0\right\rangle I_z \left|0\right\rangle I \left|1\right\rangle I_z \left|0\right\rangle + c_3 I \left|0\right\rangle I_z \left|0\right\rangle I \left|1\right\rangle I_z \left|1\right\rangle\right) \\
&+ 2\pi J_{20} \left(c_4 I \left|0\right\rangle I_z \left|1\right\rangle I \left|0\right\rangle I_z \left|0\right\rangle + c_5 I \left|0\right\rangle I_z \left|1\right\rangle I \left|1\right\rangle I_z \left|1\right\rangle\right) \\
&+ 2\pi J_{20} \left(c_6 I \left|0\right\rangle I_z \left|1\right\rangle I \left|1\right\rangle I_z \left|1\right\rangle + c_7 I \left|1\right\rangle I_z \left|0\right\rangle I \left|0\right\rangle I_z \left|0\right\rangle\right) \\
&+ 2\pi J_{20} \left(c_8 I \left|1\right\rangle I_z \left|0\right\rangle I \left|0\right\rangle I_z \left|1\right\rangle + c_9 I \left|1\right\rangle I_z \left|0\right\rangle I \left|1\right\rangle I_z \left|0\right\rangle\right) \\
&+ 2\pi J_{20} \left(c_{10} I \left|1\right\rangle I_z \left|0\right\rangle I \left|1\right\rangle I_z \left|1\right\rangle + c_{11} I \left|1\right\rangle I_z \left|1\right\rangle I \left|0\right\rangle I_z \left|0\right\rangle\right) \\
&+ 2\pi J_{20} \left(c_{12} I \left|1\right\rangle I_z \left|1\right\rangle I \left|0\right\rangle I_z \left|1\right\rangle + c_{13} I \left|1\right\rangle I_z \left|1\right\rangle I \left|0\right\rangle I_z \left|1\right\rangle\right) \\
&+ +2\pi J_{20} \left(c_{14} I \left|1\right\rangle I_z \left|1\right\rangle I \left|1\right\rangle I_z \left|0\right\rangle + c_{15} I \left|1\right\rangle I_z \left|1\right\rangle I \left|1\right\rangle I_z \left|1\right\rangle\right) \\
&+ 2\pi J_{30} \left(c_0 I_z \left|0\right\rangle I \left|0\right\rangle I \left|0\right\rangle I_z \left|0\right\rangle + c_1 I_z \left|0\right\rangle I \left|0\right\rangle I \left|0\right\rangle I_z \left|1\right\rangle\right) \\
&+ 2\pi J_{30} \left(c_2 I_z \left|0\right\rangle I \left|0\right\rangle I \left|1\right\rangle I_z \left|0\right\rangle + c_3 I_z \left|0\right\rangle I \left|0\right\rangle I \left|1\right\rangle I_z \left|1\right\rangle\right) \\
&+ 2\pi J_{30} \left(c_4 I_z \left|0\right\rangle I \left|1\right\rangle I \left|0\right\rangle I_z \left|0\right\rangle + c_5 I_z \left|0\right\rangle I \left|1\right\rangle I \left|1\right\rangle I_z \left|1\right\rangle\right) \\
&+ 2\pi J_{30} \left(c_6 I_z \left|0\right\rangle I \left|1\right\rangle I \left|1\right\rangle I_z \left|1\right\rangle + c_7 I_z \left|1\right\rangle I \left|0\right\rangle I \left|0\right\rangle I_z \left|0\right\rangle\right) \\
&+ 2\pi J_{30} \left(c_8 I_z \left|1\right\rangle I \left|0\right\rangle I \left|0\right\rangle I_z \left|1\right\rangle + c_9 I_z \left|1\right\rangle I \left|0\right\rangle I \left|1\right\rangle I_z \left|0\right\rangle\right) \\
&+ 2\pi J_{30} \left(c_{10} I_z \left|1\right\rangle I \left|0\right\rangle I \left|1\right\rangle I_z \left|1\right\rangle + c_{11} I_z \left|1\right\rangle I \left|1\right\rangle I \left|0\right\rangle I_z \left|0\right\rangle\right) \\
&+ 2\pi J_{30} \left(c_{12} I_z \left|1\right\rangle I \left|1\right\rangle I \left|0\right\rangle I_z \left|1\right\rangle + c_{13} I_z \left|1\right\rangle I \left|1\right\rangle I \left|0\right\rangle I_z \left|1\right\rangle\right) \\
&+ 2\pi J_{30} \left(c_{14} I_z \left|1\right\rangle I \left|1\right\rangle I \left|1\right\rangle I_z \left|0\right\rangle + c_{15} I_z \left|1\right\rangle I \left|1\right\rangle I \left|1\right\rangle I_z \left|1\right\rangle\right) \\
&+ 2\pi J_{21} \left(c_0 I \left|0\right\rangle I_z \left|0\right\rangle I_z \left|0\right\rangle I \left|0\right\rangle + c_1 I \left|0\right\rangle I_z \left|0\right\rangle I_z \left|0\right\rangle I \left|1\right\rangle\right) \\
&+ 2\pi J_{21} \left(c_2 I \left|0\right\rangle I_z \left|0\right\rangle I_z \left|1\right\rangle I \left|0\right\rangle + c_3 I \left|0\right\rangle I_z \left|0\right\rangle I_z \left|1\right\rangle I \left|1\right\rangle\right) \\
&+ 2\pi J_{21} \left(c_4 I \left|0\right\rangle I_z \left|1\right\rangle I_z \left|0\right\rangle I \left|0\right\rangle + c_5 I \left|0\right\rangle I \left|1\right\rangle I \left|1\right\rangle I \left|1\right\rangle\right) \\
&+ 2\pi J_{21} \left(c_6 I \left|0\right\rangle I_z \left|1\right\rangle I_z \left|1\right\rangle I \left|1\right\rangle + c_7 I \left|1\right\rangle I_z \left|0\right\rangle I_z \left|0\right\rangle I \left|0\right\rangle\right) \\
&+ 2\pi J_{21} \left(c_8 I \left|1\right\rangle I_z \left|0\right\rangle I_z \left|0\right\rangle I \left|1\right\rangle + c_9 I \left|1\right\rangle I_z \left|0\right\rangle I_z \left|1\right\rangle I \left|0\right\rangle\right) \\
&+ 2\pi J_{21} \left(c_{10} I \left|1\right\rangle I \left|0\right\rangle I_z \left|1\right\rangle I_z \left|1\right\rangle + c_{11} I \left|1\right\rangle I_z \left|1\right\rangle I_z \left|0\right\rangle I \left|0\right\rangle\right) \\
&+ 2\pi J_{21} \left(c_{12} I \left|1\right\rangle I_z \left|1\right\rangle I_z \left|0\right\rangle I \left|1\right\rangle + c_{13} I \left|1\right\rangle I_z \left|1\right\rangle I \left|0\right\rangle I_z \left|1\right\rangle\right) \\
&+ 2\pi J_{21} \left(c_{14} I \left|1\right\rangle I \left|1\right\rangle I \left|1\right\rangle I \left|0\right\rangle + c_{15} I \left|1\right\rangle I_z \left|1\right\rangle I_z \left|1\right\rangle I \left|1\right\rangle\right)
\end{aligned}
$$

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\begin{aligned}
&+ 2\pi J_{31} \left(c_0 I_z \left|0\right\rangle I \left|0\right\rangle I_z \left|0\right\rangle I \left|0\right\rangle + c_1 I_z \left|0\right\rangle I \left|0\right\rangle I_z \left|0\right\rangle I \left|1\right\rangle\right)\\
&+ 2\pi J_{31} \left(c_2 I_z \left|0\right\rangle I \left|0\right\rangle I_z \left|1\right\rangle I \left|0\right\rangle + c_3 I_z \left|0\right\rangle I \left|0\right\rangle I_z \left|1\right\rangle I \left|1\right\rangle\right)\\
&+ 2\pi J_{31} \left(c_4 I_z \left|0\right\rangle I \left|1\right\rangle I_z \left|0\right\rangle I \left|0\right\rangle + c_5 I_z \left|0\right\rangle I \left|1\right\rangle I_z \left|1\right\rangle I \left|1\right\rangle\right)\\
&+ 2\pi J_{31} \left(c_6 I_z \left|0\right\rangle I \left|1\right\rangle I_z \left|1\right\rangle I \left|1\right\rangle + c_7 I_z \left|1\right\rangle I \left|0\right\rangle I_z \left|0\right\rangle I \left|0\right\rangle\right)\\
&+ 2\pi J_{31} \left(c_8 I_z \left|1\right\rangle I \left|0\right\rangle I_z \left|0\right\rangle I \left|1\right\rangle + c_9 I_z \left|1\right\rangle I \left|0\right\rangle I_z \left|1\right\rangle I \left|0\right\rangle\right)\\
&+ 2\pi J_{31} \left(c_{10} I_z \left|1\right\rangle I \left|0\right\rangle I_z \left|1\right\rangle I \left|1\right\rangle + c_{11} I_z \left|1\right\rangle I \left|1\right\rangle I_z \left|0\right\rangle I \left|0\right\rangle\right)\\
&+ 2\pi J_{31} \left(c_{12} I_z \left|1\right\rangle I \left|1\right\rangle I_z \left|0\right\rangle I \left|1\right\rangle + c_{13} I_z \left|1\right\rangle I \left|1\right\rangle I_z \left|0\right\rangle I \left|1\right\rangle\right)\\
&+ 2\pi J_{31} \left(c_{14} I_z \left|1\right\rangle I \left|1\right\rangle I_z \left|1\right\rangle I \left|0\right\rangle + c_{15} I_z \left|1\right\rangle I \left|1\right\rangle I_z \left|1\right\rangle I \left|1\right\rangle\right)\\
&+ 2\pi J_{32} \left(c_0 I_z \left|0\right\rangle I_z \left|0\right\rangle I \left|0\right\rangle I \left|0\right\rangle + c_1 I_z \left|0\right\rangle I_z \left|0\right\rangle I \left|0\right\rangle I \left|1\right\rangle\right)\\
&+ 2\pi J_{32} \left(c_2 I_z \left|0\right\rangle I_z \left|0\right\rangle I \left|1\right\rangle I \left|0\right\rangle + c_3 I_z \left|0\right\rangle I_z \left|0\right\rangle I \left|1\right\rangle I \left|1\right\rangle\right)\\
&+ 2\pi J_{32} \left(c_4 I_z \left|0\right\rangle I_z \left|1\right\rangle I \left|0\right\rangle I \left|0\right\rangle + c_5 I_z \left|0\right\rangle I_z \left|1\right\rangle I \left|1\right\rangle I \left|1\right\rangle\right)\\
&+ 2\pi J_{32} \left(c_6 I_z \left|0\right\rangle I_z \left|1\right\rangle I \left|1\right\rangle I \left|1\right\rangle + c_7 I_z \left|1\right\rangle I_z \left|0\right\rangle I \left|0\right\rangle I \left|0\right\rangle\right)\\
&+ 2\pi J_{32} \left(c_8 I_z \left|1\right\rangle I_z \left|0\right\rangle I \left|0\right\rangle I \left|1\right\rangle + c_9 I_z \left|1\right\rangle I_z \left|0\right\rangle I \left|1\right\rangle I \left|0\right\rangle\right)\\
&+ 2\pi J_{32} \left(c_{10} I_z \left|1\right\rangle I_z \left|0\right\rangle I \left|1\right\rangle I \left|1\right\rangle + c_{11} I_z \left|1\right\rangle I_z \left|1\right\rangle I \left|0\right\rangle I \left|0\right\rangle\right)\\
&+ 2\pi J_{32} \left(c_{12} I_z \left|1\right\rangle I_z \left|1\right\rangle I \left|0\right\rangle I \left|1\right\rangle + c_{13} I_z \left|1\right\rangle I_z \left|1\right\rangle I \left|0\right\rangle I \left|1\right\rangle\right)\\
&+ 2\pi J_{32} \left(c_{14} I_z \left|1\right\rangle I \left|1\right\rangle I_z \left|1\right\rangle I \left|0\right\rangle + c_{15} I_z \left|1\right\rangle I_z \left|1\right\rangle I \left|1\right\rangle I \left|1\right\rangle\right)
\end{aligned}
$$

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\begin{aligned}
&= \omega_0 \left(c_0 \left|0\right\rangle \left|0\right\rangle \left|0\right\rangle \frac{1}{2} \left|0\right\rangle + c_1 \left|0\right\rangle \left|0\right\rangle \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle + c_2 \left|0\right\rangle \left|0\right\rangle \left|1\right\rangle \frac{1}{2} \left|0\right\rangle \right) \\
&+ \omega_0 \left(c_3 \left|0\right\rangle \left|0\right\rangle \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle + c_4 \left|0\right\rangle \left|1\right\rangle \left|0\right\rangle \frac{1}{2} \left|0\right\rangle + c_5 \left|0\right\rangle \left|1\right\rangle \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \right) \\
&+ \omega_0 \left(c_6 \left|0\right\rangle \left|1\right\rangle \left|1\right\rangle \frac{1}{2} \left|0\right\rangle + c_7 \left|0\right\rangle \left|1\right\rangle \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle + c_8 \left|1\right\rangle \left|0\right\rangle \left|0\right\rangle \frac{1}{2} \left|0\right\rangle \right) \\
&+ \omega_0 \left(c_9 \left|1\right\rangle \left|0\right\rangle \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle + c_{10} \left|1\right\rangle \left|0\right\rangle \left|1\right\rangle \frac{1}{2} \left|0\right\rangle + c_{11} \left|1\right\rangle \left|0\right\rangle \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \right) \\
&+ \omega_0 \left(c_{12} \left|1\right\rangle \left|1\right\rangle \left|0\right\rangle \frac{1}{2} \left|0\right\rangle + c_{13} \left|1\right\rangle \left|1\right\rangle \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle + c_{14} \left|1\right\rangle \left|1\right\rangle \left|1\right\rangle \frac{1}{2} \left|0\right\rangle \right) \\
&+ \omega_0 \left(c_{15} \left|1\right\rangle \left|1\right\rangle \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \right) \\
&+ \omega_1 \left(c_0 \left|0\right\rangle \left|0\right\rangle \frac{1}{2} \left|0\right\rangle \left|0\right\rangle + c_1 \left|0\right\rangle \left|0\right\rangle \frac{1}{2} \left|0\right\rangle \left|1\right\rangle + c_2 \left|0\right\rangle \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left|0\right\rangle \right) \\
&+ \omega_1 \left(c_3 \left|0\right\rangle \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left|1\right\rangle + c_4 \left|0\right\rangle \left|1\right\rangle \frac{1}{2} \left|0\right\rangle \left|0\right\rangle + c_5 \left|0\right\rangle \left|1\right\rangle \frac{1}{2} \left|0\right\rangle \left|1\right\rangle \right) \\
&+ \omega_1 \left(c_6 \left|0\right\rangle \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left|0\right\rangle + c_7 \left|0\right\rangle \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left|1\right\rangle + c_8 \left|1\right\rangle \left|0\right\rangle \frac{1}{2} \left|0\right\rangle \left|0\right\rangle \right) \\
&+ \omega_1 \left(c_9 \left|1\right\rangle \left|0\right\rangle \frac{1}{2} \left|0\right\rangle \left|1\right\rangle + c_{10} \left|1\right\rangle \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left|0\right\rangle + c_{11} \left|1\right\rangle \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left|1\right\rangle \right) \\
&+ \omega_1 \left(c_{12} \left|1\right\rangle \left|1\right\rangle \frac{1}{2} \left|0\right\rangle \left|0\right\rangle + c_{13} \left|1\right\rangle \left|1\right\rangle \frac{1}{2} \left|0\right\rangle \left|1\right\rangle + c_{14} \left|1\right\rangle \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left|0\right\rangle \right) \\
&+ \omega_1 \left(c_{15} \left|1\right\rangle \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left|1\right\rangle \right) \\
&+ \omega_2 \left(c_0 \left|0\right\rangle \frac{1}{2} \left|0\right\rangle \left|0\right\rangle \left|0\right\rangle + c_1 \left|0\right\rangle \frac{1}{2} \left|0\right\rangle \left|0\right\rangle \left|1\right\rangle + c_2 \left|0\right\rangle \frac{1}{2} \left|0\right\rangle \left|1\right\rangle \left|0\right\rangle \right) \\
&+ \omega_2 \left(c_3 \left|0\right\rangle \frac{1}{2} \left|0\right\rangle \left|1\right\rangle \left|1\right\rangle + c_4 \frac{1}{2} \left|0\right\rangle \left|1\right\rangle \left|0\right\rangle \left|0\right\rangle + c_5 \left|0\right\rangle \frac{1}{2} \left|1\right\rangle \left|0\right\rangle \left|1\right\rangle \right) \\
&+ \omega_2 \left(c_6 \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left|1\right\rangle \left|0\right\rangle + c_7 \left|0\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left|1\right\rangle \left|1\right\rangle + c_8 \left|1\right\rangle \frac{1}{2} \left|0\right\rangle \left|0\right\rangle \left|0\right\rangle \right) \\
&+ \omega_2 \left(c_9 \left|1\right\rangle \frac{1}{2} \left|0\right\rangle \left|0\right\rangle \left|1\right\rangle + c_{10} \left|1\right\rangle \frac{1}{2} \left|0\right\rangle \left|1\right\rangle \left|0\right\rangle + c_{11} \left|1\right\rangle \frac{1}{2} \left|0\right\rangle \left|1\right\rangle \left|1\right\rangle \right) \\
&+ \omega_2 \left(c_{12} \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left|0\right\rangle \left|0\right\rangle + c_{13} \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left|0\right\rangle \left|1\right\rangle + c_{14} \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left|1\right\rangle \left|0\right\rangle \right) \\
&+ \omega_2 \left(c_{15} \left|1\right\rangle \left(-\frac{1}{2}\right) \left|1\right\rangle \left|1\right\rangle \left|1\right\rangle \right) \\
&+ \omega_3 \left(c_0 \frac{1}{2} \left|0\right\rangle \left|0\right\rangle \left|0\right\rangle \left|0\right\rangle + c_1 \frac{1}{2} \left|0\right\rangle \left|0\right\rangle \left|0\right\rangle \left|1\right\rangle + c_2 \frac{1}{2} \left|0\right\rangle \left|0\right\rangle \left|1\right\rangle \left|0\right\rangle \right) \\
&+ \omega_3 \left(c_3 \frac{1}{2} \left|0\right\rangle \left|0\right\rangle \left|1\right\rangle \left|1\right\rangle + c_4 \frac{1}{2} \left|0\right\rangle \left|1\right\rangle \left|0\right\rangle \left|0\right\rangle + c_5 \frac{1}{2} \left|0\right\rangle \left|1\right\rangle \left|0\right\rangle \left|1\right\rangle \right) \\
&+ \omega_3 \left(c_6 \frac{1}{2} \left|0\right\rangle \left|1\right\rangle \left|1\right\rangle \left|0\right\rangle + c_7 \frac{1}{2} \left|0\right\rangle \left|1\right\rangle \left|1\right\rangle \left|1\right\rangle + c_8 \left(-\frac{1}{2}\right) \left|1\right\rangle \left|0\right\rangle \left|0\right\rangle \left|0\right\rangle \right) \\
&+ \omega_3 \left(c_9 \left(-\frac{1}{2}\right) \left|1\right\rangle \left|0\right\rangle \left|0\right\rangle \left|1\right\rangle + c_{10} \left(-\frac{1}{2}\right) \left|1\right\rangle \left|0\right\rangle \left|1\right\rangle \left|0\right\rangle + c_{11} \left(-\frac{1}{2}\right) \left|1\right\rangle \left|0\right\rangle \left|1\right\rangle \left|1\right\rangle \right)
\end{aligned}
$$

$$+ \omega_3 \left(c_{12} \left(-\frac{1}{2}\right) |1\rangle |1\rangle |0\rangle |0\rangle + c_{13} \left(-\frac{1}{2}\right) |1\rangle |1\rangle |0\rangle |1\rangle + c_{14} \left(-\frac{1}{2}\right) |1\rangle |1\rangle |1\rangle |0\rangle \right)$$
$$+ \omega_3 \left(c_{15} \left(-\frac{1}{2}\right) |1\rangle |1\rangle |1\rangle |1\rangle \right)$$
$$+ 2\pi J_{10} \left(c_0 |0\rangle |0\rangle \frac{1}{2} |0\rangle \frac{1}{2} |0\rangle + c_1 |0\rangle |0\rangle \frac{1}{2} |0\rangle \left(-\frac{1}{2}\right) |1\rangle + c_2 |0\rangle |0\rangle \left(-\frac{1}{2}\right) |1\rangle \frac{1}{2} |0\rangle \right)$$
$$+ 2\pi J_{10} \left(c_3 |0\rangle |0\rangle \frac{1}{2} |1\rangle \left(-\frac{1}{2}\right) |1\rangle + c_4 |0\rangle |1\rangle \frac{1}{2} |0\rangle \frac{1}{2} |0\rangle + c_5 |0\rangle |1\rangle \frac{1}{2} |0\rangle \left(-\frac{1}{2}\right) |1\rangle \right)$$
$$+ 2\pi J_{10} \left(c_6 |0\rangle |1\rangle \left(-\frac{1}{2}\right) |1\rangle \frac{1}{2} |0\rangle + c_7 |0\rangle |1\rangle \left(-\frac{1}{2}\right) |1\rangle \left(-\frac{1}{2}\right) |1\rangle + c_8 |1\rangle |0\rangle \frac{1}{2} |0\rangle \frac{1}{2} |0\rangle \right)$$
$$+ 2\pi J_{10} \left(c_9 |1\rangle |0\rangle \frac{1}{2} |0\rangle \left(-\frac{1}{2}\right) |1\rangle + c_{10} |1\rangle |0\rangle \left(-\frac{1}{2}\right) |1\rangle \frac{1}{2} |0\rangle + c_{11} |1\rangle |0\rangle \left(-\frac{1}{2}\right) |1\rangle \left(-\frac{1}{2}\right) |1\rangle \right)$$
$$+ 2\pi J_{10} \left(c_{12} |1\rangle |1\rangle \frac{1}{2} |0\rangle \frac{1}{2} |0\rangle + c_{13} |1\rangle |1\rangle \frac{1}{2} |0\rangle \left(-\frac{1}{2}\right) |1\rangle + c_{14} |1\rangle |1\rangle \left(-\frac{1}{2}\right) |1\rangle \frac{1}{2} |0\rangle \right)$$
$$+ 2\pi J_{10} \left(c_{15} |1\rangle |1\rangle \left(-\frac{1}{2}\right) |1\rangle \left(-\frac{1}{2}\right) |1\rangle \right)$$
$$+ 2\pi J_{20} \left(c_0 |0\rangle \frac{1}{2} |0\rangle |0\rangle \frac{1}{2} |0\rangle + c_1 |0\rangle \frac{1}{2} |0\rangle |0\rangle \left(-\frac{1}{2}\right) |1\rangle + c_2 |0\rangle \frac{1}{2} |0\rangle |1\rangle \frac{1}{2} |0\rangle \right)$$
$$+ 2\pi J_{20} \left(c_3 |0\rangle \frac{1}{2} |0\rangle |1\rangle \left(-\frac{1}{2}\right) |1\rangle + c_4 |0\rangle \left(-\frac{1}{2}\right) |1\rangle |0\rangle \frac{1}{2} |0\rangle + c_5 |0\rangle \left(-\frac{1}{2}\right) |1\rangle |0\rangle \left(-\frac{1}{2}\right) |1\rangle \right)$$
$$+ 2\pi J_{20} \left(c_6 |0\rangle \left(-\frac{1}{2}\right) |1\rangle |1\rangle \frac{1}{2} |0\rangle + c_7 |0\rangle \left(-\frac{1}{2}\right) |1\rangle |1\rangle \left(-\frac{1}{2}\right) |1\rangle + c_8 |1\rangle \frac{1}{2} |0\rangle |0\rangle \frac{1}{2} |0\rangle \right)$$
$$+ 2\pi J_{20} \left(c_9 |1\rangle \frac{1}{2} |0\rangle |0\rangle \left(-\frac{1}{2}\right) |1\rangle + c_{10} |1\rangle \frac{1}{2} |0\rangle |1\rangle \frac{1}{2} |0\rangle + c_{11} |1\rangle \frac{1}{2} |0\rangle |1\rangle \left(-\frac{1}{2}\right) |1\rangle \right)$$
$$+ 2\pi J_{20} \left(c_{12} |1\rangle \left(-\frac{1}{2}\right) |1\rangle |0\rangle \frac{1}{2} |0\rangle + c_{13} |1\rangle \left(-\frac{1}{2}\right) |1\rangle |0\rangle \left(-\frac{1}{2}\right) |1\rangle + c_{14} |1\rangle \left(-\frac{1}{2}\right) |1\rangle |1\rangle \frac{1}{2} |0\rangle \right)$$
$$+ 2\pi J_{20} \left(c_{15} |1\rangle \left(-\frac{1}{2}\right) |1\rangle |1\rangle \left(-\frac{1}{2}\right) |1\rangle \right)$$
$$+ 2\pi J_{30} \left(c_0 \frac{1}{2} |0\rangle |0\rangle |0\rangle \frac{1}{2} |0\rangle + c_1 \frac{1}{2} |0\rangle |0\rangle |0\rangle \left(-\frac{1}{2}\right) |1\rangle + c_2 \frac{1}{2} |0\rangle |0\rangle |1\rangle \frac{1}{2} |0\rangle \right)$$
$$+ 2\pi J_{30} \left(c_3 \frac{1}{2} |0\rangle |0\rangle |1\rangle \left(-\frac{1}{2}\right) |1\rangle + c_4 \frac{1}{2} |0\rangle |1\rangle |0\rangle \frac{1}{2} |0\rangle + c_5 \frac{1}{2} |0\rangle |1\rangle |0\rangle \left(-\frac{1}{2}\right) |1\rangle \right)$$
$$+ 2\pi J_{30} \left(c_6 \frac{1}{2} |0\rangle |1\rangle |1\rangle \frac{1}{2} |0\rangle + c_7 \frac{1}{2} |0\rangle |1\rangle |1\rangle \left(-\frac{1}{2}\right) |1\rangle + c_8 \left(-\frac{1}{2}\right) |1\rangle |0\rangle |0\rangle \frac{1}{2} |0\rangle \right)$$
$$+ 2\pi J_{30} \left(c_9 \left(-\frac{1}{2}\right) |1\rangle |0\rangle |0\rangle \left(-\frac{1}{2}\right) |1\rangle + c_{10} \left(-\frac{1}{2}\right) |1\rangle |0\rangle |1\rangle \frac{1}{2} |0\rangle + c_{11} \left(-\frac{1}{2}\right) |1\rangle |0\rangle |1\rangle \left(-\frac{1}{2}\right) |1\rangle \right)$$
$$+ 2\pi J_{30} \left(c_{12} \left(-\frac{1}{2}\right) |1\rangle |1\rangle |0\rangle \frac{1}{2} |0\rangle + c_{13} \left(-\frac{1}{2}\right) |1\rangle |1\rangle |0\rangle \left(-\frac{1}{2}\right) |1\rangle + c_{14} \left(-\frac{1}{2}\right) |1\rangle |1\rangle |1\rangle \frac{1}{2} |0\rangle \right)$$
$$+ 2\pi J_{30} \left(c_{15} \left(-\frac{1}{2}\right) |1\rangle |1\rangle |1\rangle \left(-\frac{1}{2}\right) |1\rangle \right)$$
$$+ 2\pi J_{21} \left(c_0 |0\rangle \frac{1}{2} |0\rangle \frac{1}{2} |0\rangle |0\rangle + c_1 |0\rangle \frac{1}{2} |0\rangle \frac{1}{2} |0\rangle |1\rangle + c_2 |0\rangle \frac{1}{2} |0\rangle \left(-\frac{1}{2}\right) |1\rangle |0\rangle \right)$$
$$+ 2\pi J_{21} \left(c_3 |0\rangle \frac{1}{2} |0\rangle \left(-\frac{1}{2}\right) |1\rangle |1\rangle + c_4 |0\rangle \left(-\frac{1}{2}\right) |1\rangle \frac{1}{2} |0\rangle |0\rangle + c_5 |0\rangle \left(-\frac{1}{2}\right) |1\rangle |0\rangle \left(-\frac{1}{2}\right) |1\rangle \right)$$

$$
\begin{aligned}
&+ 2\pi J_{21} \left(c_6 |0\rangle \left(-\frac{1}{2}\right) |1\rangle \left(-\frac{1}{2}\right) |1\rangle |0\rangle + c_7 |0\rangle \left(-\frac{1}{2}\right) |1\rangle \left(-\frac{1}{2}\right) |1\rangle |1\rangle \right) \\
&+ 2\pi J_{21} \left(c_8 |1\rangle \frac{1}{2} |0\rangle \frac{1}{2} |0\rangle |0\rangle + c_9 |1\rangle \frac{1}{2} |0\rangle \frac{1}{2} |0\rangle |1\rangle \right) \\
&+ 2\pi J_{21} \left(c_{10} |1\rangle \frac{1}{2} |0\rangle \left(-\frac{1}{2}\right) |1\rangle |0\rangle + c_{11} |1\rangle \frac{1}{2} |0\rangle \left(-\frac{1}{2}\right) |1\rangle |1\rangle \right) \\
&+ 2\pi J_{31} \left(c_{12} |1\rangle \left(-\frac{1}{2}\right) |1\rangle \frac{1}{2} |0\rangle |0\rangle + c_{13} |1\rangle \left(-\frac{1}{2}\right) |1\rangle \frac{1}{2} |0\rangle |1\rangle \right) \\
&+ 2\pi J_{31} \left(c_{14} |1\rangle |1\rangle \left(-\frac{1}{2}\right) |1\rangle \frac{1}{2} |0\rangle + c_{15} |1\rangle \left(-\frac{1}{2}\right) |1\rangle \left(-\frac{1}{2}\right) |1\rangle |1\rangle \right) \\
&+ 2\pi J_{31} \left(c_0 \frac{1}{2} |0\rangle |0\rangle \frac{1}{2} |0\rangle |0\rangle + c_1 \frac{1}{2} |0\rangle |0\rangle \frac{1}{2} |0\rangle |1\rangle \right) \\
&+ 2\pi J_{31} \left(c_2 \frac{1}{2} |0\rangle |0\rangle \left(-\frac{1}{2}\right) |1\rangle |0\rangle + c_3 \frac{1}{2} |0\rangle |0\rangle \left(-\frac{1}{2}\right) |1\rangle |1\rangle \right) \\
&+ 2\pi J_{31} \left(c_4 \frac{1}{2} |0\rangle |1\rangle \frac{1}{2} |0\rangle |0\rangle + c_5 \frac{1}{2} |0\rangle |1\rangle \frac{1}{2} |0\rangle |1\rangle \right) \\
&+ 2\pi J_{31} \left(c_6 \frac{1}{2} |0\rangle |1\rangle \left(-\frac{1}{2}\right) |1\rangle |0\rangle + c_7 \frac{1}{2} |0\rangle |1\rangle \left(-\frac{1}{2}\right) |1\rangle |1\rangle \right) \\
&+ 2\pi J_{31} \left(c_8 \left(-\frac{1}{2}\right) |1\rangle |0\rangle \frac{1}{2} |0\rangle |0\rangle + c_9 \left(-\frac{1}{2}\right) |1\rangle |0\rangle \frac{1}{2} |0\rangle |1\rangle \right) \\
&+ 2\pi J_{31} \left(c_{10} \left(-\frac{1}{2}\right) |1\rangle |0\rangle \left(-\frac{1}{2}\right) |1\rangle |0\rangle + c_{11} \left(-\frac{1}{2}\right) |1\rangle |0\rangle \left(-\frac{1}{2}\right) |1\rangle |1\rangle \right) \\
&+ 2\pi J_{31} \left(c_{12} \left(-\frac{1}{2}\right) |1\rangle |1\rangle \frac{1}{2} |0\rangle |0\rangle + c_{13} \left(-\frac{1}{2}\right) |1\rangle |1\rangle \frac{1}{2} |0\rangle |1\rangle \right) \\
&+ 2\pi J_{31} \left(c_{14} \left(-\frac{1}{2}\right) |1\rangle |1\rangle \left(-\frac{1}{2}\right) |1\rangle |0\rangle + c_{15} \left(-\frac{1}{2}\right) |1\rangle |1\rangle \left(-\frac{1}{2}\right) |1\rangle |1\rangle \right) \\
&+ 2\pi J_{32} \left(c_0 \frac{1}{2} |0\rangle \frac{1}{2} |0\rangle |0\rangle |0\rangle + c_1 \frac{1}{2} |0\rangle \frac{1}{2} |0\rangle |0\rangle |1\rangle + c_2 \frac{1}{2} |0\rangle \frac{1}{2} |0\rangle |1\rangle |0\rangle \right) \\
&+ 2\pi J_{32} \left(c_3 \frac{1}{2} |0\rangle \frac{1}{2} |0\rangle |1\rangle |1\rangle + c_4 \frac{1}{2} |0\rangle \left(-\frac{1}{2}\right) |1\rangle |0\rangle |0\rangle + c_5 \frac{1}{2} |0\rangle \left(-\frac{1}{2}\right) |1\rangle |0\rangle |1\rangle \right) \\
&+ 2\pi J_{32} \left(c_6 \frac{1}{2} |0\rangle \left(-\frac{1}{2}\right) |1\rangle |1\rangle |0\rangle + c_7 \frac{1}{2} |0\rangle \left(-\frac{1}{2}\right) |1\rangle |1\rangle |1\rangle + c_8 \left(-\frac{1}{2}\right) |1\rangle \frac{1}{2} |0\rangle |0\rangle |0\rangle \right) \\
&+ 2\pi J_{32} \left(c_9 \left(-\frac{1}{2}\right) |1\rangle \frac{1}{2} |0\rangle |0\rangle |1\rangle + c_{10} \left(-\frac{1}{2}\right) |1\rangle \frac{1}{2} |0\rangle |1\rangle |0\rangle + c_{11} \left(-\frac{1}{2}\right) |1\rangle \frac{1}{2} |0\rangle |1\rangle |1\rangle \right) \\
&+ 2\pi J_{32} \left(c_{12} \left(-\frac{1}{2}\right) |1\rangle \left(-\frac{1}{2}\right) |1\rangle |0\rangle |0\rangle + c_{13} \left(-\frac{1}{2}\right) |1\rangle \left(-\frac{1}{2}\right) |1\rangle |0\rangle |1\rangle + c_{14} \left(-\frac{1}{2}\right) |1\rangle \left(-\frac{1}{2}\right) |1\rangle |1\rangle |0\rangle \right) \\
&+ 2\pi J_{32} \left(c_{15} \left(-\frac{1}{2}\right) |1\rangle \left(-\frac{1}{2}\right) |1\rangle |1\rangle |1\rangle \right) \\
&= \frac{\omega_0}{2} \left(c_0 |0000\rangle - c_1 |0001\rangle + c_2 |0010\rangle \right)
\end{aligned}
\quad (1
$$

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\begin{aligned}
&+ \frac{\omega_0}{2}\left(-c_3\left|0011\right\rangle + c_4\left|0100\right\rangle - c_5\left|0101\right\rangle\right) \\
&+ \frac{\omega_0}{2}\left(c_6\left|0110\right\rangle - c_7\left|0111\right\rangle + c_8\left|1000\right\rangle\right) \\
&+ \frac{\omega_0}{2}\left(-c_9\left|1001\right\rangle + c_{10}\left|1010\right\rangle - c_{11}\left|1011\right\rangle\right) \\
&+ \frac{\omega_0}{2}\left(c_{12}\left|1100\right\rangle - c_{13}\left|1101\right\rangle + c_{14}\left|1110\right\rangle\right) \\
&- \frac{\omega_0}{2}c_{15}\left|1111\right\rangle \\
&+ \frac{\omega_1}{2}\left(c_0\left|0000\right\rangle + c_1\left|0001\right\rangle - c_2\left|0010\right\rangle\right) \\
&+ \frac{\omega_1}{2}\left(-c_3\left|0011\right\rangle + c_4\left|0100\right\rangle + c_5\left|0101\right\rangle\right) \\
&+ \frac{\omega_1}{2}\left(-c_6\left|0110\right\rangle - c_7\left|0111\right\rangle + c_8\left|1000\right\rangle\right) \\
&+ \frac{\omega_1}{2}\left(+c_9\left|1001\right\rangle - c_{10}\left|1010\right\rangle - c_{11}\left|1011\right\rangle\right) \\
&+ \frac{\omega_1}{2}\left(c_{12}\left|1100\right\rangle + c_{13}\left|1101\right\rangle - c_{14}\left|1110\right\rangle\right) \\
&- \frac{\omega_1}{2}c_{15}\left|1111\right\rangle \\
&+ \frac{\omega_2}{2}\left(c_0\left|0000\right\rangle + c_1\left|0001\right\rangle + c_2\left|0010\right\rangle\right) \\
&+ \frac{\omega_2}{2}\left(+c_3\left|0011\right\rangle - c_4\left|0100\right\rangle - c_5\left|0101\right\rangle\right) \\
&+ \frac{\omega_2}{2}\left(-c_6\left|0110\right\rangle - c_7\left|0111\right\rangle + c_8\left|1000\right\rangle\right) \\
&+ \frac{\omega_2}{2}\left(c_9\left|1001\right\rangle + c_{10}\left|1010\right\rangle + c_{11}\left|1011\right\rangle\right) \\
&+ \frac{\omega_2}{2}\left(-c_{12}\left|1100\right\rangle - c_{13}\left|1101\right\rangle - c_{14}\left|1110\right\rangle\right)
\end{aligned}
$$

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\begin{aligned}
&- \frac{\omega_2}{2} c_{15} \left|1111\right\rangle \\
&+ \frac{\omega_3}{2} \left(c_0 \left|0000\right\rangle + c_1 \left|0001\right\rangle + c_2 \left|0010\right\rangle\right) \\
&+ \frac{\omega_3}{2} \left(c_3 \left|0011\right\rangle + c_4 \left|0100\right\rangle + c_5 \left|0101\right\rangle\right) \\
&+ \frac{\omega_3}{2} \left(+c_6 \left|0110\right\rangle + c_7 \left|0111\right\rangle - c_8 \left|1000\right\rangle\right) \\
&+ \frac{\omega_3}{2} \left(-c_9 \left|1001\right\rangle - c_{10} \left|1010\right\rangle - c_{11} \left|1011\right\rangle\right) \\
&+ \frac{\omega_3}{2} \left(-c_{12} \left|1100\right\rangle - c_{13} \left|1101\right\rangle - c_{14} \left|1110\right\rangle\right) \\
&- \frac{\omega_3}{2} c_{15} \left|1111\right\rangle \\
&+ \frac{\pi J_{10}}{2} \left(c_0 \left|0000\right\rangle - c_1 \left|0001\right\rangle - c_2 \left|0010\right\rangle\right) \\
&+ \frac{\pi J_{10}}{2} \left(c_3 \left|0011\right\rangle + c_4 \left|0100\right\rangle - c_5 \left|0101\right\rangle\right) \\
&+ \frac{\pi J_{10}}{2} \left(-c_6 \left|0110\right\rangle + c_7 \left|0111\right\rangle + c_8 \left|1000\right\rangle\right) \\
&+ \frac{\pi J_{10}}{2} \left(-c_9 \left|1001\right\rangle - c_{10} \left|1010\right\rangle + c_{11} \left|1011\right\rangle\right) \\
&+ \frac{\pi J_{10}}{2} \left(c_{12} \left|1100\right\rangle - c_{13} \left|1101\right\rangle - c_{14} \left|1110\right\rangle\right) \\
&+ \frac{\pi J_{10}}{2} c_{15} \left|1111\right\rangle \\
&+ \frac{\pi J_{20}}{2} \left(c_0 \left|0000\right\rangle - c_1 \left|0001\right\rangle + c_2 \left|0010\right\rangle\right) \\
&+ \frac{\pi J_{20}}{2} \left(-c_3 \left|0011\right\rangle - c_4 \left|0100\right\rangle + c_5 \left|0101\right\rangle\right) \\
&+ \frac{\pi J_{20}}{2} \left(-c_6 \left|0110\right\rangle + c_7 \left|0111\right\rangle + c_8 \left|1000\right\rangle\right)
\end{aligned}
$$

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\begin{aligned}
&+ \frac{\pi J_{20}}{2} \left(-c_9 \left|1001\right\rangle + c_{10} \left|1010\right\rangle - c_{11} \left|1011\right\rangle\right) \\
&+ \frac{\pi J_{20}}{2} \left(-c_{12} \left|1100\right\rangle + c_{13} \left|1101\right\rangle - c_{14} \left|1110\right\rangle\right) \\
&+ \frac{\pi J_{20}}{2} c_{15} \left|1111\right\rangle \\
&+ \frac{\pi J_{30}}{2} \left(c_0 \left|0000\right\rangle - c_1 \left|0001\right\rangle + c_2 \left|0010\right\rangle\right) \\
&+ \frac{\pi J_{30}}{2} \left(-c_3 \left|0011\right\rangle + c_4 \left|0100\right\rangle - c_5 \left|0101\right\rangle\right) \\
&+ \frac{\pi J_{30}}{2} \left(+c_6 \left|0110\right\rangle - c_7 \left|0111\right\rangle - c_8 \left|1000\right\rangle\right) \\
&+ \frac{\pi J_{30}}{2} \left(c_9 \left|1001\right\rangle - c_{10} \left|1010\right\rangle + c_{11} \left|1011\right\rangle\right) \\
&+ \frac{\pi J_{30}}{2} \left(-c_{12} \left|1100\right\rangle + c_{13} \left|1101\right\rangle - c_{14} \left|1110\right\rangle\right) \\
&+ \frac{\pi J_{30}}{2} c_{15} \left|1111\right\rangle \\
&+ \frac{\pi J_{21}}{2} \left(c_0 \left|0000\right\rangle + c_1 \left|0001\right\rangle - c_2 \left|0010\right\rangle\right) \\
&+ \frac{\pi J_{21}}{2} \left(-c_3 \left|0011\right\rangle - c_4 \left|0100\right\rangle - c_5 \left|0101\right\rangle\right) \\
&+ \frac{\pi J_{21}}{2} \left(+c_6 \left|0110\right\rangle + c_7 \left|0111\right\rangle + c_8 \left|1000\right\rangle\right) \\
&+ \frac{\pi J_{21}}{2} \left(c_9 \left|1001\right\rangle - c_{10} \left|1010\right\rangle - c_{11} \left|1011\right\rangle\right) \\
&+ \frac{\pi J_{21}}{2} \left(-c_{12} \left|1100\right\rangle - c_{13} \left|1101\right\rangle + c_{14} \left|1110\right\rangle\right) \\
&+ \frac{\pi J_{21}}{2} c_{15} \left|1111\right\rangle
\end{aligned}
$$

$$
\begin{aligned}
&+ \frac{\pi J_{31}}{2} \left(c_0 \left|0000\right\rangle + c_1 \left|0001\right\rangle - c_2 \left|0010\right\rangle\right) \\
&+ \frac{\pi J_{31}}{2} \left(-c_3 \left|0011\right\rangle + c_4 \left|0100\right\rangle + c_5 \left|0101\right\rangle\right) \\
&+ \frac{\pi J_{31}}{2} \left(-c_6 \left|0110\right\rangle - c_7 \left|0111\right\rangle - c_8 \left|1000\right\rangle\right) \\
&+ \frac{\pi J_{31}}{2} \left(-c_9 \left|1001\right\rangle + c_{10} \left|1010\right\rangle + c_{11} \left|1011\right\rangle\right) \\
&+ \frac{\pi J_{31}}{2} \left(-c_{12} \left|1100\right\rangle - c_{13} \left|1101\right\rangle + c_{14} \left|1110\right\rangle\right) \\
&+ \frac{\pi J_{31}}{2} c_{15} \left|1111\right\rangle \\
&+ \frac{\pi J_{32}}{2} \left(c_0 \left|0000\right\rangle + c_1 \left|0001\right\rangle + c_2 \left|0010\right\rangle\right) \\
&+ \frac{\pi J_{32}}{2} \left(c_3 \left|0011\right\rangle - c_4 \left|0100\right\rangle - c_5 \left|0101\right\rangle\right) \\
&+ \frac{\pi J_{32}}{2} \left(-c_6 \left|0110\right\rangle - c_7 \left|0111\right\rangle - c_8 \left|1000\right\rangle\right) \\
&+ \frac{\pi J_{32}}{2} \left(-c_9 \left|1001\right\rangle - c_{10} \left|1010\right\rangle - c_{11} \left|1011\right\rangle\right) \\
&+ \frac{\pi J_{32}}{2} \left(c_{12} \left|1100\right\rangle + c_{13} \left|1101\right\rangle + c_{14} \left|1110\right\rangle\right) \\
&+ \frac{\pi J_{32}}{2} c_{15} \left|1111\right\rangle
\end{aligned}
$$

$$
\begin{aligned}
&= \frac{\omega_0 + \omega_1 + \omega_2 + \omega_3 + \pi J_{10} + \pi J_{20} + \pi J_{30} + \pi J_{21} + \pi J_{31} + \pi J_{32}}{2} c_0 \left|0000\right\rangle) \\
&+ \frac{-\omega_0 + \omega_1 + \omega_2 + \omega_3 - \pi J_{10} - \pi J_{20} - \pi J_{30} + \pi J_{21} + \pi J_{31} + \pi J_{32}}{2} c_1 \left|0001\right\rangle) \\
&+ \frac{\omega_0 - \omega_1 + \omega_2 + \omega_3 - \pi J_{10} + \pi J_{20} + \pi J_{30} - \pi J_{21} - \pi J_{31} + \pi J_{32}}{2} c_2 \left|0010\right\rangle) \\
&+ \frac{-\omega_0 - \omega_1 + \omega_2 + \omega_3 + \pi J_{10} - \pi J_{20} - \pi J_{30} - \pi J_{21} - \pi J_{31} + \pi J_{32}}{2} c_3 \left|0011\right\rangle) \\
&+ \frac{\omega_0 + \omega_1 - \omega_2 + \omega_3 + \pi J_{10} - \pi J_{20} + \pi J_{30} - \pi J_{21} + \pi J_{31} - \pi J_{32}}{2} c_4 \left|0100\right\rangle) \\
&+ \frac{-\omega_0 + \omega_1 - \omega_2 + \omega_3 - \pi J_{10} + \pi J_{20} - \pi J_{30} - \pi J_{21} + \pi J_{31} - \pi J_{32}}{2} c_5 \left|0101\right\rangle) \\
&+ \frac{\omega_0 - \omega_1 - \omega_2 + \omega_3 - \pi J_{10} - \pi J_{20} + \pi J_{30} + \pi J_{21} - \pi J_{31} - \pi J_{32}}{2} c_6 \left|0110\right\rangle) \\
&+ \frac{-\omega_0 - \omega_1 - \omega_2 + \omega_3 + \pi J_{10} + \pi J_{20} - \pi J_{30} + \pi J_{21} - \pi J_{31} - \pi J_{32}}{2} c_7 \left|0111\right\rangle) \\
&+ \frac{\omega_0 + \omega_1 + \omega_2 - \omega_3 + \pi J_{10} + \pi J_{20} - \pi J_{30} + \pi J_{21} - \pi J_{31} - \pi J_{32}}{2} c_8 \left|1000\right\rangle) \\
&+ \frac{-\omega_0 + \omega_1 + \omega_2 - \omega_3 - \pi J_{10} - \pi J_{20} + \pi J_{30} + \pi J_{21} - \pi J_{31} - \pi J_{32}}{2} c_9 \left|1001\right\rangle) \\
&+ \frac{\omega_0 - \omega_1 + \omega_2 - \omega_3 - \pi J_{10} + \pi J_{20} - \pi J_{30} - \pi J_{21} + \pi J_{31} - \pi J_{32}}{2} c_{10} \left|1010\right\rangle) \\
&+ \frac{-\omega_0 - \omega_1 + \omega_2 - \omega_3 + \pi J_{10} - \pi J_{20} + \pi J_{30} - \pi J_{21} + \pi J_{31} - \pi J_{32}}{2} c_{11} \left|1011\right\rangle) \\
&+ \frac{\omega_0 + \omega_1 - \omega_2 - \omega_3 + \pi J_{10} - \pi J_{20} - \pi J_{30} - \pi J_{21} - \pi J_{31} + \pi J_{32}}{2} c_{12} \left|1100\right\rangle) \\
&+ \frac{-\omega_0 + \omega_1 - \omega_2 - \omega_3 - \pi J_{10} + \pi J_{20} + \pi J_{30} - \pi J_{21} - \pi J_{31} + \pi J_{32}}{2} c_{13} \left|1101\right\rangle) \\
&+ \frac{\omega_0 - \omega_1 - \omega_2 - \omega_3 - \pi J_{10} - \pi J_{20} - \pi J_{30} + \pi J_{21} + \pi J_{31} + \pi J_{32}}{2} c_{14} \left|1110\right\rangle) \\
&+ \frac{-\omega_0 - \omega_1 - \omega_2 - \omega_3 + \pi J_{10} + \pi J_{20} + \pi J_{30} + \pi J_{21} + \pi J_{31} + \pi J_{32}}{2} c_{15} \left|1111\right\rangle)
\end{aligned} \tag{144}
$$

maka dengan demikian dapat leel energi dalam 4 qubit dapat di buat dalam bentuk tabel berrikut:

n	$E_{4,n}$
0	$\frac{\omega_0+\omega_1+\omega_2+\omega_3+\pi J_{10}+\pi J_{20}+\pi J_{30}+\pi J_{21}+\pi J_{31}+\pi J_{32}}{2}$
1	$\frac{-\omega_0+\omega_1+\omega_2+\omega_3-\pi J_{10}-\pi J_{20}-\pi J_{30}+\pi J_{21}+\pi J_{31}+\pi J_{32}}{2}$
2	$\frac{\omega_0-\omega_1+\omega_2+\omega_3-\pi J_{10}+\pi J_{20}+\pi J_{30}-\pi J_{21}-\pi J_{31}+\pi J_{32}}{2}$
3	$\frac{-\omega_0-\omega_1+\omega_2+\omega_3+\pi J_{10}-\pi J_{20}-\pi J_{30}-\pi J_{21}-\pi J_{31}+\pi J_{32}}{2}$
4	$\frac{\omega_0+\omega_1-\omega_2+\omega_3+\pi J_{10}-\pi J_{20}+\pi J_{30}-\pi J_{21}+\pi J_{31}-\pi J_{32}}{2}$
5	$\frac{-\omega_0+\omega_1-\omega_2+\omega_3-\pi J_{10}+\pi J_{20}-\pi J_{30}-\pi J_{21}+\pi J_{31}-\pi J_{32}}{2}$
6	$\frac{\omega_0-\omega_1-\omega_2+\omega_3-\pi J_{10}-\pi J_{20}+\pi J_{30}+\pi J_{21}-\pi J_{31}-\pi J_{32}}{2}$
7	$\frac{-\omega_0-\omega_1-\omega_2+\omega_3+\pi J_{10}+\pi J_{20}-\pi J_{30}+\pi J_{21}-\pi J_{31}-\pi J_{32}}{2}$
8	$\frac{\omega_0+\omega_1+\omega_2-\omega_3+\pi J_{10}+\pi J_{20}-\pi J_{30}+\pi J_{21}-\pi J_{31}-\pi J_{32}}{2}c_8$
9	$\frac{-\omega_0+\omega_1+\omega_2-\omega_3-\pi J_{10}-\pi J_{20}+\pi J_{30}+\pi J_{21}-\pi J_{31}-\pi J_{32}}{2}$
10	$\frac{\omega_0-\omega_1+\omega_2-\omega_3-\pi J_{10}+\pi J_{20}-\pi J_{30}-\pi J_{21}+\pi J_{31}-\pi J_{32}}{2}$
11	$\frac{-\omega_0-\omega_1+\omega_2-\omega_3+\pi J_{10}-\pi J_{20}+\pi J_{30}-\pi J_{21}+\pi J_{31}-\pi J_{32}}{2}$
12	$\frac{\omega_0+\omega_1-\omega_2-\omega_3+\pi J_{10}-\pi J_{20}-\pi J_{30}-\pi J_{21}-\pi J_{31}+\pi J_{32}}{2}$
13	$\frac{-\omega_0+\omega_1-\omega_2-\omega_3-\pi J_{10}+\pi J_{20}+\pi J_{30}-\pi J_{21}-\pi J_{31}+\pi J_{32}}{2}$
14	$\frac{\omega_0-\omega_1-\omega_2-\omega_3-\pi J_{10}-\pi J_{20}-\pi J_{30}+\pi J_{21}+\pi J_{31}+\pi J_{32}}{2}$
15	$\frac{-\omega_0-\omega_1-\omega_2-\omega_3+\pi J_{10}+\pi J_{20}+\pi J_{30}+\pi J_{21}+\pi J_{31}+\pi J_{32}}{2}$

maka dengan demikian berdasarkan tabel energi daripada sistem 1 qubit, 2 qubit, 3 qubit didapatkan pola umun untuk sistem level energi untuk N-qubit, yaitu sebagai berikut:

$$E_{N,n} = \sum_{i=1}^{N-1} \left(-\frac{1}{2}\right)^{x_i} \omega_i + \pi \sum_{k=1}^{N-1} \sum_{i=0}^{N-2} \left(-\frac{1}{2}\right)^{x_i \oplus x_k} J_{kl} \quad (145)$$

dengan $k \neq l$

BAB V

PENERAPAN ALGORITMA DEUTSCH-JOZSA DALAM SISTEM 4 QUBIT

Dalam aplikasi algoritma 4 qubit maka langkah yang harus kita cari pertama kali adalah kemungkinan -kemungkinan fungsi konstan dan fungsi setimbang, yaitu sebagai berikut: sebelumnya kita definisikan bahwa qubit masukan

$$|\psi\rangle = |x_3 x_2 x_1 x_0\rangle \tag{146}$$

maka dapat kita ambil beberapa kemungkinan untuk fungsi konstan dan fungsi setimbang yaitu sebagai berikut:

$$\begin{aligned}
f_{k0} &= 0 && \text{(konstan0)} \\
f_{k1} &= 1 && \text{(konstan1)} \\
f_{s0} &= x_3 && \text{(setimbang0)} \\
f_{s1} &= x_1 \oplus x_0 && \text{(setimbang1)} \\
f_{s2} &= x_2 \oplus x_1 \oplus x_1 && \text{(setimbang2)} \\
f_{s3} &= x_3 \oplus x_2 \oplus x_1 \oplus x_1 && \text{(setimbang3)} \\
f_{s4} &= x_2 x_1 \oplus x_0 && \text{(setimbang4)}
\end{aligned} \tag{147}$$

maka dapat kita buat tabel untuk contoh fungsi-fungsi kotak hitam di atas, yaitu sebagai berikut:

$\|x_3x_2x_1x_0\rangle$	f_{k0}	f_{k1}	f_{s0}	f_{s1}	f_{s2}	f_{s3}	f_{s4}
$\|0000\rangle$	0	1	0	0	0	0	0
$\|0001\rangle$	0	1	0	1	1	1	1
$\|0010\rangle$	0	1	0	1	1	1	0
$\|0011\rangle$	0	1	0	0	0	0	1
$\|0100\rangle$	0	1	0	0	1	1	0
$\|0101\rangle$	0	1	0	1	0	0	1
$\|0110\rangle$	0	1	0	1	0	0	1
$\|0111\rangle$	0	1	0	0	1	1	0
$\|1000\rangle$	0	1	1	0	0	1	0
$\|1001\rangle$	0	1	1	1	1	0	1
$\|1010\rangle$	0	1	1	1	1	0	0
$\|1011\rangle$	0	1	1	0	0	1	1
$\|1100\rangle$	0	1	1	0	1	0	0
$\|1101\rangle$	0	1	1	1	0	1	1
$\|1110\rangle$	0	1	1	1	0	1	1
$\|1111\rangle$	0	1	1	0	1	0	0
total kemungkinan	1	1	8	12	8	2	24

kemudian dikarenakan operator unitary memenuhi:

$$\begin{aligned} U_k &= U_f \otimes I \\ U_f &= (-1)^f(x)\,|\psi\rangle \end{aligned} \tag{148}$$

maka dengan demikian operator unitary untuk fungsi kotak hitam dapat di tuliskan sebagai berikut:

$$\begin{aligned} U_{k0} &= I \otimes I \otimes I \otimes I \\ U_{k1} &= -I \otimes I \otimes I \otimes I \\ U_{s0} &= I \otimes I \otimes I \otimes \sigma_z \\ U_{s1} &= I \otimes I \otimes \sigma_z \otimes \sigma_z \\ U_{s2} &= I \otimes \sigma_z \otimes \sigma_z \otimes \sigma_z \\ U_{s3} &= \sigma_z \otimes \sigma_z \otimes \sigma_z \otimes \sigma_z \\ U_{s4} &= I \otimes ([I \otimes \sigma_z] \oplus [\sigma_z \otimes \sigma_z]) \end{aligned} \tag{149}$$

di dalam algoritma Deutsh josza untuk 4 qubit dilakukan beberapa operasi terhadap operator, berikut adalah diagram daripada operator-operator tersebut: berdasarkan diagram

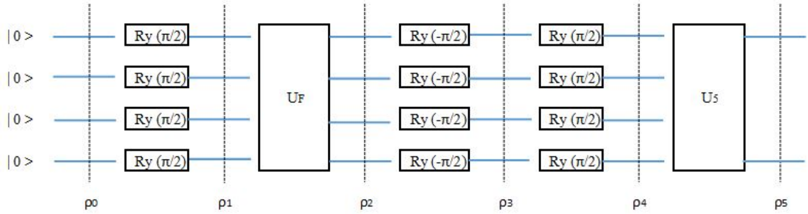

Figure 1: Diagram Blok NMR 4 qubit

diatas maka dapat kita tuliskan bahwa

$$|\psi\rangle = |0000\rangle = |0\rangle \otimes |0\rangle \otimes |0\rangle \otimes |0\rangle = \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \tag{150}$$

dan untuk operator densitasnya yaitu:

$$\rho_0 = |0000\rangle\langle 0000|$$

$$= \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \otimes \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

$$= \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix} \tag{151}$$

maka matrik ρ_0 diatas dapat di pecah kembali dalam direct product matriks berikut:

$$
\begin{aligned}
\rho_0 &= \begin{bmatrix}1 & 0\\0 & 0\end{bmatrix} \otimes \begin{bmatrix}1 & 0\\0 & 0\end{bmatrix} \otimes \begin{bmatrix}1 & 0\\0 & 0\end{bmatrix} \otimes \begin{bmatrix}1 & 0\\0 & 0\end{bmatrix} \\
&= \left[\frac{1}{2}\begin{bmatrix}1 & 0\\0 & 1\end{bmatrix} + \frac{1}{2}\begin{bmatrix}1 & 0\\0 & -1\end{bmatrix}\right] \otimes \left[\frac{1}{2}\begin{bmatrix}1 & 0\\0 & 1\end{bmatrix} + \frac{1}{2}\begin{bmatrix}1 & 0\\0 & -1\end{bmatrix}\right] \\
&\otimes \left[\frac{1}{2}\begin{bmatrix}1 & 0\\0 & 1\end{bmatrix} + \frac{1}{2}\begin{bmatrix}1 & 0\\0 & -1\end{bmatrix}\right] \otimes \left[\frac{1}{2}\begin{bmatrix}1 & 0\\0 & 1\end{bmatrix} + \frac{1}{2}\begin{bmatrix}1 & 0\\0 & -1\end{bmatrix}\right] \\
&= \left(\frac{1}{2}I + I_z\right) \otimes \left(\frac{1}{2}I + I_z\right) \otimes \left(\frac{1}{2}I + I_z\right) \otimes \left(\frac{1}{2}I + I_z\right) \\
&= \frac{1}{4}\left[\frac{1}{4}I \otimes I \otimes I \otimes I + \frac{1}{2}\left(I \otimes I \otimes I \otimes I_z + I \otimes I \otimes I_z \otimes I\right)\right] \\
&+ \frac{1}{4}\left[\frac{1}{2}\left(I \otimes I_z \otimes I \otimes I + I_z \otimes I \otimes I \otimes I\right)\right] \\
&+ \frac{1}{4}\left[I \otimes I \otimes I_z \otimes I_z + I \otimes I_z \otimes I \otimes I_z + I \otimes I_z \otimes I_z \otimes I\right] \\
&+ \frac{1}{4}\left[I_z \otimes I \otimes I \otimes I_z + I_{3z} \otimes I \otimes I_z \otimes I\right] \\
&+ \frac{1}{4}\left[I_z I_z \otimes I \otimes I + 2\left(I \otimes I_z \otimes I_z \otimes I_z + I_z \otimes I \otimes I_z \otimes I_z\right)\right] \\
&+ \frac{1}{4}\left[2\left(I_z \otimes I_z \otimes I \otimes I_z + I_z \otimes I_z \otimes I_z \otimes I\right)\right] \\
&+ I_z \otimes I_z \otimes I_z \otimes I_z \\
&= \frac{1}{4}\left[\frac{1}{4}I + \frac{1}{2}\left(I_{0z} + I_{1z} + I_{2z} + I_{3z}\right) + I_{1z}I_{0z}\right] \\
&+ \frac{1}{4}\left[I_{2z}I_{0z} + I_{2z}I_{1z} + I_{3z}I_{0z} + I_{3z}I_{1z}\right] \\
&+ \frac{1}{4}\left[I_{3z}I_{2z} + 2\left(I_{2z}I_{1z}I_{0z} + I_{3z}I_{1z}I_{0z} + I_{3z}I_{2z}I_{0z} + I_{3z}I_{2z}I_{1z}\right)\right] \\
&+ \frac{1}{4}\left[4I_{3z}I_{2z}I_{1z}I_{0z}\right]
\end{aligned} \tag{152}
$$

maka dalam keadaan kesetimbangan termal ρ_0 dapat didekati dengan :

$$
\begin{aligned}
\rho_0 &\approx I_{3z} + I_{2z} + I_{1z} + I_{0z} \\
&\approx I_z \otimes I \otimes I \otimes I + I \otimes I \otimes I_z \otimes I + I \otimes I_z \otimes I \otimes I + I_z \otimes I \otimes I \otimes I \\
&\approx \frac{1}{2}
\begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1
\end{pmatrix}
\end{aligned}
$$

$$
+\frac{1}{2}\begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1
\end{pmatrix}
$$

$$
+\,\frac{1}{2}\begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1
\end{pmatrix}
$$

$$
+\frac{1}{2}\begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1
\end{pmatrix}
$$

$$
= \frac{1}{2}\begin{pmatrix}
4 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -2 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -2 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -2 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -4
\end{pmatrix}
$$

$$
= \begin{pmatrix}
2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -2
\end{pmatrix} \quad (153)
$$

selain itu dari diagram di atas dapat juga diketahui bahwa operator uniter total dalam algoritma deutsch-josza adalah sebagai berikut:

$$
U_{tot} = U_5 U_4 U_3 U_2 U_1 \quad (154)
$$

dimana

$$
U_1 = R_y\left(\frac{\pi}{2}\right) \otimes R_y\left(\frac{\pi}{2}\right) \otimes R_y\left(\frac{\pi}{2}\right) \otimes R_y\left(\frac{\pi}{2}\right)
$$

$$
= \frac{1}{4} \begin{pmatrix}
1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & 1 & -1 & -1 & 1 \\
1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 \\
1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 \\
1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 \\
1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 \\
1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 \\
1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\
1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \\
1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\
1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\
1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\
1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\
1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\
1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1
\end{pmatrix}
$$

$$
\begin{aligned}
&U_2 = U_f \Rightarrow \text{(fungsi kotak hitam)} \\
&U_3 = R_y\left(\frac{-\pi}{2}\right) \otimes R_y\left(\frac{-\pi}{2}\right) \otimes R_y\left(\frac{-\pi}{2}\right) \otimes R_y\left(\frac{-\pi}{2}\right) \\
&U_4 = R_y\left(\frac{\pi}{2}\right) \otimes R_y\left(\frac{\pi}{2}\right) \otimes R_y\left(\frac{\pi}{2}\right) \otimes R_y\left(\frac{\pi}{2}\right) \\
&U_5 = e^{-iHt}
\end{aligned} \tag{155}
$$

maka dari perkalian operator uniter tersebut dapat dilakukan perkalian terlebih dahulu antara U_4U_3, yaitu sebagai berikut:

$$
\begin{aligned}
U_4U_3 = &\left[R_y\left(\frac{\pi}{2}\right) \otimes R_y\left(\frac{\pi}{2}\right) \otimes R_y\left(\frac{\pi}{2}\right) \otimes R_y\left(\frac{\pi}{2}\right)\right] \\
&\times \left[R_y\left(\frac{-\pi}{2}\right) \otimes R_y\left(\frac{-\pi}{2}\right) \otimes R_y\left(\frac{-\pi}{2}\right) \otimes R_y\left(\frac{-\pi}{2}\right)\right] \\
&= R_y\left(\frac{\pi}{2}\right) R_y\left(\frac{-\pi}{2}\right) \otimes R_y\left(\frac{\pi}{2}\right) R_y\left(\frac{-\pi}{2}\right) \otimes R_y\left(\frac{\pi}{2}\right) R_y\left(\frac{-\pi}{2}\right) \\
&\otimes R_y\left(\frac{\pi}{2}\right) R_y\left(\frac{-\pi}{2}\right) \\
&= I \otimes I \otimes I \otimes I
\end{aligned} \tag{156}
$$

sehingga hal ini membuat operator uniter totalnya menjadi

$$
\begin{aligned}
U_{tot} &= U_5\left(I \otimes I \otimes I \otimes I\right) U_2U_1 \\
&= U_5U_2U_1
\end{aligned} \tag{157}
$$

langkah selanjutnya adalah menentukan U_5, dimana bentuk hamiltonian dalam sistem 4 qubit adalah sebagai berikut:

$$\begin{aligned} H = &\omega_0 I \otimes I \otimes I \otimes I_z + \omega_1 I \otimes I \otimes I_z \otimes I + \omega_2 I \otimes I_z \otimes I \otimes I \\ &+ \omega_3 I_z \otimes I \otimes I \otimes I + 2\pi J_{10} I \otimes I \otimes I_z \otimes I_z \\ &+ 2\pi J_{20} I \otimes I_z \otimes I \otimes I_z + 2\pi J_{30} I_z \otimes I \otimes I \otimes I_z \\ &+ 2\pi J_{21} I \otimes I_z \otimes I_z \otimes I + 2\pi J_{31} I_z \otimes I \otimes I_z \otimes I \\ &+ 2\pi J_{32} I_z \otimes I_z \otimes I \otimes I \end{aligned} \tag{158}$$

maka didapatkan

$$\begin{aligned} U_5 = &\exp\left[-i\left(\omega_0 I \otimes I \otimes I \otimes I_z + \omega_1 I \otimes I \otimes I_z \otimes I + \omega_2 I \otimes I_z \otimes I \otimes I + \omega_3 I_z \otimes I \otimes I \otimes I\right) t\right] \\ &\times \exp\left[-i\left(2\pi J_{10} I \otimes I \otimes I_z \otimes I_z + 2\pi J_{20} I \otimes I_z \otimes I \otimes I_z + 2\pi J_{30} I_z \otimes I \otimes I \otimes I_z\right) t\right] \\ &\times \exp\left[-i\left(2\pi J_{21} I \otimes I_z \otimes I_z \otimes I + 2\pi J_{31} I_z \otimes I \otimes I_z \otimes I + 2\pi J_{32} I_z \otimes I_z \otimes I \otimes I\right) t\right] \\ &= R\left(\omega_0 t\right) R\left(\omega_1 t\right) R\left(\omega_2 t\right) R\left(\omega_3 t\right) R\left(\pi J_{10} t\right) R\left(\pi J_{20} t\right) R\left(\pi J_{30} t\right) R\left(\pi J_{21} t\right) R\left(\pi J_{31} t\right) R\left(\pi J_{32} t\right) \end{aligned} \tag{159}$$

kita definisikan bahwa

$$\begin{aligned} \theta_0 &= \frac{\omega_0 t}{2} \\ \theta_1 &= \frac{\omega_1 t}{2} \\ \theta_2 &= \frac{\omega_2 t}{2} \\ \theta_3 &= \frac{\omega_3 t}{2} \\ \theta_4 &= \frac{\pi J_{10}}{2} t \\ \theta_5 &= \frac{\pi J_{20}}{2} t \\ \theta_6 &= \frac{\pi J_{30}}{2} t \\ \theta_7 &= \frac{\pi J_{21}}{2} t \\ \theta_8 &= \frac{\pi J_{31}}{2} t \\ \theta_9 &= \frac{\pi J_{32}}{2} t \end{aligned} \tag{160}$$

maka pers. 14 dapat dituliskan sebagai berikut:

$$U_5 = R(2\theta_0)\, R(2\theta_1)\, R(2\theta_2)\, R(2\theta_3)\, R(4\theta_4)\, R(4\theta_5)\, R(4\theta_6) \\ R(4\theta_7)\, R(4\theta_8)\, R(4\theta_9) \tag{161}$$

dimana

$$
\begin{aligned}
R\left(2\theta_0\right) &= e^{-i\omega_0 I\otimes I\otimes I\otimes I_z t} \\
&= e^{\frac{-i\omega_3 t}{2} I\otimes I\otimes I\otimes \sigma_z} \\
&= \cos\theta_0 I\otimes I\otimes I\otimes I - i\sin\theta_0 I\otimes I\otimes I\otimes \sigma_z \\
&= \cos\theta_0 \begin{pmatrix}
1&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&1&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&1&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&1&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&1&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&1&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&1&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&1&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&1&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&1&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&1&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&1&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&1&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&1&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&1&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&1
\end{pmatrix}
\end{aligned}
$$

$$-\,i\sin\theta_0\begin{pmatrix}
1&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&-1&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&1&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&-1&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&1&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&-1&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&1&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&-1&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&1&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&-1&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&1&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&-1&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&1&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&-1&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&1&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&-1
\end{pmatrix}$$

$$
= \begin{pmatrix}
e^{-i\theta_0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & e^{i\theta_0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & e^{-i\theta_0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & e^{i\theta_0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & e^{-i\theta_0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & e^{i\theta_0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_0} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_0} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_0} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_0} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_0} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_0} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_0}
\end{pmatrix} \tag{162}
$$

$$
\begin{aligned}
R\left(2\theta_1\right) &= e^{-i\omega_1 I\otimes I\otimes I_z\otimes I t} \\
&= e^{\frac{-i\omega_1 t}{2} I\otimes I\otimes \sigma_z\otimes I} \\
&= \cos\theta_1 I\otimes I\otimes I\otimes I - i\sin\theta_1 I\otimes I\otimes \sigma_z\otimes I \\
&= \cos\theta_1 \begin{pmatrix}
1&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&1&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&1&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&1&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&1&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&1&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&1&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&1&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&1&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&1&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&1&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&1&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&1&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&1&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&1&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&1
\end{pmatrix}
\end{aligned}
$$

$$-\,i\sin\theta_1 \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \end{pmatrix}$$

$$= \begin{pmatrix}
e^{-i\theta_1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & e^{-i\theta_1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & e^{i\theta_1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & e^{i\theta_1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & e^{-i\theta_1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & e^{-i\theta_1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_1} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_1} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_1} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_1} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_1} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_1} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_1}
\end{pmatrix} \tag{163}$$

$$
\begin{aligned}
R\left(2\theta_2\right) &= e^{-i\omega_2 I\otimes I\otimes I_z\otimes I t} \\
&= e^{\frac{-i\omega_2 t}{2} I\otimes\sigma_z\otimes I\otimes I} \\
&= \cos\theta_2 I\otimes I\otimes I\otimes I - i\sin\theta_1 I\otimes\sigma_z\otimes I\otimes I \\
&= \cos\theta_2 \begin{pmatrix}
1&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&1&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&1&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&1&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&1&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&1&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&1&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&1&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&1&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&1&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&1&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&1&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&1&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&1&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&1&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&1
\end{pmatrix}
\end{aligned}
$$

$$
- i \sin\theta_2 \begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1
\end{pmatrix}
$$

$$
= \begin{pmatrix}
e^{-i\theta_2} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & e^{-i\theta_2} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & e^{-i\theta_2} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & e^{-i\theta_2} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & e^{i\theta_2} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & e^{i\theta_2} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_2} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_2} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_2} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_2} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_2} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_2} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_2} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_2} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_2} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_2}
\end{pmatrix} \quad (164)
$$

$$
\begin{aligned}
R\left(2\theta_3\right) &= e^{-i\omega_3 I_z \otimes I \otimes I \otimes I t} \\
&= e^{\frac{-i\omega_3 t}{2}\sigma_z \otimes I \otimes I \otimes I} \\
&= \cos\theta_3 I \otimes I \otimes I \otimes I - i\sin\theta_3 \sigma_z \otimes I \otimes I \otimes I \\
&= \cos\theta_3 \begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{pmatrix}
\end{aligned}
$$

$$
- i \sin\theta_3 \begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1
\end{pmatrix}
$$

$$
= \begin{pmatrix}
e^{-i\theta_3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & e^{-i\theta_3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & e^{-i\theta_3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & e^{-i\theta_3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & e^{-i\theta_3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & e^{-i\theta_3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_3} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_3} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_3} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_3} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_3} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_3} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_3}
\end{pmatrix} \tag{165}
$$

$$
\begin{aligned}
R\left(4\theta_4\right) &= e^{-i2\pi J_{10} I\otimes I\otimes I_z\otimes I_z t} \\
&= e^{-i\frac{\pi J_{10} t}{2} I\otimes I\otimes \sigma_z\otimes \sigma_z} \\
&= \cos\theta_4 I\otimes I\otimes I\otimes I - i\sin\theta_4 I\otimes I\otimes \sigma_z\otimes\sigma_z \\
&= \cos\theta_4 \begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{pmatrix}
\end{aligned}
$$

$$
-\,i\sin\theta_4\begin{pmatrix}
1&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&-1&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&-1&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&1&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&1&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&-1&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&-1&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&1&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&1&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&-1&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&-1&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&1&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&1&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&-1&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&-1&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&1
\end{pmatrix}
$$

$$
= \begin{pmatrix}
e^{-i\theta_4} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & e^{i\theta_4} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & e^{i\theta_4} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & e^{-i\theta_4} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & e^{-i\theta_4} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & e^{i\theta_4} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_4} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_4} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_4} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_4} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_4} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_4} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_4} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_4} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_4} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_4}
\end{pmatrix} \tag{166}
$$

$$
\begin{aligned}
R\left(4\theta_5\right) &= e^{-i2\pi J_{20} I\otimes I_z\otimes I\otimes I_z t} \\
&= e^{-i\frac{\pi J_{20} t}{2} I\otimes \sigma_z\otimes I\otimes \sigma_z} \\
&= \cos\theta_5 I\otimes I\otimes I\otimes I - i\sin\theta_5 I\otimes \sigma_z\otimes I\otimes \sigma_z \\
&= \cos\theta_5 \begin{pmatrix}
1&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&1&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&1&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&1&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&1&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&1&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&1&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&1&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&1&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&1&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&1&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&1&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&1&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&1&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&1&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&1
\end{pmatrix}
\end{aligned}
$$

$$
-\,i\sin\theta_5
\begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{pmatrix}
$$

$$
= \begin{pmatrix}
e^{-i\theta_5} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & e^{i\theta_5} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & e^{-i\theta_5} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & e^{i\theta_5} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & e^{i\theta_5} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & e^{-i\theta_5} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_5} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_5} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_5} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_5} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_5} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_5} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_5} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_5} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_5} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_5}
\end{pmatrix} \tag{167}
$$

$$
\begin{aligned}
R\left(4\theta_6\right) &= e^{-i2\pi J_{30} I_z \otimes I \otimes I \otimes I_z t} \\
&= e^{-i\frac{\pi J_{30} t}{2}\sigma_z \otimes I \otimes I \otimes \sigma_z} \\
&= \cos\theta_6 I \otimes I \otimes I \otimes I - i\sin\theta_6 \sigma_z \otimes I \otimes I \otimes \sigma_z \\
&= \cos\theta_6 \begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{pmatrix}
\end{aligned}
$$

$$
-\,i\sin\theta_6 \begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{pmatrix}
$$

$$
= \begin{pmatrix}
e^{-i\theta_6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & e^{i\theta_6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & e^{-i\theta_6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & e^{i\theta_6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & e^{-i\theta_6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & e^{i\theta_6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_6} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_6} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_6} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_6} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_6} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_6} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_6}
\end{pmatrix} \tag{168}
$$

$$
\begin{aligned}
R\left(4\theta_7\right) &= e^{-i2\pi J_{21} I\otimes I_z\otimes I_z\otimes I t} \\
&= e^{-i\frac{\pi J_{21} t}{2} I\otimes\sigma_z} \otimes \sigma_z \otimes I \\
&= \cos\theta_7 I \otimes I \otimes I \otimes I - i\sin\theta_7 I \otimes \sigma_z \otimes \sigma_z \otimes I \\
&= \cos\theta_7 \begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{pmatrix}
\end{aligned}
$$

$$
- i \sin \theta_7 \begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1
\end{pmatrix}
$$

$$
= \begin{pmatrix}
e^{-i\theta_7} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & e^{-i\theta_7} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & e^{i\theta_7} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & e^{i\theta_7} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & e^{i\theta_7} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & e^{i\theta_7} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_7} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_7} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_7} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_7} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_7} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_7} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_7} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_7} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_7} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_7}
\end{pmatrix} \tag{169}
$$

$$
\begin{aligned}
R\left(4\theta_8\right) &= e^{-i2\pi J_{31} I_z \otimes I \otimes I_z \otimes I t} \\
&= e^{-i\frac{\pi J_{31} t}{2}\sigma_z \otimes I \otimes \sigma_z \otimes I} \\
&= \cos\theta_8 I \otimes I \otimes I \otimes I - i\sin\theta_8 \sigma_z \otimes I \otimes \sigma_z \otimes I \\
&= \cos\theta_8 \begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{pmatrix}
\end{aligned}
$$

$$
- i \sin \theta_8 \begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{pmatrix}
$$

$$
= \begin{pmatrix}
e^{-i\theta_8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & e^{-i\theta_8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & e^{i\theta_8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & e^{i\theta_8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & e^{-i\theta_8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & e^{-i\theta_8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_8} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_8} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_8} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_8} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_7} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_8} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_8}
\end{pmatrix} \tag{170}
$$

$$
\begin{aligned}
R\left(4\theta_9\right) &= e^{-i2\pi J_{32} I_z \otimes I_z \otimes I \otimes I t} \\
&= e^{-i\frac{\pi J_{32} t}{2}\sigma_z \otimes \sigma_z \otimes I \otimes I} \\
&= \cos\theta_9 I \otimes I \otimes I \otimes I - i\sin\theta_9 \sigma_z \otimes \sigma_z \otimes I \otimes I \\
&= \cos\theta_9 \begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{pmatrix}
\end{aligned}
$$

$$
- i \sin\theta_9 \begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{pmatrix}
$$

$$
= \begin{pmatrix}
e^{-i\theta_9} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & e^{-i\theta_9} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & e^{-i\theta_9} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & e^{-i\theta_9} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & e^{i\theta_9} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & e^{i\theta_9} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_9} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_9} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_9} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_9} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_9} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{i\theta_9} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_9} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_9} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_9} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{-i\theta_9}
\end{pmatrix} \tag{171}
$$

maka dengan demikian didapatkan untuk operator U_5 adalah

$$U_5 = \begin{pmatrix}
e^{\beta_0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & e^{\beta_1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & e^{\beta_2} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & e^{\beta_3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & e^{\beta_4} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & e^{\beta_5} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_7} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_9} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_10} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_11} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_12} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_13} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_15}
\end{pmatrix} \tag{172}$$

dengan

$$\begin{array}{cc} \beta_0 = -iE_{4,0}t & \beta_1 = -iE_{4,1}t \\ \beta_2 = -iE_{4,2}t & \beta_3 = -iE_{4,3}t \\ \beta_4 = -iE_{4,4}t & \beta_5 = -iE_{4,5}t \\ \beta_6 = -iE_{4,6}t & \beta_7 = -iE_{4,7}t \\ \beta_8 = -iE_{4,8}t & \beta_9 = -iE_{4,9}t \\ \beta_1 0 = -iE_{4,10}t & \beta_1 1 = -iE_{4,11}t \\ \beta_1 2 = -iE_{4,12}t & \beta_1 3 = -iE_{4,13}t \\ \beta_1 4 = -iE_{4,14}t & \beta_1 5 = -iE_{4,15}t \end{array} \tag{173}$$

dan

$$\begin{aligned}
E_0 &= \frac{1}{2}\left[\omega_0 + \omega_1 + \omega_2 + \omega_3 + \pi J_{10} + \pi J_{20} + \pi J_{30} + \pi J_{21} + \pi J_{31} + \pi J_{32}\right] \\
E_1 &= \frac{1}{2}\left[-\omega_0 + \omega_1 + \omega_2 + \omega_3 - \pi J_{10} - \pi J_{20} + \pi J_{30} + \pi J_{21} - \pi J_{31} + \pi J_{32}\right] \\
E_2 &= \frac{1}{2}\left[\omega_0 - \omega_1 + \omega_2 + \omega_3 - \pi J_{10} + \pi J_{20} + \pi J_{30} - \pi J_{21} - \pi J_{31} + \pi J_{32}\right] \\
E_3 &= \frac{1}{2}\left[-\omega_0 - \omega_1 + \omega_2 + \omega_3 + \pi J_{10} - \pi J_{20} - \pi J_{30} - \pi J_{21} - \pi J_{31} + \pi J_{32}\right] \\
E_4 &= \frac{1}{2}\left[\omega_0 + \omega_1 - \omega_2 + \omega_3 + \pi J_{10} + \pi J_{20} + \pi J_{30} - \pi J_{21} + \pi J_{31} - \pi J_{32}\right] \\
E_5 &= \frac{1}{2}\left[-\omega_0 + \omega_1 - \omega_2 + \omega_3 - \pi J_{10} + \pi J_{20} - \pi J_{30} - \pi J_{21} + \pi J_{31} - \pi J_{32}\right] \\
E_6 &= \frac{1}{2}\left[\omega_0 - \omega_1 - \omega_2 + \omega_3 - \pi J_{10} - \pi J_{20} + \pi J_{30} + \pi J_{21} - \pi J_{31} + \pi J_{32}\right] \\
E_7 &= \frac{1}{2}\left[-\omega_0 - \omega_1 - \omega_2 + \omega_3 + \pi J_{10} + \pi J_{20} = \pi J_{30} + \pi J_{21} - \pi J_{31} - \pi J_{32}\right] \\
E_8 &= \frac{1}{2}\left[\omega_0 + \omega_1 + \omega_2 - \omega_3 + \pi J_{10} + \pi J_{20} - \pi J_{30} + \pi J_{21} - \pi J_{31} - \pi J_{32}\right] \\
E_9 &= \frac{1}{2}\left[-\omega_0 + \omega_1 + \omega_2 - \omega_3 - \pi J_{10} - \pi J_{20} + \pi J_{30} + \pi J_{21} - \pi J_{31} - \pi J_{32}\right] \\
E_1 0 &= \frac{1}{2}\left[\omega_0 - \omega_1 + \omega_2 - \omega_3 - \pi J_{10} + \pi J_{20} - \pi J_{30} - \pi J_{21} + \pi J_{31} - \pi J_{32}\right] \\
E_1 1 &= \frac{1}{2}\left[-\omega_0 - \omega_1 + \omega_2 - \omega_3 + \pi J_{10} - \pi J_{20} + \pi J_{30} - \pi J_{21} + \pi J_{31} - \pi J_{32}\right] \\
E_1 2 &= \frac{1}{2}\left[\omega_0 + \omega_1 - \omega_2 - \omega_3 + \pi J_{10} - \pi J_{20} - \pi J_{30} - \pi J_{21} - \pi J_{31} + \pi J_{32}\right] \\
E_1 3 &= \frac{1}{2}\left[-\omega_0 + \omega_1 - \omega_2 - \omega_3 - \pi J_{10} + \pi J_{20} + \pi J_{30} - \pi J_{21} - \pi J_{31} + \pi J_{32}\right] \\
E_1 4 &= \frac{1}{2}\left[\omega_0 - \omega_1 - \omega_2 - \omega_3 - \pi J_{10} - \pi J_{20} - \pi J_{30} + \pi J_{21} + \pi J_{31} + \pi J_{32}\right] \\
E_1 5 &= \frac{1}{2}\left[-\omega_0 - \omega_1 - \omega_2 - \omega_3 + \pi J_{10} + \pi J_{20} + \pi J_{30} + \pi J_{21} + \pi J_{31} + \pi J_{32}\right]
\end{aligned} \tag{174}$$

apabila kita mengambil kasus untuk $U_2 = U_{k0} = I \otimes I \otimes I \otimes I$ maka operator unitary totalnya menjadi

$$
\begin{aligned}
U &= U_5 \left(I \otimes I \otimes I \otimes I \right) U_1 \\
&= U_5 U_1 \\
&= \frac{1}{4} \begin{pmatrix}
e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} \\
e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} \\
e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} \\
e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} \\
e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} \\
e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} \\
e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} \\
e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} \\
e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} \\
e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} \\
e^{\beta_10} & -e^{\beta_10} & e^{\beta_10} & -e^{\beta_10} & -e^{\beta_10} & e^{\beta_10} & -e^{\beta_10} & e^{\beta_10} & e^{\beta_10} & -e^{\beta_10} & e^{\beta_10} & -e^{\beta_10} & -e^{\beta_10} & e^{\beta_10} & -e^{\beta_10} & e^{\beta_10} \\
e^{\beta_11} & e^{\beta_11} & e^{\beta_11} & e^{\beta_11} & -e^{\beta_11} & -e^{\beta_11} & -e^{\beta_11} & -e^{\beta_11} & e^{\beta_11} & e^{\beta_11} & e^{\beta_11} & e^{\beta_11} & -e^{\beta_11} & -e^{\beta_11} & -e^{\beta_11} & -e^{\beta_11} \\
e^{\beta_12} & -e^{\beta_12} & -e^{\beta_12} & e^{\beta_12} & e^{\beta_12} & -e^{\beta_12} & -e^{\beta_12} & e^{\beta_12} & e^{\beta_12} & -e^{\beta_12} & -e^{\beta_12} & e^{\beta_12} & e^{\beta_12} & -e^{\beta_12} & -e^{\beta_12} & e^{\beta_12} \\
e^{\beta_13} & e^{\beta_13} & -e^{\beta_13} & -e^{\beta_13} & e^{\beta_13} & e^{\beta_13} & -e^{\beta_13} & -e^{\beta_13} & e^{\beta_13} & e^{\beta_13} & -e^{\beta_13} & -e^{\beta_13} & e^{\beta_13} & e^{\beta_13} & -e^{\beta_13} & -e^{\beta_13} \\
e^{\beta_14} & -e^{\beta_14} & e^{\beta_14} & -e^{\beta_14} & e^{\beta_14} & -e^{\beta_14} & e^{\beta_14} & -e^{\beta_14} & e^{\beta_14} & -e^{\beta_14} & e^{\beta_14} & -e^{\beta_14} & e^{\beta_14} & -e^{\beta_14} & e^{\beta_14} & -e^{\beta_14} \\
e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15}
\end{pmatrix}
\end{aligned}
\tag{175}
$$

dan

$$
U^\dagger = \frac{1}{4}\begin{pmatrix}
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}}
\end{pmatrix} \qquad (176)
$$

maka dengan demikian kita dapatkan untuk nilai ρ_5 adalah

$$
\begin{aligned}
\rho_5 &= U\rho_0 U^\dagger \\
&= \frac{1}{4}\begin{pmatrix}
e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} \\
e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} \\
e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} \\
e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} \\
e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} \\
e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} \\
e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} \\
e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} \\
e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} \\
e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} \\
e^{\beta_10} & -e^{\beta_10} & e^{\beta_10} & -e^{\beta_10} & -e^{\beta_10} & e^{\beta_10} & -e^{\beta_10} & e^{\beta_10} & e^{\beta_10} & -e^{\beta_10} & e^{\beta_10} & -e^{\beta_10} & -e^{\beta_10} & e^{\beta_10} & -e^{\beta_10} & e^{\beta_10} \\
e^{\beta_11} & e^{\beta_11} & e^{\beta_11} & e^{\beta_11} & -e^{\beta_11} & -e^{\beta_11} & -e^{\beta_11} & -e^{\beta_11} & e^{\beta_11} & e^{\beta_11} & e^{\beta_11} & e^{\beta_11} & -e^{\beta_11} & -e^{\beta_11} & -e^{\beta_11} & -e^{\beta_11} \\
e^{\beta_12} & -e^{\beta_12} & -e^{\beta_12} & e^{\beta_12} & e^{\beta_12} & -e^{\beta_12} & -e^{\beta_12} & e^{\beta_12} & e^{\beta_12} & -e^{\beta_12} & -e^{\beta_12} & e^{\beta_12} & e^{\beta_12} & -e^{\beta_12} & -e^{\beta_12} & e^{\beta_12} \\
e^{\beta_13} & e^{\beta_13} & -e^{\beta_13} & -e^{\beta_13} & e^{\beta_13} & e^{\beta_13} & -e^{\beta_13} & -e^{\beta_13} & e^{\beta_13} & e^{\beta_13} & -e^{\beta_13} & -e^{\beta_13} & e^{\beta_13} & e^{\beta_13} & -e^{\beta_13} & -e^{\beta_13} \\
e^{\beta_14} & -e^{\beta_14} & e^{\beta_14} & -e^{\beta_14} & e^{\beta_14} & -e^{\beta_14} & e^{\beta_14} & -e^{\beta_14} & e^{\beta_14} & -e^{\beta_14} & e^{\beta_14} & -e^{\beta_14} & e^{\beta_14} & -e^{\beta_14} & e^{\beta_14} & -e^{\beta_14} \\
e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15} & e^{\beta_15}
\end{pmatrix}
\end{aligned}
$$

$$
\times \begin{pmatrix}
2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -2
\end{pmatrix}
$$

$$
\times \frac{1}{4}
\begin{pmatrix}
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}}
\end{pmatrix}
$$

$$
= \frac{1}{16}\begin{pmatrix}
0 & 8\rho_{0,1} & 8\rho_{0,2} & 0 & 8\rho_{0,4} & 0 & 0 & 0 & 8\rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
8\rho_{1,0} & 0 & 0 & 8\rho_{1,3} & 0 & 8\rho_{1,5} & 0 & 0 & 0 & 8\rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
8\rho_{2,0} & 0 & 0 & 8\rho_{2,3} & 0 & 0 & 8\rho_{2,6} & 0 & 0 & 0 & 8\rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & 8\rho_{3,1} & 8\rho_{3,2} & 0 & 0 & 0 & 0 & 8\rho_{3,7} & 0 & 0 & 8\rho_{3,11} & 0 & 0 & 0 & 0 & 0 \\
8\rho_{40} & 0 & 0 & 0 & 0 & 8\rho_{4,5} & 8\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & 8\rho_{4,12} & 0 & 0 & 0 \\
0 & 8\rho_{4,1} & 0 & 0 & 8\rho_{5,4} & 0 & 0 & 8\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & 8\rho_{5,13} & 0 & 0 \\
0 & 0 & 8\rho_{6,2} & 0 & 8\rho_{6,4} & 0 & 0 & 8\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & 8\rho_{6,14} & 0 \\
0 & 0 & 0 & 8\rho_{7,3} & 0 & 8\rho_{7,5} & 8\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 8\rho_{7,15} \\
8\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 8\rho_{8,9} & 8\rho_{8,10} & 0 & 8\rho_{8,12} & 0 & 0 & 0 \\
0 & 8\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & 8\rho_{9,8} & 0 & 0 & 8\rho_{9,11} & 0 & 8\rho_{9,13} & 0 & 0 \\
0 & 0 & 8\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & 8\rho_{10,8} & 0 & 0 & 8\rho_{10,11} & 0 & 0 & 8\rho_{10,14} & 0 \\
0 & 0 & 0 & 8\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & 8\rho_{11,9} & 8\rho_{11,10} & 0 & 0 & 0 & 0 & 8\rho_{11,15} \\
0 & 0 & 0 & 0 & 8\rho_{12,4} & 0 & 0 & 0 & 8\rho_{12,8} & 0 & 0 & 0 & 0 & 8\rho_{12,13} & 8\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 8\rho_{13,5} & 0 & 0 & 0 & 8\rho_{13,9} & 0 & 0 & 8\rho_{13,12} & 0 & 0 & 8\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & 8\rho_{14,6} & 0 & 0 & 0 & 8\rho_{14,10} & 0 & 8\rho_{14,12} & 0 & 0 & 8\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 8\rho_{15,7} & 0 & 0 & 0 & 8\rho_{15,11} & 0 & 8\rho 15, 13 & 8\rho_{15,14} & 0
\end{pmatrix} \tag{177}
$$

$$
= \frac{1}{2}\begin{pmatrix}
0 & \rho_{0,1} & \rho_{0,2} & 0 & \rho_{0,4} & 0 & 0 & 0 & \rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{1,0} & 0 & 0 & \rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & \rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{2,0} & 0 & 0 & \rho_{2,3} & 0 & 0 & \rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{3,1} & \rho_{3,2} & 0 & 0 & 0 & 0 & \rho_{3,7} & 0 & 0 & \rho_{3,11} & 0 & 0 & 0 & 0 & 0 \\
\rho_{40} & 0 & 0 & 0 & 0 & \rho_{4,5} & \rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{4,1} & 0 & 0 & \rho_{5,4} & 0 & 0 & \rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & \rho_{6,2} & 0 & \rho_{6,4} & 0 & 0 & \rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & \rho_{7,5} & \rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{8,9} & \rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & \rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{9,8} & 0 & 0 & \rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & \rho_{10,2} & 0 & 0 & 0 & 0 & 0 & \rho_{10,8} & 0 & 0 & \rho_{10,11} & 0 & 0 & \rho_{10,14} & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & \rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & \rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & \rho_{12,13} & \rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & \rho_{13,12} & 0 & 0 & \rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & \rho_{14,12} & 0 & 0 & \rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & \rho 15, 13 & \rho_{15,14} & 0
\end{pmatrix} \tag{178}
$$

dengan

$$
\begin{array}{cc}
\rho_{0,1} = \rho_{1,0}{}^{*} = e^{\beta_0-\beta_1} & \rho_{6,7} = \rho_{7,6}{}^{*} = e^{\beta_6-\beta_7} \\
\rho_{0,2} = \rho_{2,0}{}^{*} = e^{\beta_0-\beta_2} & \rho_{6,14} = \rho_{14,6}{}^{*} = e^{\beta_6-\beta_14} \\
\rho_{0,8} = \rho_{8,0}{}^{*} = e^{\beta_8-\beta_1} & \rho_{8,9} = \rho_{9,8}{}^{*} = e^{\beta_8-\beta_9} \\
\rho_{1,3} = \rho_{3,1}{}^{*} = e^{\beta_1-\beta_3} & \rho_{8,10} = \rho_{10,8}{}^{*} = e^{\beta_8-\beta_{10}} \\
\rho_{1,5} = \rho_{5,1}{}^{*} = e^{\beta_1-\beta_5} & \rho_{8,12} = \rho_{12,8}{}^{*} = e^{\beta_8-\beta_{12}} \\
\rho_{1,9} = \rho_{9,1}{}^{*} = e^{\beta_1-\beta_9} & \rho_{9,11} = \rho_{11,9}{}^{*} = e^{\beta_9-\beta_{11}} \\
\rho_{2,3} = \rho_{3,2}{}^{*} = e^{\beta_2-\beta_3} & \rho_{9,13} = \rho_{13,9}{}^{*} = e^{\beta_9-\beta_{13}} \\
\rho_{2,6} = \rho_{6,2}{}^{*} = e^{\beta_2-\beta_6} & \rho_{10,11} = \rho_{11,10}{}^{*} = e^{\beta_{10}-\beta_{11}} \\
\rho_{2,10} = \rho_{10,2}{}^{*} = e^{\beta_2-\beta_10} & \rho_{10,14} = \rho_{14,10}{}^{*} = e^{\beta_{10}-\beta_{14}} \\
\rho_{3,7} = \rho_{7,3}{}^{*} = e^{\beta_3-\beta_7} & \rho_{12,13} = \rho_{13,12}{}^{*} = e^{\beta_{12}-\beta_{13}} \\
\rho_{3,11} = \rho_{11,3}{}^{*} = e^{\beta_3-\beta_11} & \rho_{12,14} = \rho_{14,12}{}^{*} = e^{\beta_{12}-\beta_{14}} \\
\rho_{4,5} = \rho_{5,4}{}^{*} = e^{\beta_4-\beta_5} & \rho_{11,15} = \rho_{15,11}{}^{*} = e^{\beta_{11}-\beta_{15}} \\
\rho_{4,6} = \rho_{6,4}{}^{*} = e^{\beta_4-\beta_6} & \rho_{13,15} = \rho_{15,13}{}^{*} = e^{\beta_{13}-\beta_{15}} \\
\rho_{4,12} = \rho_{12,4}{}^{*} = e^{\beta_4-\beta_12} & \rho_{14,15} = \rho_{14,15}{}^{*} = e^{\beta_{14}-\beta_{15}} \\
\rho_{5,7} = \rho_{7,5}{}^{*} = e^{\beta_5-\beta_7} & \rho_{15,7} = \rho_{7,15}{}^{*} = e^{\beta_7-\beta_{15}} \\
\rho_{5,13} = \rho_{13,5}{}^{*} = e^{\beta_5-\beta_13} & \rho_{0,4} = \rho_{4,0}{}^{*} = e^{\beta_0-\beta_4}
\end{array}
\tag{179}
$$

dan

$$
\begin{array}{ll}
\beta_0-\beta_1=-i\left(E_{4,0}-E_{4,1}\right)t & \beta_0-\beta_2=-i\left(E_{4,0}-E_{4,2}\right)t \\
\beta_0-\beta_4=-i\left(E_{4,0}-E_{4,4}\right)t & \beta_0-\beta_8=-i\left(E_{4,0}-E_{4,8}\right)t \\
\beta_1-\beta_3=-i\left(E_{4,1}-E_{4,3}\right)t & \beta_1-\beta_5=-i\left(E_{4,1}-E_{4,5}\right)t \\
\beta_1-\beta_9=-i\left(E_{4,1}-E_{4,9}\right)t & \beta_2-\beta_3=-i\left(E_{4,2}-E_{4,3}\right)t \\
\beta_2-\beta_6=-i\left(E_{4,2}-E_{4,6}\right)t & \beta_2-\beta_{10}=-i\left(E_{4,2}-E_{4,10}\right)t \\
\beta_3-\beta_7=-i\left(E_{4,3}-E_{4,7}\right)t & \beta_3-\beta_{11}=-i\left(E_{4,3}-E_{4,11}\right)t \\
\beta_4-\beta_5=-i\left(E_{4,4}-E_{4,5}\right)t & \beta_4-\beta_6=-i\left(E_{4,4}-E_{4,6}\right)t \\
\beta_4-\beta_{12}=-i\left(E_{4,4}-E_{4,12}\right)t & \beta_5-\beta_7=-i\left(E_{4,5}-E_{4,7}\right)t \\
\beta_5-\beta_{13}=-i\left(E_{4,5}-E_{4,13}\right)t & \beta_6-\beta_7=-i\left(E_{4,6}-E_{4,7}\right)t \\
\beta_6-\beta_{14}=-i\left(E_{4,6}-E_{4,14}\right)t & \beta_8-\beta_9=-i\left(E_{4,8}-E_{4,9}\right)t \\
\beta_8-\beta_{10}=-i\left(E_{4,8}-E_{4,10}\right)t & \beta_8-\beta_{12}=-i\left(E_{4,8}-E_{4,12}\right)t \\
\beta_9-\beta_{11}=-i\left(E_{4,9}-E_{4,11}\right)t & \beta_9-\beta_{13}=-i\left(E_{4,9}-E_{4,13}\right)t \\
\beta_{10}-\beta_{11}=-i\left(E_{4,10}-E_{4,11}\right)t & \beta_{10}-\beta_{14}=-i\left(E_{4,10}-E_{4,14}\right)t \\
\beta_{12}-\beta_{13}=-i\left(E_{4,12}-E_{4,13}\right)t & \beta_{12}-\beta_{14}=-i\left(E_{4,12}-E_{4,14}\right)t \\
\beta_{11}-\beta_{15}=-i\left(E_{4,11}-E_{4,15}\right)t & \beta_{13}-\beta_{15}=-i\left(E_{4,13}-E_{4,15}\right)t \\
\beta_{14}-\beta_{15}=-i\left(E_{4,14}-E_{4,15}\right)t & \beta_{15}-\beta_7=-i\left(E_{4,15}-E_{4,7}\right)t
\end{array}
\tag{180}
$$

dan

$$
\begin{array}{cc}
E_{4,0} - E4,1 = \omega_0 + \pi J_{10} + \pi J_{20} + \pi J_{30} & E_{4,0} - E4,2 = \omega_1 + \pi J_{10} + \pi J_{21} + \pi J_{31} \\
E_{4,0} - E4,4 = \omega_2 + \pi J_{20} + \pi J_{21} + \pi J_{32} & E_{4,0} - E4,8 = \omega_3 + \pi J_{30} + \pi J_{31} + \pi J_{32} \\
E_{4,1} - E4,3 = \omega_1 - \pi J_{10} + \pi J_{21} + \pi J_{31} & E_{4,1} - E4,5 = \omega_2 - \pi J_{20} + \pi J_{21} + \pi J_{32} \\
E_{4,1} - E4,9 = \omega_3 - \pi J_{30} + \pi J_{310} + \pi J_{32} & E_{4,2} - E4,3 = \omega_0 - \pi J_{10} + \pi J_{20} + \pi J_{30} \\
E_{4,2} - E4,6 = \omega_2 + \pi J_{20} - \pi J_{21} + \pi J_{32} & E_{4,2} - E4,10 = \omega_3 + \pi J_{30} - \pi J_{31} + \pi J_{32} \\
E_{4,3} - E4,7 = \omega_2 - \pi J_{20} - \pi J_{21} + \pi J_{32} & E_{4,3} - E4,11 = \omega_3 - \pi J_{30} - \pi J_{31} + \pi J_{32} \\
E_{4,4} - E4,5 = \omega_0 + \pi J_{10} - \pi J_{20} + \pi J_{30} & E_{4,4} - E4,6 = \omega_1 + \pi J_{10} - \pi J_{21} + \pi J_{31} \\
E_{4,4} - E4,12 = \omega_3 + \pi J_{30} + \pi J_{31} - \pi J_{32} & E_{4,5} - E4,7 = \omega_1 - \pi J_{10} - \pi J_{21} + \pi J_{31} \\
E_{4,5} - E4,13 = \omega_3 - \pi J_{30} + \pi J_{31} - \pi J_{32} & E_{4,6} - E4,7 = \omega_0 - \pi J_{10} - \pi J_{20} + \pi J_{30} \\
E_{4,6} - E4,14 = \omega_3 + \pi J_{30} - \pi J_{31} - \pi J_{32} & E_{4,8} - E4,9 = \omega_0 + \pi J_{10} + \pi J_{20} - \pi J_{30} \\
E_{4,8} - E4,10 = \omega_1 + \pi J_{21} - \pi J_{31} + \pi J_{30} & E_{4,8} - E4,12 = \omega_2 + \pi J_{20} + \pi J_{21} - \pi J_{32} \\
E_{4,9} - E4,11 = \omega_1 - \pi J_{10} + \pi J_{21} - \pi J_{32} & E_{4,10} - E4,11 = \omega_0 - \pi J_{10} + \pi J_{20} - \pi J_{30} \\
E_{4,10} - E4,14 = \omega_2 + \pi J_{20} - \pi J_{21} - \pi J_{32} & E_{4,12} - E4,13 = \omega_0 + \pi J_{10} - \pi J_{20} - \pi J_{30} \\
E_{4,12} - E4,14 = \omega_1 + \pi J_{10} - \pi J_{21} - \pi J_{31} & E_{4,11} - E4,15 = \omega_2 - \pi J_{20} - \pi J_{21} - \pi J_{32} \\
E_{4,13} - E4,15 = \omega_1 - \pi J_{10} - \pi J_{21} - \pi J_{31} & E_{4,14} - E4,15 = \omega_0 - \pi J_{10} - \pi J_{20} - \pi J_{30} \\
E_{4,9} - E4,13 = \omega_2 - \pi J_{20} + \pi J_{21} - \pi J_{32} & E_{4,15} - E4,7 = \omega_3 + \pi J_{30} + \pi J_{31} + \pi J_{32}
\end{array}
\quad (181)
$$

maka dengan demikian suku-suku tidak nol dari matriks ρ_5 menjadi:

$$\begin{aligned}
\rho_{0,1} = {\rho_{1,0}}^* &= e^{-i(\omega_0+\pi J_{10}+\pi J_{20}+\pi J_{30})t} \\
\rho_{0,2} = {\rho_{2,0}}^* &= e^{-i(\omega_1+\pi J_{10}+\pi J_{21}+\pi J_{31})t} \\
\rho_{0,4} = {\rho_{4,0}}^* &= e^{-i(\omega_2+\pi J_{20}+\pi J_{21}+\pi J_{32})t} \\
\rho_{0,8} = {\rho_{8,0}}^* &= e^{-i(\omega_3+\pi J_{30}+\pi J_{31}+\pi J_{32})t} \\
\rho_{1,3} = {\rho_{3,1}}^* &= e^{-i(\omega_1-\pi J_{10}+\pi J_{21}+\pi J_{31})t} \\
\rho_{1,5} = {\rho_{5,1}}^* &= e^{-i(\omega_2-\pi J_{20}+\pi J_{21}+\pi J_{32})t} \\
\rho_{1,9} = {\rho_{9,1}}^* &= e^{-i(\omega_3-\pi J_{30}+\pi J_{310}+\pi J_{32})t} \\
\rho_{2,3} = {\rho_{3,2}}^* &= e^{-i(\omega_0-\pi J_{10}+\pi J_{20}+\pi J_{30})t} \\
\rho_{2,6} = {\rho_{6,2}}^* &= e^{-i(\omega_2+\pi J_{20}-\pi J_{21}+\pi J_{32})t} \\
\rho_{2,10} = {\rho_{10,2}}^* &= e^{-i(\omega_3+\pi J_{30}-\pi J_{31}+\pi J_{32})t} \\
\rho_{3,7} = {\rho_{7,3}}^* &= e^{-i(\omega_2-\pi J_{20}-\pi J_{21}+\pi J_{32})t} \\
\rho_{3,11} = {\rho_{11,3}}^* &= e^{-i(\omega_3-\pi J_{30}-\pi J_{31}+\pi J_{32})t} \\
\rho_{4,5} = {\rho_{5,4}}^* &= e^{-i(\omega_0+\pi J_{10}-\pi J_{20}+\pi J_{30})t} \\
\rho_{4,6} = {\rho_{6,4}}^* &= e^{-i(\omega_1+\pi J_{10}-\pi J_{21}+\pi J_{31})t} \\
\rho_{4,12} = {\rho_{12,4}}^* &= e^{-i(\omega_3+\pi J_{30}+\pi J_{31}-\pi J_{32})t} \\
\rho_{5,7} = {\rho_{7,5}}^* &= e^{-i(\omega_1-\pi J_{10}-\pi J_{21}+\pi J_{31})t} \\
\rho_{5,13} = {\rho_{13,5}}^* &= e^{-i(\omega_3-\pi J_{30}+\pi J_{31}-\pi J_{32})t} \\
\rho_{6,7} = {\rho_{7,6}}^* &= e^{-i(\omega_0-\pi J_{10}-\pi J_{20}+\pi J_{30})t} \\
\rho_{6,14} = {\rho_{14,6}}^* &= e^{-i(\omega_3+\pi J_{30}-\pi J_{31}-\pi J_{32})t} \\
\rho_{8,9} = {\rho_{9,8}}^* &= e^{-i(\omega_0+\pi J_{10}+\pi J_{20}-\pi J_{30})t} \\
\rho_{8,10} = {\rho_{10,8}}^* &= e^{-i(\omega_1+\pi J_{21}-\pi J_{31}+\pi J_{30})t} \\
\rho_{8,12} = {\rho_{12,8}}^* &= e^{-i(\omega_2+\pi J_{20}+\pi J_{21}-\pi J_{32})t}
\end{aligned} \tag{182}$$

$$
\begin{aligned}
\rho_{9,11} = \rho_{11,9}{}^* &= e^{-i(\omega_1 - \pi J_{10} + \pi J_{21} - \pi J_{32})t} \\
\rho_{10,11} = \rho_{11,10}{}^* &= e^{-i(\omega_0 - \pi J_{10} + \pi J_{20} - \pi J_{30})t} \\
\rho_{10,14} = \rho_{14,10}{}^* &= e^{-i(\omega_2 + \pi J_{20} - \pi J_{21} - \pi J_{32})t} \\
\rho_{12,13} = \rho_{13,12}{}^* &= e^{-i(\omega_0 + \pi J_{10} - \pi J_{20} - \pi J_{30})t} \\
\rho_{12,14} = \rho_{14,12}{}^* &= e^{-i(\omega_1 + \pi J_{10} - \pi J_{21} - \pi J_{31})t} \\
\rho_{11,15} = \rho_{15,11}{}^* &= e^{-i(\omega_2 - \pi J_{20} - \pi J_{21} - \pi J_{32})t} \\
\rho_{7,15} = \rho_{15,7}{}^* &= e^{-i(\omega_3 - \pi J_{30} - \pi J_{31} - \pi J_{32})t} \\
\rho_{13,15} = \rho_{15,13}{}^* &= e^{-i(\omega_1 - \pi J_{10} - \pi J_{21} - \pi J_{31})t} \\
\rho_{14,15} = \rho_{15,14}{}^* &= e^{-i(\omega_0 - \pi J_{10} - \pi J_{20} - \pi J_{30})t} \\
\rho_{9,13} = \rho_{13,9}{}^* &= e^{-i(\omega_2 - \pi J_{20} + \pi J_{21} - \pi J_{32})t}
\end{aligned}
\tag{183}
$$

setelah di dapatkan matriks densitas ρ_5 maka dapat diukur nilai magetisasi dari sistem M_+, untuk mengukur nilai magnetisasi sebelumnya harus ditentukan terlebih dahulu representasi matriks daripada operator penaik dari masing-masing qubit : yaitu sebagai berikut:

$$\begin{aligned}
I_{0+} &= I \otimes I \otimes I \otimes (I_x + iI_y) \\
&= \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \otimes \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \otimes \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \otimes \begin{pmatrix} 0 & 1 \\ 0 & 0 \end{pmatrix} \\
&= \begin{pmatrix}
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
\end{aligned} \tag{184}$$

$$
\begin{aligned}
I_{1+} &= I \otimes I \otimes (I_x + iI_y) \otimes I \\
&= \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \otimes \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \otimes \begin{pmatrix} 0 & 1 \\ 0 & 0 \end{pmatrix} \otimes \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \\
&= \begin{pmatrix}
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
\end{aligned} \tag{185}
$$

$$
\begin{aligned}
I_{2+} &= I \otimes (I_x + iI_y) \otimes I \otimes I \\
&= \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \otimes \begin{pmatrix} 0 & 1 \\ 0 & 0 \end{pmatrix} \otimes \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \otimes \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \\
&= \begin{pmatrix}
0&0&0&0&1&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&1&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&1&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&1&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&1&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&1&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&1&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&1&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&1\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0
\end{pmatrix}
\end{aligned}
\tag{186}
$$

$$
\begin{aligned}
I_{3+} &= (I_x + iI_y) \otimes I \otimes I \otimes I \\
&= \begin{pmatrix} 0 & 1 \\ 0 & 0 \end{pmatrix} \otimes \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \otimes \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \otimes \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \\
&= \begin{pmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
\end{aligned}
\tag{187}
$$

maka dapat ditentukan nilai magnetisasi dari masing-masing qubitnya yaitu sebagai berikut:

$$
(I_{3+}\rho_5) = \begin{pmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$
\times \frac{1}{2}
\begin{pmatrix}
0 & \rho_{0,1} & \rho_{0,2} & 0 & \rho_{0,4} & 0 & 0 & 0 & \rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{1,0} & 0 & 0 & \rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & \rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{2,0} & 0 & 0 & \rho_{2,3} & 0 & 0 & \rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{3,1} & \rho_{3,2} & 0 & 0 & 0 & 0 & \rho_{3,7} & 0 & 0 & \rho_{3,11} & 0 & 0 & 0 & 0 & 0 \\
\rho_{40} & 0 & 0 & 0 & 0 & \rho_{4,5} & \rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{5,1} & 0 & 0 & \rho_{5,4} & 0 & 0 & \rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & \rho_{6,2} & 0 & \rho_{6,4} & 0 & 0 & \rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & \rho_{7,5} & \rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{8,9} & \rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & \rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{9,8} & 0 & 0 & \rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & \rho_{10,2} & 0 & 0 & 0 & 0 & 0 & \rho_{10,8} & 0 & 0 & \rho_{10,11} & 0 & 0 & \rho_{10,14} & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & \rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & \rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & \rho_{12,13} & \rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & \rho_{13,12} & 0 & 0 & \rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & \rho_{14,12} & 0 & 0 & \rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & \rho 15, 13 & \rho_{15,14} & 0
\end{pmatrix}
$$

$$
= \frac{1}{2}\begin{pmatrix}
\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{8,9} & \rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & \rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{9,8} & 0 & 0 & \rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & \rho_{10,2} & 0 & 0 & 0 & 0 & 0 & \rho_{10,8} & 0 & 0 & \rho_{10,11} & 0 & 0 & \rho_{10,14} & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & \rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & \rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & \rho_{12,13} & \rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & \rho_{13,12} & 0 & 0 & \rho_{13,15} \\
0 & 0 & 0 & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & \rho_{14,12} & 0 & 0 & \rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & \rho_{15,13} & \rho_{15,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$
\begin{aligned}
M_{3+} &= \langle I_{3+} \rangle = tr\left(I_{3+}\rho_5\right) \\
&= \rho_{8,0} + \rho_{9,1} + \rho_{10,2} + \rho_{11,3} + \rho_{12,4} + \rho_{13,5} + \rho_{14,6} + \rho_{15,7}
\end{aligned} \tag{188}
$$

dan

$$
(I_{2+}\rho_5) = \begin{pmatrix}
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$
\times \frac{1}{2}
\begin{pmatrix}
0 & \rho_{0,1} & \rho_{0,2} & 0 & \rho_{0,4} & 0 & 0 & 0 & \rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{1,0} & 0 & 0 & \rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & \rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{2,0} & 0 & 0 & \rho_{2,3} & 0 & 0 & \rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{3,1} & \rho_{3,2} & 0 & 0 & 0 & 0 & \rho_{3,7} & 0 & 0 & \rho_{3,11} & 0 & 0 & 0 & 0 & 0 \\
\rho_{40} & 0 & 0 & 0 & 0 & \rho_{4,5} & \rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{5,1} & 0 & 0 & \rho_{5,4} & 0 & 0 & \rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & \rho_{6,2} & 0 & \rho_{6,4} & 0 & 0 & \rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & \rho_{7,5} & \rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{8,9} & \rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & \rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{9,8} & 0 & 0 & \rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & \rho_{10,2} & 0 & 0 & 0 & 0 & 0 & \rho_{10,8} & 0 & 0 & \rho_{10,11} & 0 & 0 & \rho_{10,14} & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & \rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & \rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & \rho_{12,13} & \rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & \rho_{13,12} & 0 & 0 & \rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & \rho_{14,12} & 0 & 0 & \rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & \rho 15, 13 & \rho_{15,14} & 0
\end{pmatrix}
$$

$$
= \frac{1}{2}\begin{pmatrix}
\rho_{4,0} & 0 & 0 & 0 & 0 & \rho_{4,5} & \rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{5,1} & 0 & 0 & \rho_{5,4} & 0 & 0 & \rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & \rho_{6,2} & 0 & \rho_{6,4} & 0 & 0 & \rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & \rho_{7,5} & \rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & \rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & \rho_{12,13} & \rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & \rho_{13,12} & 0 & 0 & \rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & \rho_{14,12} & 0 & 0 & \rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & \rho 15,13 & \rho_{15,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix} \tag{189}
$$

$$
\begin{aligned}
M_{2+} &= \langle I_{2+} \rangle = tr\left(I_{2+}\rho_5\right) \\
&= \rho_{4,0} + \rho_{5,1} + \rho_{6,2} + \rho_{7,3} + \rho_{12,8} + \rho_{13,9} + \rho_{14,10} + \rho_{15,11}
\end{aligned}
\tag{190}
$$

dan

$$
(I_{1+}\rho_5) = \begin{pmatrix}
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$
\times \frac{1}{2}
\begin{pmatrix}
0 & \rho_{0,1} & \rho_{0,2} & 0 & \rho_{0,4} & 0 & 0 & 0 & \rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{1,0} & 0 & 0 & \rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & \rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{2,0} & 0 & 0 & \rho_{2,3} & 0 & 0 & \rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{3,1} & \rho_{3,2} & 0 & 0 & 0 & 0 & \rho_{3,7} & 0 & 0 & \rho_{3,11} & 0 & 0 & 0 & 0 & 0 \\
\rho_{40} & 0 & 0 & 0 & 0 & \rho_{4,5} & \rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{5,1} & 0 & 0 & \rho_{5,4} & 0 & 0 & \rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & \rho_{6,2} & 0 & \rho_{6,4} & 0 & 0 & \rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & \rho_{7,5} & \rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{8,9} & \rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & \rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{9,8} & 0 & 0 & \rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & \rho_{10,2} & 0 & 0 & 0 & 0 & 0 & \rho_{10,8} & 0 & 0 & \rho_{10,11} & 0 & 0 & \rho_{10,14} & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & \rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & \rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & \rho_{12,13} & \rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & \rho_{13,12} & 0 & 0 & \rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & \rho_{14,12} & 0 & 0 & \rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & \rho 15, 13 & \rho_{15,14} & 0
\end{pmatrix}
$$

$$
= \frac{1}{2} \begin{pmatrix}
\rho_{2,0} & 0 & 0 & \rho_{2,3} & 0 & 0 & \rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{3,1} & \rho_{3,2} & 0 & 0 & 0 & 0 & \rho_{3,7} & 0 & 0 & \rho_{3,11} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & \rho_{6,2} & 0 & \rho_{6,4} & 0 & 0 & \rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & \rho_{7,5} & \rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & \rho_{10,2} & 0 & 0 & 0 & 0 & 0 & \rho_{10,8} & 0 & 0 & \rho_{10,11} & 0 & 0 & \rho_{10,14} & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & \rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & \rho_{14,12} & 0 & 0 & \rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & \rho 15, 13 & \rho_{15,14} & 0
\end{pmatrix} \tag{191}
$$

$$
\begin{aligned}
M_{1+} &= \langle I_{1+} \rangle = tr\left(I_{1+}\rho_5\right) \\
&= \rho_{2,0} + \rho_{3,1} + \rho_{6,4} + \rho_{7,5} + \rho_{10,8} + \rho_{11,9} + \rho_{14,12} + \rho_{15,13}
\end{aligned} \tag{192}
$$

dan

$$
(I_{0+}\rho_5) = \begin{pmatrix}
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$\times \frac{1}{2} \begin{pmatrix}
0 & \rho_{0,1} & \rho_{0,2} & 0 & \rho_{0,4} & 0 & 0 & 0 & \rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{1,0} & 0 & 0 & \rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & \rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{2,0} & 0 & 0 & \rho_{2,3} & 0 & 0 & \rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{3,1} & \rho_{3,2} & 0 & 0 & 0 & 0 & \rho_{3,7} & 0 & 0 & \rho_{3,11} & 0 & 0 & 0 & 0 & 0 \\
\rho_{40} & 0 & 0 & 0 & 0 & \rho_{4,5} & \rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{5,1} & 0 & 0 & \rho_{5,4} & 0 & 0 & \rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & \rho_{6,2} & 0 & \rho_{6,4} & 0 & 0 & \rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & \rho_{7,5} & \rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{8,9} & \rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & \rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{9,8} & 0 & 0 & \rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & \rho_{10,2} & 0 & 0 & 0 & 0 & 0 & \rho_{10,8} & 0 & 0 & \rho_{10,11} & 0 & 0 & \rho_{10,14} & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & \rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & \rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & \rho_{12,13} & \rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & \rho_{13,12} & 0 & 0 & \rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & \rho_{14,12} & 0 & 0 & \rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & \rho 15, 13 & \rho_{15,14} & 0
\end{pmatrix}$$

$$
= \frac{1}{2}
\begin{pmatrix}
\rho_{1,0} & 0 & 0 & \rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & \rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{3,1} & \rho_{3,2} & 0 & 0 & 0 & 0 & \rho_{3,7} & 0 & 0 & \rho_{3,11} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{5,1} & 0 & 0 & \rho_{5,4} & 0 & 0 & \rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & \rho_{7,5} & \rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{9,8} & 0 & 0 & \rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & \rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & \rho_{13,12} & 0 & 0 & \rho_{13,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & \rho 15,13 & \rho_{15,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
\tag{193}
$$

$$
\begin{aligned}
M_{0+} &= \langle I_{0+} \rangle = tr\left(I_{0+}\rho_5\right) \\
&= \rho_{1,0} + \rho_{3,2} + \rho_{5,2} + \rho_{7,6} + \rho_{9,8} + \rho_{11,10} + \rho_{13,12} + \rho_{15,14}
\end{aligned} \tag{194}
$$

maka dengan demikian nilai magnetisasi total dari sistem adalah sebagai berikut:

$$
\begin{aligned}
M_{tot} &= M_{3+} + M_{2+} + M_{1+} + M_{0+} \\
&= \rho_{8,0} + \rho_{9,1} + \rho_{10,2} + \rho_{11,3} + \rho_{12,4} + \rho_{13,5} + \rho_{14,6} + \rho_{15,7} \\
&+ \rho_{4,0} + \rho_{5,1} + \rho_{6,2} + \rho_{7,3} + \rho_{12,8} + \rho_{13,9} + \rho_{14,10} + \rho_{15,11} \\
&+ \rho_{2,0} + \rho_{3,1} + \rho_{6,4} + \rho_{7,5} + \rho_{10,8} + \rho_{11,9} + \rho_{14,12} + \rho_{15,13} \\
&+ \rho_{1,0} + \rho_{3,2} + \rho_{5,4} + \rho_{7,6} + \rho_{9,8} + \rho_{11,10} + \rho_{13,12} + \rho_{15,14} \\
&= e^{i(\omega_3+\pi J_{30}+\pi J_{31}+\pi J_{32})t} + e^{i(\omega_3-\pi J_{30}+\pi J_{31}+\pi J_{32})t} \\
&+ e^{i(\omega_3+\pi J_{30}-\pi J_{31}+\pi J_{32})t} + e^{i(\omega_3-\pi J_{30}-\pi J_{31}+\pi J_{32})t} \\
&+ e^{i(\omega_3+\pi J_{30}+\pi J_{31}-\pi J_{32})t} + e^{i(\omega_3-\pi J_{30}+\pi J_{31}-\pi J_{32})t} \\
&+ e^{i(\omega_3+\pi J_{30}-\pi J_{31}-\pi J_{32})t} + e^{i(\omega_3-\pi J_{30}-\pi J_{31}-\pi J_{32})t} \\
&+ e^{i(\omega_2+\pi J_{20}+\pi J_{21}+\pi J_{32})t} + e^{i(\omega_2-\pi J_{20}+\pi J_{21}+\pi J_{32})t} \\
&+ e^{i(\omega_2+\pi J_{20}-\pi J_{21}+\pi J_{32})t} + e^{i(\omega_2-\pi J_{20}-\pi J_{21}+\pi J_{32})t} \\
&+ e^{i(\omega_2+\pi J_{20}+\pi J_{21}-\pi J_{32})t} + e^{i(\omega_2-\pi J_{20}+\pi J_{21}-\pi J_{32})t} \\
&+ e^{i(\omega_2+\pi J_{20}-\pi J_{21}-\pi J_{32})t} + e^{i(\omega_2-\pi J_{20}-\pi J_{21}-\pi J_{32})t} \\
&+ e^{i(\omega_1+\pi J_{10}+\pi J_{21}+\pi J_{31})t} + e^{i(\omega_1-\pi J_{10}+\pi J_{21}+\pi J_{31})t} \\
&+ e^{i(\omega_1+\pi J_{10}-\pi J_{21}+\pi J_{31})t} + e^{i(\omega_1-\pi J_{10}-\pi J_{21}+\pi J_{31})t} \\
&+ e^{i(\omega_1+\pi J_{21}-\pi J_{31}+\pi J_{30})t} + e^{i(\omega_1-\pi J_{10}+\pi J_{21}-\pi J_{32})t} \\
&+ e^{i(\omega_1+\pi J_{10}-\pi J_{21}-\pi J_{31})t} + e^{i(\omega_1-\pi J_{10}-\pi J_{21}-\pi J_{31})t} \\
&+ e^{i(\omega_0+\pi J_{10}+\pi J_{20}+\pi J_{30})t} + e^{i(\omega_0-\pi J_{10}+\pi J_{20}+\pi J_{30})t} \\
&+ e^{i(\omega_0+\pi J_{10}-\pi J_{20}+\pi J_{30})t} + e^{i(\omega_0-\pi J_{10}-\pi J_{20}+\pi J_{30})t} \\
&+ e^{i(\omega_0+\pi J_{10}+\pi J_{20}-\pi J_{30})t} + e^{i(\omega_0-\pi J_{10}+\pi J_{20}-\pi J_{30})t} \\
&+ e^{i(\omega_0+\pi J_{10}-\pi J_{20}-\pi J_{30})t} + e^{i(\omega_0-\pi J_{10}-\pi J_{20}-\pi J_{30})t}
\end{aligned} \tag{195}
$$

kemudian didapatkan juga untuk sinyal FID sebagai berikut:

$$\begin{aligned}
S &= M_{tot} e^{-R_2 t} \\
&= e^{-(R_2 - i(\omega_3 + \pi J_{30} + \pi J_{31} + \pi J_{32}))t} + e^{-(R_2 - i(\omega_3 - \pi J_{30} + \pi J_{31} + \pi J_{32}))t} \\
&+ e^{-(R_2 - i(\omega_3 + \pi J_{30} - \pi J_{31} + \pi J_{32}))t} + e^{-(R_2 - i(\omega_3 - \pi J_{30} - \pi J_{31} + \pi J_{32}))t} \\
&+ e^{-(R_2 - i(\omega_3 + \pi J_{30} + \pi J_{31} - \pi J_{32}))t} + e^{-(R_2 - i(\omega_3 - \pi J_{30} + \pi J_{31} - \pi J_{32}))t} \\
&+ e^{-(R_2 - i(\omega_3 + \pi J_{30} - \pi J_{31} - \pi J_{32}))t} + e^{-(R_2 - i(\omega_3 - \pi J_{30} - \pi J_{31} - \pi J_{32}))t} \\
&+ e^{-(R_2 - i(\omega_2 + \pi J_{20} + \pi J_{21} + \pi J_{32}))t} + e^{-(R_2 - i(\omega_2 - \pi J_{20} + \pi J_{21} + \pi J_{32}))t} \\
&+ e^{-(R_2 - i(\omega_2 + \pi J_{20} - \pi J_{21} + \pi J_{32}))t} + e^{-(R_2 - i(\omega_2 - \pi J_{20} - \pi J_{21} + \pi J_{32}))t} \\
&+ e^{-(R_2 - i(\omega_2 + \pi J_{20} + \pi J_{21} - \pi J_{32}))t} + e^{-(R_2 - i(\omega_2 - \pi J_{20} + \pi J_{21} - \pi J_{32}))t} \\
&+ e^{-(R_2 - i(\omega_2 + \pi J_{20} - \pi J_{21} - \pi J_{32}))t} + e^{-(R_2 - i(\omega_2 - \pi J_{20} - \pi J_{21} - \pi J_{32}))t} \\
&+ e^{-(R_2 - i(\omega_1 + \pi J_{10} + \pi J_{21} + \pi J_{31}))t} + e^{-(R_2 - i(\omega_1 - \pi J_{10} + \pi J_{21} + \pi J_{31}))t} \\
&+ e^{-(R_2 - i(\omega_1 + \pi J_{10} - \pi J_{21} + \pi J_{31}))t} + e^{-(R_2 - i(\omega_1 - \pi J_{10} - \pi J_{21} + \pi J_{31}))t} \\
&+ e^{-(R_2 - i(\omega_1 + \pi J_{21} - \pi J_{31} + \pi J_{30}))t} + e^{-(R_2 - i(\omega_1 - \pi J_{10} + \pi J_{21} - \pi J_{32}))t} \\
&+ e^{-(R_2 - i(\omega_1 + \pi J_{10} - \pi J_{21} - \pi J_{31}))t} + e^{-(R_2 - i(\omega_1 - \pi J_{10} - \pi J_{21} - \pi J_{31}))t} \\
&+ e^{-(R_2 - i(\omega_0 + \pi J_{10} + \pi J_{20} + \pi J_{30}))t} + e^{-(R_2 - i(\omega_0 - \pi J_{10} + \pi J_{20} + \pi J_{30}))t} \\
&+ e^{-(R_2 - i(\omega_0 + \pi J_{10} - \pi J_{20} + \pi J_{30}))t} + e^{-(R_2 - i(\omega_0 - \pi J_{10} - \pi J_{20} + \pi J_{30}))t} \\
&+ e^{-(R_2 - i(\omega_0 + \pi J_{10} + \pi J_{20} - \pi J_{30}))t} + e^{-(R_2 - i(\omega_0 - \pi J_{10} + \pi J_{20} - \pi J_{30}))t} \\
&+ e^{-(R_2 - i(\omega_0 + \pi J_{10} - \pi J_{20} - \pi J_{30}))t} + e^{-(R_2 - i(\omega_0 - \pi J_{10} - \pi J_{20} - \pi J_{30}))t}
\end{aligned} \tag{196}$$

dimana $R_2 = \frac{1}{T_2}$

kemudian dapat di cari terlebih dahulu untuk perkalian antara $S(t)\,e^{-i\omega t}$ yaitu sebagi berikut:

$$
\begin{aligned}
S(t)\,e^{-i\omega t} &= e^{-(R_2-i(\omega_3-\omega+\pi J_{30}+\pi J_{31}+\pi J_{32}))t} \\
&+ e^{-(R_2-i(\omega_3-\omega-\pi J_{30}+\pi J_{31}+\pi J_{32}))t} \\
&+ e^{-(R_2-i(\omega_3-\omega+\pi J_{30}-\pi J_{31}+\pi J_{32}))t} \\
&+ e^{-(R_2-i(\omega_3-\omega-\pi J_{30}-\pi J_{31}+\pi J_{32}))t} \\
&+ e^{-(R_2-i(\omega_3-\omega+\pi J_{30}+\pi J_{31}-\pi J_{32}))t} \\
&+ e^{-(R_2-i(\omega_3-\omega-\pi J_{30}+\pi J_{31}-\pi J_{32}))t} \\
&+ e^{-(R_2-i(\omega_3-\omega+\pi J_{30}-\pi J_{31}-\pi J_{32}))t} \\
&+ e^{-(R_2-i(\omega_3-\omega-\pi J_{30}-\pi J_{31}-\pi J_{32}))t} \\
&+ e^{-(R_2-i(\omega_2-\omega+\pi J_{20}+\pi J_{21}+\pi J_{32}))t} \\
&+ e^{-(R_2-i(\omega_2-\omega-\pi J_{20}+\pi J_{21}+\pi J_{32}))t} \\
&+ e^{-(R_2-i(\omega_2-\omega+\pi J_{20}-\pi J_{21}+\pi J_{32}))t} \\
&+ e^{-(R_2-i(\omega_2-\omega-\pi J_{20}-\pi J_{21}+\pi J_{32}))t} \\
&+ e^{-(R_2-i(\omega_2-\omega+\pi J_{20}+\pi J_{21}-\pi J_{32}))t} \\
&+ e^{-(R_2-i(\omega_2-\omega-\pi J_{20}+\pi J_{21}-\pi J_{32}))t} \\
&+ e^{-(R_2-i(\omega_2-\omega+\pi J_{20}-\pi J_{21}-\pi J_{32}))t} \\
&+ e^{-(R_2-i(\omega_2-\omega-\pi J_{20}-\pi J_{21}-\pi J_{32}))t} \\
&+ e^{-(R_2-i(\omega_1-\omega+\pi J_{10}+\pi J_{21}+\pi J_{31}))t} \\
&+ e^{-(R_2-i(\omega_1-\omega-\pi J_{10}+\pi J_{21}+\pi J_{31}))t} \\
&+ e^{-(R_2-i(\omega_1-\omega+\pi J_{10}-\pi J_{21}+\pi J_{31}))t}
\end{aligned}
$$

$$
\begin{aligned}
&+ e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}))t} \\
&+ e^{-(R_2 - i(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}))t} \\
&+ e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}))t} \\
&+ e^{-(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}))t} \\
&+ e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}))t} \\
&+ e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}))t} \\
&+ e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}))t} \\
&+ e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}))t} \\
&+ e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}))t} \\
&+ e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}))t} \\
&+ e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}))t} \\
&+ e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}))t} \\
&+ e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}))t}
\end{aligned} \tag{197}
$$

Transformasi Fourirer dari sinyal FiD adalah sebagai berikut:

$$
\begin{aligned}
S(\omega) = &\int_0^\infty S(t)\, e^{-i\omega t}\, dt \\
= &\frac{e^{-(R_2 - i(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}))} \\
+ &\frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}))} \\
+ &\frac{e^{-(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}))} \\
+ &\frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))} \\
+ &\frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))} \\
+ &\frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}))} \\
+ &\frac{e^{-(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}))} \\
+ &\frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}))} \\
+ &\frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}))} \\
+ &\frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}))} \\
+ &\frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}))} \\
+ &\frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}))} \\
+ &\frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}))} \\
+ &\frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}))} \\
+ &\frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}))} \\
+ &\frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}))}
\end{aligned}
$$

$$
\begin{aligned}
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}))t}}{-\left(R_2 - i\left(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}\right)\right)} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}))t}}{-\left(R_2 - i\left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}\right)\right)} \\
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}))t}}{-\left(R_2 - i\left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}\right)\right)} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}))t}}{-\left(R_2 - i\left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}\right)\right)} \\
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}))t}}{-\left(R_2 - i\left(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}\right)\right)} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}))t}}{-\left(R_2 - i\left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}\right)\right)} \\
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}))t}}{-\left(R_2 - i\left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}\right)\right)} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}))t}}{-\left(R_2 - i\left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}\right)\right)} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}))t}}{-\left(R_2 - i\left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}\right)\right)} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}))t}}{-\left(R_2 - i\left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}\right)\right)} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}))t}}{-\left(R_2 - i\left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}\right)\right)} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}))t}}{-\left(R_2 - i\left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}\right)\right)} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}))t}}{-\left(R_2 - i\left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}\right)\right)} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}))t}}{-\left(R_2 - i\left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}\right)\right)} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}))t}}{-\left(R_2 - i\left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}\right)\right)} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}))t}}{-\left(R_2 - i\left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}\right)\right)}
\end{aligned}
$$

$$
\begin{aligned}
&= \frac{1}{(R_2 - i(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}))} + \frac{1}{(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}))} + \frac{1}{(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))} + \frac{1}{(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}))} + \frac{1}{(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}))} + \frac{1}{(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}))} + \frac{1}{(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}))} + \frac{1}{(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}))} + \frac{1}{(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}))} + \frac{1}{(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}))} \\
&+ \frac{1}{(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}))} + \frac{1}{(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}))} \\
&+ \frac{1}{(R_2 - i(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}))} + \frac{1}{(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}))} + \frac{1}{(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}))} \\
&+ \frac{1}{(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}))} + \frac{1}{(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}))} \\
&+ \frac{1}{(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}))} + \frac{1}{(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}))} \\
&+ \frac{1}{(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}))} + \frac{1}{(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}))} \\
&+ \frac{1}{(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}))} + \frac{1}{(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}))}
\end{aligned}
$$

$$
\begin{aligned}
&= \frac{R_2 + i\left(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}\right)^2} + \frac{R_2 + i\left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}\right)^2} + \frac{R_2 + i\left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}\right)}{{R_2}^2 + \left(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}\right)^2} + \frac{R_2 + i\left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}\right)^2} + \frac{R_2 + i\left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}\right)^2} + \frac{R_2 + i\left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}\right)^2} + \frac{R_2 + i\left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}\right)}{R_2 + \left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}\right)^2} + \frac{R_2 + i\left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}\right)}{R_2 + \left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}\right)^2} + \frac{R_2 + i\left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}\right)^2}
\end{aligned}
$$

maka dengan demikian diperoleh :

$$
\begin{aligned}
A(\omega) = {} & \frac{R_2}{{R_2}^2 + (\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31})^2} + \frac{R_2}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31})^2} + \frac{R_2}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30})^2} + \frac{R_2}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31})^2} + \frac{R_2}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30})^2} + \frac{R_2}{{R_2}^2 + (\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30})^2} + \frac{R_2}{R_2 + (\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30})^2} + \frac{R_2}{R_2 + (\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30})^2} + \frac{R_2}{{R_2}^2 + (\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30})^2}
\end{aligned}
\tag{198}
$$

dan diperoleh juga:

$$
\begin{aligned}
D(\omega) = & \frac{i(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32})^2} + \frac{i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32})^2} \\
& + \frac{i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32})^2} + \frac{i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})^2} \\
& + \frac{i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})^2} + \frac{i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32})^2} \\
& + \frac{i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32})^2} + \frac{i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32})^2} \\
& + \frac{i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32})^2} + \frac{i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32})^2} \\
& + \frac{i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32})^2} + \frac{i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32})^2} \\
& + \frac{i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32})^2} + \frac{i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32})^2} \\
& + \frac{i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32})^2} + \frac{i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32})^2} \\
& + \frac{i(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31})^2} + \frac{i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31})^2} \\
& + \frac{i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31})^2} + \frac{i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31})^2} \\
& + \frac{i(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30})}{{R_2}^2 + (\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30})^2} + \frac{i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32})}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32})^2} \\
& + \frac{i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31})^2} + \frac{i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31})^2} \\
& + \frac{i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30})^2} + \frac{i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30})^2} \\
& + \frac{i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30})^2} + \frac{i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30})}{R_2 + (\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30})^2} \\
& + \frac{i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30})^2} + \frac{i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30})}{R_2 + (\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30})^2} \\
& + \frac{i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30})^2} + \frac{i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30})^2}
\end{aligned}
\tag{199}
$$

kita telah memperoleh persamaan (162) yang menggambarkan nilai magnetisasi pada sumbu-x. Berikut adalah grafik daripada persamaan (162), diamana data yang dipakai untuk masing-masing qubit adalah sebesar $\omega_3 = 500MHz, \omega_2 = 300MHz, \omega_1 = 202MHz, \omega_0 = 126MHz, J_{32} = 12, J_{31} =$

$11, J_{21} = 10, J_{30} = 9, J_{20} = 8; J_{10} = 7, R_2 = 7$ spektrum

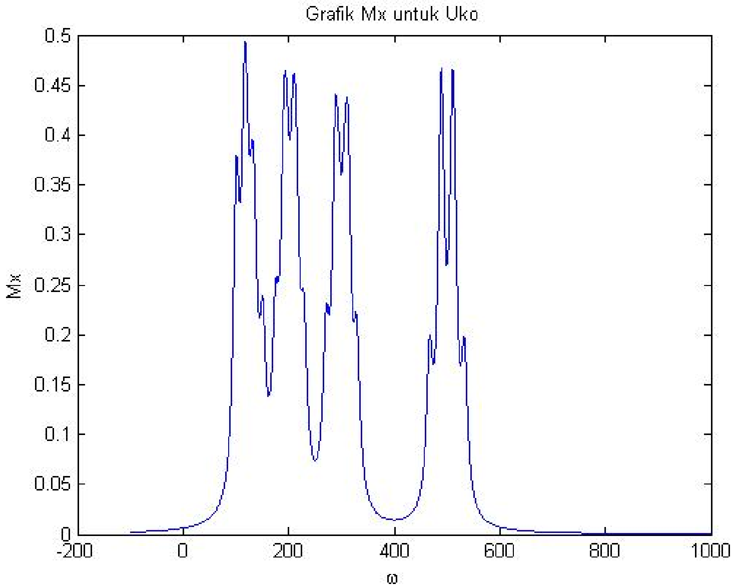

Figure 2: Grafik untuk Uko

yang terbentuk menggambarkan 4 buah puncak tertinggi dari doblet dimana setiap spektrum berisi 2 puncak tertinggi, secara berturut-turut multiplet dari kiri ke kanan merepresentasikan dari qubit-3, qubit-2, qubit-1, qubit-0. masing-masing multiplet terdiri dari 2 puncak yang mengarah keatas hal ini mengindikiasikan bahwa setiap qubit adalah dalam keadaan spin up, atau keadaan $|0\rangle$, jadi pembacaan hasil algoritma berupa $|000\rangle$. Kedua puncak yang mengarah keatas dari setiap qubit menunjukkan bahwa tidak muncul keadaan terbelit dalam sistem 4 qubit apabila $U_2 = Uk0$.

apabila diambil kasus untuk $U_2 = \sigma_z \otimes I \otimes I \otimes I$ maka diperoleh untuk bentuk operator uniter totalnya adalah sebagai berikut:

$$
\begin{aligned}
U &= U_5 U_2 U_1 \\
&= U_5 \left(\sigma_z \otimes I \otimes I \otimes I\right) U_1 \\
&= \begin{pmatrix}
e^{\beta_0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & e^{\beta_1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & e^{\beta_2} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & e^{\beta_3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & e^{\beta_4} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & e^{\beta_5} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_7} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_9} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_10} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_11} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_12} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_13} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_15}
\end{pmatrix}
\end{aligned}
$$

$$
\times \begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1
\end{pmatrix}
$$

$$
\times \frac{1}{4}\begin{pmatrix}
1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & 1 & -1 & -1 & 1 \\
1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 \\
1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 \\
1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 \\
1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 \\
1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 \\
1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\
1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \\
1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\
1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\
1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\
1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\
1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\
1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1
\end{pmatrix}
$$

$$
= \frac{1}{4}\begin{pmatrix}
e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} \\
e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} \\
e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} \\
e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} \\
e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} \\
e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} \\
e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} \\
e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} \\
-e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} \\
-e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} \\
-e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} \\
-e^{\beta_{11}} & e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & -e^{\beta_{11}} & e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} \\
-e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} \\
-e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} \\
-e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} \\
-e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}}
\end{pmatrix} \tag{200}
$$

$$U^\dagger = \begin{pmatrix}
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}}
\end{pmatrix} \tag{201}$$

maka dengan demikian kita dapatkan untuk nilai ρ_5 adalah

$$
\begin{aligned}
\rho_5 &= U\rho_0 U^\dagger \\
&= \frac{1}{4}\left(\begin{array}{cccccccccccccccc}
e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} \\
e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} \\
e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} \\
e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} \\
e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} \\
e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} \\
e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} \\
e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} \\
-e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} \\
-e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} \\
-e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} \\
-e^{\beta_{11}} & e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & -e^{\beta_{11}} & e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} \\
-e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} \\
-e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} \\
-e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} \\
-e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}}
\end{array}\right)
\end{aligned}
$$

$$
\times \begin{pmatrix}
2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -2
\end{pmatrix}
$$

$$\times \frac{1}{4} \begin{pmatrix}
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}}
\end{pmatrix}$$

$$
= \frac{1}{16} \begin{pmatrix}
0 & 8\rho_{0,1} & 8\rho_{0,2} & 0 & 8\rho_{0,4} & 0 & 0 & 0 & -8\rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
8\rho_{1,0} & 0 & 0 & 8\rho_{1,3} & 0 & 8\rho_{1,5} & 0 & 0 & 0 & -8\rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
8\rho_{2,0} & 0 & 0 & 8\rho_{2,3} & 0 & 0 & 8\rho_{2,6} & 0 & 0 & 0 & -8\rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & 8\rho_{3,1} & 8\rho_{3,2} & 0 & 0 & 0 & 0 & 8\rho_{3,7} & 0 & 0 & 0 & -8\rho_{3,11} & 0 & 0 & 0 & 0 \\
8\rho_{40} & 0 & 0 & 0 & 0 & 8\rho_{4,5} & 8\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & -8\rho_{4,12} & 0 & 0 & 0 \\
0 & 8\rho_{4,1} & 0 & 0 & 8\rho_{5,4} & 0 & 0 & 8\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & -8\rho_{5,13} & 0 & 0 \\
0 & 0 & 8\rho_{6,2} & 0 & 8\rho_{6,4} & 0 & 0 & 8\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & -8\rho_{6,14} & 0 \\
0 & 0 & 0 & 8\rho_{7,3} & 0 & 8\rho_{7,5} & 8\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -8\rho_{7,15} \\
-8\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 8\rho_{8,9} & 8\rho_{8,10} & 0 & 8\rho_{8,12} & 0 & 0 & 0 \\
0 & 8-\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & 8\rho_{9,8} & 0 & 0 & 8\rho_{9,11} & 0 & 8\rho_{9,13} & 0 & 0 \\
0 & 0 & -8\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & 8\rho_{10,8} & 0 & 0 & 8\rho_{10,11} & 0 & 0 & 8\rho_{10,14} & 0 \\
0 & 0 & 0 & -8\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & 8\rho_{11,9} & 8\rho_{11,10} & 0 & 0 & 0 & 0 & 8\rho_{11,15} \\
0 & 0 & 0 & 0 & -8\rho_{12,4} & 0 & 0 & 0 & 8\rho_{12,8} & 0 & 0 & 0 & 0 & 8\rho_{12,13} & 8\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & -8\rho_{13,5} & 0 & 0 & 0 & 8\rho_{13,9} & 0 & 0 & 8\rho_{13,12} & 0 & 0 & 8\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & -8\rho_{14,6} & 0 & 0 & 0 & 8\rho_{14,10} & 0 & 8\rho_{14,12} & 0 & 0 & 8\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -8\rho_{15,7} & 0 & 0 & 0 & 8\rho_{15,11} & 0 & 8\rho 15, 13 & 8\rho_{15,14} & 0
\end{pmatrix} \tag{202}
$$

$$
= \frac{1}{2} \begin{pmatrix}
0 & \rho_{0,1} & \rho_{0,2} & 0 & \rho_{0,4} & 0 & 0 & 0 & -\rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{1,0} & 0 & 0 & \rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & -\rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{2,0} & 0 & 0 & \rho_{2,3} & 0 & 0 & \rho_{2,6} & 0 & 0 & 0 & -\rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{3,1} & \rho_{3,2} & 0 & 0 & 0 & 0 & \rho_{3,7} & 0 & 0 & 0 & -\rho_{3,11} & 0 & 0 & 0 & 0 \\
\rho_{40} & 0 & 0 & 0 & 0 & \rho_{4,5} & \rho_{4,6} & 0 & 0 & 0 & 0 & 0 & -\rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{4,1} & 0 & 0 & \rho_{5,4} & 0 & 0 & \rho_{5,7} & 0 & 0 & 0 & 0 & 0 & -\rho_{5,13} & 0 & 0 \\
0 & 0 & \rho_{6,2} & 0 & \rho_{6,4} & 0 & 0 & \rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{6,14} & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & \rho_{7,5} & \rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{7,15} \\
-\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{8,9} & \rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & -\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{9,8} & 0 & 0 & \rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & -\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & \rho_{10,8} & 0 & 0 & \rho_{10,11} & 0 & 0 & \rho_{10,14} & 0 \\
0 & 0 & 0 & -\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & \rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & -\rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & \rho_{12,13} & \rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & -\rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & \rho_{13,12} & 0 & 0 & \rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & -\rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & \rho_{14,12} & 0 & 0 & \rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & \rho 15, 13 & \rho_{15,14} & 0
\end{pmatrix} \tag{203}
$$

dengan

$$
\begin{aligned}
\rho_{0,1} = {\rho_{1,0}}^* = e^{\beta_0-\beta_1} \qquad & \rho_{6,7} = {\rho_{7,6}}^* = e^{\beta_6-\beta_7} \\
\rho_{0,2} = {\rho_{2,0}}^* = e^{\beta_0-\beta_2} \qquad & \rho_{6,14} = {\rho_{14,6}}^* = e^{\beta_6-\beta_14} \\
\rho_{0,8} = {\rho_{8,0}}^* = e^{\beta_8-\beta_1} \qquad & \rho_{8,9} = {\rho_{9,8}}^* = e^{\beta_8-\beta_9} \\
\rho_{1,3} = {\rho_{3,1}}^* = e^{\beta_1-\beta_3} \qquad & \rho_{8,10} = {\rho_{10,8}}^* = e^{\beta_8-\beta_{10}} \\
\rho_{1,5} = {\rho_{5,1}}^* = e^{\beta_1-\beta_5} \qquad & \rho_{8,12} = {\rho_{12,8}}^* = e^{\beta_8-\beta_{12}} \\
\rho_{1,9} = {\rho_{9,1}}^* = e^{\beta_1-\beta_9} \qquad & \rho_{9,11} = {\rho_{11,9}}^* = e^{\beta_9-\beta_{11}} \\
\rho_{2,3} = {\rho_{3,2}}^* = e^{\beta_2-\beta_3} \qquad & \rho_{9,13} = {\rho_{13,9}}^* = e^{\beta_9-\beta_{13}} \\
\rho_{2,6} = {\rho_{6,2}}^* = e^{\beta_2-\beta_6} \qquad & \rho_{10,11} = {\rho_{11,10}}^* = e^{\beta_{10}-\beta_{11}} \\
\rho_{2,10} = {\rho_{10,2}}^* = e^{\beta_2-\beta_10} \qquad & \rho_{10,14} = {\rho_{14,10}}^* = e^{\beta_{10}-\beta_{14}} \\
\rho_{3,7} = {\rho_{7,3}}^* = e^{\beta_3-\beta_7} \qquad & \rho_{12,13} = {\rho_{13,12}}^* = e^{\beta_{12}-\beta_{13}} \\
\rho_{3,11} = {\rho_{11,3}}^* = e^{\beta_3-\beta_11} \qquad & \rho_{12,14} = {\rho_{14,12}}^* = e^{\beta_{12}-\beta_{14}} \\
\rho_{4,5} = {\rho_{5,4}}^* = e^{\beta_4-\beta_5} \qquad & \rho_{11,15} = {\rho_{15,11}}^* = e^{\beta_{11}-\beta_{15}} \\
\rho_{4,6} = {\rho_{6,4}}^* = e^{\beta_4-\beta_6} \qquad & \rho_{13,15} = {\rho_{15,13}}^* = e^{\beta_{13}-\beta_{15}} \\
\rho_{4,12} = {\rho_{12,4}}^* = e^{\beta_4-\beta_12} \qquad & \rho_{14,15} = {\rho_{14,15}}^* = e^{\beta_{14}-\beta_{15}} \\
\rho_{5,7} = {\rho_{7,5}}^* = e^{\beta_5-\beta_7} \qquad & \rho_{15,7} = {\rho_{7,15}}^* = e^{\beta_7-\beta_{15}} \\
\rho_{5,13} = {\rho_{13,5}}^* = e^{\beta_5-\beta_13} \qquad & \rho_{0,4} = {\rho_{4,0}}^* = e^{\beta_0-\beta_4}
\end{aligned} \tag{204}
$$

dan

$$
\begin{array}{cc}
\beta_0 - \beta_1 = -i\left(E_{4,0} - E_{4,1}\right)t & \beta_0 - \beta_2 = -i\left(E_{4,0} - E_{4,2}\right)t \\
\beta_0 - \beta_4 = -i\left(E_{4,0} - E_{4,4}\right)t & \beta_0 - \beta_8 = -i\left(E_{4,0} - E_{4,8}\right)t \\
\beta_1 - \beta_3 = -i\left(E_{4,1} - E_{4,3}\right)t & \beta_1 - \beta_5 = -i\left(E_{4,1} - E_{4,5}\right)t \\
\beta_1 - \beta_9 = -i\left(E_{4,1} - E_{4,9}\right)t & \beta_2 - \beta_3 = -i\left(E_{4,2} - E_{4,3}\right)t \\
\beta_2 - \beta_6 = -i\left(E_{4,2} - E_{4,6}\right)t & \beta_2 - \beta_{10} = -i\left(E_{4,2} - E_{4,10}\right)t \\
\beta_3 - \beta_7 = -i\left(E_{4,3} - E_{4,7}\right)t & \beta_3 - \beta_{11} = -i\left(E_{4,3} - E_{4,11}\right)t \\
\beta_4 - \beta_5 = -i\left(E_{4,4} - E_{4,5}\right)t & \beta_4 - \beta_6 = -i\left(E_{4,4} - E_{4,6}\right)t \\
\beta_4 - \beta_{12} = -i\left(E_{4,4} - E_{4,12}\right)t & \beta_5 - \beta_7 = -i\left(E_{4,5} - E_{4,7}\right)t \\
\beta_5 - \beta_{13} = -i\left(E_{4,5} - E_{4,13}\right)t & \beta_6 - \beta_7 = -i\left(E_{4,6} - E_{4,7}\right)t \\
\beta_6 - \beta_{14} = -i\left(E_{4,6} - E_{4,14}\right)t & \beta_8 - \beta_9 = -i\left(E_{4,8} - E_{4,9}\right)t \\
\beta_8 - \beta_{10} = -i\left(E_{4,8} - E_{4,10}\right)t & \beta_8 - \beta_{12} = -i\left(E_{4,8} - E_{4,12}\right)t \\
\beta_9 - \beta_{11} = -i\left(E_{4,9} - E_{4,11}\right)t & \beta_9 - \beta_{13} = -i\left(E_{4,9} - E_{4,13}\right)t \\
\beta_{10} - \beta_{11} = -i\left(E_{4,10} - E_{4,11}\right)t & \beta_{10} - \beta_{14} = -i\left(E_{4,10} - E_{4,14}\right)t \\
\beta_{12} - \beta_{13} = -i\left(E_{4,12} - E_{4,13}\right)t & \beta_{12} - \beta_{14} = -i\left(E_{4,12} - E_{4,14}\right)t \\
\beta_{11} - \beta_{15} = -i\left(E_{4,11} - E_{4,15}\right)t & \beta_{13} - \beta_{15} = -i\left(E_{4,13} - E_{4,15}\right)t \\
\beta_{14} - \beta_{15} = -i\left(E_{4,14} - E_{4,15}\right)t & \beta_{15} - \beta_7 = -i\left(E_{4,15} - E_{4,7}\right)t
\end{array}
\tag{205}
$$

dan

$$
\begin{aligned}
E_{4,0} - E4,1 &= \omega_0 + \pi J_{10} + \pi J_{20} + \pi J_{30} & E_{4,0} - E4,2 &= \omega_1 + \pi J_{10} + \pi J_{21} + \pi J_{31} \\
E_{4,0} - E4,4 &= \omega_2 + \pi J_{20} + \pi J_{21} + \pi J_{32} & E_{4,0} - E4,8 &= \omega_3 + \pi J_{30} + \pi J_{31} + \pi J_{32} \\
E_{4,1} - E4,3 &= \omega_1 - \pi J_{10} + \pi J_{21} + \pi J_{31} & E_{4,1} - E4,5 &= \omega_2 - \pi J_{20} + \pi J_{21} + \pi J_{32} \\
E_{4,1} - E4,9 &= \omega_3 - \pi J_{30} + \pi J_{310} + \pi J_{32} & E_{4,2} - E4,3 &= \omega_0 - \pi J_{10} + \pi J_{20} + \pi J_{30} \\
E_{4,2} - E4,6 &= \omega_2 + \pi J_{20} - \pi J_{21} + \pi J_{32} & E_{4,2} - E4,10 &= \omega_3 + \pi J_{30} - \pi J_{31} + \pi J_{32} \\
E_{4,3} - E4,7 &= \omega_2 - \pi J_{20} - \pi J_{21} + \pi J_{32} & E_{4,3} - E4,11 &= \omega_3 - \pi J_{30} - \pi J_{31} + \pi J_{32} \\
E_{4,4} - E4,5 &= \omega_0 + \pi J_{10} - \pi J_{20} + \pi J_{30} & E_{4,4} - E4,6 &= \omega_1 + \pi J_{10} - \pi J_{21} + \pi J_{31} \\
E_{4,4} - E4,12 &= \omega_3 + \pi J_{30} + \pi J_{31} - \pi J_{32} & E_{4,5} - E4,7 &= \omega_1 - \pi J_{10} - \pi J_{21} + \pi J_{31} \\
E_{4,5} - E4,13 &= \omega_3 - \pi J_{30} + \pi J_{31} - \pi J_{32} & E_{4,6} - E4,7 &= \omega_0 - \pi J_{10} - \pi J_{20} + \pi J_{30} \\
E_{4,6} - E4,14 &= \omega_3 + \pi J_{30} - \pi J_{31} - \pi J_{32} & E_{4,8} - E4,9 &= \omega_0 + \pi J_{10} + \pi J_{20} - \pi J_{30} \\
E_{4,8} - E4,10 &= \omega_1 + \pi J_{21} - \pi J_{31} + \pi J_{30} & E_{4,8} - E4,12 &= \omega_2 + \pi J_{20} + \pi J_{21} - \pi J_{32} \\
E_{4,9} - E4,11 &= \omega_1 - \pi J_{10} + \pi J_{21} - \pi J_{32} & E_{4,10} - E4,11 &= \omega_0 - \pi J_{10} + \pi J_{20} - \pi J_{30} \\
E_{4,10} - E4,14 &= \omega_2 + \pi J_{20} - \pi J_{21} - \pi J_{32} & E_{4,12} - E4,13 &= \omega_0 + \pi J_{10} - \pi J_{20} - \pi J_{30} \\
E_{4,12} - E4,14 &= \omega_1 + \pi J_{10} - \pi J_{21} - \pi J_{31} & E_{4,11} - E4,15 &= \omega_2 - \pi J_{20} - \pi J_{21} - \pi J_{32} \\
E_{4,13} - E4,15 &= \omega_1 - \pi J_{10} - \pi J_{21} - \pi J_{31} & E_{4,14} - E4,15 &= \omega_0 - \pi J_{10} - \pi J_{20} - \pi J_{30} \\
E_{4,9} - E4,13 &= \omega_2 - \pi J_{20} + \pi J_{21} - \pi J_{32} & E_{4,15} - E4,7 &= \omega_3 + \pi J_{30} + \pi J_{31} + \pi J_{32}
\end{aligned}
\tag{206}
$$

maka dengan demikian suku-suku tidak nol dari matriks ρ_5 menjadi:

$$
\begin{aligned}
\rho_{0,1} = \rho_{1,0}{}^* &= e^{-i(\omega_0+\pi J_{10}+\pi J_{20}+\pi J_{30})t}\\
\rho_{0,2} = \rho_{2,0}{}^* &= e^{-i(\omega_1+\pi J_{10}+\pi J_{21}+\pi J_{31})t}\\
\rho_{0,4} = \rho_{4,0}{}^* &= e^{-i(\omega_2+\pi J_{20}+\pi J_{21}+\pi J_{32})t}\\
\rho_{0,8} = \rho_{8,0}{}^* &= e^{-i(\omega_3+\pi J_{30}+\pi J_{31}+\pi J_{32})t}\\
\rho_{1,3} = \rho_{3,1}{}^* &= e^{-i(\omega_1-\pi J_{10}+\pi J_{21}+\pi J_{31})t}\\
\rho_{1,5} = \rho_{5,1}{}^* &= e^{-i(\omega_2-\pi J_{20}+\pi J_{21}+\pi J_{32})t}\\
\rho_{1,9} = \rho_{9,1}{}^* &= e^{-i(\omega_3-\pi J_{30}+\pi J_{310}+\pi J_{32})t}\\
\rho_{2,3} = \rho_{3,2}{}^* &= e^{-i(\omega_0-\pi J_{10}+\pi J_{20}+\pi J_{30})t}\\
\rho_{2,6} = \rho_{6,2}{}^* &= e^{-i(\omega_2+\pi J_{20}-\pi J_{21}+\pi J_{32})t}\\
\rho_{2,10} = \rho_{10,2}{}^* &= e^{-i(\omega_3+\pi J_{30}-\pi J_{31}+\pi J_{32})t}\\
\rho_{3,7} = \rho_{7,3}{}^* &= e^{-i(\omega_2-\pi J_{20}-\pi J_{21}+\pi J_{32})t}\\
\rho_{3,11} = \rho_{11,3}{}^* &= e^{-i(\omega_3-\pi J_{30}-\pi J_{31}+\pi J_{32})t}\\
\rho_{4,5} = \rho_{5,4}{}^* &= e^{-i(\omega_0+\pi J_{10}-\pi J_{20}+\pi J_{30})t}\\
\rho_{4,6} = \rho_{6,4}{}^* &= e^{-i(\omega_1+\pi J_{10}-\pi J_{21}+\pi J_{31})t}\\
\rho_{4,12} = \rho_{12,4}{}^* &= e^{-i(\omega_3+\pi J_{30}+\pi J_{31}-\pi J_{32})t}\\
\rho_{5,7} = \rho_{7,5}{}^* &= e^{-i(\omega_1-\pi J_{10}-\pi J_{21}+\pi J_{31})t}\\
\rho_{5,13} = \rho_{13,5}{}^* &= e^{-i(\omega_3-\pi J_{30}+\pi J_{31}-\pi J_{32})t}\\
\rho_{6,7} = \rho_{7,6}{}^* &= e^{-i(\omega_0-\pi J_{10}-\pi J_{20}+\pi J_{30})t}\\
\rho_{6,14} = \rho_{14,6}{}^* &= e^{-i(\omega_3+\pi J_{30}-\pi J_{31}-\pi J_{32})t}\\
\rho_{8,9} = \rho_{9,8}{}^* &= e^{-i(\omega_0+\pi J_{10}+\pi J_{20}-\pi J_{30})t}\\
\rho_{8,10} = \rho_{10,8}{}^* &= e^{-i(\omega_1+\pi J_{21}-\pi J_{31}+\pi J_{30})t}\\
\rho_{8,12} = \rho_{12,8}{}^* &= e^{-i(\omega_2+\pi J_{20}+\pi J_{21}-\pi J_{32})t}\\
\rho_{9,11} = \rho_{11,9}{}^* &= e^{-i(\omega_1-\pi J_{10}+\pi J_{21}-\pi J_{32})t}\\
\rho_{10,11} = \rho_{11,10}{}^* &= e^{-i(\omega_0-\pi J_{10}+\pi J_{20}-\pi J_{30})t}\\
\rho_{10,14} = \rho_{14,10}{}^* &= e^{-i(\omega_2+\pi J_{20}-\pi J_{21}-\pi J_{32})t}\\
\rho_{12,13} = \rho_{13,12}{}^* &= e^{-i(\omega_0+\pi J_{10}-\pi J_{20}-\pi J_{30})t}\\
\rho_{12,14} = \rho_{14,12}{}^* &= e^{-i(\omega_1+\pi J_{10}-\pi J_{21}-\pi J_{31})t}\\
\rho_{11,15} = \rho_{15,11}{}^* &= e^{-i(\omega_2-\pi J_{20}-\pi J_{21}-\pi J_{32})t}\\
\rho_{7,15} = \rho_{15,7}{}^* &= e^{-i(\omega_3-\pi J_{30}-\pi J_{31}-\pi J_{32})t}\\
\rho_{13,15} = \rho_{15,13}{}^* &= e^{-i(\omega_1-\pi J_{10}-\pi J_{21}-\pi J_{31})t}\\
\rho_{14,15} = \rho_{15,14}{}^* &= e^{-i(\omega_0-\pi J_{10}-\pi J_{20}-\pi J_{30})t}\\
\rho_{9,13} = \rho_{13,9}{}^* &= e^{-i(\omega_2-\pi J_{20}+\pi J_{21}-\pi J_{32})t}
\end{aligned}
\tag{207}
$$

maka dapat ditentukan nilai magnetisasi dari masing-masing qubitnya yaitu sebagai berikut:

$$
(I_{3+}\rho_5) = \begin{pmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$
\times \frac{1}{2}
\begin{pmatrix}
0 & \rho_{0,1} & \rho_{0,2} & 0 & \rho_{0,4} & 0 & 0 & 0 & -\rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{1,0} & 0 & 0 & \rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & -\rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{2,0} & 0 & 0 & \rho_{2,3} & 0 & 0 & \rho_{2,6} & 0 & 0 & 0 & -\rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{3,1} & \rho_{3,2} & 0 & 0 & 0 & 0 & \rho_{3,7} & 0 & 0 & -\rho_{3,11} & 0 & 0 & 0 & 0 & 0 \\
\rho_{40} & 0 & 0 & 0 & 0 & \rho_{4,5} & \rho_{4,6} & 0 & 0 & 0 & 0 & 0 & -\rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{4,1} & 0 & 0 & \rho_{5,4} & 0 & 0 & \rho_{5,7} & 0 & 0 & 0 & 0 & 0 & -\rho_{5,13} & 0 & 0 \\
0 & 0 & \rho_{6,2} & 0 & \rho_{6,4} & 0 & 0 & \rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{6,14} & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & \rho_{7,5} & \rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{7,15} \\
-\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{8,9} & \rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & -\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{9,8} & 0 & 0 & \rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & -\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & \rho_{10,8} & 0 & 0 & \rho_{10,11} & 0 & 0 & \rho_{10,14} & 0 \\
0 & 0 & 0 & -\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & \rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & -\rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & \rho_{12,13} & \rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & -\rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & \rho_{13,12} & 0 & 0 & \rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & -\rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & \rho_{14,12} & 0 & 0 & \rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & \rho 15,13 & \rho_{15,14} & 0
\end{pmatrix}
$$

$$
= \frac{1}{2} \begin{pmatrix}
-\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{8,9} & \rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & -\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{9,8} & 0 & 0 & \rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & -\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & \rho_{10,8} & 0 & 0 & \rho_{10,11} & 0 & 0 & \rho_{10,14} & 0 \\
0 & 0 & 0 & -\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & \rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & -\rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & \rho_{12,13} & \rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & -\rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & \rho_{13,12} & 0 & 0 & \rho_{13,15} \\
0 & 0 & 0 & 0 & 0 & 0 & -\rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & \rho_{14,12} & 0 & 0 & \rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & \rho_{15,13} & \rho_{15,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$
\begin{aligned}
M_{3+} &= \langle I_{3+} \rangle = tr\left(I_{3+}\rho_5\right) \\
&= -\left(\rho_{8,0} + \rho_{9,1} + \rho_{10,2} + \rho_{11,3} + \rho_{12,4} + \rho_{13,5} + \rho_{14,6} + \rho_{15,7}\right)
\end{aligned}
\tag{208}
$$

dan

$$
(I_{2+}\rho_5) = \begin{pmatrix}
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$
\times \frac{1}{2}
\begin{pmatrix}
0 & \rho_{0,1} & \rho_{0,2} & 0 & \rho_{0,4} & 0 & 0 & 0 & -\rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{1,0} & 0 & 0 & \rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & -\rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{2,0} & 0 & 0 & \rho_{2,3} & 0 & 0 & \rho_{2,6} & 0 & 0 & 0 & -\rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{3,1} & \rho_{3,2} & 0 & 0 & 0 & 0 & \rho_{3,7} & 0 & 0 & -\rho_{3,11} & 0 & 0 & 0 & 0 & 0 \\
\rho_{40} & 0 & 0 & 0 & 0 & \rho_{4,5} & \rho_{4,6} & 0 & 0 & 0 & 0 & 0 & -\rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{4,1} & 0 & 0 & \rho_{5,4} & 0 & 0 & \rho_{5,7} & 0 & 0 & 0 & 0 & 0 & -\rho_{5,13} & 0 & 0 \\
0 & 0 & \rho_{6,2} & 0 & \rho_{6,4} & 0 & 0 & \rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{6,14} & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & \rho_{7,5} & \rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{7,15} \\
-\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{8,9} & \rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & -\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{9,8} & 0 & 0 & \rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & -\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & \rho_{10,8} & 0 & 0 & \rho_{10,11} & 0 & 0 & \rho_{10,14} & 0 \\
0 & 0 & 0 & -\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & \rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & -\rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & \rho_{12,13} & \rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & -\rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & \rho_{13,12} & 0 & 0 & \rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & -\rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & \rho_{14,12} & 0 & 0 & \rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & \rho 15, 13 & \rho_{15,14} & 0
\end{pmatrix}
$$

$$
= \frac{1}{2}\begin{pmatrix}
\rho_{4,0} & 0 & 0 & 0 & 0 & \rho_{4,5} & \rho_{4,6} & 0 & 0 & 0 & 0 & 0 & -\rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{5,1} & 0 & 0 & \rho_{5,4} & 0 & 0 & \rho_{5,7} & 0 & 0 & 0 & 0 & 0 & -\rho_{5,13} & 0 & 0 \\
0 & 0 & \rho_{6,2} & 0 & \rho_{6,4} & 0 & 0 & \rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{6,14} & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & \rho_{7,5} & \rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{7,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & -\rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & \rho_{12,13} & \rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & -\rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & \rho_{13,12} & 0 & 0 & \rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & -\rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & \rho_{14,12} & 0 & 0 & \rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & \rho 15, 13 & \rho_{15,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix} \tag{209}
$$

$$
\begin{aligned}
M_{2+} &= \langle I_{2+} \rangle = tr\left(I_{2+}\rho_5\right) \\
&= \rho_{4,0} + \rho_{5,1} + \rho_{6,2} + \rho_{7,3} + \rho_{12,8} + \rho_{13,9} + \rho_{14,10} + \rho_{15,11}
\end{aligned}
\tag{210}
$$

dan

$$
(I_{1+}\rho_5) = \begin{pmatrix}
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$
\times \frac{1}{2}\begin{pmatrix}
0 & \rho_{0,1} & \rho_{0,2} & 0 & \rho_{0,4} & 0 & 0 & 0 & -\rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{1,0} & 0 & 0 & \rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & -\rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{2,0} & 0 & 0 & \rho_{2,3} & 0 & 0 & \rho_{2,6} & 0 & 0 & 0 & -\rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{3,1} & \rho_{3,2} & 0 & 0 & 0 & 0 & \rho_{3,7} & 0 & 0 & -\rho_{3,11} & 0 & 0 & 0 & 0 & 0 \\
\rho_{40} & 0 & 0 & 0 & 0 & \rho_{4,5} & \rho_{4,6} & 0 & 0 & 0 & 0 & 0 & -\rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{4,1} & 0 & 0 & \rho_{5,4} & 0 & 0 & \rho_{5,7} & 0 & 0 & 0 & 0 & 0 & -\rho_{5,13} & 0 & 0 \\
0 & 0 & \rho_{6,2} & 0 & \rho_{6,4} & 0 & 0 & \rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{6,14} & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & \rho_{7,5} & \rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{7,15} \\
-\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{8,9} & \rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & -\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{9,8} & 0 & 0 & \rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & -\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & \rho_{10,8} & 0 & 0 & \rho_{10,11} & 0 & 0 & \rho_{10,14} & 0 \\
0 & 0 & 0 & -\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & \rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & -\rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & \rho_{12,13} & \rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & -\rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & \rho_{13,12} & 0 & 0 & \rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & -\rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & \rho_{14,12} & 0 & 0 & \rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & \rho 15,13 & \rho_{15,14} & 0
\end{pmatrix}
$$

$$
= \frac{1}{2} \begin{pmatrix}
\rho_{2,0} & 0 & 0 & \rho_{2,3} & 0 & 0 & \rho_{2,6} & 0 & 0 & 0 & -\rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{3,1} & \rho_{3,2} & 0 & 0 & 0 & 0 & \rho_{3,7} & 0 & 0 & -\rho_{3,11} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & \rho_{6,2} & 0 & \rho_{6,4} & 0 & 0 & \rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{6,14} & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & \rho_{7,5} & \rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{7,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & -\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & \rho_{10,8} & 0 & 0 & \rho_{10,11} & 0 & 0 & \rho_{10,14} & 0 \\
0 & 0 & 0 & -\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & \rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & & 0 & 0 & 0 & -\rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & \rho_{14,12} & 0 & 0 & \rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & \rho 15, 13 & \rho_{15,14} & 0
\end{pmatrix} \tag{211}
$$

$$
\begin{aligned}
M_{1+} &= \langle I_{2+} \rangle = tr\left(I_{2+}\rho_5\right) \\
&= \rho_{2,0} + \rho_{3,1} + \rho_{6,4} + \rho_{7,5} + \rho_{10,8} + \rho_{11,9} + \rho_{14,12} + \rho_{15,13}
\end{aligned}
\tag{212}
$$

dan

$$
(I_{0+}\rho_5) = \begin{pmatrix}
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$\times \frac{1}{2} \begin{pmatrix}
0 & \rho_{0,1} & \rho_{0,2} & 0 & \rho_{0,4} & 0 & 0 & 0 & -\rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{1,0} & 0 & 0 & \rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & -\rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{2,0} & 0 & 0 & \rho_{2,3} & 0 & 0 & \rho_{2,6} & 0 & 0 & 0 & -\rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{3,1} & \rho_{3,2} & 0 & 0 & 0 & 0 & \rho_{3,7} & 0 & 0 & -\rho_{3,11} & 0 & 0 & 0 & 0 & 0 \\
\rho_{40} & 0 & 0 & 0 & 0 & \rho_{4,5} & \rho_{4,6} & 0 & 0 & 0 & 0 & 0 & -\rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{4,1} & 0 & 0 & \rho_{5,4} & 0 & 0 & \rho_{5,7} & 0 & 0 & 0 & 0 & 0 & -\rho_{5,13} & 0 & 0 \\
0 & 0 & \rho_{6,2} & 0 & \rho_{6,4} & 0 & 0 & \rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{6,14} & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & \rho_{7,5} & \rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{7,15} \\
-\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{8,9} & \rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & -\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{9,8} & 0 & 0 & \rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & -\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & \rho_{10,8} & 0 & 0 & \rho_{10,11} & 0 & 0 & \rho_{10,14} & 0 \\
0 & 0 & 0 & -\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & \rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & -\rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & \rho_{12,13} & \rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & -\rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & \rho_{13,12} & 0 & 0 & \rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & -\rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & \rho_{14,12} & 0 & 0 & \rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & \rho 15,13 & \rho_{15,14} & 0
\end{pmatrix}$$

$$
= \frac{1}{2} \begin{pmatrix}
\rho_{1,0} & 0 & 0 & \rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & -\rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{3,1} & \rho_{3,2} & 0 & 0 & 0 & 0 & \rho_{3,7} & 0 & 0 & -\rho_{3,11} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{5,1} & 0 & 0 & \rho_{5,4} & 0 & 0 & \rho_{5,7} & 0 & 0 & 0 & 0 & 0 & -\rho_{5,13} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & \rho_{7,5} & \rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{7,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{9,8} & 0 & 0 & \rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & \rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & -\rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & \rho_{13,12} & 0 & 0 & \rho_{13,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & \rho 15, 13 & \rho_{15,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix} \tag{213}
$$

$$
\begin{aligned}
M_{0+} &= \langle I_{0+} \rangle = tr\left(I_{0+}\rho_5\right) \\
&= \rho_{1,0} + \rho_{3,2} + \rho_{5,2} + \rho_{7,6} + \rho_{9,8} + \rho_{11,10} + \rho_{13,12} + \rho_{15,14}
\end{aligned} \tag{214}
$$

maka dengan demikian nilai magnetisasi total dari sistem adalah sebagai berikut:

$$
\begin{aligned}
M_{tot} &= M_{3+} + M_{2+} + M_{1+} + M_{0+} \\
&= -\rho_{8,0} - \rho_{9,1} - \rho_{10,2} - \rho_{11,3} - \rho_{12,4} - \rho_{13,5} - \rho_{14,6} - \rho_{15,7} \\
&+ \rho_{4,0} + \rho_{5,1} + \rho_{6,2} + \rho_{7,3} + \rho_{12,8} + \rho_{13,9} + \rho_{14,10} + \rho_{15,11} \\
&+ \rho_{2,0} + \rho_{3,1} + \rho_{6,4} + \rho_{7,5} + \rho_{10,8} + \rho_{11,9} + \rho_{14,12} + \rho_{15,13} \\
&+ \rho_{1,0} + \rho_{3,2} + \rho_{5,4} + \rho_{7,6} + \rho_{9,8} + \rho_{11,10} + \rho_{13,12} + \rho_{15,14} \\
&= -e^{i(\omega_3+\pi J_{30}+\pi J_{31}+\pi J_{32})t} - e^{i(\omega_3-\pi J_{30}+\pi J_{31}+\pi J_{32})t} \\
&- e^{i(\omega_3+\pi J_{30}-\pi J_{31}+\pi J_{32})t} - e^{i(\omega_3-\pi J_{30}-\pi J_{31}+\pi J_{32})t} \\
&- e^{i(\omega_3+\pi J_{30}+\pi J_{31}-\pi J_{32})t} - e^{i(\omega_3-\pi J_{30}+\pi J_{31}-\pi J_{32})t} \\
&- e^{i(\omega_3+\pi J_{30}-\pi J_{31}-\pi J_{32})t} - e^{i(\omega_3-\pi J_{30}-\pi J_{31}-\pi J_{32})t} \\
&+ e^{i(\omega_2+\pi J_{20}+\pi J_{21}+\pi J_{32})t} + e^{i(\omega_2-\pi J_{20}+\pi J_{21}+\pi J_{32})t} \\
&+ e^{i(\omega_2+\pi J_{20}-\pi J_{21}+\pi J_{32})t} + e^{i(\omega_2-\pi J_{20}-\pi J_{21}+\pi J_{32})t} \\
&+ e^{i(\omega_2+\pi J_{20}+\pi J_{21}-\pi J_{32})t} + e^{i(\omega_2-\pi J_{20}+\pi J_{21}-\pi J_{32})t} \\
&+ e^{i(\omega_2+\pi J_{20}-\pi J_{21}-\pi J_{32})t} + e^{i(\omega_2-\pi J_{20}-\pi J_{21}-\pi J_{32})t} \\
&+ e^{i(\omega_1+\pi J_{10}+\pi J_{21}+\pi J_{31})t} + e^{i(\omega_1-\pi J_{10}+\pi J_{21}+\pi J_{31})t} \\
&+ e^{i(\omega_1+\pi J_{10}-\pi J_{21}+\pi J_{31})t} + e^{i(\omega_1-\pi J_{10}-\pi J_{21}+\pi J_{31})t} \\
&+ e^{i(\omega_1+\pi J_{21}-\pi J_{31}+\pi J_{30})t} + e^{i(\omega_1-\pi J_{10}+\pi J_{21}-\pi J_{32})t} \\
&+ e^{i(\omega_1+\pi J_{10}-\pi J_{21}-\pi J_{31})t} + e^{i(\omega_1-\pi J_{10}-\pi J_{21}-\pi J_{31})t} \\
&+ e^{i(\omega_0+\pi J_{10}+\pi J_{20}+\pi J_{30})t} + e^{i(\omega_0-\pi J_{10}+\pi J_{20}+\pi J_{30})t} \\
&+ e^{i(\omega_0+\pi J_{10}-\pi J_{20}+\pi J_{30})t} + e^{i(\omega_0-\pi J_{10}-\pi J_{20}+\pi J_{30})t} \\
&+ e^{i(\omega_0+\pi J_{10}+\pi J_{20}-\pi J_{30})t} + e^{i(\omega_0-\pi J_{10}+\pi J_{20}-\pi J_{30})t} \\
&+ e^{i(\omega_0+\pi J_{10}-\pi J_{20}-\pi J_{30})t} + e^{i(\omega_0-\pi J_{10}-\pi J_{20}-\pi J_{30})t}
\end{aligned} \tag{215}
$$

kemudian didapatkan juga untuk sinyal FID sebagai berikut:

$$
\begin{aligned}
S = {} & M_{tot} e^{-R_2 t} \\
& = -e^{-(R_2 - i(\omega_3 + \pi J_{30} + \pi J_{31} + \pi J_{32}))t} - e^{-(R_2 - i(\omega_3 - \pi J_{30} + \pi J_{31} + \pi J_{32}))t} \\
& - e^{-(R_2 - i(\omega_3 + \pi J_{30} - \pi J_{31} + \pi J_{32}))t} - e^{-(R_2 - i(\omega_3 - \pi J_{30} - \pi J_{31} + \pi J_{32}))t} \\
& - e^{-(R_2 - i(\omega_3 + \pi J_{30} + \pi J_{31} - \pi J_{32}))t} - e^{-(R_2 - i(\omega_3 - \pi J_{30} + \pi J_{31} - \pi J_{32}))t} \\
& - e^{-(R_2 - i(\omega_3 + \pi J_{30} - \pi J_{31} - \pi J_{32}))t} - e^{-(R_2 - i(\omega_3 - \pi J_{30} - \pi J_{31} - \pi J_{32}))t} \\
& + e^{-(R_2 - i(\omega_2 + \pi J_{20} + \pi J_{21} + \pi J_{32}))t} + e^{-(R_2 - i(\omega_2 - \pi J_{20} + \pi J_{21} + \pi J_{32}))t} \\
& + e^{-(R_2 - i(\omega_2 + \pi J_{20} - \pi J_{21} + \pi J_{32}))t} + e^{-(R_2 - i(\omega_2 - \pi J_{20} - \pi J_{21} + \pi J_{32}))t} \\
& + e^{-(R_2 - i(\omega_2 + \pi J_{20} + \pi J_{21} - \pi J_{32}))t} + e^{-(R_2 - i(\omega_2 - \pi J_{20} + \pi J_{21} - \pi J_{32}))t} \\
& + e^{-(R_2 - i(\omega_2 + \pi J_{20} - \pi J_{21} - \pi J_{32}))t} + e^{-(R_2 - i(\omega_2 - \pi J_{20} - \pi J_{21} - \pi J_{32}))t} \\
& + e^{-(R_2 - i(\omega_1 + \pi J_{10} + \pi J_{21} + \pi J_{31}))t} + e^{-(R_2 - i(\omega_1 - \pi J_{10} + \pi J_{21} + \pi J_{31}))t} \\
& + e^{-(R_2 - i(\omega_1 + \pi J_{10} - \pi J_{21} + \pi J_{31}))t} + e^{-(R_2 - i(\omega_1 - \pi J_{10} - \pi J_{21} + \pi J_{31}))t} \\
& + e^{-(R_2 - i(\omega_1 + \pi J_{21} - \pi J_{31} + \pi J_{30}))t} + e^{-(R_2 - i(\omega_1 - \pi J_{10} + \pi J_{21} - \pi J_{32}))t} \\
& + e^{-(R_2 - i(\omega_1 + \pi J_{10} - \pi J_{21} - \pi J_{31}))t} + e^{-(R_2 - i(\omega_1 - \pi J_{10} - \pi J_{21} - \pi J_{31}))t} \\
& + e^{-(R_2 - i(\omega_0 + \pi J_{10} + \pi J_{20} + \pi J_{30}))t} + e^{-(R_2 - i(\omega_0 - \pi J_{10} + \pi J_{20} + \pi J_{30}))t} \\
& + e^{-(R_2 - i(\omega_0 + \pi J_{10} - \pi J_{20} + \pi J_{30}))t} + e^{-(R_2 - i(\omega_0 - \pi J_{10} - \pi J_{20} + \pi J_{30}))t} \\
& + e^{-(R_2 - i(\omega_0 + \pi J_{10} + \pi J_{20} - \pi J_{30}))t} + e^{-(R_2 - i(\omega_0 - \pi J_{10} + \pi J_{20} - \pi J_{30}))t} \\
& + e^{-(R_2 - i(\omega_0 + \pi J_{10} - \pi J_{20} - \pi J_{30}))t} + e^{-(R_2 - i(\omega_0 - \pi J_{10} - \pi J_{20} - \pi J_{30}))t}
\end{aligned} \tag{216}
$$

dimana $R_2 = \frac{1}{T_2}$

kemudian dapat di cari terlebih dahulu untuk perkalian antara $S(t)\, e^{-i\omega t}$ yaitu sebagi berikut:

$$
\begin{aligned}
S(t)\, e^{-i\omega t} = & -e^{-(R_2 - i(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}))t} - e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}))t} \\
& - e^{-(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}))t} - e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))t} \\
& - e^{-(R_2 - i(\omega_3 - \omega + \pi J_{30} + \pi J_{31} - \pi J_{32}))t} - e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}))t} \\
& - e^{-(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}))t} - e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}))t} \\
& + e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}))t} + e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}))t} \\
& + e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}))t} + e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}))t} \\
& + e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}))t} + e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}))t} \\
& + e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}))t} + e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}))t} \\
& + e^{-(R_2 - i(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}))t} + e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}))t} \\
& + e^{-(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}))t} + e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}))t} \\
& + e^{-(R_2 - i(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}))t} + e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}))t} \\
& + e^{-(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}))t} + e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}))t} \\
& + e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}))t} + e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}))t} \\
& + e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}))t} + e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}))t} \\
& + e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}))t} + e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}))t} \\
& + e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}))t} + e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}))t}
\end{aligned} \tag{217}
$$

Transformasi Fourirer dari sinyal FiD adalah sebagai berikut:

$$
\begin{aligned}
S(\omega) &= \int_{0}^{\infty} S(t)\, e^{-i\omega t}\, dt \\
&= \frac{e^{-(R_2 - i(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}))t}}{(R_2 - i(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}))t}}{(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}))t}}{(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))t}}{(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))t}}{(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}))t}}{(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}))t}}{(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}))t}}{(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}))t}}{(R_2 - i(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}))} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}))t}}{(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}))} \\
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}))t}}{(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}))} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}))t}}{(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}))} \\
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}))t}}{(R_2 - i(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}))} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}))t}}{(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}))t}}{(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}))} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}))t}}{(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}))} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}))t}}{-(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}))} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}))t}}{-(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}))} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}))t}}{-(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}))} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}))t}}{-(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}))} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}))t}}{-(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}))} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}))t}}{-(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}))} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}))t}}{-(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}))} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}))t}}{-(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}))}
\end{aligned}
$$

$$
\begin{aligned}
= &\frac{-1}{(R_2 - i(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}))} - \frac{1}{(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}))} \\
- &\frac{1}{(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}))} - \frac{1}{(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))} \\
- &\frac{1}{(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))} - \frac{1}{(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}))} \\
- &\frac{1}{(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}))} - \frac{1}{(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}))} \\
+ &\frac{1}{(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}))} + \frac{1}{(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}))} \\
+ &\frac{1}{(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}))} + \frac{1}{(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}))} \\
+ &\frac{1}{(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}))} + \frac{1}{(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}))} \\
+ &\frac{1}{(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}))} + \frac{1}{(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}))} \\
+ &\frac{1}{(R_2 - i(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}))} + \frac{1}{(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}))} \\
+ &\frac{1}{(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}))} + \frac{1}{(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}))} \\
+ &\frac{1}{(R_2 - i(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}))} + \frac{1}{(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}))} \\
+ &\frac{1}{(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}))} + \frac{1}{(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}))} \\
+ &\frac{1}{(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}))} + \frac{1}{(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}))} \\
+ &\frac{1}{(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}))} + \frac{1}{(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}))} \\
+ &\frac{1}{(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}))} + \frac{1}{(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}))} \\
+ &\frac{1}{(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}))} + \frac{1}{(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}))}
\end{aligned}
$$

$$
\begin{aligned}
&= -\frac{R_2 + i\left(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}\right)^2} - \frac{R_2 + i\left(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}\right)^2} \\
&- \frac{R_2 + i\left(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}\right)^2} - \frac{R_2 + i\left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}\right)^2} \\
&- \frac{R_2 + i\left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}\right)^2} - \frac{R_2 + i\left(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}\right)^2} \\
&- \frac{R_2 + i\left(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}\right)^2} - \frac{R_2 + i\left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}\right)^2} + \frac{R_2 + i\left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}\right)^2} + \frac{R_2 + i\left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}\right)}{{R_2}^2 + \left(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}\right)^2} + \frac{R_2 + i\left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}\right)^2} + \frac{R_2 + i\left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}\right)^2} + \frac{R_2 + i\left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}\right)^2} + \frac{R_2 + i\left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}\right)}{R_2 + \left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}\right)^2} + \frac{R_2 + i\left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}\right)}{R_2 + \left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}\right)^2} + \frac{R_2 + i\left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}\right)^2}
\end{aligned}
$$

maka dengan demikian diperoleh :

$$
\begin{aligned}
A(\omega) = & -\frac{R_2}{{R_2}^2 + (\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32})^2} - \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32})^2} \\
& - \frac{R_2}{{R_2}^2 - (\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32})^2} - \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})^2} - \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32})^2} - \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31})^2} + \frac{R_2}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31})^2} + \frac{R_2}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30})^2} + \frac{R_2}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31})^2} + \frac{R_2}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30})^2} + \frac{R_2}{{R_2}^2 + (\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30})^2} + \frac{R_2}{R_2 + (\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30})^2} + \frac{R_2}{R_2 + (\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30})^2} + \frac{R_2}{{R_2}^2 + (\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30})^2}
\end{aligned}
\tag{218}
$$

dan diperoleh juga:

$$
\begin{aligned}
D(\omega) = & -\frac{i(\omega_3-\omega+\pi J_{30}+\pi J_{31}+\pi J_{32})}{{R_2}^2+(\omega_3-\omega+\pi J_{30}+\pi J_{31}+\pi J_{32})^2}-\frac{i(\omega_3-\omega-\pi J_{30}+\pi J_{31}+\pi J_{32})}{{R_2}^2+(\omega_3-\omega-\pi J_{30}+\pi J_{31}+\pi J_{32})^2} \\
& -\frac{i(\omega_3-\omega+\pi J_{30}-\pi J_{31}+\pi J_{32})}{{R_2}^2+(\omega_3-\omega+\pi J_{30}-\pi J_{31}+\pi J_{32})^2}-\frac{i(\omega_3-\omega-\pi J_{30}-\pi J_{31}+\pi J_{32})}{{R_2}^2+(\omega_3-\omega-\pi J_{30}-\pi J_{31}+\pi J_{32})^2} \\
& -\frac{i(\omega_3-\omega-\pi J_{30}-\pi J_{31}+\pi J_{32})}{{R_2}^2+(\omega_3-\omega-\pi J_{30}-\pi J_{31}+\pi J_{32})^2}-\frac{i(\omega_3-\omega-\pi J_{30}+\pi J_{31}-\pi J_{32})}{{R_2}^2+(\omega_3-\omega-\pi J_{30}+\pi J_{31}-\pi J_{32})^2} \\
& -\frac{i(\omega_3-\omega+\pi J_{30}-\pi J_{31}-\pi J_{32})}{{R_2}^2+(\omega_3-\omega+\pi J_{30}-\pi J_{31}-\pi J_{32})^2}-\frac{i(\omega_3-\omega-\pi J_{30}-\pi J_{31}-\pi J_{32})}{{R_2}^2+(\omega_3-\omega-\pi J_{30}-\pi J_{31}-\pi J_{32})^2} \\
& +\frac{i(\omega_2-\omega+\pi J_{20}+\pi J_{21}+\pi J_{32})}{{R_2}^2+(\omega_2-\omega+\pi J_{20}+\pi J_{21}+\pi J_{32})^2}+\frac{i(\omega_2-\omega-\pi J_{20}+\pi J_{21}+\pi J_{32})}{{R_2}^2+(\omega_2-\omega-\pi J_{20}+\pi J_{21}+\pi J_{32})^2} \\
& +\frac{i(\omega_2-\omega+\pi J_{20}-\pi J_{21}+\pi J_{32})}{{R_2}^2+(\omega_2-\omega+\pi J_{20}-\pi J_{21}+\pi J_{32})^2}+\frac{i(\omega_2-\omega-\pi J_{20}-\pi J_{21}+\pi J_{32})}{{R_2}^2+(\omega_2-\omega-\pi J_{20}-\pi J_{21}+\pi J_{32})^2} \\
& +\frac{i(\omega_2-\omega+\pi J_{20}+\pi J_{21}-\pi J_{32})}{{R_2}^2+(\omega_2-\omega+\pi J_{20}+\pi J_{21}-\pi J_{32})^2}+\frac{i(\omega_2-\omega-\pi J_{20}+\pi J_{21}-\pi J_{32})}{{R_2}^2+(\omega_2-\omega-\pi J_{20}+\pi J_{21}-\pi J_{32})^2} \\
& +\frac{i(\omega_2-\omega+\pi J_{20}-\pi J_{21}-\pi J_{32})}{{R_2}^2+(\omega_2-\omega+\pi J_{20}-\pi J_{21}-\pi J_{32})^2}+\frac{i(\omega_2-\omega-\pi J_{20}-\pi J_{21}-\pi J_{32})}{{R_2}^2+(\omega_2-\omega-\pi J_{20}-\pi J_{21}-\pi J_{32})^2} \\
& +\frac{i(\omega_1-\omega+\pi J_{10}+\pi J_{21}+\pi J_{31})}{{R_2}^2+(\omega_1-\omega+\pi J_{10}+\pi J_{21}+\pi J_{31})^2}+\frac{i(\omega_1-\omega-\pi J_{10}+\pi J_{21}+\pi J_{31})}{{R_2}^2+(\omega_1-\omega-\pi J_{10}+\pi J_{21}+\pi J_{31})^2} \\
& +\frac{i(\omega_1-\omega+\pi J_{10}-\pi J_{21}+\pi J_{31})}{{R_2}^2+(\omega_1-\omega+\pi J_{10}-\pi J_{21}+\pi J_{31})^2}+\frac{i(\omega_1-\omega-\pi J_{10}-\pi J_{21}+\pi J_{31})}{{R_2}^2+(\omega_1-\omega-\pi J_{10}-\pi J_{21}+\pi J_{31})^2} \\
& +\frac{i(\omega_1-\omega+\pi J_{21}-\pi J_{31}+\pi J_{30})}{{R_2}^2+(\omega_1-\omega+\pi J_{21}-\pi J_{31}+\pi J_{30})^2}+\frac{i(\omega_1-\omega-\pi J_{10}+\pi J_{21}-\pi J_{32})}{{R_2}^2+(\omega_1-\omega-\pi J_{10}+\pi J_{21}-\pi J_{32})^2} \\
& +\frac{i(\omega_1-\omega+\pi J_{10}-\pi J_{21}-\pi J_{31})}{{R_2}^2+(\omega_1-\omega+\pi J_{10}-\pi J_{21}-\pi J_{31})^2}+\frac{i(\omega_1-\omega-\pi J_{10}-\pi J_{21}-\pi J_{31})}{{R_2}^2+(\omega_1-\omega-\pi J_{10}-\pi J_{21}-\pi J_{31})^2} \\
& +\frac{i(\omega_0-\omega+\pi J_{10}+\pi J_{20}+\pi J_{30})}{{R_2}^2+(\omega_0-\omega+\pi J_{10}+\pi J_{20}+\pi J_{30})^2}+\frac{i(\omega_0-\omega-\pi J_{10}+\pi J_{20}+\pi J_{30})}{{R_2}^2+(\omega_0-\omega-\pi J_{10}+\pi J_{20}+\pi J_{30})^2} \\
& +\frac{i(\omega_0-\omega+\pi J_{10}-\pi J_{20}+\pi J_{30})}{{R_2}^2+(\omega_0-\omega+\pi J_{10}-\pi J_{20}+\pi J_{30})^2}+\frac{i(\omega_0-\omega-\pi J_{10}-\pi J_{20}+\pi J_{30})}{R_2+(\omega_0-\omega-\pi J_{10}-\pi J_{20}+\pi J_{30})^2} \\
& +\frac{i(\omega_0-\omega+\pi J_{10}+\pi J_{20}-\pi J_{30})}{{R_2}^2+(\omega_0-\omega+\pi J_{10}+\pi J_{20}-\pi J_{30})^2}+\frac{i(\omega_0-\omega-\pi J_{10}+\pi J_{20}-\pi J_{30})}{R_2+(\omega_0-\omega-\pi J_{10}+\pi J_{20}-\pi J_{30})^2} \\
& +\frac{i(\omega_0-\omega+\pi J_{10}-\pi J_{20}-\pi J_{30})}{{R_2}^2+(\omega_0-\omega+\pi J_{10}-\pi J_{20}-\pi J_{30})^2}+\frac{i(\omega_0-\omega-\pi J_{10}-\pi J_{20}-\pi J_{30})}{{R_2}^2+(\omega_0-\omega-\pi J_{10}-\pi J_{20}-\pi J_{30})^2}
\end{aligned}
\tag{219}
$$

berdasarkan persamaan (182) maka didapatkan grafik sebagai berikut:

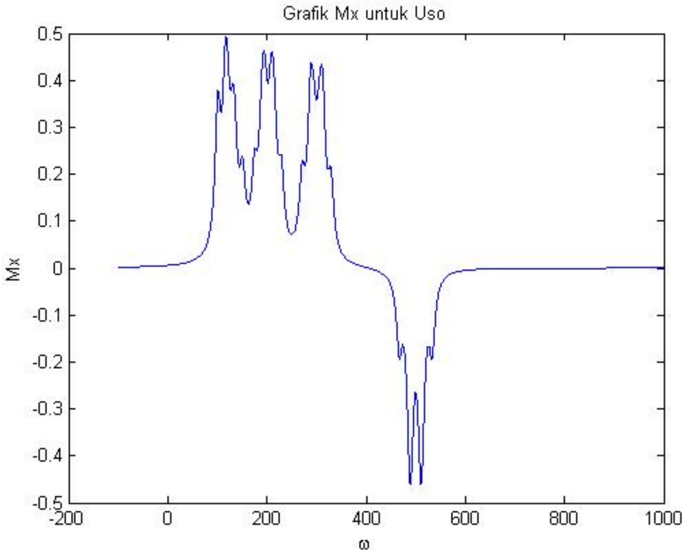

Figure 3: Grafik untuk Us0

data yang dipakai untuk masing-masing qubit adalah sebesar $\omega_3 = 500MHz, \omega_2 = 300MHz, \omega_1 = 202MHz, \omega_0 = 126MHz, J_{32} = 12, J_{31} = 11, J_{21} = 10, J_{30} = 9, J_{20} = 8, J_{10} = 7, R_2 = 7$. untuk$u_2 = U_{s0} = \sigma_z \otimes I \otimes I \otimes I$ berdasarkan grafik Mx untuk U_{s0} maka didapatkan ada 3 multiplet mengarah keatas dan 1 multiplet mengarah ke bahwa dan dapat diketahui bahwa multiplet yang mengrah keatas adalah qubit-3, qubit-2, dan qubit-1 sedangkan multiplet yang mengarah ke bawah adalah qubit-0, sehingga hal ini mengindikasikan keadaan down-up-up-up atau $|0001\rangle$. berdasarkan grafik tersebut diketahui bahwa 2 puncak mengarah mengikuti arah 4 puncak multiplet sehingga tidak terjadi keadaan terbelit untuk $U_2 = U_{s0}$

Dengan cara yang serupa dihasilkan komponen magnetisasi terhadap sumbu-x utnuk fungsi-fungsi lainnya, berikut adalah grafik-grafiknya:

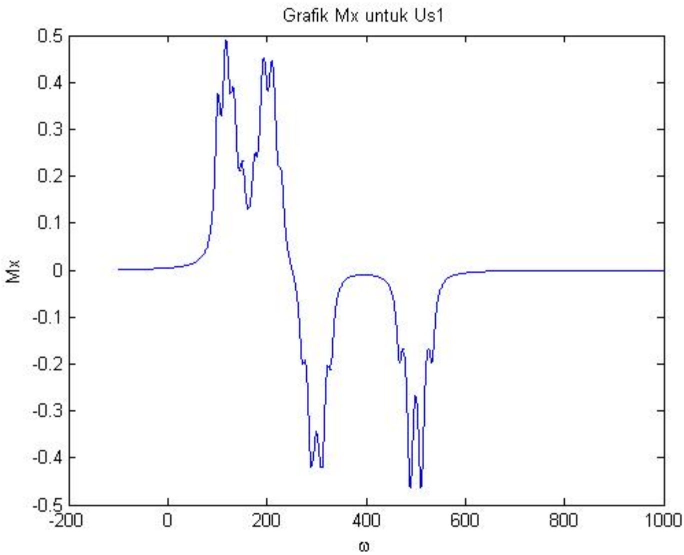

Figure 4: Grafik untuk Us1

untuk $u_2 = U_{s1} = I \otimes I \otimes \sigma_z \otimes \sigma_z$ dapat diketahui berdasarkan grafik diatas bahwa ada 2 multiplet yang mengarah keatas dan 2 yang lain mengarah kebawah. Sehingga didapatkan keadaan up-up-down-down, secara berturut-turut berikut adalah qubit yang mengalami keadaan tersebut yaitu: qubit-3(up), qubit-2(up), qubit-1(down) dan qubit-0 (down), sehingga keadaan dari sistem tersebut adalah $|0011\rangle$. Berdasarkan arah 2 puncak pada masing-masing multiplet menunjukkan keadaan terbelit juga belum terjadi untuk $U_2 = U_{s1}$

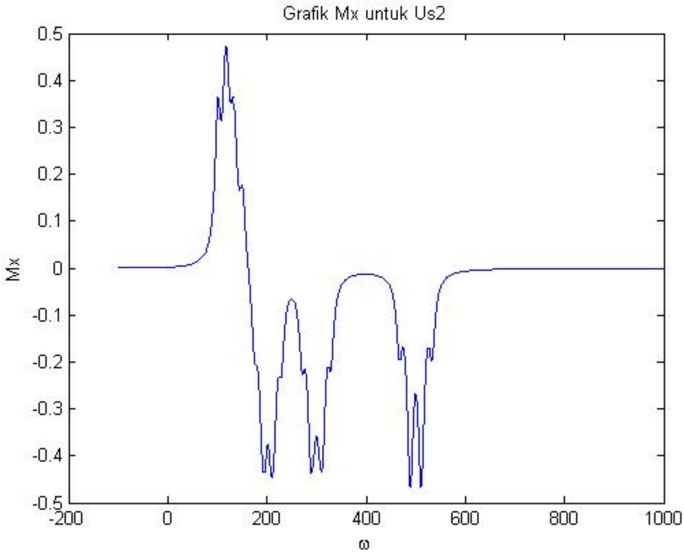

Figure 5: Grafik untuk Us2

berdasarkan Grafik Mx utuk U_{s2} maka dapat diketahui bahwa ada 1 buah qubit dalam keadaan up dan 3 qubit yang lainnya dalam keadaan down, sehingga secara berturut-turut qubit-qubit tersebut adalah qubit-3(up), qubit-2(down), qubit-1(down), qubit-0(down). Maka dengan demikian grafik tersebut menunjukkan sistem dengan keadaan $|0111\rangle$, Selain itu bersdasarkan arah 2 puncak dalam masing-masing multipletnya menunjukkan arah yang sama dengan arah puncak multipletnya, maka diketahui belum terjadi keadaan terbelit untuk sistem $u_2 = U_{s2} = I \otimes \sigma_z \otimes \sigma_z \otimes \sigma_z$

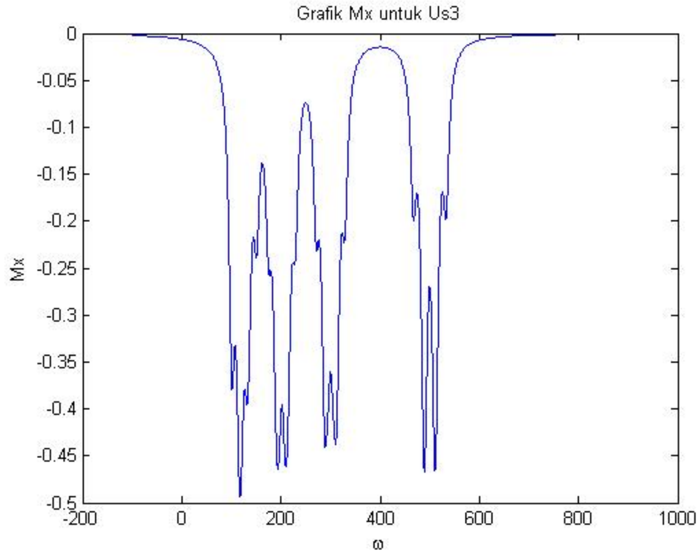

Figure 6: Grafik untuk Us3

berdasarkan Grafik Mx utuk U_{s3} dapat diketahui bahwa keempat puncak multiblet berada di bawah nol, hal ini menunjukkan bahwa semua qubit mengalami keadaan down, sehingga sistem ini menunjukkan keadaan $|1111\rangle$, dan berdasrakan arah 2 puncak dari masing-masing multipletnya mengikuti arah puncak multiplet sehingga tidak terjadi keadaan terbelit untuk keadaan $u_2 = U_{s3} = \sigma_z \otimes \sigma_z \otimes \sigma_z \otimes \sigma_z$

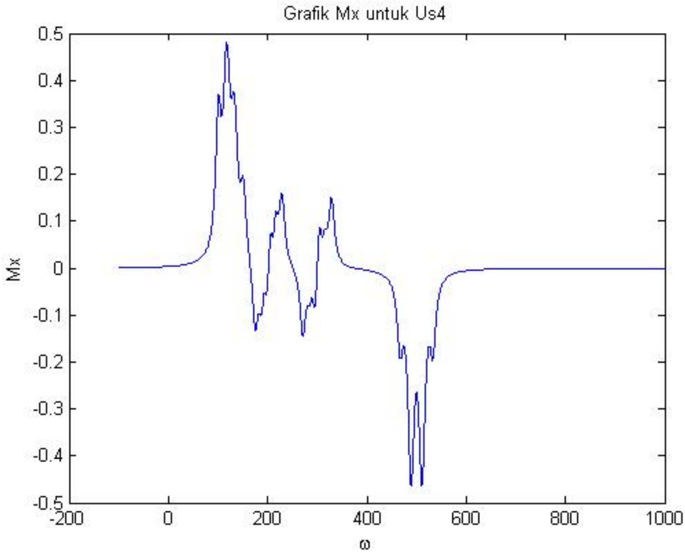

Figure 7: Grafik untuk Us4

berdasarkan Grafik Mx utuk U_{s4} dapat diketahui bahwa 1 buah qubit dalam keadan up, 2 buah qubit dalam keadaan yang tercampur, dan 1 buah qubit dalam keadaan down. untuk 2 buah qubit yang dalam keadaan campuran adalah qubit-2 dan qubit-1, sehingga keadaan terbelit sudah terjadi untuk sistem dengan $U_{s4} = I \otimes ([I \otimes \sigma_z] \oplus [\sigma_z \otimes \sigma_z])$

"Halaman ini sengaja dikosongkan"

BAB VI
KESIMPULAN

Berdasarkan Analisa Penerapan Algoritma Deutsch-Jozsa dalam sistem 4 qubit diperoleh kesimpulan sebgai berikut:

1. Didapatkan spektrum dlam sistem 4 qubit terdiri dari 4 puncak

2. setiap puncak menggambarkan keadaan dari masing-masing qubit, dari kiri ke kanan secara berurutan merupakan puncak qubit ke 3,2,1 dan 0.

3. karakterisasi puncak up dan down menggambarkan keadaan spin up dan spin down.

4. berdasarkan Grafik Mx untuk $U_{ko}, U_{s1}, U_{s2}, U_{s3}, U_{s4}$ menggambarkan keadaan dari ψ_{out} dari masing-masing fungsi yaitu sebagai berikut:

$$\begin{aligned}
|\psi_{k0}\rangle &= \frac{1}{\sqrt{2}} |0000\rangle \, [|0\rangle - |1\rangle] \\
|\psi_{s0}\rangle &= \frac{1}{\sqrt{2}} |1000\rangle \, [|0\rangle - |1\rangle] \\
|\psi_{s1}\rangle &= \frac{1}{\sqrt{2}} |0011\rangle \, [|0\rangle - |1\rangle] \\
|\psi_{s2}\rangle &= \frac{1}{\sqrt{2}} |0111\rangle \, [|0\rangle - |1\rangle] \\
|\psi_{s3}\rangle &= \frac{1}{\sqrt{2}} |1111\rangle \, [|0\rangle - |1\rangle]
\end{aligned} \tag{220}$$

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lampiran

7.1 Penerapan Algoritma Deutsch jozsa 4 qubit untuk U2 = Us1

apabila diambil kasus untuk $U_2 = I \otimes I \otimes \sigma_z \otimes \sigma_z$ maka diperoleh untuk bentuk operator uniter totalnya adalah sebagai berikut:

$$
\begin{aligned}
U &= U_5 U_2 U_1 \\
&= U_5 \left(\sigma_z \otimes I \otimes I \otimes I\right) U_1 \\
&= \begin{pmatrix}
e^{\beta_0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & e^{\beta_1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & e^{\beta_2} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & e^{\beta_3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & e^{\beta_4} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & e^{\beta_5} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_7} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_9} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_1 0} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_1 1} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_1 2} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_1 3} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_1 4} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_1 5}
\end{pmatrix}
\end{aligned}
$$

$$
\times \begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{pmatrix}
$$

$$
\times \frac{1}{4}\begin{pmatrix}
1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & 1 & -1 & -1 & 1 \\
1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 \\
1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 \\
1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 \\
1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 \\
1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 \\
1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\
1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \\
1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\
1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\
1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\
1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\
1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\
1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1
\end{pmatrix}
$$

$$
= \frac{1}{4}\begin{pmatrix}
e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} \\
-e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} \\
-e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} \\
e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} \\
e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} \\
-e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} \\
-e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} \\
e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} \\
e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} \\
-e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} \\
-e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} \\
e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} \\
e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} \\
-e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} \\
-e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} \\
e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}}
\end{pmatrix} \tag{221}
$$

$$U^\dagger = \begin{pmatrix}
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}}
\end{pmatrix} \quad (222)$$

maka dengan demikian kita dapatkan untuk nilai ρ_5 adalah

$$
\begin{aligned}
\rho_5 &= U\rho_0U^\dagger \\
&= \frac{1}{4}\begin{pmatrix}
e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} \\
-e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} \\
-e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} \\
e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} \\
e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} \\
-e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} \\
-e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} \\
e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} \\
e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} \\
-e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} \\
-e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} \\
e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} \\
e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} \\
-e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} \\
-e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} \\
e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}}
\end{pmatrix}
\end{aligned}
$$

$$
\times \begin{pmatrix}
2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -2
\end{pmatrix}
$$

$$
\times \frac{1}{4} \begin{pmatrix}
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}}
\end{pmatrix}
$$

$$
= \frac{1}{16}\begin{pmatrix}
0 & -8\rho_{0,1} & -8\rho_{0,2} & 0 & 8\rho_{0,4} & 0 & 0 & 0 & -8\rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-8\rho_{1,0} & 0 & 0 & -8\rho_{1,3} & 0 & 8\rho_{1,5} & 0 & 0 & 0 & -8\rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
-8\rho_{2,0} & 0 & 0 & -8\rho_{2,3} & 0 & 0 & 8\rho_{2,6} & 0 & 0 & 0 & -8\rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & -8\rho_{3,1} & -8\rho_{3,2} & 0 & 0 & 0 & 0 & 8\rho_{3,7} & 0 & 0 & 0 & -8\rho_{3,11} & 0 & 0 & 0 & 0 \\
8\rho_{40} & 0 & 0 & 0 & 0 & -8\rho_{4,5} & -8\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & 8\rho_{4,12} & 0 & 0 & 0 \\
0 & 8\rho_{4,1} & 0 & 0 & -8\rho_{5,4} & 0 & 0 & -8\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & 8\rho_{5,13} & 0 & 0 \\
0 & 0 & 8\rho_{6,2} & 0 & -8\rho_{6,4} & 0 & 0 & -8\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & 8\rho_{6,14} & 0 \\
0 & 0 & 0 & 8\rho_{7,3} & 0 & -8\rho_{7,5} & -8\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -8\rho_{7,15} \\
-8\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -8\rho_{8,9} & -8\rho_{8,10} & 0 & 8\rho_{8,12} & 0 & 0 & 0 \\
0 & -8\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -8\rho_{9,8} & 0 & 0 & -8\rho_{9,11} & 0 & 8\rho_{9,13} & 0 & 0 \\
0 & 0 & -8\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -8\rho_{10,8} & 0 & 0 & -8\rho_{10,11} & 0 & 0 & 8\rho_{10,14} & 0 \\
0 & 0 & 0 & -8\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -8\rho_{11,9} & -8\rho_{11,10} & 0 & 0 & 0 & 0 & 8\rho_{11,15} \\
0 & 0 & 0 & 0 & -8\rho_{12,4} & 0 & 0 & 0 & 8\rho_{12,8} & 0 & 0 & 0 & 0 & -8\rho_{12,13} & -8\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & -8\rho_{13,5} & 0 & 0 & 0 & 8\rho_{13,9} & 0 & 0 & -8\rho_{13,12} & 0 & 0 & -8\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & -8\rho_{14,6} & 0 & 0 & 0 & 8\rho_{14,10} & 0 & -8\rho_{14,12} & 0 & 0 & -8\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -8\rho_{15,7} & 0 & 0 & 0 & 8\rho_{15,11} & 0 & -8\rho 15,13 & -8\rho_{15,14} & 0
\end{pmatrix} \qquad (22
$$

$$
= \frac{1}{2} \begin{pmatrix}
0 & -\rho_{0,1} & -\rho_{0,2} & 0 & \rho_{0,4} & 0 & 0 & 0 & -\rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{1,0} & 0 & 0 & -\rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & -\rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & \rho_{2,6} & 0 & 0 & 0 & -\rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & \rho_{3,7} & 0 & 0 & 0 & -\rho_{3,11} & 0 & 0 & 0 & 0 \\
\rho_{40} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{4,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & \rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{7,15} \\
-\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{8,9} & -\rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & -\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & -\rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & -\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -\rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & \rho_{10,14} & 0 \\
0 & 0 & 0 & -\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & -\rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & -\rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & -\rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & -\rho 15, 13 & -\rho_{15,14} & 0
\end{pmatrix} \tag{224}
$$

dengan

$$
\begin{array}{cc}
\rho_{0,1} = \rho_{1,0}{}^* = e^{\beta_0 - \beta_1} & \rho_{6,7} = \rho_{7,6}{}^* = e^{\beta_6 - \beta_7} \\
\rho_{0,2} = \rho_{2,0}{}^* = e^{\beta_0 - \beta_2} & \rho_{6,14} = \rho_{14,6}{}^* = e^{\beta_6 - \beta_1 4} \\
\rho_{0,8} = \rho_{8,0}{}^* = e^{\beta_8 - \beta_1} & \rho_{8,9} = \rho_{9,8}{}^* = e^{\beta_8 - \beta_9} \\
\rho_{1,3} = \rho_{3,1}{}^* = e^{\beta_1 - \beta_3} & \rho_{8,10} = \rho_{10,8}{}^* = e^{\beta_8 - \beta_{10}} \\
\rho_{1,5} = \rho_{5,1}{}^* = e^{\beta_1 - \beta_5} & \rho_{8,12} = \rho_{12,8}{}^* = e^{\beta_8 - \beta_{12}} \\
\rho_{1,9} = \rho_{9,1}{}^* = e^{\beta_1 - \beta_9} & \rho_{9,11} = \rho_{11,9}{}^* = e^{\beta_9 - \beta_{11}} \\
\rho_{2,3} = \rho_{3,2}{}^* = e^{\beta_2 - \beta_3} & \rho_{9,13} = \rho_{13,9}{}^* = e^{\beta_9 - \beta_{13}} \\
\rho_{2,6} = \rho_{6,2}{}^* = e^{\beta_2 - \beta_6} & \rho_{10,11} = \rho_{11,10}{}^* = e^{\beta_{10} - \beta_{11}} \\
\rho_{2,10} = \rho_{10,2}{}^* = e^{\beta_2 - \beta_1 0} & \rho_{10,14} = \rho_{14,10}{}^* = e^{\beta_{10} - \beta_{14}} \\
\rho_{3,7} = \rho_{7,3}{}^* = e^{\beta_3 - \beta_7} & \rho_{12,13} = \rho_{13,12}{}^* = e^{\beta_{12} - \beta_{13}} \\
\rho_{3,11} = \rho_{11,3}{}^* = e^{\beta_3 - \beta_1 1} & \rho_{12,14} = \rho_{14,12}{}^* = e^{\beta_{12} - \beta_{14}} \\
\rho_{4,5} = \rho_{5,4}{}^* = e^{\beta_4 - \beta_5} & \rho_{11,15} = \rho_{15,11}{}^* = e^{\beta_{11} - \beta_{15}} \\
\rho_{4,6} = \rho_{6,4}{}^* = e^{\beta_4 - \beta_6} & \rho_{13,15} = \rho_{15,13}{}^* = e^{\beta_{13} - \beta_{15}} \\
\rho_{4,12} = \rho_{12,4}{}^* = e^{\beta_4 - \beta_1 2} & \rho_{14,15} = \rho_{14,15}{}^* = e^{\beta_{14} - \beta_{15}} \\
\rho_{5,7} = \rho_{7,5}{}^* = e^{\beta_5 - \beta_7} & \rho_{15,7} = \rho_{7,15}{}^* = e^{\beta_7 - \beta_{15}} \\
\rho_{5,13} = \rho_{13,5}{}^* = e^{\beta_5 - \beta_1 3} & \rho_{0,4} = \rho_{4,0}{}^* = e^{\beta_0 - \beta_4}
\end{array}
\tag{225}
$$

dan

$$\begin{aligned}
\beta_0 - \beta_1 &= -i\left(E_{4,0} - E_{4,1}\right)t & \beta_0 - \beta_2 &= -i\left(E_{4,0} - E_{4,2}\right)t \\
\beta_0 - \beta_4 &= -i\left(E_{4,0} - E_{4,4}\right)t & \beta_0 - \beta_8 &= -i\left(E_{4,0} - E_{4,8}\right)t \\
\beta_1 - \beta_3 &= -i\left(E_{4,1} - E_{4,3}\right)t & \beta_1 - \beta_5 &= -i\left(E_{4,1} - E_{4,5}\right)t \\
\beta_1 - \beta_9 &= -i\left(E_{4,1} - E_{4,9}\right)t & \beta_2 - \beta_3 &= -i\left(E_{4,2} - E_{4,3}\right)t \\
\beta_2 - \beta_6 &= -i\left(E_{4,2} - E_{4,6}\right)t & \beta_2 - \beta_{10} &= -i\left(E_{4,2} - E_{4,10}\right)t \\
\beta_3 - \beta_7 &= -i\left(E_{4,3} - E_{4,7}\right)t & \beta_3 - \beta_{11} &= -i\left(E_{4,3} - E_{4,11}\right)t \\
\beta_4 - \beta_5 &= -i\left(E_{4,4} - E_{4,5}\right)t & \beta_4 - \beta_6 &= -i\left(E_{4,4} - E_{4,6}\right)t \\
\beta_4 - \beta_{12} &= -i\left(E_{4,4} - E_{4,12}\right)t & \beta_5 - \beta_7 &= -i\left(E_{4,5} - E_{4,7}\right)t \\
\beta_5 - \beta_{13} &= -i\left(E_{4,5} - E_{4,13}\right)t & \beta_6 - \beta_7 &= -i\left(E_{4,6} - E_{4,7}\right)t \\
\beta_6 - \beta_{14} &= -i\left(E_{4,6} - E_{4,14}\right)t & \beta_8 - \beta_9 &= -i\left(E_{4,8} - E_{4,9}\right)t \\
\beta_8 - \beta_{10} &= -i\left(E_{4,8} - E_{4,10}\right)t & \beta_8 - \beta_{12} &= -i\left(E_{4,8} - E_{4,12}\right)t \\
\beta_9 - \beta_{11} &= -i\left(E_{4,9} - E_{4,11}\right)t & \beta_9 - \beta_{13} &= -i\left(E_{4,9} - E_{4,13}\right)t \\
\beta_{10} - \beta_{11} &= -i\left(E_{4,10} - E_{4,11}\right)t & \beta_{10} - \beta_{14} &= -i\left(E_{4,10} - E_{4,14}\right)t \\
\beta_{12} - \beta_{13} &= -i\left(E_{4,12} - E_{4,13}\right)t & \beta_{12} - \beta_{14} &= -i\left(E_{4,12} - E_{4,14}\right)t \\
\beta_{11} - \beta_{15} &= -i\left(E_{4,11} - E_{4,15}\right)t & \beta_{13} - \beta_{15} &= -i\left(E_{4,13} - E_{4,15}\right)t \\
\beta_{14} - \beta_{15} &= -i\left(E_{4,14} - E_{4,15}\right)t & \beta_{15} - \beta_7 &= -i\left(E_{4,15} - E_{4,7}\right)t
\end{aligned} \tag{226}$$

dan

$$
\begin{array}{cc}
E_{4,0} - E4,1 = \omega_0 + \pi J_{10} + \pi J_{20} + \pi J_{30} & E_{4,0} - E4,2 = \omega_1 + \pi J_{10} + \pi J_{21} + \pi J_{31} \\
E_{4,0} - E4,4 = \omega_2 + \pi J_{20} + \pi J_{21} + \pi J_{32} & E_{4,0} - E4,8 = \omega_3 + \pi J_{30} + \pi J_{31} + \pi J_{32} \\
E_{4,1} - E4,3 = \omega_1 - \pi J_{10} + \pi J_{21} + \pi J_{31} & E_{4,1} - E4,5 = \omega_2 - \pi J_{20} + \pi J_{21} + \pi J_{32} \\
E_{4,1} - E4,9 = \omega_3 - \pi J_{30} + \pi J_{310} + \pi J_{32} & E_{4,2} - E4,3 = \omega_0 - \pi J_{10} + \pi J_{20} + \pi J_{30} \\
E_{4,2} - E4,6 = \omega_2 + \pi J_{20} - \pi J_{21} + \pi J_{32} & E_{4,2} - E4,10 = \omega_3 + \pi J_{30} - \pi J_{31} + \pi J_{32} \\
E_{4,3} - E4,7 = \omega_2 - \pi J_{20} - \pi J_{21} + \pi J_{32} & E_{4,3} - E4,11 = \omega_3 - \pi J_{30} - \pi J_{31} + \pi J_{32} \\
E_{4,4} - E4,5 = \omega_0 + \pi J_{10} - \pi J_{20} + \pi J_{30} & E_{4,4} - E4,6 = \omega_1 + \pi J_{10} - \pi J_{21} + \pi J_{31} \\
E_{4,4} - E4,12 = \omega_3 + \pi J_{30} + \pi J_{31} - \pi J_{32} & E_{4,5} - E4,7 = \omega_1 - \pi J_{10} - \pi J_{21} + \pi J_{31} \\
E_{4,5} - E4,13 = \omega_3 - \pi J_{30} + \pi J_{31} - \pi J_{32} & E_{4,6} - E4,7 = \omega_0 - \pi J_{10} - \pi J_{20} + \pi J_{30} \\
E_{4,6} - E4,14 = \omega_3 + \pi J_{30} - \pi J_{31} - \pi J_{32} & E_{4,8} - E4,9 = \omega_0 + \pi J_{10} + \pi J_{20} - \pi J_{30} \\
E_{4,8} - E4,10 = \omega_1 + \pi J_{21} - \pi J_{31} + \pi J_{30} & E_{4,8} - E4,12 = \omega_2 + \pi J_{20} + \pi J_{21} - \pi J_{32} \\
E_{4,9} - E4,11 = \omega_1 - \pi J_{10} + \pi J_{21} - \pi J_{32} & E_{4,10} - E4,11 = \omega_0 - \pi J_{10} + \pi J_{20} - \pi J_{30} \\
E_{4,10} - E4,14 = \omega_2 + \pi J_{20} - \pi J_{21} - \pi J_{32} & E_{4,12} - E4,13 = \omega_0 + \pi J_{10} - \pi J_{20} - \pi J_{30} \\
E_{4,12} - E4,14 = \omega_1 + \pi J_{10} - \pi J_{21} - \pi J_{31} & E_{4,11} - E4,15 = \omega_2 - \pi J_{20} - \pi J_{21} - \pi J_{32} \\
E_{4,13} - E4,15 = \omega_1 - \pi J_{10} - \pi J_{21} - \pi J_{31} & E_{4,14} - E4,15 = \omega_0 - \pi J_{10} - \pi J_{20} - \pi J_{30} \\
E_{4,9} - E4,13 = \omega_2 - \pi J_{20} + \pi J_{21} - \pi J_{32} & E_{4,15} - E4,7 = \omega_3 + \pi J_{30} + \pi J_{31} + \pi J_{32}
\end{array}
\tag{227}
$$

maka dapat ditentukan nilai magnetisasi dari masing-masing qubitnya yaitu sebagai berikut:

$$(I_{3+}\rho_5) = \begin{pmatrix}
0&0&0&0&0&0&0&1&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&1&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&1&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&1&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&1&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&1&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&1&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&1&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&1\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0
\end{pmatrix}$$

$$
\times \frac{1}{2}
\begin{pmatrix}
0 & -\rho_{0,1} & -\rho_{0,2} & 0 & \rho_{0,4} & 0 & 0 & 0 & -\rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{1,0} & 0 & 0 & -\rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & -\rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & \rho_{2,6} & 0 & 0 & 0 & -\rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & \rho_{3,7} & 0 & 0 & 0 & -\rho_{3,11} & 0 & 0 & 0 & 0 \\
\rho_{40} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{4,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & \rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{7,15} \\
-\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{8,9} & -\rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & -\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & -\rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & -\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -\rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & \rho_{10,14} & 0 \\
0 & 0 & 0 & -\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & -\rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & -\rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & {} & 0 & 0 & 0 & -\rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & -\rho 15,13 & -\rho_{15,14} & 0
\end{pmatrix}
$$

$$
= \frac{1}{2}\begin{pmatrix}
\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{8,9} & -\rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & \rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & -\rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & \rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -\rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & \rho_{10,14} & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & \rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & 0 & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & -\rho_{15,13} & -\rho_{15,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$
\begin{aligned}
M_{3+} &= \langle I_{3+} \rangle = tr\,(I_{3+}\rho_5) \\
&= \rho_{8,0} + \rho_{9,1} + \rho_{10,2} + \rho_{11,3} + \rho_{12,4} + \rho_{13,5} + \rho_{14,6} + \rho_{15,7}
\end{aligned}
\tag{228}
$$

dan

$$
(I_{2+}\rho_5) = \begin{pmatrix}
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$
\times \frac{1}{2} \begin{pmatrix}
0 & -\rho_{0,1} & -\rho_{0,2} & 0 & \rho_{0,4} & 0 & 0 & 0 & -\rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{1,0} & 0 & 0 & -\rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & -\rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & \rho_{2,6} & 0 & 0 & 0 & -\rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & \rho_{3,7} & 0 & 0 & 0 & -\rho_{3,11} & 0 & 0 & 0 & 0 \\
\rho_{40} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{4,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & \rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{7,15} \\
-\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{8,9} & -\rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & -\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & -\rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & -\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -\rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & \rho_{10,14} & 0 \\
0 & 0 & 0 & -\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & -\rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & -\rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & -\rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & -\rho 15, 13 & -\rho_{15,14} & 0
\end{pmatrix}
$$

$$
= \frac{1}{2} \begin{pmatrix}
\rho_{4,0} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{5,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & \rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & \rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & -\rho 15, 13 & -\rho_{15,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix} \tag{229}
$$

$$
\begin{aligned}
M_{2+} &= \langle I_{2+} \rangle = tr\left(I_{2+}\rho_5\right) \\
&= \rho_{4,0} + \rho_{5,1} + \rho_{6,2} + \rho_{7,3} + \rho_{12,8} + \rho_{13,9} + \rho_{14,10} + \rho_{15,11}
\end{aligned} \tag{230}
$$

dan

$$
(I_{1+}\rho_5) = \begin{pmatrix}
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$\times \frac{1}{2}\begin{pmatrix}
0 & -\rho_{0,1} & -\rho_{0,2} & 0 & \rho_{0,4} & 0 & 0 & 0 & -\rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{1,0} & 0 & 0 & -\rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & -\rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & \rho_{2,6} & 0 & 0 & 0 & -\rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & \rho_{3,7} & 0 & 0 & 0 & -\rho_{3,11} & 0 & 0 & 0 & 0 \\
\rho_{40} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{4,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & \rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{7,15} \\
-\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{8,9} & -\rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & -\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & -\rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & -\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -\rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & \rho_{10,14} & 0 \\
0 & 0 & 0 & -\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & -\rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & -\rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & -\rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & -\rho 15,13 & -\rho_{15,14} & 0
\end{pmatrix}$$

$$
= \frac{1}{2}\begin{pmatrix}
-\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & \rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & \rho_{3,7} & 0 & 0 & \rho_{3,11} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & \rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & \rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -\rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & \rho_{10,14} & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & -\rho 15,13 & -\rho_{15,14} & 0
\end{pmatrix} \tag{231}
$$

$$
\begin{aligned}
M_{1+} &= \langle I_{1+} \rangle = tr\left(I_{1+}\rho_5\right) \\
&= -\left(\rho_{2,0} + \rho_{3,1} + \rho_{6,4} + \rho_{7,5} + \rho_{10,8} + \rho_{11,9} + \rho_{14,12} + \rho_{15,13}\right)
\end{aligned}
\tag{232}
$$

dan

$$
(I_{0+}\rho_5) = \begin{pmatrix}
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$
\times \frac{1}{2}
\begin{pmatrix}
0 & -\rho_{0,1} & -\rho_{0,2} & 0 & \rho_{0,4} & 0 & 0 & 0 & -\rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{1,0} & 0 & 0 & -\rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & -\rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & \rho_{2,6} & 0 & 0 & 0 & -\rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & \rho_{3,7} & 0 & 0 & 0 & -\rho_{3,11} & 0 & 0 & 0 & 0 \\
\rho_{40} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{4,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & \rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{7,15} \\
-\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{8,9} & -\rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & -\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & -\rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & -\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -\rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & \rho_{10,14} & 0 \\
0 & 0 & 0 & -\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & -\rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & -\rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & -\rho_{14,6} & 0 & 0 & 0 & \rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & -\rho 15,13 & -\rho_{15,14} & 0
\end{pmatrix}
$$

$$
= \frac{1}{2} \begin{pmatrix}
-\rho_{1,0} & 0 & 0 & -\rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & \rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & \rho_{3,7} & 0 & 0 & \rho_{3,11} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{5,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & -\rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & \rho_{11,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & -\rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & \rho_{15,11} & 0 & -\rho 15,13 & -\rho_{15,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix} \tag{233}
$$

$$
\begin{aligned}
M_{0+} &= \langle I_{0+} \rangle = tr\left(I_{0+}\rho_5\right) \\
&= -\left(\rho_{1,0} + \rho_{3,2} + \rho_{5,2} + \rho_{7,6} + \rho_{9,8} + \rho_{11,10} + \rho_{13,12} + \rho_{15,14}\right)
\end{aligned} \tag{234}
$$

maka dengan demikian nilai magnetisasi total dari sistem adalah sebagai berikut:

$$
\begin{aligned}
M_{tot} &= M_{3+} + M_{2+} + M_{1+} + M_{0+} \\
&= \rho_{8,0} + \rho_{9,1} + \rho_{10,2} + \rho_{11,3} + \rho_{12,4} + \rho_{13,5} + \rho_{14,6} + \rho_{15,7} \\
&+ \rho_{4,0} + \rho_{5,1} + \rho_{6,2} + \rho_{7,3} + \rho_{12,8} + \rho_{13,9} + \rho_{14,10} + \rho_{15,11} \\
&- \left(\rho_{2,0} + \rho_{3,1} + \rho_{6,4} + \rho_{7,5} + \rho_{10,8} + \rho_{11,9} + \rho_{14,12} + \rho_{15,13}\right) \\
&- \left(\rho_{1,0} + \rho_{3,2} + \rho_{5,4} + \rho_{7,6} + \rho_{9,8} + \rho_{11,10} + \rho_{13,12} + \rho_{15,14}\right) \\
&= +e^{i(\omega_3+\pi J_{30}+\pi J_{31}+\pi J_{32})t} + e^{i(\omega_3-\pi J_{30}+\pi J_{31}+\pi J_{32})t} \\
&+ e^{i(\omega_3+\pi J_{30}-\pi J_{31}+\pi J_{32})t} + e^{i(\omega_3-\pi J_{30}-\pi J_{31}+\pi J_{32})t} \\
&+ e^{i(\omega_3+\pi J_{30}+\pi J_{31}-\pi J_{32})t} + e^{i(\omega_3-\pi J_{30}+\pi J_{31}-\pi J_{32})t} \\
&+ e^{i(\omega_3+\pi J_{30}-\pi J_{31}-\pi J_{32})t} + e^{i(\omega_3-\pi J_{30}-\pi J_{31}-\pi J_{32})t} \\
&+ e^{i(\omega_2+\pi J_{20}+\pi J_{21}+\pi J_{32})t} + e^{i(\omega_2-\pi J_{20}+\pi J_{21}+\pi J_{32})t} \\
&+ e^{i(\omega_2+\pi J_{20}-\pi J_{21}+\pi J_{32})t} + e^{i(\omega_2-\pi J_{20}-\pi J_{21}+\pi J_{32})t} \\
&+ e^{i(\omega_2+\pi J_{20}+\pi J_{21}-\pi J_{32})t} + e^{i(\omega_2-\pi J_{20}+\pi J_{21}-\pi J_{32})t} \\
&+ e^{i(\omega_2+\pi J_{20}-\pi J_{21}-\pi J_{32})t} + e^{i(\omega_2-\pi J_{20}-\pi J_{21}-\pi J_{32})t} \\
&- e^{i(\omega_1+\pi J_{10}+\pi J_{21}+\pi J_{31})t} - e^{i(\omega_1-\pi J_{10}+\pi J_{21}+\pi J_{31})t} \\
&- e^{i(\omega_1+\pi J_{10}-\pi J_{21}+\pi J_{31})t} - e^{i(\omega_1-\pi J_{10}-\pi J_{21}+\pi J_{31})t} \\
&- e^{i(\omega_1+\pi J_{21}-\pi J_{31}+\pi J_{30})t} - e^{i(\omega_1-\pi J_{10}+\pi J_{21}-\pi J_{32})t} \\
&- e^{i(\omega_1+\pi J_{10}-\pi J_{21}-\pi J_{31})t} - e^{i(\omega_1-\pi J_{10}-\pi J_{21}-\pi J_{31})t} \\
&- e^{i(\omega_0+\pi J_{10}+\pi J_{20}+\pi J_{30})t} - e^{i(\omega_0-\pi J_{10}+\pi J_{20}+\pi J_{30})t} \\
&- e^{i(\omega_0+\pi J_{10}-\pi J_{20}+\pi J_{30})t} - e^{i(\omega_0-\pi J_{10}-\pi J_{20}+\pi J_{30})t} \\
&- e^{i(\omega_0+\pi J_{10}+\pi J_{20}-\pi J_{30})t} - e^{i(\omega_0-\pi J_{10}+\pi J_{20}-\pi J_{30})t} \\
&- e^{i(\omega_0+\pi J_{10}-\pi J_{20}-\pi J_{30})t} - e^{i(\omega_0-\pi J_{10}-\pi J_{20}-\pi J_{30})t}
\end{aligned} \tag{235}
$$

kemudian didapatkan juga untuk sinyal FID sebagai berikut:

$$
\begin{aligned}
S &= M_{tot} e^{-R_2 t} \\
&= e^{-(R_2 - i(\omega_3 + \pi J_{30} + \pi J_{31} + \pi J_{32}))t} + e^{-(R_2 - i(\omega_3 - \pi J_{30} + \pi J_{31} + \pi J_{32}))t} \\
&+ e^{-(R_2 - i(\omega_3 + \pi J_{30} - \pi J_{31} + \pi J_{32}))t} + e^{-(R_2 - i(\omega_3 - \pi J_{30} - \pi J_{31} + \pi J_{32}))t} \\
&+ e^{-(R_2 - i(\omega_3 + \pi J_{30} + \pi J_{31} - \pi J_{32}))t} + e^{-(R_2 - i(\omega_3 - \pi J_{30} + \pi J_{31} - \pi J_{32}))t} \\
& e^{-(R_2 - i(\omega_3 + \pi J_{30} - \pi J_{31} - \pi J_{32}))t} + e^{-(R_2 - i(\omega_3 - \pi J_{30} - \pi J_{31} - \pi J_{32}))t} \\
&+ e^{-(R_2 - i(\omega_2 + \pi J_{20} + \pi J_{21} + \pi J_{32}))t} + e^{-(R_2 - i(\omega_2 - \pi J_{20} + \pi J_{21} + \pi J_{32}))t} \\
&+ e^{-(R_2 - i(\omega_2 + \pi J_{20} - \pi J_{21} + \pi J_{32}))t} + e^{-(R_2 - i(\omega_2 - \pi J_{20} - \pi J_{21} + \pi J_{32}))t} \\
&+ e^{-(R_2 - i(\omega_2 + \pi J_{20} + \pi J_{21} - \pi J_{32}))t} + e^{-(R_2 - i(\omega_2 - \pi J_{20} + \pi J_{21} - \pi J_{32}))t} \\
&+ e^{-(R_2 - i(\omega_2 + \pi J_{20} - \pi J_{21} - \pi J_{32}))t} + e^{-(R_2 - i(\omega_2 - \pi J_{20} - \pi J_{21} - \pi J_{32}))t} \\
&- e^{-(R_2 - i(\omega_1 + \pi J_{10} + \pi J_{21} + \pi J_{31}))t} - e^{-(R_2 - i(\omega_1 - \pi J_{10} + \pi J_{21} + \pi J_{31}))t} \\
&- e^{-(R_2 - i(\omega_1 + \pi J_{10} - \pi J_{21} + \pi J_{31}))t} - e^{-(R_2 - i(\omega_1 - \pi J_{10} - \pi J_{21} + \pi J_{31}))t} \\
&- e^{-(R_2 - i(\omega_1 + \pi J_{21} - \pi J_{31} + \pi J_{30}))t} - e^{-(R_2 - i(\omega_1 - \pi J_{10} + \pi J_{21} - \pi J_{32}))t} \\
&- e^{-(R_2 - i(\omega_1 + \pi J_{10} - \pi J_{21} - \pi J_{31}))t} - e^{-(R_2 - i(\omega_1 - \pi J_{10} - \pi J_{21} - \pi J_{31}))t} \\
&- e^{-(R_2 - i(\omega_0 + \pi J_{10} + \pi J_{20} + \pi J_{30}))t} - e^{-(R_2 - i(\omega_0 - \pi J_{10} + \pi J_{20} + \pi J_{30}))t} \\
&- e^{-(R_2 - i(\omega_0 + \pi J_{10} - \pi J_{20} + \pi J_{30}))t} - e^{-(R_2 - i(\omega_0 - \pi J_{10} - \pi J_{20} + \pi J_{30}))t} \\
&- e^{-(R_2 - i(\omega_0 + \pi J_{10} + \pi J_{20} - \pi J_{30}))t} - e^{-(R_2 - i(\omega_0 - \pi J_{10} + \pi J_{20} - \pi J_{30}))t} \\
&- e^{-(R_2 - i(\omega_0 + \pi J_{10} - \pi J_{20} - \pi J_{30}))t} - e^{-(R_2 - i(\omega_0 - \pi J_{10} - \pi J_{20} - \pi J_{30}))t}
\end{aligned}
\tag{236}
$$

dimana $R_2 = \frac{1}{T_2}$

kemudian dapat di cari terlebih dahulu untuk perkalian antara $S(t)\,e^{-i\omega t}$ yaitu sebagi berikut:

$$
\begin{aligned}
S(t)\,e^{-i\omega t} = {} & e^{-(R_2-i(\omega_3-\omega+\pi J_{30}+\pi J_{31}+\pi J_{32}))t} + e^{-(R_2-i(\omega_3-\omega-\pi J_{30}+\pi J_{31}+\pi J_{32}))t} \\
& + e^{-(R_2-i(\omega_3-\omega+\pi J_{30}-\pi J_{31}+\pi J_{32}))t} + e^{-(R_2-i(\omega_3-\omega-\pi J_{30}-\pi J_{31}+\pi J_{32}))t} \\
& + e^{-(R_2-i(\omega_3-\omega+\pi J_{30}+\pi J_{31}-\pi J_{32}))t} + e^{-(R_2-i(\omega_3-\omega-\pi J_{30}+\pi J_{31}-\pi J_{32}))t} \\
& + e^{-(R_2-i(\omega_3-\omega+\pi J_{30}-\pi J_{31}-\pi J_{32}))t} + e^{-(R_2-i(\omega_3-\omega-\pi J_{30}-\pi J_{31}-\pi J_{32}))t} \\
& + e^{-(R_2-i(\omega_2-\omega+\pi J_{20}+\pi J_{21}+\pi J_{32}))t} + e^{-(R_2-i(\omega_2-\omega-\pi J_{20}+\pi J_{21}+\pi J_{32}))t} \\
& + e^{-(R_2-i(\omega_2-\omega+\pi J_{20}-\pi J_{21}+\pi J_{32}))t} + e^{-(R_2-i(\omega_2-\omega-\pi J_{20}-\pi J_{21}+\pi J_{32}))t} \\
& + e^{-(R_2-i(\omega_2-\omega+\pi J_{20}+\pi J_{21}-\pi J_{32}))t} + e^{-(R_2-i(\omega_2-\omega-\pi J_{20}+\pi J_{21}-\pi J_{32}))t} \\
& + e^{-(R_2-i(\omega_2-\omega+\pi J_{20}-\pi J_{21}-\pi J_{32}))t} + e^{-(R_2-i(\omega_2-\omega-\pi J_{20}-\pi J_{21}-\pi J_{32}))t} \\
& - e^{-(R_2-i(\omega_1-\omega+\pi J_{10}+\pi J_{21}+\pi J_{31}))t} - e^{-(R_2-i(\omega_1-\omega-\pi J_{10}+\pi J_{21}+\pi J_{31}))t} \\
& - e^{-(R_2-i(\omega_1-\omega+\pi J_{10}-\pi J_{21}+\pi J_{31}))t} - e^{-(R_2-i(\omega_1-\omega-\pi J_{10}-\pi J_{21}+\pi J_{31}))t} \\
& - e^{-(R_2-i(\omega_1-\omega+\pi J_{21}-\pi J_{31}+\pi J_{30}))t} - e^{-(R_2-i(\omega_1-\omega-\pi J_{10}+\pi J_{21}-\pi J_{32}))t} \\
& - e^{-(R_2-i(\omega_1-\omega+\pi J_{10}-\pi J_{21}-\pi J_{31}))t} - e^{-(R_2-i(\omega_1-\omega-\pi J_{10}-\pi J_{21}-\pi J_{31}))t} \\
& - e^{-(R_2-i(\omega_0-\omega+\pi J_{10}+\pi J_{20}+\pi J_{30}))t} - e^{-(R_2-i(\omega_0-\omega-\pi J_{10}+\pi J_{20}+\pi J_{30}))t} \\
& - e^{-(R_2-i(\omega_0-\omega+\pi J_{10}-\pi J_{20}+\pi J_{30}))t} - e^{-(R_2-i(\omega_0-\omega-\pi J_{10}-\pi J_{20}+\pi J_{30}))t} \\
& - e^{-(R_2-i(\omega_0-\omega+\pi J_{10}+\pi J_{20}-\pi J_{30}))t} - e^{-(R_2-i(\omega_0-\omega-\pi J_{10}+\pi J_{20}-\pi J_{30}))t} \\
& - e^{-(R_2-i(\omega_0-\omega+\pi J_{10}-\pi J_{20}-\pi J_{30}))t} - e^{-(R_2-i(\omega_0-\omega-\pi J_{10}-\pi J_{20}-\pi J_{30}))t}
\end{aligned}
\tag{237}
$$

Transformasi Fourirer dari sinyal FiD adalah sebagai berikut:

$$
\begin{aligned}
S(\omega) &= \int_{0}^{\infty} S(t)\, e^{-i\omega t}\, dt \\
&= \frac{e^{-(R_2 - i(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}))t}}{(R_2 - i(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}))} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}))t}}{(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}))} \\
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}))t}}{(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}))} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}))t}}{(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}))} \\
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}))t}}{(R_2 - i(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}))} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}))t}}{(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}))t}}{(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}))} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}))t}}{(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}))} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}))} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}))} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}))} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}))} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}))} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}))} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}))} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}))}
\end{aligned}
$$

$$
\begin{aligned}
&= \frac{-1}{(R_2 - i\,(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}))} - \frac{1}{(R_2 - i\,(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}))} \\
&- \frac{1}{(R_2 - i\,(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}))} - \frac{1}{(R_2 - i\,(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))} \\
&- \frac{1}{(R_2 - i\,(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))} - \frac{1}{(R_2 - i\,(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}))} \\
&- \frac{1}{(R_2 - i\,(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}))} - \frac{1}{(R_2 - i\,(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i\,(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}))} + \frac{1}{(R_2 - i\,(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i\,(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}))} + \frac{1}{(R_2 - i\,(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i\,(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}))} + \frac{1}{(R_2 - i\,(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i\,(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}))} + \frac{1}{(R_2 - i\,(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i\,(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}))} + \frac{1}{(R_2 - i\,(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}))} \\
&+ \frac{1}{(R_2 - i\,(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}))} + \frac{1}{(R_2 - i\,(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}))} \\
&+ \frac{1}{(R_2 - i\,(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}))} + \frac{1}{(R_2 - i\,(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i\,(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}))} + \frac{1}{(R_2 - i\,(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}))} \\
&+ \frac{1}{(R_2 - i\,(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}))} + \frac{1}{(R_2 - i\,(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}))} \\
&+ \frac{1}{(R_2 - i\,(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}))} + \frac{1}{(R_2 - i\,(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}))} \\
&+ \frac{1}{(R_2 - i\,(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}))} + \frac{1}{(R_2 - i\,(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}))} \\
&+ \frac{1}{(R_2 - i\,(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}))} + \frac{1}{(R_2 - i\,(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}))}
\end{aligned}
$$

$$
\begin{aligned}
&= \frac{R_2 + i\left(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}\right)^2} \\
&- \frac{R_2 + i\left(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}\right)^2} - \frac{R_2 + i\left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}\right)^2} \\
&- \frac{R_2 + i\left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}\right)^2} - \frac{R_2 + i\left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}\right)^2} \\
&- \frac{R_2 + i\left(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}\right)}{{R_2}^2 + \left(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}\right)^2} - \frac{R_2 + i\left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}\right)^2} \\
&- \frac{R_2 + i\left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}\right)^2} - \frac{R_2 + i\left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}\right)^2} \\
&- \frac{R_2 + i\left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}\right)^2} - \frac{R_2 + i\left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}\right)^2} \\
&- \frac{R_2 + i\left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}\right)^2} - \frac{R_2 + i\left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}\right)}{R_2 + \left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}\right)^2} \\
&- \frac{R_2 + i\left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}\right)^2} - \frac{R_2 + i\left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}\right)}{R_2 + \left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}\right)^2} \\
&- \frac{R_2 + i\left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}\right)^2} - \frac{R_2 + i\left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}\right)^2}
\end{aligned}
$$

maka dengan demikian diperoleh :

$$
\begin{aligned}
A\left(\omega\right) = & \frac{R_2}{{R_2}^2 + (\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 - (\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31})^2} - \frac{R_2}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31})^2} - \frac{R_2}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30})^2} - \frac{R_2}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31})^2} - \frac{R_2}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30})^2} - \frac{R_2}{{R_2}^2 + (\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30})^2} - \frac{R_2}{R_2 + (\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30})^2} - \frac{R_2}{R_2 + (\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30})^2} - \frac{R_2}{{R_2}^2 + (\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30})^2}
\end{aligned}
\tag{238}
$$

dan diperoleh juga:

$$
\begin{aligned}
D(\omega) = & \frac{i(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32})}{R_2{}^2 + (\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32})^2} + \frac{i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32})}{R_2{}^2 + (\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32})^2} \\
& + \frac{i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32})}{R_2{}^2 + (\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32})^2} + \frac{i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})}{R_2{}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})^2} \\
& + \frac{i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})}{R_2{}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})^2} + \frac{i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32})}{R_2{}^2 + (\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32})^2} \\
& + \frac{i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32})}{R_2{}^2 + (\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32})^2} + \frac{i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32})}{R_2{}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32})^2} \\
& + \frac{i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32})}{R_2{}^2 + (\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32})^2} + \frac{i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32})}{R_2{}^2 + (\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32})^2} \\
& + \frac{i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32})}{R_2{}^2 + (\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32})^2} + \frac{i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32})}{R_2{}^2 + (\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32})^2} \\
& + \frac{i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32})}{R_2{}^2 + (\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32})^2} + \frac{i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32})}{R_2{}^2 + (\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32})^2} \\
& + \frac{i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32})}{R_2{}^2 + (\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32})^2} + \frac{i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32})}{R_2{}^2 + (\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32})^2} \\
& - \frac{i(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31})}{R_2{}^2 + (\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31})^2} - \frac{i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31})}{R_2{}^2 + (\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31})^2} \\
& - \frac{i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31})}{R_2{}^2 + (\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31})^2} - \frac{i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31})}{R_2{}^2 + (\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31})^2} \\
& - \frac{i(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30})}{R_2{}^2 + (\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30})^2} - \frac{i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32})}{R_2{}^2 + (\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32})^2} \\
& - \frac{i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31})}{R_2{}^2 + (\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31})^2} - \frac{i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31})}{R_2{}^2 + (\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31})^2} \\
& - \frac{i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30})}{R_2{}^2 + (\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30})^2} - \frac{i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30})}{R_2{}^2 + (\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30})^2} \\
& - \frac{i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30})}{R_2{}^2 + (\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30})^2} - \frac{i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30})}{R_2 + (\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30})^2} \\
& - \frac{i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30})}{R_2{}^2 + (\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30})^2} - \frac{i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30})}{R_2 + (\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30})^2} \\
& - \frac{i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30})}{R_2{}^2 + (\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30})^2} - \frac{i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30})}{R_2{}^2 + (\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30})^2}
\end{aligned}
\tag{239}
$$

7.2 Penerapan Algoritma Deutsch jozsa 4 qubit untuk U2 = Us2

apabila diambil kasus untuk $U_2 = I \otimes \sigma_z \otimes \sigma_z \otimes \sigma_z$ maka diperoleh untuk bentuk operator uniter totalnya adalah sebagai berikut:

$$
\begin{aligned}
U &= U_5 U_2 U_1 \\
&= U_5 \left(\sigma_z \otimes I \otimes I \otimes I\right) U_1 \\
&= \begin{pmatrix}
e^{\beta_0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & e^{\beta_1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & e^{\beta_2} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & e^{\beta_3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & e^{\beta_4} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & e^{\beta_5} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_7} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_9} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_10} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_11} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_12} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_13} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_15}
\end{pmatrix}
\end{aligned}
$$

$$
\times \begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1
\end{pmatrix}
$$

$$
\times \frac{1}{4}
\begin{pmatrix}
1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & 1 & -1 & -1 & 1 \\
1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 \\
1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 \\
1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 \\
1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 \\
1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 \\
1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\
1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \\
1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\
1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\
1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\
1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\
1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\
1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1
\end{pmatrix}
$$

$$
= \frac{1}{4} \begin{pmatrix}
e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} \\
-e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} \\
-e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} \\
e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} \\
-e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} \\
e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} \\
e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} \\
-e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} \\
e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} \\
-e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} \\
-e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} \\
e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} \\
-e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} \\
e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} \\
e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} \\
-e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}}
\end{pmatrix} \tag{240}
$$

$$U^{\dagger} = \begin{pmatrix}
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}}
\end{pmatrix} \tag{241}$$

maka dengan demikian kita dapatkan untuk nilai ρ_5 adalah

$$
\begin{aligned}
\rho_5 &= U\rho_0 U^\dagger \\
&= \frac{1}{4}\begin{pmatrix}
e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} \\
-e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} \\
-e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} \\
e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} \\
-e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} \\
e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} \\
e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} \\
-e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} \\
e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} \\
-e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} \\
-e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} \\
e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} \\
-e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} \\
e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} \\
e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} \\
-e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}} & -e^{\beta_{15}}
\end{pmatrix}
\end{aligned}
$$

$$
\times \begin{pmatrix}
2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -2
\end{pmatrix}
$$

$$
\times \frac{1}{4}
\begin{pmatrix}
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & -e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & -e^{-\beta_{15}}
\end{pmatrix}
$$

$$
= \frac{1}{16} \left(\begin{array}{cccccccccccccccc}
0 & -8\rho_{0,1} & -8\rho_{0,2} & 0 & -8\rho_{0,4} & 0 & 0 & 0 & 8\rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-8\rho_{1,0} & 0 & 0 & -8\rho_{1,3} & 0 & -8\rho_{1,5} & 0 & 0 & 0 & 8\rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
-8\rho_{2,0} & 0 & 0 & -8\rho_{2,3} & 0 & 0 & -8\rho_{2,6} & 0 & 0 & 0 & 8\rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & -8\rho_{3,1} & -8\rho_{3,2} & 0 & 0 & 0 & 0 & -8\rho_{3,7} & 0 & 0 & 0 & 8\rho_{3,11} & 0 & 0 & 0 & 0 \\
-8\rho_{4,0} & 0 & 0 & 0 & 0 & -8\rho_{4,5} & -8\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & 8\rho_{4,12} & 0 & 0 & 0 \\
0 & -8\rho_{4,1} & 0 & 0 & -8\rho_{5,4} & 0 & 0 & -8\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & 8\rho_{5,13} & 0 & 0 \\
0 & 0 & -8\rho_{6,2} & 0 & -8\rho_{6,4} & 0 & 0 & -8\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & 8\rho_{6,14} & 0 \\
0 & 0 & 0 & -8\rho_{7,3} & 0 & -8\rho_{7,5} & -8\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 8\rho_{7,15} \\
8\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -8\rho_{8,9} & -8\rho_{8,10} & 0 & -8\rho_{8,12} & 0 & 0 & 0 \\
0 & 8\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -8\rho_{9,8} & 0 & 0 & -8\rho_{9,11} & 0 & -8\rho_{9,13} & 0 & 0 \\
0 & 0 & 8\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -8\rho_{10,8} & 0 & 0 & -8\rho_{10,11} & 0 & 0 & -8\rho_{10,14} & 0 \\
0 & 0 & 0 & 8\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -8\rho_{11,9} & -8\rho_{11,10} & 0 & 0 & 0 & 0 & -8\rho_{11,15} \\
0 & 0 & 0 & 0 & 8\rho_{12,4} & 0 & 0 & 0 & -8\rho_{12,8} & 0 & 0 & 0 & 0 & -8\rho_{12,13} & -8\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 8\rho_{13,5} & 0 & 0 & 0 & -8\rho_{13,9} & 0 & 0 & -8\rho_{13,12} & 0 & 0 & -8\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & 8\rho_{14,6} & 0 & 0 & 0 & -8\rho_{14,10} & 0 & -8\rho_{14,12} & 0 & 0 & -8\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 8\rho_{15,7} & 0 & 0 & 0 & -8\rho_{15,11} & 0 & -8\rho 15, 13 & -8\rho_{15,14} & 0
\end{array} \right) \quad (242)
$$

$$
= \frac{1}{2} \begin{pmatrix}
0 & -\rho_{0,1} & -\rho_{0,2} & 0 & -\rho_{0,4} & 0 & 0 & 0 & \rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{1,0} & 0 & 0 & -\rho_{1,3} & 0 & -\rho_{1,5} & 0 & 0 & 0 & \rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & -\rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & -\rho_{3,7} & 0 & 0 & 0 & \rho_{3,11} & 0 & 0 & 0 & 0 \\
-\rho_{4,0} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & -\rho_{4,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & -\rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{8,9} & -\rho_{8,10} & 0 & -\rho_{8,12} & 0 & 0 & 0 \\
0 & \rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & -\rho_{9,11} & 0 & -\rho_{9,13} & 0 & 0 \\
0 & 0 & \rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -\rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & -\rho_{10,14} & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & \rho_{12,4} & 0 & 0 & 0 & -\rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & -\rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho 15, 13 & -\rho_{15,14} & 0
\end{pmatrix} \tag{243}
$$

dengan

$$
\begin{array}{cc}
\rho_{0,1} = \rho_{1,0}{}^* = e^{\beta_0-\beta_1} & \rho_{6,7} = \rho_{7,6}{}^* = e^{\beta_6-\beta_7} \\
\rho_{0,2} = \rho_{2,0}{}^* = e^{\beta_0-\beta_2} & \rho_{6,14} = \rho_{14,6}{}^* = e^{\beta_6-\beta_14} \\
\rho_{0,8} = \rho_{8,0}{}^* = e^{\beta_8-\beta_1} & \rho_{8,9} = \rho_{9,8}{}^* = e^{\beta_8-\beta_9} \\
\rho_{1,3} = \rho_{3,1}{}^* = e^{\beta_1-\beta_3} & \rho_{8,10} = \rho_{10,8}{}^* = e^{\beta_8-\beta_{10}} \\
\rho_{1,5} = \rho_{5,1}{}^* = e^{\beta_1-\beta_5} & \rho_{8,12} = \rho_{12,8}{}^* = e^{\beta_8-\beta_{12}} \\
\rho_{1,9} = \rho_{9,1}{}^* = e^{\beta_1-\beta_9} & \rho_{9,11} = \rho_{11,9}{}^* = e^{\beta_9-\beta_{11}} \\
\rho_{2,3} = \rho_{3,2}{}^* = e^{\beta_2-\beta_3} & \rho_{9,13} = \rho_{13,9}{}^* = e^{\beta_9-\beta_{13}} \\
\rho_{2,6} = \rho_{6,2}{}^* = e^{\beta_2-\beta_6} & \rho_{10,11} = \rho_{11,10}{}^* = e^{\beta_{10}-\beta_{11}} \\
\rho_{2,10} = \rho_{10,2}{}^* = e^{\beta_2-\beta_10} & \rho_{10,14} = \rho_{14,10}{}^* = e^{\beta_{10}-\beta_{14}} \\
\rho_{3,7} = \rho_{7,3}{}^* = e^{\beta_3-\beta_7} & \rho_{12,13} = \rho_{13,12}{}^* = e^{\beta_{12}-\beta_{13}} \\
\rho_{3,11} = \rho_{11,3}{}^* = e^{\beta_3-\beta_11} & \rho_{12,14} = \rho_{14,12}{}^* = e^{\beta_{12}-\beta_{14}} \\
\rho_{4,5} = \rho_{5,4}{}^* = e^{\beta_4-\beta_5} & \rho_{11,15} = \rho_{15,11}{}^* = e^{\beta_{11}-\beta_{15}} \\
\rho_{4,6} = \rho_{6,4}{}^* = e^{\beta_4-\beta_6} & \rho_{13,15} = \rho_{15,13}{}^* = e^{\beta_{13}-\beta_{15}} \\
\rho_{4,12} = \rho_{12,4}{}^* = e^{\beta_4-\beta_12} & \rho_{14,15} = \rho_{14,15}{}^* = e^{\beta_{14}-\beta_{15}} \\
\rho_{5,7} = \rho_{7,5}{}^* = e^{\beta_5-\beta_7} & \rho_{15,7} = \rho_{7,15}{}^* = e^{\beta_7-\beta_{15}} \\
\rho_{5,13} = \rho_{13,5}{}^* = e^{\beta_5-\beta_13} & \rho_{0,4} = \rho_{4,0}{}^* = e^{\beta_0-\beta_4}
\end{array}
\tag{244}
$$

dan

$$\begin{array}{rr}
\beta_0 - \beta_1 = -i\left(E_{4,0} - E_{4,1}\right)t & \beta_0 - \beta_2 = -i\left(E_{4,0} - E_{4,2}\right)t \\
\beta_0 - \beta_4 = -i\left(E_{4,0} - E_{4,4}\right)t & \beta_0 - \beta_8 = -i\left(E_{4,0} - E_{4,8}\right)t \\
\beta_1 - \beta_3 = -i\left(E_{4,1} - E_{4,3}\right)t & \beta_1 - \beta_5 = -i\left(E_{4,1} - E_{4,5}\right)t \\
\beta_1 - \beta_9 = -i\left(E_{4,1} - E_{4,9}\right)t & \beta_2 - \beta_3 = -i\left(E_{4,2} - E_{4,3}\right)t \\
\beta_2 - \beta_6 = -i\left(E_{4,2} - E_{4,6}\right)t & \beta_2 - \beta_{10} = -i\left(E_{4,2} - E_{4,10}\right)t \\
\beta_3 - \beta_7 = -i\left(E_{4,3} - E_{4,7}\right)t & \beta_3 - \beta_{11} = -i\left(E_{4,3} - E_{4,11}\right)t \\
\beta_4 - \beta_5 = -i\left(E_{4,4} - E_{4,5}\right)t & \beta_4 - \beta_6 = -i\left(E_{4,4} - E_{4,6}\right)t \\
\beta_4 - \beta_{12} = -i\left(E_{4,4} - E_{4,12}\right)t & \beta_5 - \beta_7 = -i\left(E_{4,5} - E_{4,7}\right)t \\
\beta_5 - \beta_{13} = -i\left(E_{4,5} - E_{4,13}\right)t & \beta_6 - \beta_7 = -i\left(E_{4,6} - E_{4,7}\right)t \\
\beta_6 - \beta_{14} = -i\left(E_{4,6} - E_{4,14}\right)t & \beta_8 - \beta_9 = -i\left(E_{4,8} - E_{4,9}\right)t \\
\beta_8 - \beta_{10} = -i\left(E_{4,8} - E_{4,10}\right)t & \beta_8 - \beta_{12} = -i\left(E_{4,8} - E_{4,12}\right)t \\
\beta_9 - \beta_{11} = -i\left(E_{4,9} - E_{4,11}\right)t & \beta_9 - \beta_{13} = -i\left(E_{4,9} - E_{4,13}\right)t \\
\beta_{10} - \beta_{11} = -i\left(E_{4,10} - E_{4,11}\right)t & \beta_{10} - \beta_{14} = -i\left(E_{4,10} - E_{4,14}\right)t \\
\beta_{12} - \beta_{13} = -i\left(E_{4,12} - E_{4,13}\right)t & \beta_{12} - \beta_{14} = -i\left(E_{4,12} - E_{4,14}\right)t \\
\beta_{11} - \beta_{15} = -i\left(E_{4,11} - E_{4,15}\right)t & \beta_{13} - \beta_{15} = -i\left(E_{4,13} - E_{4,15}\right)t \\
\beta_{14} - \beta_{15} = -i\left(E_{4,14} - E_{4,15}\right)t & \beta_{15} - \beta_7 = -i\left(E_{4,15} - E_{4,7}\right)t
\end{array} \tag{245}$$

dan

$$\begin{aligned}
E_{4,0} - E4,1 &= \omega_0 + \pi J_{10} + \pi J_{20} + \pi J_{30} & E_{4,0} - E4,2 &= \omega_1 + \pi J_{10} + \pi J_{21} + \pi J_{31} \\
E_{4,0} - E4,4 &= \omega_2 + \pi J_{20} + \pi J_{21} + \pi J_{32} & E_{4,0} - E4,8 &= \omega_3 + \pi J_{30} + \pi J_{31} + \pi J_{32} \\
E_{4,1} - E4,3 &= \omega_1 - \pi J_{10} + \pi J_{21} + \pi J_{31} & E_{4,1} - E4,5 &= \omega_2 - \pi J_{20} + \pi J_{21} + \pi J_{32} \\
E_{4,1} - E4,9 &= \omega_3 - \pi J_{30} + \pi J_{310} + \pi J_{32} & E_{4,2} - E4,3 &= \omega_0 - \pi J_{10} + \pi J_{20} + \pi J_{30} \\
E_{4,2} - E4,6 &= \omega_2 + \pi J_{20} - \pi J_{21} + \pi J_{32} & E_{4,2} - E4,10 &= \omega_3 + \pi J_{30} - \pi J_{31} + \pi J_{32} \\
E_{4,3} - E4,7 &= \omega_2 - \pi J_{20} - \pi J_{21} + \pi J_{32} & E_{4,3} - E4,11 &= \omega_3 - \pi J_{30} - \pi J_{31} + \pi J_{32} \\
E_{4,4} - E4,5 &= \omega_0 + \pi J_{10} - \pi J_{20} + \pi J_{30} & E_{4,4} - E4,6 &= \omega_1 + \pi J_{10} - \pi J_{21} + \pi J_{31} \\
E_{4,4} - E4,12 &= \omega_3 + \pi J_{30} + \pi J_{31} - \pi J_{32} & E_{4,5} - E4,7 &= \omega_1 - \pi J_{10} - \pi J_{21} + \pi J_{31} \\
E_{4,5} - E4,13 &= \omega_3 - \pi J_{30} + \pi J_{31} - \pi J_{32} & E_{4,6} - E4,7 &= \omega_0 - \pi J_{10} - \pi J_{20} + \pi J_{30} \\
E_{4,6} - E4,14 &= \omega_3 + \pi J_{30} - \pi J_{31} - \pi J_{32} & E_{4,8} - E4,9 &= \omega_0 + \pi J_{10} + \pi J_{20} - \pi J_{30} \\
E_{4,8} - E4,10 &= \omega_1 + \pi J_{21} - \pi J_{31} + \pi J_{30} & E_{4,8} - E4,12 &= \omega_2 + \pi J_{20} + \pi J_{21} - \pi J_{32} \\
E_{4,9} - E4,11 &= \omega_1 - \pi J_{10} + \pi J_{21} - \pi J_{32} & E_{4,10} - E4,11 &= \omega_0 - \pi J_{10} + \pi J_{20} - \pi J_{30} \\
E_{4,10} - E4,14 &= \omega_2 + \pi J_{20} - \pi J_{21} - \pi J_{32} & E_{4,12} - E4,13 &= \omega_0 + \pi J_{10} - \pi J_{20} - \pi J_{30} \\
E_{4,12} - E4,14 &= \omega_1 + \pi J_{10} - \pi J_{21} - \pi J_{31} & E_{4,11} - E4,15 &= \omega_2 - \pi J_{20} - \pi J_{21} - \pi J_{32} \\
E_{4,13} - E4,15 &= \omega_1 - \pi J_{10} - \pi J_{21} - \pi J_{31} & E_{4,14} - E4,15 &= \omega_0 - \pi J_{10} - \pi J_{20} - \pi J_{30} \\
E_{4,9} - E4,13 &= \omega_2 - \pi J_{20} + \pi J_{21} - \pi J_{32} & E_{4,15} - E4,7 &= \omega_3 + \pi J_{30} + \pi J_{31} + \pi J_{32}
\end{aligned} \tag{246}$$

maka dapat ditentukan nilai magnetisasi dari masing-masing qubitnya yaitu sebagai berikut:

$$(I_{3+}\rho_5) = \begin{pmatrix}
0&0&0&0&0&0&0&1&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&1&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&1&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&1&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&1&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&1&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&1&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&1&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&1\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0
\end{pmatrix}$$

$$
\times \frac{1}{2}
\begin{pmatrix}
0 & -\rho_{0,1} & -\rho_{0,2} & 0 & -\rho_{0,4} & 0 & 0 & 0 & \rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{1,0} & 0 & 0 & -\rho_{1,3} & 0 & -\rho_{1,5} & 0 & 0 & 0 & \rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & -\rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & -\rho_{3,7} & 0 & 0 & 0 & \rho_{3,11} & 0 & 0 & 0 & 0 \\
-\rho_{4,0} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & -\rho_{4,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & -\rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{8,9} & -\rho_{8,10} & 0 & -\rho_{8,12} & 0 & 0 & 0 \\
0 & \rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & -\rho_{9,11} & 0 & -\rho_{9,13} & 0 & 0 \\
0 & 0 & \rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -\rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & -\rho_{10,14} & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & \rho_{12,4} & 0 & 0 & 0 & -\rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & -\rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho 15, 13 & -\rho_{15,14} & 0
\end{pmatrix}
$$

$$
= \frac{1}{2} \begin{pmatrix}
\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{8,9} & -\rho_{8,10} & 0 & -\rho_{8,12} & 0 & 0 & 0 \\
0 & \rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & -\rho_{9,11} & 0 & -\rho_{9,13} & 0 & 0 \\
0 & 0 & \rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -\rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & -\rho_{10,14} & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & \rho_{12,4} & 0 & 0 & 0 & -\rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & -\rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & 0 & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho_{15,13} & -\rho_{15,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$
\begin{aligned}
M_{3+} &= \langle I_{3+} \rangle = tr\left(I_{3+}\rho_5\right) \\
&= \rho_{8,0} + \rho_{9,1} + \rho_{10,2} + \rho_{11,3} + \rho_{12,4} + \rho_{13,5} + \rho_{14,6} + \rho_{15,7}
\end{aligned}
\tag{247}
$$

dan

$$
(I_{2+}\rho_5) = \begin{pmatrix}
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$
\times \frac{1}{2}
\begin{pmatrix}
0 & -\rho_{0,1} & -\rho_{0,2} & 0 & -\rho_{0,4} & 0 & 0 & 0 & \rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{1,0} & 0 & 0 & -\rho_{1,3} & 0 & -\rho_{1,5} & 0 & 0 & 0 & \rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & -\rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & -\rho_{3,7} & 0 & 0 & 0 & \rho_{3,11} & 0 & 0 & 0 & 0 \\
-\rho_{4,0} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & -\rho_{4,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & -\rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{8,9} & -\rho_{8,10} & 0 & -\rho_{8,12} & 0 & 0 & 0 \\
0 & \rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & -\rho_{9,11} & 0 & -\rho_{9,13} & 0 & 0 \\
0 & 0 & \rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -\rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & -\rho_{10,14} & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & \rho_{12,4} & 0 & 0 & 0 & -\rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & -\rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & {} & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho 15, 13 & -\rho_{15,14} & 0
\end{pmatrix}
$$

$$
= \frac{1}{2} \begin{pmatrix}
-\rho_{4,0} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & -\rho_{5,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & -\rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & \rho_{12,4} & 0 & 0 & 0 & -\rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & -\rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho 15,13 & -\rho_{15,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix} \tag{248}
$$

$$
\begin{aligned}
M_{2+} &= \langle I_{2+} \rangle = tr\left(I_{2+}\rho_5\right) \\
&= -\left(\rho_{4,0} + \rho_{5,1} + \rho_{6,2} + \rho_{7,3} + \rho_{12,8} + \rho_{13,9} + \rho_{14,10} + \rho_{15,11}\right)
\end{aligned}
\tag{249}
$$

dan

$$
(I_{1+}\rho_5) = \begin{pmatrix}
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$\times\ \frac{1}{2}\begin{pmatrix}
0 & -\rho_{0,1} & -\rho_{0,2} & 0 & -\rho_{0,4} & 0 & 0 & 0 & \rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{1,0} & 0 & 0 & -\rho_{1,3} & 0 & -\rho_{1,5} & 0 & 0 & 0 & \rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & -\rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & -\rho_{3,7} & 0 & 0 & 0 & \rho_{3,11} & 0 & 0 & 0 & 0 \\
-\rho_{4,0} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & -\rho_{4,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & -\rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{8,9} & -\rho_{8,10} & 0 & -\rho_{8,12} & 0 & 0 & 0 \\
0 & \rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & -\rho_{9,11} & 0 & -\rho_{9,13} & 0 & 0 \\
0 & 0 & \rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -\rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & -\rho_{10,14} & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & \rho_{12,4} & 0 & 0 & 0 & -\rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & -\rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho 15,13 & -\rho_{15,14} & 0
\end{pmatrix}$$

$$
= \frac{1}{2} \begin{pmatrix}
-\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & -\rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & -\rho_{3,7} & 0 & 0 & 0 & \rho_{3,11} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & -\rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & \rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -\rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & -\rho_{10,14} & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho_{15,13} & -\rho_{15,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix} \tag{250}
$$

$$
\begin{aligned}
M_{1+} &= \langle I_{1+} \rangle = tr\left(I_{1+}\rho_5\right) \\
&= -\left(\rho_{2,0} + \rho_{3,1} + \rho_{6,4} + \rho_{7,5} + \rho_{10,8} + \rho_{11,9} + \rho_{14,12} + \rho_{15,13}\right)
\end{aligned} \tag{251}
$$

dan

$$
(I_{0+}\rho_5) = \begin{pmatrix}
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$\times \frac{1}{2} \begin{pmatrix}
0 & -\rho_{0,1} & -\rho_{0,2} & 0 & -\rho_{0,4} & 0 & 0 & 0 & \rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{1,0} & 0 & 0 & -\rho_{1,3} & 0 & -\rho_{1,5} & 0 & 0 & 0 & \rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & -\rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & -\rho_{3,7} & 0 & 0 & 0 & \rho_{3,11} & 0 & 0 & 0 & 0 \\
-\rho_{4,0} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & -\rho_{4,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & -\rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{8,9} & -\rho_{8,10} & 0 & -\rho_{8,12} & 0 & 0 & 0 \\
0 & \rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & -\rho_{9,11} & 0 & -\rho_{9,13} & 0 & 0 \\
0 & 0 & \rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -\rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & -\rho_{10,14} & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & \rho_{12,4} & 0 & 0 & 0 & -\rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & -\rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho 15, 13 & -\rho_{15,14} & 0
\end{pmatrix}$$

$$
= \frac{1}{2} \begin{pmatrix}
-\rho_{1,0} & 0 & 0 & -\rho_{1,3} & 0 & -\rho_{1,5} & 0 & 0 & 0 & \rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & -\rho_{3,7} & 0 & 0 & \rho_{3,11} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{5,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & -\rho_{9,11} & 0 & -\rho_{9,13} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & -\rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho 15, 13 & -\rho_{15,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix} \tag{252}
$$

$$
\begin{aligned}
M_{0+} &= \langle I_{0+} \rangle = tr\left(I_{0+}\rho_5\right) \\
&= -\left(\rho_{1,0} + \rho_{3,2} + \rho_{5,2} + \rho_{7,6} + \rho_{9,8} + \rho_{11,10} + \rho_{13,12} + \rho_{15,14}\right)
\end{aligned} \tag{253}
$$

maka dengan demikian nilai magnetisasi total dari sistem adalah sebagai berikut:

$$
\begin{aligned}
M_{tot} &= M_{3+} + M_{2+} + M_{1+} + M_{0+} \\
&= \rho_{8,0} + \rho_{9,1} + \rho_{10,2} + \rho_{11,3} + \rho_{12,4} + \rho_{13,5} + \rho_{14,6} + \rho_{15,7} \\
&- \rho_{4,0} - \rho_{5,1} - \rho_{6,2} - \rho_{7,3} - \rho_{12,8} - \rho_{13,9} - \rho_{14,10} - \rho_{15,11} \\
&- \left(\rho_{2,0} + \rho_{3,1} + \rho_{6,4} + \rho_{7,5} + \rho_{10,8} + \rho_{11,9} + \rho_{14,12} + \rho_{15,13}\right) \\
&- \left(\rho_{1,0} + \rho_{3,2} + \rho_{5,4} + \rho_{7,6} + \rho_{9,8} + \rho_{11,10} + \rho_{13,12} + \rho_{15,14}\right) \\
&= e^{i(\omega_3+\pi J_{30}+\pi J_{31}+\pi J_{32})t} + e^{i(\omega_3-\pi J_{30}+\pi J_{31}+\pi J_{32})t} \\
&+ e^{i(\omega_3+\pi J_{30}-\pi J_{31}+\pi J_{32})t} + e^{i(\omega_3-\pi J_{30}-\pi J_{31}+\pi J_{32})t} \\
&+ e^{i(\omega_3+\pi J_{30}+\pi J_{31}-\pi J_{32})t} + e^{i(\omega_3-\pi J_{30}+\pi J_{31}-\pi J_{32})t} \\
&+ e^{i(\omega_3+\pi J_{30}-\pi J_{31}-\pi J_{32})t} + e^{i(\omega_3-\pi J_{30}-\pi J_{31}-\pi J_{32})t} \\
&- e^{i(\omega_2+\pi J_{20}+\pi J_{21}+\pi J_{32})t} - e^{i(\omega_2-\pi J_{20}+\pi J_{21}+\pi J_{32})t} \\
&- e^{i(\omega_2+\pi J_{20}-\pi J_{21}+\pi J_{32})t} - e^{i(\omega_2-\pi J_{20}-\pi J_{21}+\pi J_{32})t} \\
&- e^{i(\omega_2+\pi J_{20}+\pi J_{21}-\pi J_{32})t} - e^{i(\omega_2-\pi J_{20}+\pi J_{21}-\pi J_{32})t} \\
&- e^{i(\omega_2+\pi J_{20}-\pi J_{21}-\pi J_{32})t} - e^{i(\omega_2-\pi J_{20}-\pi J_{21}-\pi J_{32})t} \\
&- e^{i(\omega_1+\pi J_{10}+\pi J_{21}+\pi J_{31})t} - e^{i(\omega_1-\pi J_{10}+\pi J_{21}+\pi J_{31})t} \\
&- e^{i(\omega_1+\pi J_{10}-\pi J_{21}+\pi J_{31})t} - e^{i(\omega_1-\pi J_{10}-\pi J_{21}+\pi J_{31})t} \\
&- e^{i(\omega_1+\pi J_{21}-\pi J_{31}+\pi J_{30})t} - e^{i(\omega_1-\pi J_{10}+\pi J_{21}-\pi J_{32})t} \\
&- e^{i(\omega_1+\pi J_{10}-\pi J_{21}-\pi J_{31})t} - e^{i(\omega_1-\pi J_{10}-\pi J_{21}-\pi J_{31})t} \\
&- e^{i(\omega_0+\pi J_{10}+\pi J_{20}+\pi J_{30})t} - e^{i(\omega_0-\pi J_{10}+\pi J_{20}+\pi J_{30})t} \\
&- e^{i(\omega_0+\pi J_{10}-\pi J_{20}+\pi J_{30})t} - e^{i(\omega_0-\pi J_{10}-\pi J_{20}+\pi J_{30})t} \\
&- e^{i(\omega_0+\pi J_{10}+\pi J_{20}-\pi J_{30})t} - e^{i(\omega_0-\pi J_{10}+\pi J_{20}-\pi J_{30})t} \\
&- e^{i(\omega_0+\pi J_{10}-\pi J_{20}-\pi J_{30})t} - e^{i(\omega_0-\pi J_{10}-\pi J_{20}-\pi J_{30})t}
\end{aligned} \tag{254}
$$

kemudian didapatkan juga untuk sinyal FID sebagai berikut:

$$
\begin{aligned}
S &= M_{tot} e^{-R_2 t} \\
&= e^{-(R_2-i(\omega_3+\pi J_{30}+\pi J_{31}+\pi J_{32}))t} + e^{-(R_2-i(\omega_3-\pi J_{30}+\pi J_{31}+\pi J_{32}))t} \\
&+ e^{-(R_2-i(\omega_3+\pi J_{30}-\pi J_{31}+\pi J_{32}))t} + e^{-(R_2-i(\omega_3-\pi J_{30}-\pi J_{31}+\pi J_{32}))t} \\
&+ e^{-(R_2-i(\omega_3+\pi J_{30}+\pi J_{31}-\pi J_{32}))t} + e^{-(R_2-i(\omega_3-\pi J_{30}+\pi J_{31}-\pi J_{32}))t} + e^{-(R_2-i(\omega_3+\pi J_{30}-\pi J_{31}-\pi} \\
&+ e^{-(R_2-i(\omega_3-\pi J_{30}-\pi J_{31}-\pi J_{32}))t} - e^{-(R_2-i(\omega_2+\pi J_{20}+\pi J_{21}+\pi J_{32}))t} \\
&- e^{-(R_2-i(\omega_2-\pi J_{20}+\pi J_{21}+\pi J_{32}))t} - e^{-(R_2-i(\omega_2+\pi J_{20}-\pi J_{21}+\pi J_{32}))t} \\
&- e^{-(R_2-i(\omega_2-\pi J_{20}-\pi J_{21}+\pi J_{32}))t} - e^{-(R_2-i(\omega_2+\pi J_{20}+\pi J_{21}-\pi J_{32}))t} \\
&- e^{-(R_2-i(\omega_2-\pi J_{20}+\pi J_{21}-\pi J_{32}))t} - e^{-(R_2-i(\omega_2+\pi J_{20}-\pi J_{21}-\pi J_{32}))t} \\
&- e^{-(R_2-i(\omega_2-\pi J_{20}-\pi J_{21}-\pi J_{32}))t} - e^{-(R_2-i(\omega_1+\pi J_{10}+\pi J_{21}+\pi J_{31}))t} \\
&- e^{-(R_2-i(\omega_1-\pi J_{10}+\pi J_{21}+\pi J_{31}))t} - e^{-(R_2-i(\omega_1+\pi J_{10}-\pi J_{21}+\pi J_{31}))t} \\
&- e^{-(R_2-i(\omega_1-\pi J_{10}-\pi J_{21}+\pi J_{31}))t} - e^{-(R_2-i(\omega_1+\pi J_{21}-\pi J_{31}+\pi J_{30}))t} \\
&- e^{-(R_2-i(\omega_1-\pi J_{10}+\pi J_{21}-\pi J_{32}))t} - e^{-(R_2-i(\omega_1+\pi J_{10}-\pi J_{21}-\pi J_{31}))t} \\
&- e^{-(R_2-i(\omega_1-\pi J_{10}-\pi J_{21}-\pi J_{31}))t} - e^{-(R_2-i(\omega_0+\pi J_{10}+\pi J_{20}+\pi J_{30}))t} \\
&- e^{-(R_2-i(\omega_0-\pi J_{10}+\pi J_{20}+\pi J_{30}))t} - e^{-(R_2-i(\omega_0+\pi J_{10}-\pi J_{20}+\pi J_{30}))t} \\
&- e^{-(R_2-i(\omega_0-\pi J_{10}-\pi J_{20}+\pi J_{30}))t} - e^{-(R_2-i(\omega_0+\pi J_{10}+\pi J_{20}-\pi J_{30}))t} \\
&- e^{-(R_2-i(\omega_0-\pi J_{10}+\pi J_{20}-\pi J_{30}))t} - e^{-(R_2-i(\omega_0+\pi J_{10}-\pi J_{20}-\pi J_{30}))t} - e^{-(R_2-i(\omega_0-\pi J_{10}-\pi J_{20}-\pi}
\end{aligned}
$$

dimana $R_2 = \frac{1}{T_2}$

kemudian dapat di cari terlebih dahulu untuk perkalian antara $S\left(t\right)e^{-i\omega t}$ yaitu sebagi berikut:

$$\begin{aligned}
S\left(t\right)e^{-i\omega t} &= e^{-(R_2-i(\omega_3-\omega+\pi J_{30}+\pi J_{31}+\pi J_{32}))t}+e^{-(R_2-i(\omega_3-\omega-\pi J_{30}+\pi J_{31}+\pi J_{32}))t}\\
&+e^{-(R_2-i(\omega_3-\omega+\pi J_{30}-\pi J_{31}+\pi J_{32}))t}+e^{-(R_2-i(\omega_3-\omega-\pi J_{30}-\pi J_{31}+\pi J_{32}))t}\\
&+e^{-(R_2-i(\omega_3-\omega+\pi J_{30}+\pi J_{31}-\pi J_{32}))t}+e^{-(R_2-i(\omega_3-\omega-\pi J_{30}+\pi J_{31}-\pi J_{32}))t}\\
&+e^{-(R_2-i(\omega_3-\omega+\pi J_{30}-\pi J_{31}-\pi J_{32}))t}+e^{-(R_2-i(\omega_3-\omega-\pi J_{30}-\pi J_{31}-\pi J_{32}))t}\\
&-e^{-(R_2-i(\omega_2-\omega+\pi J_{20}+\pi J_{21}+\pi J_{32}))t}-e^{-(R_2-i(\omega_2-\omega-\pi J_{20}+\pi J_{21}+\pi J_{32}))t}\\
&-e^{-(R_2-i(\omega_2-\omega+\pi J_{20}-\pi J_{21}+\pi J_{32}))t}-e^{-(R_2-i(\omega_2-\omega-\pi J_{20}-\pi J_{21}+\pi J_{32}))t}\\
&-e^{-(R_2-i(\omega_2-\omega+\pi J_{20}+\pi J_{21}-\pi J_{32}))t}-e^{-(R_2-i(\omega_2-\omega-\pi J_{20}+\pi J_{21}-\pi J_{32}))t}\\
&-e^{-(R_2-i(\omega_2-\omega+\pi J_{20}-\pi J_{21}-\pi J_{32}))t}-e^{-(R_2-i(\omega_2-\omega-\pi J_{20}-\pi J_{21}-\pi J_{32}))t}\\
&-e^{-(R_2-i(\omega_1-\omega+\pi J_{10}+\pi J_{21}+\pi J_{31}))t}-e^{-(R_2-i(\omega_1-\omega-\pi J_{10}+\pi J_{21}+\pi J_{31}))t}\\
&-e^{-(R_2-i(\omega_1-\omega+\pi J_{10}-\pi J_{21}+\pi J_{31}))t}-e^{-(R_2-i(\omega_1-\omega-\pi J_{10}-\pi J_{21}+\pi J_{31}))t}\\
&-e^{-(R_2-i(\omega_1-\omega+\pi J_{21}-\pi J_{31}+\pi J_{30}))t}-e^{-(R_2-i(\omega_1-\omega-\pi J_{10}+\pi J_{21}-\pi J_{32}))t}\\
&-e^{-(R_2-i(\omega_1-\omega+\pi J_{10}-\pi J_{21}-\pi J_{31}))t}-e^{-(R_2-i(\omega_1-\omega-\pi J_{10}-\pi J_{21}-\pi J_{31}))t}\\
&-e^{-(R_2-i(\omega_0-\omega+\pi J_{10}+\pi J_{20}+\pi J_{30}))t}-e^{-(R_2-i(\omega_0-\omega-\pi J_{10}+\pi J_{20}+\pi J_{30}))t}\\
&-e^{-(R_2-i(\omega_0-\omega+\pi J_{10}-\pi J_{20}+\pi J_{30}))t}-e^{-(R_2-i(\omega_0-\omega-\pi J_{10}-\pi J_{20}+\pi J_{30}))t}\\
&-e^{-(R_2-i(\omega_0-\omega+\pi J_{10}+\pi J_{20}-\pi J_{30}))t}-e^{-(R_2-i(\omega_0-\omega-\pi J_{10}+\pi J_{20}-\pi J_{30}))t}\\
&-e^{-(R_2-i(\omega_0-\omega+\pi J_{10}-\pi J_{20}-\pi J_{30}))t}-e^{-(R_2-i(\omega_0-\omega-\pi J_{10}-\pi J_{20}-\pi J_{30}))t}
\end{aligned} \tag{256}$$

Transformasi Fourirer dari sinyal FiD adalah sebagai berikut:

$$
\begin{aligned}
S(\omega) &= \int_0^\infty S(t)\, e^{-i\omega t}\, dt \\
&= \frac{e^{-(R_2 - i(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}))t}}{-\left(R_2 - i\left(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}\right)\right)} + \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}))t}}{-\left(R_2 - i\left(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}\right)\right)} \\
&+ \frac{e^{-(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}))t}}{-\left(R_2 - i\left(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}\right)\right)} + \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))t}}{-\left(R_2 - i\left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}\right)\right)} \\
&+ \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))t}}{-\left(R_2 - i\left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}\right)\right)} + \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}))t}}{-\left(R_2 - i\left(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}\right)\right)} \\
&+ \frac{e^{-(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}))t}}{-\left(R_2 - i\left(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}\right)\right)} + \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}))t}}{-\left(R_2 - i\left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}\right)\right)} \\
&+ \frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}))t}}{\left(R_2 - i\left(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}\right)\right)} + \frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}))t}}{\left(R_2 - i\left(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}\right)\right)} \\
&+ \frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}))t}}{\left(R_2 - i\left(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}\right)\right)} + \frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}))t}}{\left(R_2 - i\left(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}\right)\right)} \\
&+ \frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}))t}}{\left(R_2 - i\left(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}\right)\right)} + \frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}))t}}{\left(R_2 - i\left(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}\right)\right)} \\
&+ \frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}))t}}{\left(R_2 - i\left(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}\right)\right)} + \frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}))t}}{\left(R_2 - i\left(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}\right)\right)} \\
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}))t}}{\left(R_2 - i\left(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}\right)\right)} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}))t}}{\left(R_2 - i\left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}\right)\right)} \\
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}))t}}{\left(R_2 - i\left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}\right)\right)} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}))t}}{\left(R_2 - i\left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}\right)\right)} \\
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}))t}}{\left(R_2 - i\left(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}\right)\right)} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}))t}}{\left(R_2 - i\left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}\right)\right)} \\
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}))t}}{\left(R_2 - i\left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}\right)\right)} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}))t}}{\left(R_2 - i\left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}\right)\right)} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}))t}}{\left(R_2 - i\left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}\right)\right)} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}))t}}{\left(R_2 - i\left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}\right)\right)} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}))t}}{\left(R_2 - i\left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}\right)\right)} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}))t}}{\left(R_2 - i\left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}\right)\right)} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}))t}}{\left(R_2 - i\left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}\right)\right)} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}))t}}{\left(R_2 - i\left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}\right)\right)} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}))t}}{\left(R_2 - i\left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}\right)\right)} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}))t}}{\left(R_2 - i\left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}\right)\right)}
\end{aligned}
$$

$$
\begin{aligned}
&= \frac{1}{(R_2 - i\,(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}))} + \frac{1}{(R_2 - i\,(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i\,(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}))} + \frac{1}{(R_2 - i\,(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i\,(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))} + \frac{1}{(R_2 - i\,(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i\,(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}))} + \frac{1}{(R_2 - i\,(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}))} \\
&- \frac{1}{(R_2 - i\,(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}))} - \frac{1}{(R_2 - i\,(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}))} \\
&- \frac{1}{(R_2 - i\,(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}))} - \frac{1}{(R_2 - i\,(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}))} \\
&- \frac{1}{(R_2 - i\,(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}))} - \frac{1}{(R_2 - i\,(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}))} \\
&- \frac{1}{(R_2 - i\,(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}))} - \frac{1}{(R_2 - i\,(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}))} \\
&- \frac{1}{(R_2 - i\,(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}))} - \frac{1}{(R_2 - i\,(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}))} \\
&- \frac{1}{(R_2 - i\,(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}))} - \frac{1}{(R_2 - i\,(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}))} \\
&- \frac{1}{(R_2 - i\,(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}))} - \frac{1}{(R_2 - i\,(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i\,(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}))} + \frac{1}{(R_2 - i\,(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}))} \\
&- \frac{1}{(R_2 - i\,(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}))} - \frac{1}{(R_2 - i\,(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}))} \\
&+ \frac{1}{(R_2 - i\,(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}))} + \frac{1}{(R_2 - i\,(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}))} \\
&- \frac{1}{(R_2 - i\,(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}))} - \frac{1}{(R_2 - i\,(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}))} \\
&- \frac{1}{(R_2 - i\,(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}))} - \frac{1}{(R_2 - i\,(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}))}
\end{aligned}
$$

$$= \frac{R_2 + i\,(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32})^2} + \frac{R_2 + i\,(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32})^2}$$

$$+ \frac{R_2 + i\,(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32})^2} + \frac{R_2 + i\,(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})^2}$$

$$+ \frac{R_2 + i\,(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})^2} + \frac{R_2 + i\,(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32})^2}$$

$$+ \frac{R_2 + i\,(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32})^2} + \frac{R_2 + i\,(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32})^2}$$

$$- \frac{R_2 + i\,(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32})^2} - \frac{R_2 + i\,(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32})^2}$$

$$- \frac{R_2 + i\,(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32})^2} - \frac{R_2 + i\,(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32})^2}$$

$$- \frac{R_2 + i\,(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32})^2} - \frac{R_2 + i\,(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32})^2}$$

$$- \frac{R_2 + i\,(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32})^2} - \frac{R_2 + i\,(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32})^2}$$

$$- \frac{R_2 + i\,(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31})^2} - \frac{R_2 + i\,(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31})^2}$$

$$- \frac{R_2 + i\,(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31})^2} - \frac{R_2 + i\,(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31})^2}$$

$$- \frac{R_2 + i\,(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30})}{{R_2}^2 + (\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30})^2} - \frac{R_2 + i\,(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32})}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32})^2}$$

$$- \frac{R_2 + i\,(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31})^2} - \frac{R_2 + i\,(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31})^2}$$

$$- \frac{R_2 + i\,(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30})^2} - \frac{R_2 + i\,(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30})^2}$$

$$- \frac{R_2 + i\,(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30})^2} - \frac{R_2 + i\,(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30})}{R_2 + (\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30})^2}$$

$$- \frac{R_2 + i\,(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30})^2} - \frac{R_2 + i\,(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30})}{R_2 + (\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30})^2}$$

$$- \frac{R_2 + i\,(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30})^2} - \frac{R_2 + i\,(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30})^2}$$

maka dengan demikian diperoleh :

$$
\begin{aligned}
A(\omega) = {} & \frac{R_2}{R_2{}^2 + (\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32})^2} + \frac{R_2}{R_2{}^2 + (\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32})^2} \\
& + \frac{R_2}{R_2{}^2 - (\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32})^2} + \frac{R_2}{R_2{}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})^2} \\
& + \frac{R_2}{R_2{}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})^2} + \frac{R_2}{R_2{}^2 + (\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32})^2} \\
& + \frac{R_2}{R_2{}^2 + (\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32})^2} + \frac{R_2}{R_2{}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32})^2} \\
& - \frac{R_2}{R_2{}^2 + (\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32})^2} - \frac{R_2}{R_2{}^2 + (\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32})^2} \\
& - \frac{R_2}{R_2{}^2 + (\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32})^2} - \frac{R_2}{R_2{}^2 + (\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32})^2} \\
& - \frac{R_2}{R_2{}^2 + (\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32})^2} - \frac{R_2}{R_2{}^2 + (\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32})^2} \\
& - \frac{R_2}{R_2{}^2 + (\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32})^2} - \frac{R_2}{R_2{}^2 + (\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32})^2} \\
& - \frac{R_2}{R_2{}^2 + (\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31})^2} - \frac{R_2}{R_2{}^2 + (\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31})^2} \\
& - \frac{R_2}{R_2{}^2 + (\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31})^2} - \frac{R_2}{R_2{}^2 + (\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31})^2} \\
& - \frac{R_2}{R_2{}^2 + (\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30})^2} - \frac{R_2}{R_2{}^2 + (\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32})^2} \\
& - \frac{R_2}{R_2{}^2 + (\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31})^2} - \frac{R_2}{R_2{}^2 + (\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31})^2} \\
& - \frac{R_2}{R_2{}^2 + (\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30})^2} - \frac{R_2}{R_2{}^2 + (\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30})^2} \\
& - \frac{R_2}{R_2{}^2 + (\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30})^2} - \frac{R_2}{R_2 + (\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30})^2} \\
& - \frac{R_2}{R_2{}^2 + (\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30})^2} - \frac{R_2}{R_2 + (\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30})^2} \\
& - \frac{R_2}{R_2{}^2 + (\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30})^2} - \frac{R_2}{R_2{}^2 + (\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30})^2}
\end{aligned} \tag{257}
$$

dan diperoleh juga:

$$
\begin{aligned}
D\left(\omega\right) = {} & \frac{i\left(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}\right)^2} + \frac{i\left(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}\right)^2} \\
& + \frac{i\left(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}\right)^2} + \frac{i\left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}\right)^2} \\
& + \frac{i\left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}\right)^2} + \frac{i\left(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}\right)^2} \\
& + \frac{i\left(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}\right)^2} + \frac{i\left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}\right)^2} \\
& - \frac{i\left(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}\right)^2} - \frac{i\left(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}\right)^2} \\
& - \frac{i\left(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}\right)^2} - \frac{i\left(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}\right)^2} \\
& - \frac{i\left(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}\right)^2} - \frac{i\left(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}\right)^2} \\
& - \frac{i\left(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}\right)^2} - \frac{i\left(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}\right)^2} \\
& - \frac{i\left(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}\right)^2} - \frac{i\left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}\right)^2} \\
& - \frac{i\left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}\right)^2} - \frac{i\left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}\right)^2} \\
& - \frac{i\left(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}\right)}{{R_2}^2 + \left(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}\right)^2} - \frac{i\left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}\right)^2} \\
& - \frac{i\left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}\right)^2} - \frac{i\left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}\right)^2} \\
& - \frac{i\left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}\right)^2} - \frac{i\left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}\right)^2} \\
& - \frac{i\left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}\right)^2} - \frac{i\left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}\right)}{R_2 + \left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}\right)^2} \\
& - \frac{i\left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}\right)^2} - \frac{i\left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}\right)}{R_2 + \left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}\right)^2} \\
& - \frac{i\left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}\right)^2} - \frac{i\left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}\right)^2}
\end{aligned}
\tag{258}
$$

7.3 Penerapan Algoritma Deutsch jozsa 4 qubit untuk U2 = Us3

apabila diambil kasus untuk $U_2 = \sigma_z \otimes \sigma_z \otimes \sigma_z \otimes \sigma_z$ maka diperoleh untuk bentuk operator uniter totalnya adalah sebagai berikut:

$$
\begin{aligned}
U &= U_5 U_2 U_1 \\
&= U_5 \left(\sigma_z \otimes I \otimes I \otimes I\right) U_1 \\
&= \begin{pmatrix}
e^{\beta_0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & e^{\beta_1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & e^{\beta_2} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & e^{\beta_3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & e^{\beta_4} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & e^{\beta_5} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_7} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_9} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_10} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_11} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_12} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_13} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_15}
\end{pmatrix}
\end{aligned}
$$

$$\times \begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{pmatrix}$$

$$\times \frac{1}{4} \begin{pmatrix}
1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & 1 & -1 & -1 & 1 \\
1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 \\
1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 \\
1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 \\
1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 \\
1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 \\
1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\
1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \\
1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\
1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\
1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\
1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\
1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\
1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1
\end{pmatrix}$$

$$
= \frac{1}{4} \begin{pmatrix}
e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} \\
-e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} \\
-e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} \\
e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} \\
-e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} \\
e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} \\
e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} \\
-e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} \\
-e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} \\
e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} \\
e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} \\
-e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} \\
e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} \\
-e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} \\
-e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} \\
e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}}
\end{pmatrix} \tag{259}
$$

$$U^\dagger = \begin{pmatrix}
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} & \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}}
\end{pmatrix} \tag{260}$$

maka dengan demikian kita dapatkan untuk nilai ρ_5 adalah

$$
\begin{aligned}
\rho_5 &= U\rho_0 U^\dagger \\
&= \frac{1}{4}\begin{pmatrix}
e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} \\
-e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} \\
-e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} \\
e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} \\
-e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} \\
e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} \\
e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} \\
-e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} \\
-e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} \\
e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} \\
e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} \\
-e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} \\
e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} \\
-e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} \\
-e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} \\
e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}}
\end{pmatrix}
\end{aligned}
$$

$$
\times \begin{pmatrix}
2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -2
\end{pmatrix}
$$

$$
\times \frac{1}{4}
\begin{pmatrix}
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} & \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}}
\end{pmatrix}
$$

$$= \frac{1}{16}\begin{pmatrix}
0 & -8\rho_{0,1} & -8\rho_{0,2} & 0 & -8\rho_{0,4} & 0 & 0 & 0 & -8\rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-8\rho_{1,0} & 0 & 0 & -8\rho_{1,3} & 0 & -8\rho_{1,5} & 0 & 0 & 0 & -8\rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
-8\rho_{2,0} & 0 & 0 & -8\rho_{2,3} & 0 & 0 & -8\rho_{2,6} & 0 & 0 & 0 & -8\rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & -8\rho_{3,1} & -8\rho_{3,2} & 0 & 0 & 0 & 0 & -8\rho_{3,7} & 0 & 0 & 0 & -8\rho_{3,11} & 0 & 0 & 0 & 0 \\
-8\rho_{4,0} & 0 & 0 & 0 & 0 & -8\rho_{4,5} & -8\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & -8\rho_{4,12} & 0 & 0 & 0 \\
0 & -8\rho_{4,1} & 0 & 0 & -8\rho_{5,4} & 0 & 0 & -8\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & -8\rho_{5,13} & 0 & 0 \\
0 & 0 & -8\rho_{6,2} & 0 & -8\rho_{6,4} & 0 & 0 & -8\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & -8\rho_{6,14} & 0 \\
0 & 0 & 0 & -8\rho_{7,3} & 0 & -8\rho_{7,5} & -8\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -8\rho_{7,15} \\
-8\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -8\rho_{8,9} & -8\rho_{8,10} & 0 & -8\rho_{8,12} & 0 & 0 & 0 \\
0 & -8\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -8\rho_{9,8} & 0 & 0 & -8\rho_{9,11} & 0 & -8\rho_{9,13} & 0 & 0 \\
0 & 0 & -8\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -8\rho_{10,8} & 0 & 0 & -8\rho_{10,11} & 0 & 0 & -8\rho_{10,14} & 0 \\
0 & 0 & 0 & -8\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -8\rho_{11,9} & -8\rho_{11,10} & 0 & 0 & 0 & 0 & -8\rho_{11,15} \\
0 & 0 & 0 & 0 & -8\rho_{12,4} & 0 & 0 & 0 & -8\rho_{12,8} & 0 & 0 & 0 & 0 & -8\rho_{12,13} & -8\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & -8\rho_{13,5} & 0 & 0 & 0 & -8\rho_{13,9} & 0 & 0 & -8\rho_{13,12} & 0 & 0 & -8\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & -8\rho_{14,6} & 0 & 0 & 0 & -8\rho_{14,10} & 0 & -8\rho_{14,12} & 0 & 0 & -8\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -8\rho_{15,7} & 0 & 0 & 0 & -8\rho_{15,11} & 0 & -8\rho 15, 13 & -8\rho_{15,14} & 0
\end{pmatrix} \quad (26$$

$$
= \frac{1}{2} \begin{pmatrix}
0 & -\rho_{0,1} & -\rho_{0,2} & 0 & -\rho_{0,4} & 0 & 0 & 0 & -\rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{1,0} & 0 & 0 & -\rho_{1,3} & 0 & -\rho_{1,5} & 0 & 0 & 0 & -\rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & -\rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & -\rho_{3,7} & 0 & 0 & 0 & -\rho_{3,11} & 0 & 0 & 0 & 0 \\
-\rho_{4,0} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & -\rho_{4,12} & 0 & 0 & 0 \\
0 & -\rho_{4,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & -\rho_{5,13} & 0 & 0 \\
0 & 0 & -\rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{6,14} & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{7,15} \\
-\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{8,9} & -\rho_{8,10} & 0 & -\rho_{8,12} & 0 & 0 & 0 \\
0 & -\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & -\rho_{9,11} & 0 & -\rho_{9,13} & 0 & 0 \\
0 & 0 & -\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -\rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & -\rho_{10,14} & 0 \\
0 & 0 & 0 & -\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & -\rho_{12,4} & 0 & 0 & 0 & -\rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & -\rho_{13,5} & 0 & 0 & 0 & -\rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & {} & 0 & 0 & 0 & -\rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho 15, 13 & -\rho_{15,14} & 0
\end{pmatrix} \tag{262}
$$

dengan

$$
\begin{aligned}
\rho_{0,1} = {\rho_{1,0}}^* = e^{\beta_0-\beta_1} \qquad & \rho_{6,7} = {\rho_{7,6}}^* = e^{\beta_6-\beta_7} \\
\rho_{0,2} = {\rho_{2,0}}^* = e^{\beta_0-\beta_2} \qquad & \rho_{6,14} = {\rho_{14,6}}^* = e^{\beta_6-\beta_14} \\
\rho_{0,8} = {\rho_{8,0}}^* = e^{\beta_8-\beta_1} \qquad & \rho_{8,9} = {\rho_{9,8}}^* = e^{\beta_8-\beta_9} \\
\rho_{1,3} = {\rho_{3,1}}^* = e^{\beta_1-\beta_3} \qquad & \rho_{8,10} = {\rho_{10,8}}^* = e^{\beta_8-\beta_{10}} \\
\rho_{1,5} = {\rho_{5,1}}^* = e^{\beta_1-\beta_5} \qquad & \rho_{8,12} = {\rho_{12,8}}^* = e^{\beta_8-\beta_{12}} \\
\rho_{1,9} = {\rho_{9,1}}^* = e^{\beta_1-\beta_9} \qquad & \rho_{9,11} = {\rho_{11,9}}^* = e^{\beta_9-\beta_{11}} \\
\rho_{2,3} = {\rho_{3,2}}^* = e^{\beta_2-\beta_3} \qquad & \rho_{9,13} = {\rho_{13,9}}^* = e^{\beta_9-\beta_{13}} \\
\rho_{2,6} = {\rho_{6,2}}^* = e^{\beta_2-\beta_6} \qquad & \rho_{10,11} = {\rho_{11,10}}^* = e^{\beta_{10}-\beta_{11}} \\
\rho_{2,10} = {\rho_{10,2}}^* = e^{\beta_2-\beta_10} \qquad & \rho_{10,14} = {\rho_{14,10}}^* = e^{\beta_{10}-\beta_{14}} \\
\rho_{3,7} = {\rho_{7,3}}^* = e^{\beta_3-\beta_7} \qquad & \rho_{12,13} = {\rho_{13,12}}^* = e^{\beta_{12}-\beta_{13}} \\
\rho_{3,11} = {\rho_{11,3}}^* = e^{\beta_3-\beta_11} \qquad & \rho_{12,14} = {\rho_{14,12}}^* = e^{\beta_{12}-\beta_{14}} \\
\rho_{4,5} = {\rho_{5,4}}^* = e^{\beta_4-\beta_5} \qquad & \rho_{11,15} = {\rho_{15,11}}^* = e^{\beta_{11}-\beta_{15}} \\
\rho_{4,6} = {\rho_{6,4}}^* = e^{\beta_4-\beta_6} \qquad & \rho_{13,15} = {\rho_{15,13}}^* = e^{\beta_{13}-\beta_{15}} \\
\rho_{4,12} = {\rho_{12,4}}^* = e^{\beta_4-\beta_12} \qquad & \rho_{14,15} = {\rho_{14,15}}^* = e^{\beta_{14}-\beta_{15}} \\
\rho_{5,7} = {\rho_{7,5}}^* = e^{\beta_5-\beta_7} \qquad & \rho_{15,7} = {\rho_{7,15}}^* = e^{\beta_7-\beta_{15}} \\
\rho_{5,13} = {\rho_{13,5}}^* = e^{\beta_5-\beta_13} \qquad & \rho_{0,4} = {\rho_{4,0}}^* = e^{\beta_0-\beta_4}
\end{aligned}
\tag{263}
$$

dan

$$\begin{aligned}
\beta_0 - \beta_1 &= -i\left(E_{4,0} - E_{4,1}\right)t & \beta_0 - \beta_2 &= -i\left(E_{4,0} - E_{4,2}\right)t \\
\beta_0 - \beta_4 &= -i\left(E_{4,0} - E_{4,4}\right)t & \beta_0 - \beta_8 &= -i\left(E_{4,0} - E_{4,8}\right)t \\
\beta_1 - \beta_3 &= -i\left(E_{4,1} - E_{4,3}\right)t & \beta_1 - \beta_5 &= -i\left(E_{4,1} - E_{4,5}\right)t \\
\beta_1 - \beta_9 &= -i\left(E_{4,1} - E_{4,9}\right)t & \beta_2 - \beta_3 &= -i\left(E_{4,2} - E_{4,3}\right)t \\
\beta_2 - \beta_6 &= -i\left(E_{4,2} - E_{4,6}\right)t & \beta_2 - \beta_{10} &= -i\left(E_{4,2} - E_{4,10}\right)t \\
\beta_3 - \beta_7 &= -i\left(E_{4,3} - E_{4,7}\right)t & \beta_3 - \beta_{11} &= -i\left(E_{4,3} - E_{4,11}\right)t \\
\beta_4 - \beta_5 &= -i\left(E_{4,4} - E_{4,5}\right)t & \beta_4 - \beta_6 &= -i\left(E_{4,4} - E_{4,6}\right)t \\
\beta_4 - \beta_{12} &= -i\left(E_{4,4} - E_{4,12}\right)t & \beta_5 - \beta_7 &= -i\left(E_{4,5} - E_{4,7}\right)t \\
\beta_5 - \beta_{13} &= -i\left(E_{4,5} - E_{4,13}\right)t & \beta_6 - \beta_7 &= -i\left(E_{4,6} - E_{4,7}\right)t \\
\beta_6 - \beta_{14} &= -i\left(E_{4,6} - E_{4,14}\right)t & \beta_8 - \beta_9 &= -i\left(E_{4,8} - E_{4,9}\right)t \\
\beta_8 - \beta_{10} &= -i\left(E_{4,8} - E_{4,10}\right)t & \beta_8 - \beta_{12} &= -i\left(E_{4,8} - E_{4,12}\right)t \\
\beta_9 - \beta_{11} &= -i\left(E_{4,9} - E_{4,11}\right)t & \beta_9 - \beta_{13} &= -i\left(E_{4,9} - E_{4,13}\right)t \\
\beta_{10} - \beta_{11} &= -i\left(E_{4,10} - E_{4,11}\right)t & \beta_{10} - \beta_{14} &= -i\left(E_{4,10} - E_{4,14}\right)t \\
\beta_{12} - \beta_{13} &= -i\left(E_{4,12} - E_{4,13}\right)t & \beta_{12} - \beta_{14} &= -i\left(E_{4,12} - E_{4,14}\right)t \\
\beta_{11} - \beta_{15} &= -i\left(E_{4,11} - E_{4,15}\right)t & \beta_{13} - \beta_{15} &= -i\left(E_{4,13} - E_{4,15}\right)t \\
\beta_{14} - \beta_{15} &= -i\left(E_{4,14} - E_{4,15}\right)t & \beta_{15} - \beta_7 &= -i\left(E_{4,15} - E_{4,7}\right)t
\end{aligned} \tag{264}$$

dan

$$
\begin{array}{ll}
E_{4,0} - E4,1 = \omega_0 + \pi J_{10} + \pi J_{20} + \pi J_{30} & E_{4,0} - E4,2 = \omega_1 + \pi J_{10} + \pi J_{21} + \pi J_{31} \\
E_{4,0} - E4,4 = \omega_2 + \pi J_{20} + \pi J_{21} + \pi J_{32} & E_{4,0} - E4,8 = \omega_3 + \pi J_{30} + \pi J_{31} + \pi J_{32} \\
E_{4,1} - E4,3 = \omega_1 - \pi J_{10} + \pi J_{21} + \pi J_{31} & E_{4,1} - E4,5 = \omega_2 - \pi J_{20} + \pi J_{21} + \pi J_{32} \\
E_{4,1} - E4,9 = \omega_3 - \pi J_{30} + \pi J_{310} + \pi J_{32} & E_{4,2} - E4,3 = \omega_0 - \pi J_{10} + \pi J_{20} + \pi J_{30} \\
E_{4,2} - E4,6 = \omega_2 + \pi J_{20} - \pi J_{21} + \pi J_{32} & E_{4,2} - E4,10 = \omega_3 + \pi J_{30} - \pi J_{31} + \pi J_{32} \\
E_{4,3} - E4,7 = \omega_2 - \pi J_{20} - \pi J_{21} + \pi J_{32} & E_{4,3} - E4,11 = \omega_3 - \pi J_{30} - \pi J_{31} + \pi J_{32} \\
E_{4,4} - E4,5 = \omega_0 + \pi J_{10} - \pi J_{20} + \pi J_{30} & E_{4,4} - E4,6 = \omega_1 + \pi J_{10} - \pi J_{21} + \pi J_{31} \\
E_{4,4} - E4,12 = \omega_3 + \pi J_{30} + \pi J_{31} - \pi J_{32} & E_{4,5} - E4,7 = \omega_1 - \pi J_{10} - \pi J_{21} + \pi J_{31} \\
E_{4,5} - E4,13 = \omega_3 - \pi J_{30} + \pi J_{31} - \pi J_{32} & E_{4,6} - E4,7 = \omega_0 - \pi J_{10} - \pi J_{20} + \pi J_{30} \\
E_{4,6} - E4,14 = \omega_3 + \pi J_{30} - \pi J_{31} - \pi J_{32} & E_{4,8} - E4,9 = \omega_0 + \pi J_{10} + \pi J_{20} - \pi J_{30} \\
E_{4,8} - E4,10 = \omega_1 + \pi J_{21} - \pi J_{31} + \pi J_{30} & E_{4,8} - E4,12 = \omega_2 + \pi J_{20} + \pi J_{21} - \pi J_{32} \\
E_{4,9} - E4,11 = \omega_1 - \pi J_{10} + \pi J_{21} - \pi J_{32} & E_{4,10} - E4,11 = \omega_0 - \pi J_{10} + \pi J_{20} - \pi J_{30} \\
E_{4,10} - E4,14 = \omega_2 + \pi J_{20} - \pi J_{21} - \pi J_{32} & E_{4,12} - E4,13 = \omega_0 + \pi J_{10} - \pi J_{20} - \pi J_{30} \\
E_{4,12} - E4,14 = \omega_1 + \pi J_{10} - \pi J_{21} - \pi J_{31} & E_{4,11} - E4,15 = \omega_2 - \pi J_{20} - \pi J_{21} - \pi J_{32} \\
E_{4,13} - E4,15 = \omega_1 - \pi J_{10} - \pi J_{21} - \pi J_{31} & E_{4,14} - E4,15 = \omega_0 - \pi J_{10} - \pi J_{20} - \pi J_{30} \\
E_{4,9} - E4,13 = \omega_2 - \pi J_{20} + \pi J_{21} - \pi J_{32} & E_{4,15} - E4,7 = \omega_3 + \pi J_{30} + \pi J_{31} + \pi J_{32}
\end{array}
\tag{265}
$$

maka dapat ditentukan nilai magnetisasi dari masing-masing qubitnya yaitu sebagai berikut:

$$(I_{3+}\rho_5) = \begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

$$
\times \frac{1}{2} \begin{pmatrix}
0 & -\rho_{0,1} & -\rho_{0,2} & 0 & -\rho_{0,4} & 0 & 0 & 0 & -\rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{1,0} & 0 & 0 & -\rho_{1,3} & 0 & -\rho_{1,5} & 0 & 0 & 0 & -\rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & -\rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & -\rho_{3,7} & 0 & 0 & 0 & -\rho_{3,11} & 0 & 0 & 0 & 0 \\
-\rho_{4,0} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & -\rho_{4,12} & 0 & 0 & 0 \\
0 & -\rho_{4,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & -\rho_{5,13} & 0 & 0 \\
0 & 0 & -\rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{6,14} & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{7,15} \\
-\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{8,9} & -\rho_{8,10} & 0 & -\rho_{8,12} & 0 & 0 & 0 \\
0 & -\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & -\rho_{9,11} & 0 & -\rho_{9,13} & 0 & 0 \\
0 & 0 & -\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -\rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & -\rho_{10,14} & 0 \\
0 & 0 & 0 & -\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & -\rho_{12,4} & 0 & 0 & 0 & -\rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & -\rho_{13,5} & 0 & 0 & 0 & -\rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & -\rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho 15, 13 & -\rho_{15,14} & 0
\end{pmatrix}
$$

$$
= \frac{1}{2}\begin{pmatrix}
-\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{8,9} & -\rho_{8,10} & 0 & -\rho_{8,12} & 0 & 0 & 0 \\
0 & -\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & -\rho_{9,11} & 0 & -\rho_{9,13} & 0 & 0 \\
0 & 0 & -\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -\rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & -\rho_{10,14} & 0 \\
0 & 0 & 0 & -\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & -\rho_{12,4} & 0 & 0 & 0 & -\rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & -\rho_{13,5} & 0 & 0 & 0 & -\rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & 0 & 0 & 0 & 0 & -\rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho_{15,13} & -\rho_{15,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$
\begin{aligned}
M_{3+} &= \langle I_{3+} \rangle = tr\left(I_{3+}\rho_5\right) \\
&= -\left(\rho_{8,0} + \rho_{9,1} + \rho_{10,2} + \rho_{11,3} + \rho_{12,4} + \rho_{13,5} + \rho_{14,6} + \rho_{15,7}\right)
\end{aligned}
\tag{266}
$$

dan

$$
\left(I_{2+}\rho_5\right) = \begin{pmatrix}
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$
\times \frac{1}{2}
\begin{pmatrix}
0 & -\rho_{0,1} & -\rho_{0,2} & 0 & -\rho_{0,4} & 0 & 0 & 0 & -\rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{1,0} & 0 & 0 & -\rho_{1,3} & 0 & -\rho_{1,5} & 0 & 0 & 0 & -\rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & -\rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & -\rho_{3,7} & 0 & 0 & 0 & -\rho_{3,11} & 0 & 0 & 0 & 0 \\
-\rho_{4,0} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & -\rho_{4,12} & 0 & 0 & 0 \\
0 & -\rho_{4,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & -\rho_{5,13} & 0 & 0 \\
0 & 0 & -\rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{6,14} & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{7,15} \\
-\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{8,9} & -\rho_{8,10} & 0 & -\rho_{8,12} & 0 & 0 & 0 \\
0 & -\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & -\rho_{9,11} & 0 & -\rho_{9,13} & 0 & 0 \\
0 & 0 & -\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -\rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & -\rho_{10,14} & 0 \\
0 & 0 & 0 & -\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & -\rho_{12,4} & 0 & 0 & 0 & -\rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & -\rho_{13,5} & 0 & 0 & 0 & -\rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & -\rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho 15,13 & -\rho_{15,14} & 0
\end{pmatrix}
$$

$$
= \frac{1}{2} \begin{pmatrix}
-\rho_{4,0} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & -\rho_{4,12} & 0 & 0 & 0 \\
0 & -\rho_{5,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & -\rho_{5,13} & 0 & 0 \\
0 & 0 & -\rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{6,14} & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{7,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & -\rho_{12,4} & 0 & 0 & 0 & -\rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & -\rho_{13,5} & 0 & 0 & 0 & -\rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & -\rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho 15,13 & -\rho_{15,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix} \tag{267}
$$

$$
\begin{aligned}
M_{2+} &= \langle I_{2+} \rangle = tr\left(I_{2+}\rho_5\right) \\
&= -\left(\rho_{4,0} + \rho_{5,1} + \rho_{6,2} + \rho_{7,3} + \rho_{12,8} + \rho_{13,9} + \rho_{14,10} + \rho_{15,11}\right)
\end{aligned} \tag{268}
$$

dan

$$
(I_{1+}\rho_5) = \begin{pmatrix}
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$\times \frac{1}{2} \begin{pmatrix}
0 & -\rho_{0,1} & -\rho_{0,2} & 0 & -\rho_{0,4} & 0 & 0 & 0 & -\rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{1,0} & 0 & 0 & -\rho_{1,3} & 0 & -\rho_{1,5} & 0 & 0 & 0 & -\rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & -\rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & -\rho_{3,7} & 0 & 0 & 0 & -\rho_{3,11} & 0 & 0 & 0 & 0 \\
-\rho_{4,0} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & -\rho_{4,12} & 0 & 0 & 0 \\
0 & -\rho_{4,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & -\rho_{5,13} & 0 & 0 \\
0 & 0 & -\rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{6,14} & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{7,15} \\
-\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{8,9} & -\rho_{8,10} & 0 & -\rho_{8,12} & 0 & 0 & 0 \\
0 & -\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & -\rho_{9,11} & 0 & -\rho_{9,13} & 0 & 0 \\
0 & 0 & -\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -\rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & -\rho_{10,14} & 0 \\
0 & 0 & 0 & -\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & -\rho_{12,4} & 0 & 0 & 0 & -\rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & -\rho_{13,5} & 0 & 0 & 0 & -\rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & -\rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho 15,13 & -\rho_{15,14} & 0
\end{pmatrix}$$

$$
= \frac{1}{2} \begin{pmatrix}
-\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & -\rho_{2,6} & 0 & 0 & 0 & -\rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & -\rho_{3,7} & 0 & 0 & 0 & -\rho_{3,11} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & -\rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{6,14} & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{7,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & -\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -\rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & -\rho_{10,14} & 0 \\
0 & 0 & 0 & -\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & -\rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho_{15,13} & -\rho_{15,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix} \tag{269}
$$

$$
\begin{aligned}
M_{1+} &= \langle I_{1+} \rangle = tr\left(I_{1+}\rho_5\right) \\
&= -\left(\rho_{2,0} + \rho_{3,1} + \rho_{6,4} + \rho_{7,5} + \rho_{10,8} + \rho_{11,9} + \rho_{14,12} + \rho_{15,13}\right)
\end{aligned}
\tag{270}
$$

dan

$$
(I_{0+}\rho_5) = \begin{pmatrix}
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$
\times \frac{1}{2}
\begin{pmatrix}
0 & -\rho_{0,1} & -\rho_{0,2} & 0 & -\rho_{0,4} & 0 & 0 & 0 & -\rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{1,0} & 0 & 0 & -\rho_{1,3} & 0 & -\rho_{1,5} & 0 & 0 & 0 & -\rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & -\rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & -\rho_{3,7} & 0 & 0 & 0 & -\rho_{3,11} & 0 & 0 & 0 & 0 \\
-\rho_{4,0} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & -\rho_{4,12} & 0 & 0 & 0 \\
0 & -\rho_{4,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & -\rho_{5,13} & 0 & 0 \\
0 & 0 & -\rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{6,14} & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{7,15} \\
-\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{8,9} & -\rho_{8,10} & 0 & -\rho_{8,12} & 0 & 0 & 0 \\
0 & -\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & -\rho_{9,11} & 0 & -\rho_{9,13} & 0 & 0 \\
0 & 0 & -\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & -\rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & -\rho_{10,14} & 0 \\
0 & 0 & 0 & -\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & -\rho_{12,4} & 0 & 0 & 0 & -\rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & -\rho_{13,5} & 0 & 0 & 0 & -\rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & -\rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho 15,13 & -\rho_{15,14} & 0
\end{pmatrix}
$$

$$
= \frac{1}{2}\begin{pmatrix}
-\rho_{1,0} & 0 & 0 & -\rho_{1,3} & 0 & -\rho_{1,5} & 0 & 0 & 0 & -\rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & -\rho_{3,7} & 0 & 0 & -\rho_{3,11} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{5,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & -\rho_{5,13} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{7,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & -\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & -\rho_{9,11} & 0 & -\rho_{9,13} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & -\rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & -\rho_{13,5} & 0 & 0 & 0 & -\rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho 15,13 & -\rho_{15,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix} \tag{271}
$$

$$
\begin{aligned}
M_{0+} &= \langle I_{0+} \rangle = tr\left(I_{0+}\rho_5\right) \\
&= -\left(\rho_{1,0} + \rho_{3,2} + \rho_{5,2} + \rho_{7,6} + \rho_{9,8} + \rho_{11,10} + \rho_{13,12} + \rho_{15,14}\right)
\end{aligned} \tag{272}
$$

maka dengan demikian nilai magnetisasi total dari sistem adalah sebagai berikut:

$$
\begin{aligned}
M_{tot} &= M_{3+} + M_{2+} + M_{1+} + M_{0+} \\
&= -\left(\rho_{8,0} + \rho_{9,1} + \rho_{10,2} + \rho_{11,3} + \rho_{12,4} + \rho_{13,5} + \rho_{14,6} + \rho_{15,7}\right) \\
&- \rho_{4,0} - \rho_{5,1} - \rho_{6,2} - \rho_{7,3} - \rho_{12,8} - \rho_{13,9} - \rho_{14,10} - \rho_{15,11} \\
&- \left(\rho_{2,0} + \rho_{3,1} + \rho_{6,4} + \rho_{7,5} + \rho_{10,8} + \rho_{11,9} + \rho_{14,12} + \rho_{15,13}\right) \\
&- \left(\rho_{1,0} + \rho_{3,2} + \rho_{5,4} + \rho_{7,6} + \rho_{9,8} + \rho_{11,10} + \rho_{13,12} + \rho_{15,14}\right) \\
&= e^{i(\omega_3+\pi J_{30}+\pi J_{31}+\pi J_{32})t} - e^{i(\omega_3-\pi J_{30}+\pi J_{31}+\pi J_{32})t} \\
&- e^{i(\omega_3+\pi J_{30}-\pi J_{31}+\pi J_{32})t} - e^{i(\omega_3-\pi J_{30}-\pi J_{31}+\pi J_{32})t} \\
&- e^{i(\omega_3+\pi J_{30}+\pi J_{31}-\pi J_{32})t} - e^{i(\omega_3-\pi J_{30}+\pi J_{31}-\pi J_{32})t} \\
&- e^{i(\omega_3+\pi J_{30}-\pi J_{31}-\pi J_{32})t} - e^{i(\omega_3-\pi J_{30}-\pi J_{31}-\pi J_{32})t} \\
&- e^{i(\omega_2+\pi J_{20}+\pi J_{21}+\pi J_{32})t} - e^{i(\omega_2-\pi J_{20}+\pi J_{21}+\pi J_{32})t} \\
&- e^{i(\omega_2+\pi J_{20}-\pi J_{21}+\pi J_{32})t} - e^{i(\omega_2-\pi J_{20}-\pi J_{21}+\pi J_{32})t} \\
&- e^{i(\omega_2+\pi J_{20}+\pi J_{21}-\pi J_{32})t} - e^{i(\omega_2-\pi J_{20}+\pi J_{21}-\pi J_{32})t} \\
&- e^{i(\omega_2+\pi J_{20}-\pi J_{21}-\pi J_{32})t} - e^{i(\omega_2-\pi J_{20}-\pi J_{21}-\pi J_{32})t} \\
&- e^{i(\omega_1+\pi J_{10}+\pi J_{21}+\pi J_{31})t} - e^{i(\omega_1-\pi J_{10}+\pi J_{21}+\pi J_{31})t} \\
&- e^{i(\omega_1+\pi J_{10}-\pi J_{21}+\pi J_{31})t} - e^{i(\omega_1-\pi J_{10}-\pi J_{21}+\pi J_{31})t} \\
&- e^{i(\omega_1+\pi J_{21}-\pi J_{31}+\pi J_{30})t} - e^{i(\omega_1-\pi J_{10}+\pi J_{21}-\pi J_{32})t} \\
&- e^{i(\omega_1+\pi J_{10}-\pi J_{21}-\pi J_{31})t} - e^{i(\omega_1-\pi J_{10}-\pi J_{21}-\pi J_{31})t} \\
&- e^{i(\omega_0+\pi J_{10}+\pi J_{20}+\pi J_{30})t} - e^{i(\omega_0-\pi J_{10}+\pi J_{20}+\pi J_{30})t} \\
&- e^{i(\omega_0+\pi J_{10}-\pi J_{20}+\pi J_{30})t} - e^{i(\omega_0-\pi J_{10}-\pi J_{20}+\pi J_{30})t} \\
&- e^{i(\omega_0+\pi J_{10}+\pi J_{20}-\pi J_{30})t} - e^{i(\omega_0-\pi J_{10}+\pi J_{20}-\pi J_{30})t} \\
&- e^{i(\omega_0+\pi J_{10}-\pi J_{20}-\pi J_{30})t} - e^{i(\omega_0-\pi J_{10}-\pi J_{20}-\pi J_{30})t}
\end{aligned} \tag{273}
$$

kemudian didapatkan juga untuk sinyal FID sebagai berikut:

$$
\begin{aligned}
S = M_{tot} e^{-R_2 t} \\
&= -e^{-(R_2 - i(\omega_3 + \pi J_{30} + \pi J_{31} + \pi J_{32}))t} - e^{-(R_2 - i(\omega_3 - \pi J_{30} + \pi J_{31} + \pi J_{32}))t} \\
&- e^{-(R_2 - i(\omega_3 + \pi J_{30} - \pi J_{31} + \pi J_{32}))t} - e^{-(R_2 - i(\omega_3 - \pi J_{30} - \pi J_{31} + \pi J_{32}))t} \\
&- e^{-(R_2 - i(\omega_3 + \pi J_{30} + \pi J_{31} - \pi J_{32}))t} - e^{-(R_2 - i(\omega_3 - \pi J_{30} + \pi J_{31} - \pi J_{32}))t} \\
&- e^{-(R_2 - i(\omega_3 + \pi J_{30} - \pi J_{31} - \pi J_{32}))t} - e^{-(R_2 - i(\omega_3 - \pi J_{30} - \pi J_{31} - \pi J_{32}))t} \\
&- e^{-(R_2 - i(\omega_2 + \pi J_{20} + \pi J_{21} + \pi J_{32}))t} - e^{-(R_2 - i(\omega_2 - \pi J_{20} + \pi J_{21} + \pi J_{32}))t} \\
&- e^{-(R_2 - i(\omega_2 + \pi J_{20} - \pi J_{21} + \pi J_{32}))t} - e^{-(R_2 - i(\omega_2 - \pi J_{20} - \pi J_{21} + \pi J_{32}))t} \\
&- e^{-(R_2 - i(\omega_2 + \pi J_{20} + \pi J_{21} - \pi J_{32}))t} - e^{-(R_2 - i(\omega_2 - \pi J_{20} + \pi J_{21} - \pi J_{32}))t} \\
&- e^{-(R_2 - i(\omega_2 + \pi J_{20} - \pi J_{21} - \pi J_{32}))t} - e^{-(R_2 - i(\omega_2 - \pi J_{20} - \pi J_{21} - \pi J_{32}))t} \qquad (274) \\
&- e^{-(R_2 - i(\omega_1 + \pi J_{10} + \pi J_{21} + \pi J_{31}))t} - e^{-(R_2 - i(\omega_1 - \pi J_{10} + \pi J_{21} + \pi J_{31}))t} \\
&- e^{-(R_2 - i(\omega_1 + \pi J_{10} - \pi J_{21} + \pi J_{31}))t} - e^{-(R_2 - i(\omega_1 - \pi J_{10} - \pi J_{21} + \pi J_{31}))t} \\
&- e^{-(R_2 - i(\omega_1 + \pi J_{21} - \pi J_{31} + \pi J_{30}))t} - e^{-(R_2 - i(\omega_1 - \pi J_{10} + \pi J_{21} - \pi J_{32}))t} \\
&- e^{-(R_2 - i(\omega_1 + \pi J_{10} - \pi J_{21} - \pi J_{31}))t} - e^{-(R_2 - i(\omega_1 - \pi J_{10} - \pi J_{21} - \pi J_{31}))t} \\
&- e^{-(R_2 - i(\omega_0 + \pi J_{10} + \pi J_{20} + \pi J_{30}))t} - e^{-(R_2 - i(\omega_0 - \pi J_{10} + \pi J_{20} + \pi J_{30}))t} \\
&- e^{-(R_2 - i(\omega_0 + \pi J_{10} - \pi J_{20} + \pi J_{30}))t} - e^{-(R_2 - i(\omega_0 - \pi J_{10} - \pi J_{20} + \pi J_{30}))t} \\
&- e^{-(R_2 - i(\omega_0 + \pi J_{10} + \pi J_{20} - \pi J_{30}))t} - e^{-(R_2 - i(\omega_0 - \pi J_{10} + \pi J_{20} - \pi J_{30}))t} \\
&- e^{-(R_2 - i(\omega_0 + \pi J_{10} - \pi J_{20} - \pi J_{30}))t} - e^{-(R_2 - i(\omega_0 - \pi J_{10} - \pi J_{20} - \pi J_{30}))t}
\end{aligned}
$$

dimana $R_2 = \frac{1}{T_2}$

kemudian dapat di cari terlebih dahulu untuk perkalian antara $S\left(t\right)e^{-i\omega t}$ yaitu sebagi berikut:

$$
\begin{aligned}
S\left(t\right)e^{-i\omega t} = & -e^{-(R_2-i(\omega_3-\omega+\pi J_{30}+\pi J_{31}+\pi J_{32}))t} - e^{-(R_2-i(\omega_3-\omega-\pi J_{30}+\pi J_{31}+\pi J_{32}))t} \\
& - e^{-(R_2-i(\omega_3-\omega+\pi J_{30}-\pi J_{31}+\pi J_{32}))t} - e^{-(R_2-i(\omega_3-\omega-\pi J_{30}-\pi J_{31}+\pi J_{32}))t} \\
& - e^{-(R_2-i(\omega_3-\omega+\pi J_{30}+\pi J_{31}-\pi J_{32}))t} - e^{-(R_2-i(\omega_3-\omega-\pi J_{30}+\pi J_{31}-\pi J_{32}))t} \\
& - e^{-(R_2-i(\omega_3-\omega+\pi J_{30}-\pi J_{31}-\pi J_{32}))t} - e^{-(R_2-i(\omega_3-\omega-\pi J_{30}-\pi J_{31}-\pi J_{32}))t} \\
& - e^{-(R_2-i(\omega_2-\omega+\pi J_{20}+\pi J_{21}+\pi J_{32}))t} - e^{-(R_2-i(\omega_2-\omega-\pi J_{20}+\pi J_{21}+\pi J_{32}))t} \\
& - e^{-(R_2-i(\omega_2-\omega+\pi J_{20}-\pi J_{21}+\pi J_{32}))t} - e^{-(R_2-i(\omega_2-\omega-\pi J_{20}-\pi J_{21}+\pi J_{32}))t} \\
& - e^{-(R_2-i(\omega_2-\omega+\pi J_{20}+\pi J_{21}-\pi J_{32}))t} - e^{-(R_2-i(\omega_2-\omega-\pi J_{20}+\pi J_{21}-\pi J_{32}))t} \\
& - e^{-(R_2-i(\omega_2-\omega+\pi J_{20}-\pi J_{21}-\pi J_{32}))t} - e^{-(R_2-i(\omega_2-\omega-\pi J_{20}-\pi J_{21}-\pi J_{32}))t} \\
& - e^{-(R_2-i(\omega_1-\omega+\pi J_{10}+\pi J_{21}+\pi J_{31}))t} - e^{-(R_2-i(\omega_1-\omega-\pi J_{10}+\pi J_{21}+\pi J_{31}))t} \\
& - e^{-(R_2-i(\omega_1-\omega+\pi J_{10}-\pi J_{21}+\pi J_{31}))t} - e^{-(R_2-i(\omega_1-\omega-\pi J_{10}-\pi J_{21}+\pi J_{31}))t} \\
& - e^{-(R_2-i(\omega_1-\omega+\pi J_{21}-\pi J_{31}+\pi J_{30}))t} - e^{-(R_2-i(\omega_1-\omega-\pi J_{10}+\pi J_{21}-\pi J_{32}))t} \\
& - e^{-(R_2-i(\omega_1-\omega+\pi J_{10}-\pi J_{21}-\pi J_{31}))t} - e^{-(R_2-i(\omega_1-\omega-\pi J_{10}-\pi J_{21}-\pi J_{31}))t} \\
& - e^{-(R_2-i(\omega_0-\omega+\pi J_{10}+\pi J_{20}+\pi J_{30}))t} - e^{-(R_2-i(\omega_0-\omega-\pi J_{10}+\pi J_{20}+\pi J_{30}))t} \\
& - e^{-(R_2-i(\omega_0-\omega+\pi J_{10}-\pi J_{20}+\pi J_{30}))t} - e^{-(R_2-i(\omega_0-\omega-\pi J_{10}-\pi J_{20}+\pi J_{30}))t} \\
& - e^{-(R_2-i(\omega_0-\omega+\pi J_{10}+\pi J_{20}-\pi J_{30}))t} - e^{-(R_2-i(\omega_0-\omega-\pi J_{10}+\pi J_{20}-\pi J_{30}))t} \\
& - e^{-(R_2-i(\omega_0-\omega+\pi J_{10}-\pi J_{20}-\pi J_{30}))t} - e^{-(R_2-i(\omega_0-\omega-\pi J_{10}-\pi J_{20}-\pi J_{30}))t}
\end{aligned} \tag{275}
$$

Transformasi Fourirer dari sinyal FiD adalah sebagai berikut:

$$
\begin{aligned}
S(\omega) &= \int_0^\infty S(t)\, e^{-i\omega t}\, dt \\
&= \frac{e^{-(R_2 - i(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}))t}}{(R_2 - i(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}))t}}{(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}))t}}{(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))t}}{(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))t}}{(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}))t}}{(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}))t}}{(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}))t}}{(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}))t}}{(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}))t}}{(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}))t}}{(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}))t}}{(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}))t}}{(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}))t}}{(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}))t}}{(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}))t}}{(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}))t}}{(R_2 - i(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}))} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}))t}}{(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}))} \\
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}))t}}{(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}))} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}))t}}{(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}))} \\
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}))t}}{(R_2 - i(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}))} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}))t}}{(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}))t}}{(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}))} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}))t}}{(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}))} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}))} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}))} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}))} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}))} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}))} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}))} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}))} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}))}
\end{aligned}
$$

$$
\begin{aligned}
&= \frac{-1}{(R_2 - i(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}))} - \frac{1}{(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}))} \\
&- \frac{1}{(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}))} - \frac{1}{(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))} \\
&- \frac{1}{(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))} - \frac{1}{(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}))} \\
&- \frac{1}{(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}))} - \frac{1}{(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}))} \\
&- \frac{1}{(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}))} - \frac{1}{(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}))} \\
&- \frac{1}{(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}))} - \frac{1}{(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}))} \\
&- \frac{1}{(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}))} - \frac{1}{(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}))} \\
&- \frac{1}{(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}))} - \frac{1}{(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}))} \\
&- \frac{1}{(R_2 - i(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}))} - \frac{1}{(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}))} \\
&- \frac{1}{(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}))} - \frac{1}{(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}))} \\
&- \frac{1}{(R_2 - i(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}))} - \frac{1}{(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}))} \\
&- \frac{1}{(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}))} - \frac{1}{(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}))} \\
&- \frac{1}{(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}))} - \frac{1}{(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}))} \\
&- \frac{1}{(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}))} - \frac{1}{(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}))} \\
&- \frac{1}{(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}))} - \frac{1}{(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}))} \\
&- \frac{1}{(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}))} - \frac{1}{(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}))}
\end{aligned}
$$

$$
\begin{aligned}
&= -\frac{R_2 + i\,(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32})^2} - \frac{R_2 + i\,(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32})^2} \\
&- \frac{R_2 + i\,(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32})^2} - \frac{R_2 + i\,(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})^2} \\
&- \frac{R_2 + i\,(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})^2} - \frac{R_2 + i\,(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32})^2} \\
&- \frac{R_2 + i\,(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32})^2} - \frac{R_2 + i\,(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32})^2} \\
&- \frac{R_2 + i\,(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32})^2} - \frac{R_2 + i\,(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32})^2} \\
&- \frac{R_2 + i\,(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32})^2} - \frac{R_2 + i\,(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32})^2} \\
&- \frac{R_2 + i\,(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32})^2} - \frac{R_2 + i\,(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32})^2} \\
&- \frac{R_2 + i\,(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32})^2} - \frac{R_2 + i\,(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32})^2} \\
&- \frac{R_2 + i\,(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31})^2} - \frac{R_2 + i\,(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31})^2} \\
&- \frac{R_2 + i\,(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31})^2} - \frac{R_2 + i\,(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31})^2} \\
&- \frac{R_2 + i\,(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30})}{{R_2}^2 + (\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30})^2} - \frac{R_2 + i\,(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32})}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32})^2} \\
&- \frac{R_2 + i\,(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31})^2} - \frac{R_2 + i\,(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31})^2} \\
&- \frac{R_2 + i\,(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30})^2} - \frac{R_2 + i\,(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30})^2} \\
&- \frac{R_2 + i\,(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30})^2} - \frac{R_2 + i\,(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30})}{R_2 + (\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30})^2} \\
&- \frac{R_2 + i\,(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30})^2} - \frac{R_2 + i\,(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30})}{R_2 + (\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30})^2} \\
&- \frac{R_2 + i\,(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30})^2} - \frac{R_2 + i\,(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30})^2}
\end{aligned}
$$

maka dengan demikian diperoleh :

$$
\begin{aligned}
A(\omega) = & \frac{-R_2}{{R_2}^2 + (\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32})^2} - \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32})^2} \\
& - \frac{R_2}{{R_2}^2 - (\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32})^2} - \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})^2} - \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32})^2} - \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32})^2} - \frac{R_2}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32})^2} - \frac{R_2}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32})^2} - \frac{R_2}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32})^2} - \frac{R_2}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31})^2} - \frac{R_2}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31})^2} - \frac{R_2}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30})^2} - \frac{R_2}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31})^2} - \frac{R_2}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30})^2} - \frac{R_2}{{R_2}^2 + (\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30})^2} - \frac{R_2}{R_2 + (\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30})^2} - \frac{R_2}{R_2 + (\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30})^2} - \frac{R_2}{{R_2}^2 + (\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30})^2}
\end{aligned}
\quad (276)
$$

dan diperoleh juga:

$$
\begin{aligned}
D(\omega) = & \frac{-i(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32})^2} - \frac{i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32})^2} \\
& - \frac{i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32})^2} - \frac{i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})^2} \\
& - \frac{i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})^2} - \frac{i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32})^2} \\
& - \frac{i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32})^2} - \frac{i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32})}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32})^2} \\
& - \frac{i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32})^2} - \frac{i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32})^2} \\
& - \frac{i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32})^2} - \frac{i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32})^2} \\
& - \frac{i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32})^2} - \frac{i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32})^2} \\
& - \frac{i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32})^2} - \frac{i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32})}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32})^2} \\
& - \frac{i(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31})^2} - \frac{i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31})^2} \\
& - \frac{i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31})^2} - \frac{i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31})^2} \\
& - \frac{i(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30})}{{R_2}^2 + (\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30})^2} - \frac{i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32})}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32})^2} \\
& - \frac{i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31})^2} - \frac{i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31})}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31})^2} \\
& - \frac{i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30})^2} - \frac{i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30})^2} \\
& - \frac{i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30})^2} - \frac{i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30})}{R_2 + (\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30})^2} \\
& - \frac{i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30})^2} - \frac{i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30})}{R_2 + (\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30})^2} \\
& - \frac{i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30})^2} - \frac{i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30})}{{R_2}^2 + (\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30})^2}
\end{aligned}
\tag{277}
$$

7.4 Penerapan Algoritma Deutsch jozsa 4 qubit untuk U2 = Us4

apabila diambil kasus untuk $U_2 = I \otimes ([I \otimes \sigma_z] \oplus [\sigma_z \otimes \sigma_z])$ maka diperoleh untuk bentuk operator uniter totalnya adalah sebagai berikut:

$$
\begin{aligned}
U &= U_5 U_2 U_1 \\
&= U_5 \left(\sigma_z \otimes I \otimes I \otimes I\right) U_1 \\
&= \begin{pmatrix}
e^{\beta_0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & e^{\beta_1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & e^{\beta_2} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & e^{\beta_3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & e^{\beta_4} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & e^{\beta_5} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_7} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_9} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_10} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_11} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_12} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_13} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e^{\beta_15}
\end{pmatrix}
\end{aligned}
$$

$$
\times \begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{pmatrix}
$$

$$\times\ \frac{1}{4}\begin{pmatrix}
1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & 1 & -1 & -1 & 1 \\
1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 \\
1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 \\
1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 \\
1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 \\
1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 \\
1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\
1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \\
1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\
1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\
1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\
1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\
1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\
1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1
\end{pmatrix} \tag{278}$$

$$
= \frac{1}{4}\begin{pmatrix}
e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} \\
-e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} \\
e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} \\
-e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} \\
e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} \\
-e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} \\
-e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} \\
e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} \\
e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} \\
-e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} \\
e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} \\
-e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} \\
e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} \\
-e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} \\
-e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} \\
e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}}
\end{pmatrix}
$$

$$U^\dagger = \begin{pmatrix}
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}}
\end{pmatrix} \tag{279}$$

maka dengan demikian kita dapatkan untuk nilai ρ_5 adalah

$$\rho_5 = U\rho_0 U^\dagger$$

$$= \frac{1}{4}\begin{pmatrix}
e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} & -e^{\beta_0} & -e^{\beta_0} & e^{\beta_0} \\
-e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & -e^{\beta_1} & e^{\beta_1} & e^{\beta_1} \\
e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} & e^{\beta_2} & -e^{\beta_2} \\
-e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} & -e^{\beta_3} \\
e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} & -e^{\beta_4} & e^{\beta_4} & e^{\beta_4} & -e^{\beta_4} \\
-e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} & e^{\beta_5} & e^{\beta_5} & -e^{\beta_5} & -e^{\beta_5} \\
-e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} & e^{\beta_6} & -e^{\beta_6} \\
e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} & -e^{\beta_7} \\
e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} & e^{\beta_8} & e^{\beta_8} & -e^{\beta_8} \\
-e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & e^{\beta_9} & -e^{\beta_9} & -e^{\beta_9} \\
e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} & -e^{\beta_{10}} & e^{\beta_{10}} \\
-e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & -e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} & e^{\beta_{11}} \\
e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} & e^{\beta_{12}} & -e^{\beta_{12}} & -e^{\beta_{12}} & e^{\beta_{12}} \\
-e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} & -e^{\beta_{13}} & -e^{\beta_{13}} & e^{\beta_{13}} & e^{\beta_{13}} \\
-e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} & -e^{\beta_{14}} & e^{\beta_{14}} \\
e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}} & e^{\beta_{15}}
\end{pmatrix}$$

$$
\times \begin{pmatrix}
2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -2
\end{pmatrix}
$$

$$
\times \frac{1}{4}
\begin{pmatrix}
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & -e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & -e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & -e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & -e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & -e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & -e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}} \\
-e^{-\beta_0} & e^{-\beta_1} & e^{-\beta_2} & -e^{-\beta_3} & e^{-\beta_4} & -e^{-\beta_5} & e^{-\beta_6} & -e^{-\beta_7} & e^{-\beta_8} & -e^{-\beta_9} & -e^{-\beta_{10}} & e^{-\beta_{11}} & -e^{-\beta_{12}} & e^{-\beta_{13}} & -e^{-\beta_{14}} & e^{-\beta_{15}} \\
e^{-\beta_0} & e^{-\beta_1} & -e^{-\beta_2} & -e^{-\beta_3} & -e^{-\beta_4} & -e^{-\beta_5} & -e^{-\beta_6} & -e^{-\beta_7} & -e^{-\beta_8} & -e^{-\beta_9} & e^{-\beta_{10}} & e^{-\beta_{11}} & e^{-\beta_{12}} & e^{-\beta_{13}} & e^{-\beta_{14}} & e^{-\beta_{15}}
\end{pmatrix}
$$

$$
= \frac{1}{16} \begin{pmatrix}
0 & 8\rho_{0,1} & -8\rho_{0,2} & 0 & 8\rho_{0,4} & 0 & 0 & 0 & 8\rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-8\rho_{1,0} & 0 & 0 & 8\rho_{1,3} & 0 & 8\rho_{1,5} & 0 & 0 & 0 & 8\rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
8\rho_{2,0} & 0 & 0 & -8\rho_{2,3} & 0 & 0 & -8\rho_{2,6} & 0 & 0 & 0 & 8\rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & 8\rho_{3,1} & -8\rho_{3,2} & 0 & 0 & 0 & 0 & -8\rho_{3,7} & 0 & 0 & 0 & 8\rho_{3,11} & 0 & 0 & 0 & 0 \\
8\rho_{4,0} & 0 & 0 & 0 & 0 & -8\rho_{4,5} & -8\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & 8\rho_{4,12} & 0 & 0 & 0 \\
0 & 8\rho_{5,1} & 0 & 0 & -8\rho_{5,4} & 0 & 0 & -8\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & 8\rho_{5,13} & 0 & 0 \\
0 & 0 & -8\rho_{6,2} & 0 & -8\rho_{6,4} & 0 & 0 & -8\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & 8\rho_{6,14} & 0 \\
0 & 0 & 0 & -8\rho_{7,3} & 0 & -8\rho_{7,5} & -8\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 8\rho_{7,15} \\
8\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -8\rho_{8,9} & 8\rho_{8,10} & 0 & 8\rho_{8,12} & 0 & 0 & 0 \\
0 & 8\rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -8\rho_{9,8} & 0 & 0 & 8\rho_{9,11} & 0 & 8\rho_{9,13} & 0 & 0 \\
0 & 0 & 8\rho_{10,2} & 0 & 0 & 0 & 0 & 0 & 8\rho_{10,8} & 0 & 0 & -8\rho_{10,11} & 0 & 0 & -8\rho_{10,14} & 0 \\
0 & 0 & 0 & 8\rho_{11,3} & 0 & 0 & 0 & 0 & 0 & 8\rho_{11,9} & -8\rho_{11,10} & 0 & 0 & 0 & 0 & -8\rho_{11,15} \\
0 & 0 & 0 & 0 & 8\rho_{12,4} & 0 & 0 & 0 & 8\rho_{12,8} & 0 & 0 & 0 & 0 & -8\rho_{12,13} & -8\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 8\rho_{13,5} & 0 & 0 & 0 & -8\rho_{13,9} & 0 & 0 & 8\rho_{13,12} & 0 & 0 & -8\rho_{13,15} \\
0 & 0 & {} & 0 & 0 & 0 & 8\rho_{14,6} & 0 & 0 & 0 & -8\rho_{14,10} & 0 & -8\rho_{14,12} & 0 & 0 & -8\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 8\rho_{15,7} & 0 & 0 & 0 & -8\rho_{15,11} & 0 & -8\rho 15,13 & -8\rho_{15,14} & 0
\end{pmatrix} \tag{280}
$$

$$
= \frac{1}{2} \begin{pmatrix}
0 & \rho_{0,1} & -\rho_{0,2} & 0 & \rho_{0,4} & 0 & 0 & 0 & \rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{1,0} & 0 & 0 & \rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & \rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & -\rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & -\rho_{3,7} & 0 & 0 & 0 & \rho_{3,11} & 0 & 0 & 0 & 0 \\
\rho_{4,0} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{5,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & -\rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{8,9} & \rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & \rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & \rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & \rho_{10,2} & 0 & 0 & 0 & 0 & 0 & \rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & -\rho_{10,14} & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & \rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & -\rho_{13,9} & 0 & 0 & \rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho 15, 13 & -\rho_{15,14} & 0
\end{pmatrix} \tag{281}
$$

dengan

$$
\begin{array}{cc}
\rho_{0,1} = \rho_{1,0}{}^{*} = e^{\beta_0-\beta_1} & \rho_{6,7} = \rho_{7,6}{}^{*} = e^{\beta_6-\beta_7} \\
\rho_{0,2} = \rho_{2,0}{}^{*} = e^{\beta_0-\beta_2} & \rho_{6,14} = \rho_{14,6}{}^{*} = e^{\beta_6-\beta_1 4} \\
\rho_{0,8} = \rho_{8,0}{}^{*} = e^{\beta_8-\beta_1} & \rho_{8,9} = \rho_{9,8}{}^{*} = e^{\beta_8-\beta_9} \\
\rho_{1,3} = \rho_{3,1}{}^{*} = e^{\beta_1-\beta_3} & \rho_{8,10} = \rho_{10,8}{}^{*} = e^{\beta_8-\beta_{10}} \\
\rho_{1,5} = \rho_{5,1}{}^{*} = e^{\beta_1-\beta_5} & \rho_{8,12} = \rho_{12,8}{}^{*} = e^{\beta_8-\beta_{12}} \\
\rho_{1,9} = \rho_{9,1}{}^{*} = e^{\beta_1-\beta_9} & \rho_{9,11} = \rho_{11,9}{}^{*} = e^{\beta_9-\beta_{11}} \\
\rho_{2,3} = \rho_{3,2}{}^{*} = e^{\beta_2-\beta_3} & \rho_{9,13} = \rho_{13,9}{}^{*} = e^{\beta_9-\beta_{13}} \\
\rho_{2,6} = \rho_{6,2}{}^{*} = e^{\beta_2-\beta_6} & \rho_{10,11} = \rho_{11,10}{}^{*} = e^{\beta_{10}-\beta_{11}} \\
\rho_{2,10} = \rho_{10,2}{}^{*} = e^{\beta_2-\beta_1 0} & \rho_{10,14} = \rho_{14,10}{}^{*} = e^{\beta_{10}-\beta_{14}} \\
\rho_{3,7} = \rho_{7,3}{}^{*} = e^{\beta_3-\beta_7} & \rho_{12,13} = \rho_{13,12}{}^{*} = e^{\beta_{12}-\beta_{13}} \\
\rho_{3,11} = \rho_{11,3}{}^{*} = e^{\beta_3-\beta_1 1} & \rho_{12,14} = \rho_{14,12}{}^{*} = e^{\beta_{12}-\beta_{14}} \\
\rho_{4,5} = \rho_{5,4}{}^{*} = e^{\beta_4-\beta_5} & \rho_{11,15} = \rho_{15,11}{}^{*} = e^{\beta_{11}-\beta_{15}} \\
\rho_{4,6} = \rho_{6,4}{}^{*} = e^{\beta_4-\beta_6} & \rho_{13,15} = \rho_{15,13}{}^{*} = e^{\beta_{13}-\beta_{15}} \\
\rho_{4,12} = \rho_{12,4}{}^{*} = e^{\beta_4-\beta_1 2} & \rho_{14,15} = \rho_{14,15}{}^{*} = e^{\beta_{14}-\beta_{15}} \\
\rho_{5,7} = \rho_{7,5}{}^{*} = e^{\beta_5-\beta_7} & \rho_{15,7} = \rho_{7,15}{}^{*} = e^{\beta_7-\beta_{15}} \\
\rho_{5,13} = \rho_{13,5}{}^{*} = e^{\beta_5-\beta_1 3} & \rho_{0,4} = \rho_{4,0}{}^{*} = e^{\beta_0-\beta_4}
\end{array}
\qquad (282)
$$

dan

$$
\begin{aligned}
\beta_0-\beta_1&=-i\left(E_{4,0}-E_{4,1}\right)t & \beta_0-\beta_2&=-i\left(E_{4,0}-E_{4,2}\right)t\\
\beta_0-\beta_4&=-i\left(E_{4,0}-E_{4,4}\right)t & \beta_0-\beta_8&=-i\left(E_{4,0}-E_{4,8}\right)t\\
\beta_1-\beta_3&=-i\left(E_{4,1}-E_{4,3}\right)t & \beta_1-\beta_5&=-i\left(E_{4,1}-E_{4,5}\right)t\\
\beta_1-\beta_9&=-i\left(E_{4,1}-E_{4,9}\right)t & \beta_2-\beta_3&=-i\left(E_{4,2}-E_{4,3}\right)t\\
\beta_2-\beta_6&=-i\left(E_{4,2}-E_{4,6}\right)t & \beta_2-\beta_{10}&=-i\left(E_{4,2}-E_{4,10}\right)t\\
\beta_3-\beta_7&=-i\left(E_{4,3}-E_{4,7}\right)t & \beta_3-\beta_{11}&=-i\left(E_{4,3}-E_{4,11}\right)t\\
\beta_4-\beta_5&=-i\left(E_{4,4}-E_{4,5}\right)t & \beta_4-\beta_6&=-i\left(E_{4,4}-E_{4,6}\right)t\\
\beta_4-\beta_{12}&=-i\left(E_{4,4}-E_{4,12}\right)t & \beta_5-\beta_7&=-i\left(E_{4,5}-E_{4,7}\right)t\\
\beta_5-\beta_{13}&=-i\left(E_{4,5}-E_{4,13}\right)t & \beta_6-\beta_7&=-i\left(E_{4,6}-E_{4,7}\right)t\\
\beta_6-\beta_{14}&=-i\left(E_{4,6}-E_{4,14}\right)t & \beta_8-\beta_9&=-i\left(E_{4,8}-E_{4,9}\right)t\\
\beta_8-\beta_{10}&=-i\left(E_{4,8}-E_{4,10}\right)t & \beta_8-\beta_{12}&=-i\left(E_{4,8}-E_{4,12}\right)t\\
\beta_9-\beta_{11}&=-i\left(E_{4,9}-E_{4,11}\right)t & \beta_9-\beta_{13}&=-i\left(E_{4,9}-E_{4,13}\right)t\\
\beta_{10}-\beta_{11}&=-i\left(E_{4,10}-E_{4,11}\right)t & \beta_{10}-\beta_{14}&=-i\left(E_{4,10}-E_{4,14}\right)t\\
\beta_{12}-\beta_{13}&=-i\left(E_{4,12}-E_{4,13}\right)t & \beta_{12}-\beta_{14}&=-i\left(E_{4,12}-E_{4,14}\right)t\\
\beta_{11}-\beta_{15}&=-i\left(E_{4,11}-E_{4,15}\right)t & \beta_{13}-\beta_{15}&=-i\left(E_{4,13}-E_{4,15}\right)t\\
\beta_{14}-\beta_{15}&=-i\left(E_{4,14}-E_{4,15}\right)t & \beta_{15}-\beta_7&=-i\left(E_{4,15}-E_{4,7}\right)t
\end{aligned} \tag{283}
$$

dan

$$
\begin{array}{ll}
E_{4,0} - E4,1 = \omega_0 + \pi J_{10} + \pi J_{20} + \pi J_{30} & E_{4,0} - E4,2 = \omega_1 + \pi J_{10} + \pi J_{21} + \pi J_{31} \\
E_{4,0} - E4,4 = \omega_2 + \pi J_{20} + \pi J_{21} + \pi J_{32} & E_{4,0} - E4,8 = \omega_3 + \pi J_{30} + \pi J_{31} + \pi J_{32} \\
E_{4,1} - E4,3 = \omega_1 - \pi J_{10} + \pi J_{21} + \pi J_{31} & E_{4,1} - E4,5 = \omega_2 - \pi J_{20} + \pi J_{21} + \pi J_{32} \\
E_{4,1} - E4,9 = \omega_3 - \pi J_{30} + \pi J_{310} + \pi J_{32} & E_{4,2} - E4,3 = \omega_0 - \pi J_{10} + \pi J_{20} + \pi J_{30} \\
E_{4,2} - E4,6 = \omega_2 + \pi J_{20} - \pi J_{21} + \pi J_{32} & E_{4,2} - E4,10 = \omega_3 + \pi J_{30} - \pi J_{31} + \pi J_{32} \\
E_{4,3} - E4,7 = \omega_2 - \pi J_{20} - \pi J_{21} + \pi J_{32} & E_{4,3} - E4,11 = \omega_3 - \pi J_{30} - \pi J_{31} + \pi J_{32} \\
E_{4,4} - E4,5 = \omega_0 + \pi J_{10} - \pi J_{20} + \pi J_{30} & E_{4,4} - E4,6 = \omega_1 + \pi J_{10} - \pi J_{21} + \pi J_{31} \\
E_{4,4} - E4,12 = \omega_3 + \pi J_{30} + \pi J_{31} - \pi J_{32} & E_{4,5} - E4,7 = \omega_1 - \pi J_{10} - \pi J_{21} + \pi J_{31} \\
E_{4,5} - E4,13 = \omega_3 - \pi J_{30} + \pi J_{31} - \pi J_{32} & E_{4,6} - E4,7 = \omega_0 - \pi J_{10} - \pi J_{20} + \pi J_{30} \\
E_{4,6} - E4,14 = \omega_3 + \pi J_{30} - \pi J_{31} - \pi J_{32} & E_{4,8} - E4,9 = \omega_0 + \pi J_{10} + \pi J_{20} - \pi J_{30} \\
E_{4,8} - E4,10 = \omega_1 + \pi J_{21} - \pi J_{31} + \pi J_{30} & E_{4,8} - E4,12 = \omega_2 + \pi J_{20} + \pi J_{21} - \pi J_{32} \\
E_{4,9} - E4,11 = \omega_1 - \pi J_{10} + \pi J_{21} - \pi J_{32} & E_{4,10} - E4,11 = \omega_0 - \pi J_{10} + \pi J_{20} - \pi J_{30} \\
E_{4,10} - E4,14 = \omega_2 + \pi J_{20} - \pi J_{21} - \pi J_{32} & E_{4,12} - E4,13 = \omega_0 + \pi J_{10} - \pi J_{20} - \pi J_{30} \\
E_{4,12} - E4,14 = \omega_1 + \pi J_{10} - \pi J_{21} - \pi J_{31} & E_{4,11} - E4,15 = \omega_2 - \pi J_{20} - \pi J_{21} - \pi J_{32} \\
E_{4,13} - E4,15 = \omega_1 - \pi J_{10} - \pi J_{21} - \pi J_{31} & E_{4,14} - E4,15 = \omega_0 - \pi J_{10} - \pi J_{20} - \pi J_{30} \\
E_{4,9} - E4,13 = \omega_2 - \pi J_{20} + \pi J_{21} - \pi J_{32} & E_{4,15} - E4,7 = \omega_3 + \pi J_{30} + \pi J_{31} + \pi J_{32}
\end{array}
\tag{284}
$$

maka dapat ditentukan nilai magnetisasi dari masing-masing qubitnya yaitu sebagai berikut:

$$(I_{3+}\rho_5) = \begin{pmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}$$

$$
\times \frac{1}{2}
\begin{pmatrix}
0 & \rho_{0,1} & -\rho_{0,2} & 0 & \rho_{0,4} & 0 & 0 & 0 & \rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{1,0} & 0 & 0 & \rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & \rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & -\rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & -\rho_{3,7} & 0 & 0 & 0 & \rho_{3,11} & 0 & 0 & 0 & 0 \\
\rho_{4,0} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{5,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & -\rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{8,9} & \rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & \rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & \rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & \rho_{10,2} & 0 & 0 & 0 & 0 & 0 & \rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & -\rho_{10,14} & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & \rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & -\rho_{13,9} & 0 & 0 & \rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho 15, 13 & -\rho_{15,14} & 0
\end{pmatrix}
$$

$$
= \frac{1}{2}\begin{pmatrix}
\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{8,9} & -\rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & \rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & \rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & \rho_{10,2} & 0 & 0 & 0 & 0 & 0 & \rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & -\rho_{10,14} & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & \rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & 0 & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho_{15,13} & -\rho_{15,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$
\begin{aligned}
M_{3+} &= \langle I_{3+} \rangle = tr\left(I_{3+}\rho_5\right) \\
&= \rho_{8,0} + \rho_{9,1} + \rho_{10,2} + \rho_{11,3} + \rho_{12,4} + \rho_{13,5} + \rho_{14,6} + \rho_{15,7}
\end{aligned}
\tag{285}
$$

dan

$$
(I_{2+}\rho_5) = \begin{pmatrix}
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$
\times \frac{1}{2}
\begin{pmatrix}
0 & \rho_{0,1} & -\rho_{0,2} & 0 & \rho_{0,4} & 0 & 0 & 0 & \rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{1,0} & 0 & 0 & \rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & \rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & -\rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & -\rho_{3,7} & 0 & 0 & 0 & \rho_{3,11} & 0 & 0 & 0 & 0 \\
\rho_{4,0} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{5,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & -\rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{8,9} & \rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & \rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & \rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & \rho_{10,2} & 0 & 0 & 0 & 0 & 0 & \rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & -\rho_{10,14} & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & \rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & -\rho_{13,9} & 0 & 0 & \rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho 15,13 & -\rho_{15,14} & 0
\end{pmatrix}
$$

$$
= \frac{1}{2} \begin{pmatrix}
\rho_{4,0} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{5,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & -\rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & \rho_{12,4} & 0 & 0 & 0 & -\rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & \rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & -\rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & \rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & -\rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & \rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho 15, 13 & \rho_{15,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix} \tag{286}
$$

$$
\begin{aligned}
M_{2+} &= \langle I_{2+} \rangle = tr\left(I_{2+}\rho_5\right) \\
&= \rho_{4,0} + \rho_{5,1} - \rho_{6,2} - \rho_{7,3} + \rho_{12,8} + \rho_{13,9} - \rho_{14,10} - \rho_{15,11}
\end{aligned}
\tag{287}
$$

dan

$$
(I_{1+}\rho_5) = \begin{pmatrix}
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$\times \frac{1}{2} \begin{pmatrix}
0 & \rho_{0,1} & -\rho_{0,2} & 0 & \rho_{0,4} & 0 & 0 & 0 & \rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{1,0} & 0 & 0 & \rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & \rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & -\rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & -\rho_{3,7} & 0 & 0 & 0 & \rho_{3,11} & 0 & 0 & 0 & 0 \\
\rho_{4,0} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{5,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & -\rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{8,9} & \rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & \rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & \rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & \rho_{10,2} & 0 & 0 & 0 & 0 & 0 & \rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & -\rho_{10,14} & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & \rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & -\rho_{13,9} & 0 & 0 & \rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho 15, 13 & -\rho_{15,14} & 0
\end{pmatrix}$$

$$= \frac{1}{2}\begin{pmatrix}
\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & -\rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & -\rho_{3,7} & 0 & 0 & 0 & \rho_{3,11} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & -\rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & \rho_{10,2} & 0 & 0 & 0 & 0 & 0 & \rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & -\rho_{10,14} & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho_{15,13} & -\rho_{15,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix} \tag{288}$$

$$
\begin{aligned}
M_{1+} &= \langle I_{1+} \rangle = tr\left(I_{1+}\rho_5\right) \\
&= \rho_{2,0} + \rho_{3,1} - \rho_{6,4} - \rho_{7,5} + \rho_{10,8} + \rho_{11,9} - \rho_{14,12} - \rho_{15,13}
\end{aligned}
\tag{289}
$$

dan

$$
(I_{0+}\rho_5) = \begin{pmatrix}
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$
\times \frac{1}{2}
\begin{pmatrix}
0 & \rho_{0,1} & -\rho_{0,2} & 0 & \rho_{0,4} & 0 & 0 & 0 & \rho_{0,8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\rho_{1,0} & 0 & 0 & \rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & \rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
\rho_{2,0} & 0 & 0 & -\rho_{2,3} & 0 & 0 & -\rho_{2,6} & 0 & 0 & 0 & \rho_{2,10} & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & -\rho_{3,7} & 0 & 0 & 0 & \rho_{3,11} & 0 & 0 & 0 & 0 \\
\rho_{4,0} & 0 & 0 & 0 & 0 & -\rho_{4,5} & -\rho_{4,6} & 0 & 0 & 0 & 0 & 0 & \rho_{4,12} & 0 & 0 & 0 \\
0 & \rho_{5,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & -\rho_{6,2} & 0 & -\rho_{6,4} & 0 & 0 & -\rho_{6,7} & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{6,14} & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
\rho_{8,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{8,9} & \rho_{8,10} & 0 & \rho_{8,12} & 0 & 0 & 0 \\
0 & \rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & \rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & \rho_{10,2} & 0 & 0 & 0 & 0 & 0 & \rho_{10,8} & 0 & 0 & -\rho_{10,11} & 0 & 0 & -\rho_{10,14} & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & \rho_{12,4} & 0 & 0 & 0 & \rho_{12,8} & 0 & 0 & 0 & 0 & -\rho_{12,13} & -\rho_{12,14} & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & -\rho_{13,9} & 0 & 0 & \rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & {} & 0 & 0 & 0 & \rho_{14,6} & 0 & 0 & 0 & -\rho_{14,10} & 0 & -\rho_{14,12} & 0 & 0 & -\rho_{14,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho 15,13 & -\rho_{15,14} & 0
\end{pmatrix}
$$

$$
= \frac{1}{2}\begin{pmatrix}
-\rho_{1,0} & 0 & 0 & \rho_{1,3} & 0 & \rho_{1,5} & 0 & 0 & 0 & \rho_{1,9} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{3,1} & -\rho_{3,2} & 0 & 0 & 0 & 0 & -\rho_{3,7} & 0 & 0 & \rho_{3,11} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{5,1} & 0 & 0 & -\rho_{5,4} & 0 & 0 & -\rho_{5,7} & 0 & 0 & 0 & 0 & 0 & \rho_{5,13} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -\rho_{7,3} & 0 & -\rho_{7,5} & -\rho_{7,6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{7,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_{9,1} & 0 & 0 & 0 & 0 & 0 & 0 & -\rho_{9,8} & 0 & 0 & \rho_{9,11} & 0 & \rho_{9,13} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \rho_{11,3} & 0 & 0 & 0 & 0 & 0 & \rho_{11,9} & -\rho_{11,10} & 0 & 0 & 0 & 0 & -\rho_{11,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_{13,5} & 0 & 0 & 0 & \rho_{13,9} & 0 & 0 & -\rho_{13,12} & 0 & 0 & -\rho_{13,15} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_{15,7} & 0 & 0 & 0 & -\rho_{15,11} & 0 & -\rho 15,13 & -\rho_{15,14} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix} \tag{290}
$$

$$
\begin{aligned}
M_{0+} &= \langle I_{0+} \rangle = tr\left(I_{0+}\rho_5\right) \\
&= -\left(\rho_{1,0} + \rho_{3,2} + \rho_{5,2} + \rho_{7,6} + \rho_{9,8} + \rho_{11,10} + \rho_{13,12} + \rho_{15,14}\right)
\end{aligned}
\tag{291}
$$

maka dengan demikian nilai magnetisasi total dari sistem adalah sebagai berikut:

$$
\begin{aligned}
M_{tot} &= M_{3+} + M_{2+} + M_{1+} + M_{0+} \\
&= \rho_{8,0} + \rho_{9,1} + \rho_{10,2} + \rho_{11,3} + \rho_{12,4} + \rho_{13,5} + \rho_{14,6} + \rho_{15,7} \\
&+ \rho_{4,0} + \rho_{5,1} - \rho_{6,2} - \rho_{7,3} + \rho_{12,8} + \rho_{13,9} - \rho_{14,10} - \rho_{15,11} \\
&+ \rho_{2,0} + \rho_{3,1} - \rho_{6,4} - \rho_{7,5} + \rho_{10,8} + \rho_{11,9} - \rho_{14,12} - \rho_{15,13} \\
&- \left(\rho_{1,0} + \rho_{3,2} + \rho_{5,4} + \rho_{7,6} + \rho_{9,8} + \rho_{11,10} + \rho_{13,12} + \rho_{15,14}\right) \\
&= e^{i(\omega_3+\pi J_{30}+\pi J_{31}+\pi J_{32})t} + e^{i(\omega_3-\pi J_{30}+\pi J_{31}+\pi J_{32})t} \\
&+ e^{i(\omega_3+\pi J_{30}-\pi J_{31}+\pi J_{32})t} + e^{i(\omega_3-\pi J_{30}-\pi J_{31}+\pi J_{32})t} \\
&+ e^{i(\omega_3+\pi J_{30}+\pi J_{31}-\pi J_{32})t} + e^{i(\omega_3-\pi J_{30}+\pi J_{31}-\pi J_{32})t} \\
&+ e^{i(\omega_3+\pi J_{30}-\pi J_{31}-\pi J_{32})t} + e^{i(\omega_3-\pi J_{30}-\pi J_{31}-\pi J_{32})t} \\
&+ e^{i(\omega_2+\pi J_{20}+\pi J_{21}+\pi J_{32})t} + e^{i(\omega_2-\pi J_{20}+\pi J_{21}+\pi J_{32})t} \\
&- e^{i(\omega_2+\pi J_{20}-\pi J_{21}+\pi J_{32})t} - e^{i(\omega_2-\pi J_{20}-\pi J_{21}+\pi J_{32})t} \\
&+ e^{i(\omega_2+\pi J_{20}+\pi J_{21}-\pi J_{32})t} + e^{i(\omega_2-\pi J_{20}+\pi J_{21}-\pi J_{32})t} \\
&- e^{i(\omega_2+\pi J_{20}-\pi J_{21}-\pi J_{32})t} - e^{i(\omega_2-\pi J_{20}-\pi J_{21}-\pi J_{32})t} \\
&+ e^{i(\omega_1+\pi J_{10}+\pi J_{21}+\pi J_{31})t} + e^{i(\omega_1-\pi J_{10}+\pi J_{21}+\pi J_{31})t} \\
&- e^{i(\omega_1+\pi J_{10}-\pi J_{21}+\pi J_{31})t} - e^{i(\omega_1-\pi J_{10}-\pi J_{21}+\pi J_{31})t} \\
&+ e^{i(\omega_1+\pi J_{21}-\pi J_{31}+\pi J_{30})t} + e^{i(\omega_1-\pi J_{10}+\pi J_{21}-\pi J_{32})t} \\
&- e^{i(\omega_1+\pi J_{10}-\pi J_{21}-\pi J_{31})t} - e^{i(\omega_1-\pi J_{10}-\pi J_{21}-\pi J_{31})t} \\
&- e^{i(\omega_0+\pi J_{10}+\pi J_{20}+\pi J_{30})t} - e^{i(\omega_0-\pi J_{10}+\pi J_{20}+\pi J_{30})t} \\
&- e^{i(\omega_0+\pi J_{10}-\pi J_{20}+\pi J_{30})t} - e^{i(\omega_0-\pi J_{10}-\pi J_{20}+\pi J_{30})t} \\
&- e^{i(\omega_0+\pi J_{10}+\pi J_{20}-\pi J_{30})t} - e^{i(\omega_0-\pi J_{10}+\pi J_{20}-\pi J_{30})t} \\
&- e^{i(\omega_0+\pi J_{10}-\pi J_{20}-\pi J_{30})t} - e^{i(\omega_0-\pi J_{10}-\pi J_{20}-\pi J_{30})t}
\end{aligned}
\tag{292}
$$

kemudian didapatkan juga untuk sinyal FID sebagai berikut:

$$\begin{aligned}
S &= M_{tot} e^{-R_2 t} \\
&= e^{-(R_2 - i(\omega_3 + \pi J_{30} + \pi J_{31} + \pi J_{32}))t} + e^{-(R_2 - i(\omega_3 - \pi J_{30} + \pi J_{31} + \pi J_{32}))t} \\
&+ e^{-(R_2 - i(\omega_3 + \pi J_{30} - \pi J_{31} + \pi J_{32}))t} + e^{-(R_2 - i(\omega_3 - \pi J_{30} - \pi J_{31} + \pi J_{32}))t} \\
&+ e^{-(R_2 - i(\omega_3 + \pi J_{30} + \pi J_{31} - \pi J_{32}))t} + e^{-(R_2 - i(\omega_3 - \pi J_{30} + \pi J_{31} - \pi J_{32}))t} \\
&+ e^{-(R_2 - i(\omega_3 + \pi J_{30} - \pi J_{31} - \pi J_{32}))t} + e^{-(R_2 - i(\omega_3 - \pi J_{30} - \pi J_{31} - \pi J_{32}))t} \\
&+ e^{-(R_2 - i(\omega_2 + \pi J_{20} + \pi J_{21} + \pi J_{32}))t} + e^{-(R_2 - i(\omega_2 - \pi J_{20} + \pi J_{21} + \pi J_{32}))t} \\
&- e^{-(R_2 - i(\omega_2 + \pi J_{20} - \pi J_{21} + \pi J_{32}))t} - e^{-(R_2 - i(\omega_2 - \pi J_{20} - \pi J_{21} + \pi J_{32}))t} \\
&+ e^{-(R_2 - i(\omega_2 + \pi J_{20} + \pi J_{21} - \pi J_{32}))t} + e^{-(R_2 - i(\omega_2 - \pi J_{20} + \pi J_{21} - \pi J_{32}))t} \\
&- e^{-(R_2 - i(\omega_2 + \pi J_{20} - \pi J_{21} - \pi J_{32}))t} - e^{-(R_2 - i(\omega_2 - \pi J_{20} - \pi J_{21} - \pi J_{32}))t} \qquad (293) \\
&+ e^{-(R_2 - i(\omega_1 + \pi J_{10} + \pi J_{21} + \pi J_{31}))t} + e^{-(R_2 - i(\omega_1 - \pi J_{10} + \pi J_{21} + \pi J_{31}))t} \\
&- e^{-(R_2 - i(\omega_1 + \pi J_{10} - \pi J_{21} + \pi J_{31}))t} - e^{-(R_2 - i(\omega_1 - \pi J_{10} - \pi J_{21} + \pi J_{31}))t} \\
&+ e^{-(R_2 - i(\omega_1 + \pi J_{21} - \pi J_{31} + \pi J_{30}))t} + e^{-(R_2 - i(\omega_1 - \pi J_{10} + \pi J_{21} - \pi J_{32}))t} \\
&- e^{-(R_2 - i(\omega_1 + \pi J_{10} - \pi J_{21} - \pi J_{31}))t} - e^{-(R_2 - i(\omega_1 - \pi J_{10} - \pi J_{21} - \pi J_{31}))t} \\
&- e^{-(R_2 - i(\omega_0 + \pi J_{10} + \pi J_{20} + \pi J_{30}))t} - e^{-(R_2 - i(\omega_0 - \pi J_{10} + \pi J_{20} + \pi J_{30}))t} \\
&- e^{-(R_2 - i(\omega_0 + \pi J_{10} - \pi J_{20} + \pi J_{30}))t} - e^{-(R_2 - i(\omega_0 - \pi J_{10} - \pi J_{20} + \pi J_{30}))t} \\
&- e^{-(R_2 - i(\omega_0 + \pi J_{10} + \pi J_{20} - \pi J_{30}))t} - e^{-(R_2 - i(\omega_0 - \pi J_{10} + \pi J_{20} - \pi J_{30}))t} \\
&- e^{-(R_2 - i(\omega_0 + \pi J_{10} - \pi J_{20} - \pi J_{30}))t} - e^{-(R_2 - i(\omega_0 - \pi J_{10} - \pi J_{20} - \pi J_{30}))t}
\end{aligned}$$

dimana $R_2 = \frac{1}{T_2}$

kemudian dapat di cari terlebih dahulu untuk perkalian antara $S\left(t\right)e^{-i\omega t}$ yaitu sebagai berikut:

$$
\begin{aligned}
S\left(t\right)e^{-i\omega t} = {} & e^{-(R_2-i(\omega_3-\omega+\pi J_{30}+\pi J_{31}+\pi J_{32}))t} + e^{-(R_2-i(\omega_3-\omega-\pi J_{30}+\pi J_{31}+\pi J_{32}))t} \\
& + e^{-(R_2-i(\omega_3-\omega+\pi J_{30}-\pi J_{31}+\pi J_{32}))t} + e^{-(R_2-i(\omega_3-\omega-\pi J_{30}-\pi J_{31}+\pi J_{32}))t} \\
& + e^{-(R_2-i(\omega_3-\omega+\pi J_{30}+\pi J_{31}-\pi J_{32}))t} + e^{-(R_2-i(\omega_3-\omega-\pi J_{30}+\pi J_{31}-\pi J_{32}))t} \\
& + e^{-(R_2-i(\omega_3-\omega+\pi J_{30}-\pi J_{31}-\pi J_{32}))t} + e^{-(R_2-i(\omega_3-\omega-\pi J_{30}-\pi J_{31}-\pi J_{32}))t} \\
& + e^{-(R_2-i(\omega_2-\omega+\pi J_{20}+\pi J_{21}+\pi J_{32}))t} + e^{-(R_2-i(\omega_2-\omega-\pi J_{20}+\pi J_{21}+\pi J_{32}))t} \\
& - e^{-(R_2-i(\omega_2-\omega+\pi J_{20}-\pi J_{21}+\pi J_{32}))t} - e^{-(R_2-i(\omega_2-\omega-\pi J_{20}-\pi J_{21}+\pi J_{32}))t} \\
& + e^{-(R_2-i(\omega_2-\omega+\pi J_{20}+\pi J_{21}-\pi J_{32}))t} + e^{-(R_2-i(\omega_2-\omega-\pi J_{20}+\pi J_{21}-\pi J_{32}))t} \\
& - e^{-(R_2-i(\omega_2-\omega+\pi J_{20}-\pi J_{21}-\pi J_{32}))t} - e^{-(R_2-i(\omega_2-\omega-\pi J_{20}-\pi J_{21}-\pi J_{32}))t} \\
& + e^{-(R_2-i(\omega_1-\omega+\pi J_{10}+\pi J_{21}+\pi J_{31}))t} + e^{-(R_2-i(\omega_1-\omega-\pi J_{10}+\pi J_{21}+\pi J_{31}))t} \\
& - e^{-(R_2-i(\omega_1-\omega+\pi J_{10}-\pi J_{21}+\pi J_{31}))t} - e^{-(R_2-i(\omega_1-\omega-\pi J_{10}-\pi J_{21}+\pi J_{31}))t} \\
& + e^{-(R_2-i(\omega_1-\omega+\pi J_{21}-\pi J_{31}+\pi J_{30}))t} + e^{-(R_2-i(\omega_1-\omega-\pi J_{10}+\pi J_{21}-\pi J_{32}))t} \\
& - e^{-(R_2-i(\omega_1-\omega+\pi J_{10}-\pi J_{21}-\pi J_{31}))t} - e^{-(R_2-i(\omega_1-\omega-\pi J_{10}-\pi J_{21}-\pi J_{31}))t} \\
& - e^{-(R_2-i(\omega_0-\omega+\pi J_{10}+\pi J_{20}+\pi J_{30}))t} - e^{-(R_2-i(\omega_0-\omega-\pi J_{10}+\pi J_{20}+\pi J_{30}))t} \\
& - e^{-(R_2-i(\omega_0-\omega+\pi J_{10}-\pi J_{20}+\pi J_{30}))t} - e^{-(R_2-i(\omega_0-\omega-\pi J_{10}-\pi J_{20}+\pi J_{30}))t} \\
& - e^{-(R_2-i(\omega_0-\omega+\pi J_{10}+\pi J_{20}-\pi J_{30}))t} - e^{-(R_2-i(\omega_0-\omega-\pi J_{10}+\pi J_{20}-\pi J_{30}))t} \\
& - e^{-(R_2-i(\omega_0-\omega+\pi J_{10}-\pi J_{20}-\pi J_{30}))t} - e^{-(R_2-i(\omega_0-\omega-\pi J_{10}-\pi J_{20}-\pi J_{30}))t}
\end{aligned} \tag{294}
$$

Transformasi Fourirer dari sinyal FID adalah sebagai berikut:

$$
\begin{aligned}
S(\omega) &= \int_0^{\infty} S(t)\, e^{-i\omega t}\, dt \\
&= \frac{e^{-(R_2 - i(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}))t}}{-(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}))t}}{(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}))t}}{(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}))t}}{-(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}))t}}{(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}))} + \frac{e^{-(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}))t}}{(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}))}
\end{aligned}
$$

$$
\begin{aligned}
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}))t}}{-(R_2 - i(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}))} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}))t}}{-(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}))} \\
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}))t}}{(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}))} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}))t}}{(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}))} \\
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}))t}}{-(R_2 - i(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}))} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}))t}}{-(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}))} \\
&+ \frac{e^{-(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}))t}}{(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}))} + \frac{e^{-(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}))t}}{(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}))} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}))} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}))} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}))} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}))} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}))} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}))} \\
&+ \frac{e^{-(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}))} + \frac{e^{-(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}))t}}{(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}))}
\end{aligned}
$$

$$
\begin{aligned}
&= \frac{1}{(R_2 - i(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}))} + \frac{1}{(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}))} + \frac{1}{(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}))} + \frac{1}{(R_2 - i(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}))} + \frac{1}{(R_2 - i(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}))} + \frac{1}{(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}))} \\
&- \frac{1}{(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}))} - \frac{1}{(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}))} + \frac{1}{(R_2 - i(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}))} \\
&- \frac{1}{(R_2 - i(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}))} - \frac{1}{(R_2 - i(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}))} \\
&+ \frac{1}{(R_2 - i(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}))} + \frac{1}{(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}))} \\
&- \frac{1}{(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}))} - \frac{1}{(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}))} \\
&+ \frac{1}{(R_2 - i(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}))} + \frac{1}{(R_2 - i(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}))} \\
&- \frac{1}{(R_2 - i(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}))} - \frac{1}{(R_2 - i(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}))} \\
&- \frac{1}{(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}))} - \frac{1}{(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}))} \\
&+ \frac{1}{(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}))} + \frac{1}{(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}))} \\
&- \frac{1}{(R_2 - i(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}))} - \frac{1}{(R_2 - i(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}))} \\
&- \frac{1}{(R_2 - i(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}))} - \frac{1}{(R_2 - i(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}))}
\end{aligned}
$$

$$
\begin{aligned}
&= \frac{R_2 + i\left(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32}\right)^2} \\
&- \frac{R_2 + i\left(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32}\right)^2} - \frac{R_2 + i\left(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32}\right)^2} + \frac{R_2 + i\left(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32}\right)^2} \\
&- \frac{R_2 + i\left(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32}\right)^2} - \frac{R_2 + i\left(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31}\right)^2} + \frac{R_2 + i\left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31}\right)^2} \\
&- \frac{R_2 + i\left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31}\right)^2} - \frac{R_2 + i\left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31}\right)^2} \\
&+ \frac{R_2 + i\left(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}\right)}{{R_2}^2 + \left(\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30}\right)^2} + \frac{R_2 + i\left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}\right)}{{R_2}^2 + \left(\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32}\right)^2} \\
&- \frac{R_2 + i\left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31}\right)^2} - \frac{R_2 + i\left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}\right)}{{R_2}^2 + \left(\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31}\right)^2} \\
&- \frac{R_2 + i\left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30}\right)^2} - \frac{R_2 + i\left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30}\right)^2} \\
&- \frac{R_2 + i\left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30}\right)^2} - \frac{R_2 + i\left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}\right)}{R_2 + \left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30}\right)^2} \\
&- \frac{R_2 + i\left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30}\right)^2} - \frac{R_2 + i\left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}\right)}{R_2 + \left(\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30}\right)^2} \\
&- \frac{R_2 + i\left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30}\right)^2} - \frac{R_2 + i\left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}\right)}{{R_2}^2 + \left(\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30}\right)^2}
\end{aligned}
$$

maka dengan demikian diperoleh :

$$
\begin{aligned}
A(\omega) = {} & \frac{R_2}{{R_2}^2 + (\omega_3 - \omega + \pi J_{30} + \pi J_{31} + \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} + \pi J_{31} + \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 - (\omega_3 - \omega + \pi J_{30} - \pi J_{31} + \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} + \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} + \pi J_{31} - \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_3 - \omega + \pi J_{30} - \pi J_{31} - \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_3 - \omega - \pi J_{30} - \pi J_{31} - \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} + \pi J_{21} + \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} + \pi J_{21} + \pi J_{32})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} - \pi J_{21} + \pi J_{32})^2} - \frac{R_2}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} - \pi J_{21} + \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} + \pi J_{21} - \pi J_{32})^2} + \frac{R_2}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} + \pi J_{21} - \pi J_{32})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_2 - \omega + \pi J_{20} - \pi J_{21} - \pi J_{32})^2} - \frac{R_2}{{R_2}^2 + (\omega_2 - \omega - \pi J_{20} - \pi J_{21} - \pi J_{32})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} + \pi J_{21} + \pi J_{31})^2} + \frac{R_2}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} + \pi J_{21} + \pi J_{31})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} - \pi J_{21} + \pi J_{31})^2} - \frac{R_2}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} - \pi J_{21} + \pi J_{31})^2} \\
& + \frac{R_2}{{R_2}^2 + (\omega_1 - \omega + \pi J_{21} - \pi J_{31} + \pi J_{30})^2} + \frac{R_2}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} + \pi J_{21} - \pi J_{32})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_1 - \omega + \pi J_{10} - \pi J_{21} - \pi J_{31})^2} - \frac{R_2}{{R_2}^2 + (\omega_1 - \omega - \pi J_{10} - \pi J_{21} - \pi J_{31})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} + \pi J_{20} + \pi J_{30})^2} - \frac{R_2}{{R_2}^2 + (\omega_0 - \omega - \pi J_{10} + \pi J_{20} + \pi J_{30})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} - \pi J_{20} + \pi J_{30})^2} - \frac{R_2}{R_2 + (\omega_0 - \omega - \pi J_{10} - \pi J_{20} + \pi J_{30})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} + \pi J_{20} - \pi J_{30})^2} - \frac{R_2}{R_2 + (\omega_0 - \omega - \pi J_{10} + \pi J_{20} - \pi J_{30})^2} \\
& - \frac{R_2}{{R_2}^2 + (\omega_0 - \omega + \pi J_{10} - \pi J_{20} - \pi J_{30})^2} - \frac{R_2}{{R_2}^2 + (\omega_0 - \omega - \pi J_{10} - \pi J_{20} - \pi J_{30})^2}
\end{aligned} \tag{295}
$$

dan diperoleh juga:

$$
\begin{aligned}
D\left(\omega\right) = {} & \frac{i\left(\omega_3-\omega+\pi J_{30}+\pi J_{31}+\pi J_{32}\right)}{{R_2}^2+\left(\omega_3-\omega+\pi J_{30}+\pi J_{31}+\pi J_{32}\right)^2}+\frac{i\left(\omega_3-\omega-\pi J_{30}+\pi J_{31}+\pi J_{32}\right)}{{R_2}^2+\left(\omega_3-\omega-\pi J_{30}+\pi J_{31}+\pi J_{32}\right)^2} \\
& +\frac{i\left(\omega_3-\omega+\pi J_{30}-\pi J_{31}+\pi J_{32}\right)}{{R_2}^2+\left(\omega_3-\omega+\pi J_{30}-\pi J_{31}+\pi J_{32}\right)^2}+\frac{i\left(\omega_3-\omega-\pi J_{30}-\pi J_{31}+\pi J_{32}\right)}{{R_2}^2+\left(\omega_3-\omega-\pi J_{30}-\pi J_{31}+\pi J_{32}\right)^2} \\
& +\frac{i\left(\omega_3-\omega-\pi J_{30}-\pi J_{31}+\pi J_{32}\right)}{{R_2}^2+\left(\omega_3-\omega-\pi J_{30}-\pi J_{31}+\pi J_{32}\right)^2}+\frac{i\left(\omega_3-\omega-\pi J_{30}+\pi J_{31}-\pi J_{32}\right)}{{R_2}^2+\left(\omega_3-\omega-\pi J_{30}+\pi J_{31}-\pi J_{32}\right)^2} \\
& +\frac{i\left(\omega_3-\omega+\pi J_{30}-\pi J_{31}-\pi J_{32}\right)}{{R_2}^2+\left(\omega_3-\omega+\pi J_{30}-\pi J_{31}-\pi J_{32}\right)^2}+\frac{i\left(\omega_3-\omega-\pi J_{30}-\pi J_{31}-\pi J_{32}\right)}{{R_2}^2+\left(\omega_3-\omega-\pi J_{30}-\pi J_{31}-\pi J_{32}\right)^2} \\
& +\frac{i\left(\omega_2-\omega+\pi J_{20}+\pi J_{21}+\pi J_{32}\right)}{{R_2}^2+\left(\omega_2-\omega+\pi J_{20}+\pi J_{21}+\pi J_{32}\right)^2}+\frac{i\left(\omega_2-\omega-\pi J_{20}+\pi J_{21}+\pi J_{32}\right)}{{R_2}^2+\left(\omega_2-\omega-\pi J_{20}+\pi J_{21}+\pi J_{32}\right)^2} \\
& -\frac{i\left(\omega_2-\omega+\pi J_{20}-\pi J_{21}+\pi J_{32}\right)}{{R_2}^2+\left(\omega_2-\omega+\pi J_{20}-\pi J_{21}+\pi J_{32}\right)^2}-\frac{i\left(\omega_2-\omega-\pi J_{20}-\pi J_{21}+\pi J_{32}\right)}{{R_2}^2+\left(\omega_2-\omega-\pi J_{20}-\pi J_{21}+\pi J_{32}\right)^2} \\
& +\frac{i\left(\omega_2-\omega+\pi J_{20}+\pi J_{21}-\pi J_{32}\right)}{{R_2}^2+\left(\omega_2-\omega+\pi J_{20}+\pi J_{21}-\pi J_{32}\right)^2}+\frac{i\left(\omega_2-\omega-\pi J_{20}+\pi J_{21}-\pi J_{32}\right)}{{R_2}^2+\left(\omega_2-\omega-\pi J_{20}+\pi J_{21}-\pi J_{32}\right)^2} \\
& -\frac{i\left(\omega_2-\omega+\pi J_{20}-\pi J_{21}-\pi J_{32}\right)}{{R_2}^2+\left(\omega_2-\omega+\pi J_{20}-\pi J_{21}-\pi J_{32}\right)^2}-\frac{i\left(\omega_2-\omega-\pi J_{20}-\pi J_{21}-\pi J_{32}\right)}{{R_2}^2+\left(\omega_2-\omega-\pi J_{20}-\pi J_{21}-\pi J_{32}\right)^2} \\
& +\frac{i\left(\omega_1-\omega+\pi J_{10}+\pi J_{21}+\pi J_{31}\right)}{{R_2}^2+\left(\omega_1-\omega+\pi J_{10}+\pi J_{21}+\pi J_{31}\right)^2}+\frac{i\left(\omega_1-\omega-\pi J_{10}+\pi J_{21}+\pi J_{31}\right)}{{R_2}^2+\left(\omega_1-\omega-\pi J_{10}+\pi J_{21}+\pi J_{31}\right)^2} \\
& -\frac{i\left(\omega_1-\omega+\pi J_{10}-\pi J_{21}+\pi J_{31}\right)}{{R_2}^2+\left(\omega_1-\omega+\pi J_{10}-\pi J_{21}+\pi J_{31}\right)^2}-\frac{i\left(\omega_1-\omega-\pi J_{10}-\pi J_{21}+\pi J_{31}\right)}{{R_2}^2+\left(\omega_1-\omega-\pi J_{10}-\pi J_{21}+\pi J_{31}\right)^2} \\
& +\frac{i\left(\omega_1-\omega+\pi J_{21}-\pi J_{31}+\pi J_{30}\right)}{{R_2}^2+\left(\omega_1-\omega+\pi J_{21}-\pi J_{31}+\pi J_{30}\right)^2}+\frac{i\left(\omega_1-\omega-\pi J_{10}+\pi J_{21}-\pi J_{32}\right)}{{R_2}^2+\left(\omega_1-\omega-\pi J_{10}+\pi J_{21}-\pi J_{32}\right)^2} \\
& -\frac{i\left(\omega_1-\omega+\pi J_{10}-\pi J_{21}-\pi J_{31}\right)}{{R_2}^2+\left(\omega_1-\omega+\pi J_{10}-\pi J_{21}-\pi J_{31}\right)^2}-\frac{i\left(\omega_1-\omega-\pi J_{10}-\pi J_{21}-\pi J_{31}\right)}{{R_2}^2+\left(\omega_1-\omega-\pi J_{10}-\pi J_{21}-\pi J_{31}\right)^2} \\
& -\frac{i\left(\omega_0-\omega+\pi J_{10}+\pi J_{20}+\pi J_{30}\right)}{{R_2}^2+\left(\omega_0-\omega+\pi J_{10}+\pi J_{20}+\pi J_{30}\right)^2}-\frac{i\left(\omega_0-\omega-\pi J_{10}+\pi J_{20}+\pi J_{30}\right)}{{R_2}^2+\left(\omega_0-\omega-\pi J_{10}+\pi J_{20}+\pi J_{30}\right)^2} \\
& -\frac{i\left(\omega_0-\omega+\pi J_{10}-\pi J_{20}+\pi J_{30}\right)}{{R_2}^2+\left(\omega_0-\omega+\pi J_{10}-\pi J_{20}+\pi J_{30}\right)^2}-\frac{i\left(\omega_0-\omega-\pi J_{10}-\pi J_{20}+\pi J_{30}\right)}{R_2+\left(\omega_0-\omega-\pi J_{10}-\pi J_{20}+\pi J_{30}\right)^2} \\
& -\frac{i\left(\omega_0-\omega+\pi J_{10}+\pi J_{20}-\pi J_{30}\right)}{{R_2}^2+\left(\omega_0-\omega+\pi J_{10}+\pi J_{20}-\pi J_{30}\right)^2}-\frac{i\left(\omega_0-\omega-\pi J_{10}+\pi J_{20}-\pi J_{30}\right)}{R_2+\left(\omega_0-\omega-\pi J_{10}+\pi J_{20}-\pi J_{30}\right)^2} \\
& -\frac{i\left(\omega_0-\omega+\pi J_{10}-\pi J_{20}-\pi J_{30}\right)}{{R_2}^2+\left(\omega_0-\omega+\pi J_{10}-\pi J_{20}-\pi J_{30}\right)^2}-\frac{i\left(\omega_0-\omega-\pi J_{10}-\pi J_{20}-\pi J_{30}\right)}{{R_2}^2+\left(\omega_0-\omega-\pi J_{10}-\pi J_{20}-\pi J_{30}\right)^2}
\end{aligned}
\tag{296}
$$

Profil Penulis

Bayu Dwi Hatmoko atau yang lebih akrab dipanggil Bayu dilahirkan di Kota Bojonegoro pada 22 April 1994. Penulis merupakan anak kedua dari tiga bersaudara dari pasangan Bapak Sadiman dan Ibu Yukeshi Y.K. Penulis mengawali pendidikan formal di TK Dharma Wanita Jatiblimbing yang kemudian melanjutkan ke SDN Jatiblimbing II. Penulis menamatkan pendidikan menengah pertama di SMPN 3 Bojonegoro dan melanjutkan di SMAN 4 Bojonegoro. Pada tahun 2012 penulis diterima di jurusan Fisika ITS melalui jalur SNMPTN Tulis yang terdaftar dengan NRP 11 12 100 060. Penulis menggeluti bidang minat Fisika Teori selama berkuliah di Fisika ITS. Sejak SMA hingga masa perkuliahan, penulis aktif dalam kegiatan Karya Ilmiah dan ikut aktif berpartisipasi dalam kompetisi karya ilmiah. Selain itu, penulis juga aktif sebagai asisten dosen Fisika dasar dan asisten labolatorium Fisika Modern dan Gelombang. Harapan besar penulis adalah karya ini bisa bermanfaat bagi orang lain dan diri sendiri sebagai sarana pengembangan potensi diri, serta mampu menjadi pribadi yang lebih beruntung yang berlandaskan ajaran Allah SWT. Penulis lebih suka mengisi waktu luang dengan membaca. Penulis bisa dihubungi melalui email bayuhatmoko49@gmail.com.