TUGAS AKHIR – TF 145565

RANCANG BANGUN SISTEM MONITORING TEMPERATUR PADA MINI PLANT SISTEM *BLENDING* BIOETANOL DAN PREMIUM

FEBY JESSICA AYU
NRP. 2413 031 007

Dosen Pembimbing
Dr. Ir. Ali Musyafa' , M.Sc

PROGRAM STUDI D3 METROLOGI DAN INSTRUMENTASI
JURUSAN TEKNIK FISIKA
Fakultas Teknologi Industri
Institut Teknologi Sepuluh Nopember
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FINAL PROJECT – TF 145565

DESAIN OF TEMPERATURE MONITORING SYSTEM IN MINIPLANT BIOETANOL AND PREMIUM BLENDING SYSTEM

FEBY JESSICA AYU
NRP. 2413 031 007

Counselor Lecturer
Dr. Ir. Ali Musyafa' , M.Sc

DIPLOMA OF METROLOGY AND INSTRUMENTATION ENGINEERING
Department of Engineering Physics
Faculty of Industrial Technology
Sepuluh Nopember Institute of Technology
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Oleh :
FEBY JESSICA AYU
NRP. 2413 031 007

Surabaya, 27 Juli 2016
Mengetahui / Menyetujui

Dosen Pembimbing

Dr. Ir. Ali Musyafa', M.Sc.
NIPN. 19600901 198701 1 001

Ketua Jurusan Teknik Fisika FTI – ITS	Ketua Program Studi D3 Metrologi dan Instrumentasi
[redacted] Muhammad Hatta, ST, Msi, Ph.D.	**Dr. Ir. Purwadi Agus Darwito, M.Sc.**
[redacted]. 19780902 200312 1 002 002	**NIPN. 19620822 198803 1 001**

iii

TUGAS AKHIR

RANCANG BANGUN SISTEM MONITORING TEMPERATUR PADA MINI PLANT SISTEM *BLENDING* BIOETANOL DAN PREMIUM

Diajukan Untuk Memenuhi Salah Satu Syarat
Memperoleh Gelar Ahli Madya
pada
Program Studi D3 Metrologi dan Instrumentasi
Jurusan Teknik Fisika
Fakultas Teknologi Industri
Institut Teknologi Sepuluh Nopember

Oleh :
FEBY JESSICA AYU
NRP. 2413 031 007

Disetujui oleh Tim Penguji Tugas Akhir :

1. Dr. Ir. Ali Musyafa', M.Sc. .... Pembimbing
2. Ir Tutug Dhanardono, M.T .... Ketua Penguji
3. Detak Yan Pratama, S.T, M.Sc .... Dosen Penguji I
4. Arief Abdurrakhman, S.T, M.T. .... Dosen Penguji II
5. Bagus Tris Atmaja, S.T, M.T .... Dosen Penguji III

SURABAYA
27 JULI 2016

iv

RANCANG BANGUN SISTEM MONITORING TEMPERATUR PADA MINI PLANT SISTEM *BLENDING* BIOETANOL DAN PREMIUM

Nama	**:**	**Feby Jessica Ayu**
NRP	**:**	**2413 031 007**
Jurusan	**:**	**Teknik Fisika FTI-ITS Program Studi D3 Metrologi dan Instrumentasi**
Dosen Pembimbing	**:**	**Dr. Ir. Ali Musyafa', M.Sc.**

Abstrak

Telah dirancang alat eksperimen sistem monitoring temperatur pada mini plant sistem *blending* bioetanol dan premium untuk mengetahui pengaruh suhu terhadap waktu pada saat *blending*. Menggunakan sensor termokopel baut tipe K sebagai alat ukur temperatur dan AD595 sebagai rangkaian pengkondisian sinyal. Cara kerja sistem alat eksperimen ini yaitu memonitoring suhu pada saat di *blending*, menggunakan PC sebagai visualisasi data, microsoft visual basic dan LCD 16x2 sebagai display data. Sebelum sensor digunakan dilakukan kalibrasi untuk mengetahui performansi dari sensor. Kalibrasi sensor termokopel menggunakan Alat ukur *Thermometer Digital* yang sudah terkalibrasi, dari hasil kalibrasi didapatkan nilai ketidakpastian pengukuran temperatur dengan hasil Ua_1 = 0,4983, Ua_2 = 0.1162, Ub_1 = 0.00025, Ub_2 = -0,184 Uc = 0,280162. Nilai karakteristik statik dari sensor termokopel baut tipe K diantaranya Range sebesar 10 ^oC – 25^oC, Span sebesar 15^oC, Resolusi sebesar 0,01, Sensitifivitas (K) sebesar 1,0193^oC (Dari data pengujian), Histerisis sebesar 0,13 %, Akurasi sebesar 99,10% dan Kesalahan (*error)* sebesar 0,90%. Dari *blending* bioetanol dan premium dengan perbandingan bioetanol 15% dan premium 95% didapatkan tingkat homogenitas dari campuran tersebut.

Kata kunci : monitoring temperatur, sistem *blending*, termokopel, kalibrasi,

DESAIN OF TEMPERATURE MONITORING SYSTEM IN MINIPLANT BIOETANOL AND PREMIUM BLENDING SYSTEM

Name	***:***	***Feby Jessica Ayu***
NRP	***:***	***2413 031 007***
Department	***:***	***Diploma Program of Metrology and Instrumentation, Engineering Physics FTI-ITS***
Counselor Lecturer	***:***	***Dr. Ir. Ali Musyafa', M.Sc.***

Abstract

It has been designed experimental device temperature monitoring system on the mini plant blending of bioethanol and premium system to determine the effect of temperature on time when blending. Using a K-type thermocouple sensor bolt as a measurement of temperature and AD595 as a signal conditioning circuit. The system works this experimental device that is monitoring temperature at the time in the blending , use the PC as data visualization , microsoft visual basic and 16x2 LCD as the display of data. Before the calibration sensor is used to determine the performance of the sensor. Thermocouple sensor calibration using Thermometer Digital measuring instrument that has been calibrated , the calibration results obtained from the value of the uncertainty of temperature measurement results Ua_1 = *0,4983,* Ua_2 = *0.1162,* Ub_1 = *0.00025,* Ub_2 = *-0,184 Uc = 0,280162. Values of the static characteristics of type K thermocouple sensor bolt including Range 10* ^oC *–* 25^oC*, Span* 15^oC*, Resolution sebesar 0,01, Sensitifivitas (K)* 1,0193^oC *(From the test data), hysteresis 0,13 %, Accuracy* 99,10% *and Errors (error)* 0,90%. *From the blending of bioethanol and premium with a ratio of 15 % bioethanol and 95 % earned premium level of homogeneity of the mixture.*

Keywords : monitoring of temperature , blending systems , thermocouples , calibration

DAFTAR ISI

DAFTAR TABEL

DAFTAR GAMBAR

BAB I
PENDAHULUAN

1.1 Latar Belakang

Bahan bakar minyak memiliki peran yang penting dalam kehidupan manusia. Penggunaan BBM yang meningkat diakibatkan oleh kemajuan ekonomi saat ini. Adapun kebijakan pemerintah untuk mengendalikan BBM bersubsidi dan membatasi konsumsi BBM. Tetapi perlu waktu karena pembatasan itu sebaiknya dilakukan secara alami. Pembatasan BBM secara alami akan terjadi jika telah tersedia energi lainnya yang lebih murah untuk rakyat di luar BBM. Pemerintah telah memiliki Perpres No.5/2006 tentang Kebijakan Energi Nasional (KEN) untuk mewujudkan ketahanan energi nasional. Dimana salah satu sasarannya ialah mewujudkan bauran energi primer dalam peningkatan penggunaan bahan bakar nabati, khususnya bioetanol untuk mencampur premium yang akan digalakkan sampai tahun 2025. Dalam rencana bauran energi itu ditetapkan peningkatan penggunaan bioetanol sebagai campuran bahan bakar kendaraan non diesel sampai mencapai 15 % etanol dalam campuran. Sedangkan pada tahun ini kadar bioetanol yang digunakan masih sebesar 2 %.

Hal inilah yang mendasari perancangan mini *plant* sistem *blending* dimana nantinya akan didapatkan suatu produk dari hasil pengaruh pencampuran bioetanol sebesar 15 % dengan premium yang bertujuan untuk mengetahui tingkat homogenitas pada kedua jenis campuran tersebut. Bioetanol adalah sebuah bahan bakar alternatif yang diolah dari tumbuhan, dimana memiliki keunggulan mampu menurunkan emisi CO2 hingga 18 %. Sedangkan premium adalah bahan bakar kendaraan bermotor yang berwarna kuning yang jernih. Dalam hal ini proses blending tentu membutuhkan sistem monitoring temperatur untuk mengetahui suhu pada saat di blending. Oleh karena itu, pada tugas akhir ini akan membahas mengenai bagaimana merancang dan menerapkan sistem monitoring temperatur pada mini *plant* sistem *blending* bioetanol dan premium dengan menggunakan sensor suhu yaitu termokopel yang digunakan untuk mendeteksi atau mengukur temperatur pada sistem blending bioetanol dan premium karena responnya yang cepat terhadap perubahaan suhu dan juga rentang suhu operasionalnya yang luas, serta sensor termokopel ini juga tahan terhadap getaran.

1.2 Permasalahan

Permasalahan yang diangkat dalam tugas akhir ini adalah bagaimana merancang dan membangun sistem monitoring temperatur pada mini plant sistem *blending* bioetanol dan premium.

1.3 Tujuan

Tujuan utama dari tugas akhir ini adalah untuk membuat sistem monitoring temperatur pada mini plant sistem *blending* bioetanol dan premium yang terintegrasi dari sensor termokopel berbasis mikrokontroler Arduino Uno.

1.4 Batasan Masalah

Pengerjaan tugas akhir ini memerlukan beberapa batasan masalah untuk lebih memfokuskan penyelesaian permasalahan, batasan masalah tersebut adalah sebagai berikut:

1. Sensor temperatur yang digunakan adalah sensor termokopel baut tipe K
2. Mikrokontroller yang digunakan pada monitoring termperatur ini berupa Arduino Uno
3. Display pada monitoring ini berupa *Liquid Crystal Display* (LCD) dan *Visual Basic*

1.5 Manfaat

Manfaat yang didapatkan pada penyelesaian tugas akhir ini adalah sebagai sistem monitoring temperatur sistem *blending* bioetanol dan premium berbasis mikrokontroler Arduino Uno menggunakan sistem komunikasi data Visual Studio 2013 dan data disimpan secara otomatis pada Microsoft Excel. Produk dari hasil *blending* bioetanol dan premium tersebut didapatkan tingkat homogenitasnya.

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BAB II
TEORI PENUNJANG

2.1 Sistem *Blending*

Proses *blending* adalah penambahan dan pencampuran bahan-bahan aditif kedalam fraksi minyak bumi dalam rangka untuk meningkatkan kualitas produk. Bensin yang memiliki berbagai persyaratan kualitas merupakan contoh hasil minyak bumi yang paling banyak digunakan di berbagai negara dengan berbagai variasi cuaca. Untuk memenuhi kualitas bensin yang baik, terdapat sekitar 22 bahan pencampur yang dapat ditambahkan pada proses pengolahannya. Salah satu bahan yang dapat dicampur atau di *blending* adalah bioetanol dan premium.[1]

2.2 Teori Temperatur

Temperatur merupakan salah satu besaran dasar yang diakui oleh Sistem Pengukuran Internasional. Temperatur adalah kondisi penting dari suatu substrat. Temperatur adalah ukuran perbandingan dari panas tersebut. Pada aplikasi pendeteksian atau pengukuran tertentu pemilihan jenis sensor suhu perlu diperhatikan sehubungan dengan pemilihan jenis sensor suhu adalah level suhu maksimum dan minimum dari suatu substrat yang diukur. [2]

2.3 Bioetanol

Bioetanol merupakan bahan bakar dari tumbuhan yang memiliki sifat menyerupai minyak premium. Bioethanol adalah ethanol yang diproduksi dari tumbuhan dan dari fermentasi glukosa (gula) yang dilanjutkan dengan proses distilasi. Proses distilasi dapat menghasilkan etanol dengan kadar 95% volume, untuk digunakan sebagai bahan bakar (*biofuel*) perlu lebih dimurnikan lagi hingga mencapai 99 % yang lazim disebut fuel grade etanol. Bioetanol tidak saja menjadi alternatif yang sangat menarik untuk substitusi bensin, namun mampu juga menurunkan emisi CO_2. Dalam hal prestasi mobil, bioethanol dan gasohol (kombinasi bioetanol dan bensin) tidak kalah dengan bensin. Pada dasarnya pembakaran bioethanol tidak menciptakan CO_2 netto ke lingkungan karena zat yang sama akan diperlukan untuk pertumbuhan tanaman sebagai bahan baku bioetanol. Bioetanol bisa didapat dari tanaman seperti tebu, jagung, gandum, singkong, padi, lobak, gandum hitam.[1]

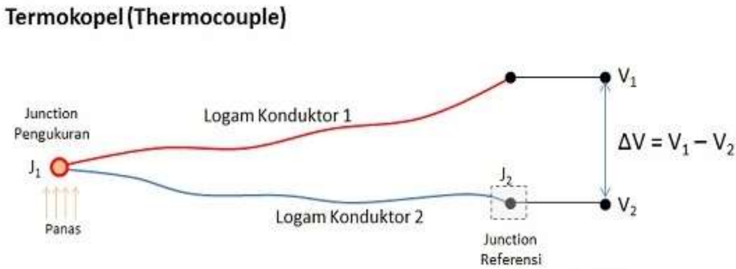
2.4 Premium

Premium adalah bahan bakar minyak jenis distilat berwarna kekuningan yang jernih. Premium merupakan BBM dengan oktan atau *Research Octane Number* (RON) terendah di antara BBM untuk kendaraan bermotor lainnya, yakni hanya 88. Pada umumnya, Premium digunakan untuk bahan bakar kendaraan bermotor bermesin bensin, seperti: mobil, sepeda motor, motor tempel, dan lain-lain. Premium menggunakan tambahan pewarna dye, mempunyai Nilai Oktan 88 dan menghasilkan NOx dan Cox dalam jumlah banyak.

2.5 Termokopel

Termokopel merupakan salah satu jenis sensor suhu yang paling populer dan sering digunakan dalam berbagai rangkaian ataupun peralatan listrik dan Elektronika yang berkaitan dengan Suhu (Temperatur). Beberapa kelebihan Termokopel yang membuatnya menjadi populer adalah responnya yang cepat terhadap perubahaan suhu dan juga rentang suhu operasionalnya yang luas yaitu berkisar diantara -200˚C hingga 2000˚C. Selain respon yang cepat dan rentang suhu yang luas, Termokopel juga tahan terhadap goncangan/getaran dan mudah digunakan.

Prinsip kerja Termokopel cukup mudah dan sederhana. Pada dasarnya Termokopel hanya terdiri dari dua kawat logam konduktor yang berbeda jenis dan digabungkan ujungnya. Satu jenis logam konduktor yang terdapat pada Termokopel akan berfungsi sebagai referensi dengan suhu konstan (tetap) sedangkan yang satunya lagi sebagai logam konduktor yang mendeteksi suhu panas. [3]



Gambar 2.1 Prinsip Kerja Termokopel

Berdasarkan Gambar 2.1, ketika kedua persimpangan atau Junction memiliki suhu yang sama, maka beda potensial atau tegangan listrik yang melalui dua persimpangan tersebut adalah "NOL" atau V1 = V2. Akan tetapi, ketika persimpangan yang terhubung dalam rangkaian diberikan suhu panas atau dihubungkan ke obyek pengukuran, maka akan terjadi perbedaan suhu diantara dua persimpangan tersebut yang kemudian menghasilkan tegangan listrik yang nilainya sebanding dengan suhu panas yang diterimanya atau V1 – V2. Tegangan Listrik yang ditimbulkan ini pada umumnya sekitar 1 µV – 70µV pada tiap derajat Celcius. [8]

Termokopel tersedia dalam berbagai ragam rentang suhu dan jenis bahan. Pada dasarnya, gabungan jenis-jenis logam konduktor yang berbeda akan menghasilkan rentang suhu operasional yang berbeda pula.

Gambar 2.2 Bentuk fisik Termokopel

Komponen utama dari *thermocouple* adalah dua jenis logam konduktor listrik yang berbeda yang dirangkai sedemikian rupa sehingga pada saat salah satu logam terkena sumber panas, sedangkan logam yang lain dijaga di temperatur yang tetap, maka rangkaian tersebut akan menghasilkan tegangan listrik tertentu yang nilainya sebanding dengan temperatur sumber panas. Penentuan kombinasi logam konduktor yang digunakan pada *thermocouple* mempengaruhi besar energi listrik yang akan dibangkitkan. Penentuan nilai tegangan listrik dari beberapa kombinasi konduktor dapat digambarkan pada grafik di bawah ini, data tersebut didapatkan dari pengujian laboratorium. Karakteristik yang berbeda-beda dari setiap kombinasi logam konduktor ini akan bermanfaat bagi kita dalam menentukan *thermocouple* yang tepat untuk digunakan pada berbagai rentan temperatur dan media yang berbeda-beda.

Komponen konduktor *thermocouple* dapat dirangkai secara seri maupun paralel sesuai dengan kebutuhan yang ada. Jika dirangkai secara seri, maka nilai tegangan total adalah jumlah dari keseluruhan tegangan yang dibangkitkan oleh masing-masing pasangan konduktor. Sedangkan jika disusun secara paralel, dan dengan syarat tiap-tiap pasangan konduktor memiliki nilai tahanan yang sama, maka besar tegangan total yang dibangkitkan adalah nilai rata-rata dari tegangan yang dibangkitkan oleh masing-masing konduktor. Kemampuan *thermocouple* untuk dirangkai secara seri maupun paralel ini bermanfaat pada saat dibutuhkannya pengukuran temperatur dengan rentan yang kecil serta ketelitian yang tinggi.

2.6 Arduino Uno

Arduino Uno adalah *board* mikrokontroler berbasis ATMega328. Arduino Uno memiliki 14 pin *input* dan *output* digital dengan sebanyak enam pin *input* tersebut dapat digunakan sebagai *output Pulse Widht Modulation* (PWM) dan 6 pin *input* analog, 16 MHz osilator kristal, koneksi USB, jack power, ICSP header, dan tombol reset. Untuk mendukung mikrokontroler agar dapat digunakan, cukup hanya menghubungkan *board* Arduino

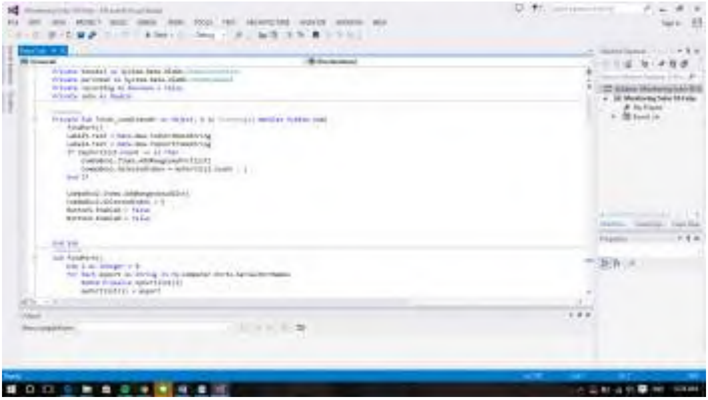
Uno ke komputer dengan menggunakan kabel USB dan AC adaptor sebagai suplai atau baterai untuk menjalankannya (Guntoro, 2013).

Gambar 2.3 Bentuk fisik Arduino Uno

2.7 *Microsoft Visual Studio* 2013

Microsoft Visual Studio merupakan sebuah perangkat lunak lengkap (*suite*) yang dapat digunakan untuk melakukan pengembangan aplikasi, baik itu aplikasi bisnis, aplikasi personal, ataupun komponen aplikasinya, dalam bentuk aplikasi console, aplikasi Windows, ataupun aplikasi Web.

Microsoft Visual Studio dapat digunakan untuk mengembangkan aplikasi dalam *native code* (dalam bentuk bahasa mesin yang berjalan di atas Windows) ataupun *managed code* (dalam bentuk *Microsoft Intermediate Language* di atas .NET Framework). Selain itu, *Visual Studio* juga dapat digunakan untuk mengembangkan aplikasi Silverlight, aplikasi *Windows Mobile* (yang berjalan di atas .NET Compact Framework).[4]



Gambar 2.4 *Software* Visual Basic 2013

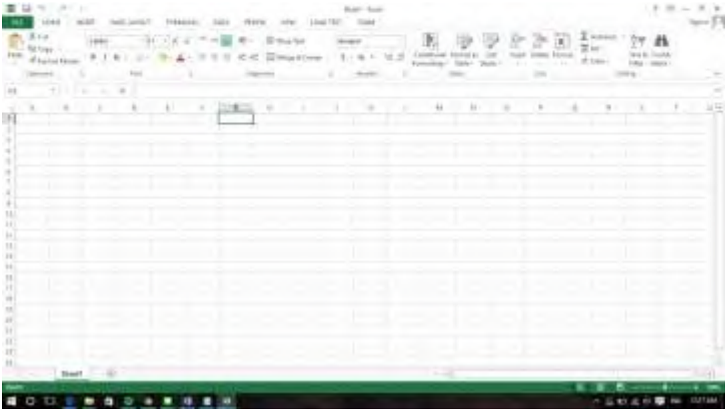
2.8 Microsoft Excel

Microsoft Excel adalah aplikasi untuk mengolah data secara otomatis yang dapat berupa perhitungan dasar, rumus, pemakaian fungsi-fungsi, pengolahan data dan tabel, pembuatan grafik dan menajemen data. Pemakaian rumus dapat berupa penambahan, pengurangan, perkalian dan lain sebagainya. Sedangkan pemakaian fungsi-fungsi dapat berupa pemakaian rumus yang bertujuan untuk menghitung dalam bentuk rumus matematika maupun non matematika

Salah satu fungsi dan kegunaan MS Excel adalah dapat digunakan untuk *data* base. Di dalam MS Excel, Data Base adalah suatu *range* yang terdiri dari *cell-cell* yang minimal memiliki satu kolom dan harus lebih dari dua baris. Beberapa istilah yang harus diketahui pada *Data Base*. Berikut ini adalah beberapa istilah di dalam membuat sebuah data base dengan MS Excel :

1. Field
   Field dalam data base Excel dapat kita katakan sebagai kolom.
2. Judul Field
   Judul Field adalah judul dari kolom tersebut.
3. Record

Isi dari kolom Excel, atau jika kita blok beberapa cell dan menjadi cell range maka itu lah yang dinamakan



Gambar 2.5 *Software* Microsoft Excel

2.9 Pengkondisi Sinyal Termokopel

Rangkaian pengkondisi sinyal berfungsi untuk mengolah sinyal dari transduser termokopel berupa tegangan yang cukup kecil menjadi tegangan yang lebih besar, sehingga output dari rangkaian ini dapat dibaca oleh untai *Analog Digital Converter* (ADC). Pada Tugas Akhir Sistem *Blending* Bioetanol dan Premium menggunakan rangkaian penguat dengan dua IC[9], yaitu:

1. AD595

   AD595 adalah *amplifier-compensator linier* yang terdapat pada suatu chip monolitas yang menghasilkan keluaran 10mV/C secara langsung dari termokopel. Berikut adalah bentuk fisik dari IC AD595:

Gambar 2.6 Bentuk fisik AD595

2. LM358
   LM358 adalah IC penguat operasional ganda (dual operational *amplifiers / Op-Amps*). Berikut merupakan bentuk fisik dari LM358:

Gambar 2.7 Bentuk fisik LM358

2.10 *Liquid Cristal Display* (LCD)

Liquid Cristal Display (LCD) adalah salah satu jenis display elektronik yang dibuat dengan teknologi CMOS logic yang bekerja dengan tidak menghasilkan cahaya tetapi memantulkan cahaya yang ada di sekelilingnya terhadap front-lit atau mentransmisikan cahaya dari back-lit.

Gambar 2.8 Bentuk fisik LCD 16x2

2.11 Teori Kalibrasi

Kalibrasi adalah kegiatan untuk menentukan kebenaran konvensional nilai penunjukkan alat ukur dan bahan ukur dengan cara membandingkan terhadap standar ukur yang mampu telusur (traceable) ke standar nasional maupun internasionaluntuk satuan ukuran dan/atau internasional dan bahan-bahan acuan tersertifikasi. [6] Tujuan kalibrasi yaitu:

1. Mencapai ketertelusuran pengukuran. Hasil pengukuran dapat dikaitkan/ditelusur sampai ke standar yang lebih tinggi/teliti (standar primer nasional dan / internasional), melalui rangkaian perbandingan yang tak terputus.
2. Menentukan deviasi (penyimpangan) kebenaran nilai konvensional penunjukan suatu instrument ukur.
3. Menjamin hasil-hasil pengukuran sesuai dengan standar Nasional maupun Internasional.

Manfaat kalibrasi adalah sebagai berikut:

1. Menjaga kondisi instrumen ukur dan bahan ukur agar tetap sesuai dengan spesefikasinya
2. Untuk mendukung sistem mutu yang diterapkan di berbagai industri pada peralatan laboratorium dan produksi yang dimiliki.
3. Bisa mengetahui perbedaan (penyimpangan) antara harga benar dengan harga yang ditunjukkan oleh alat ukur.[7]

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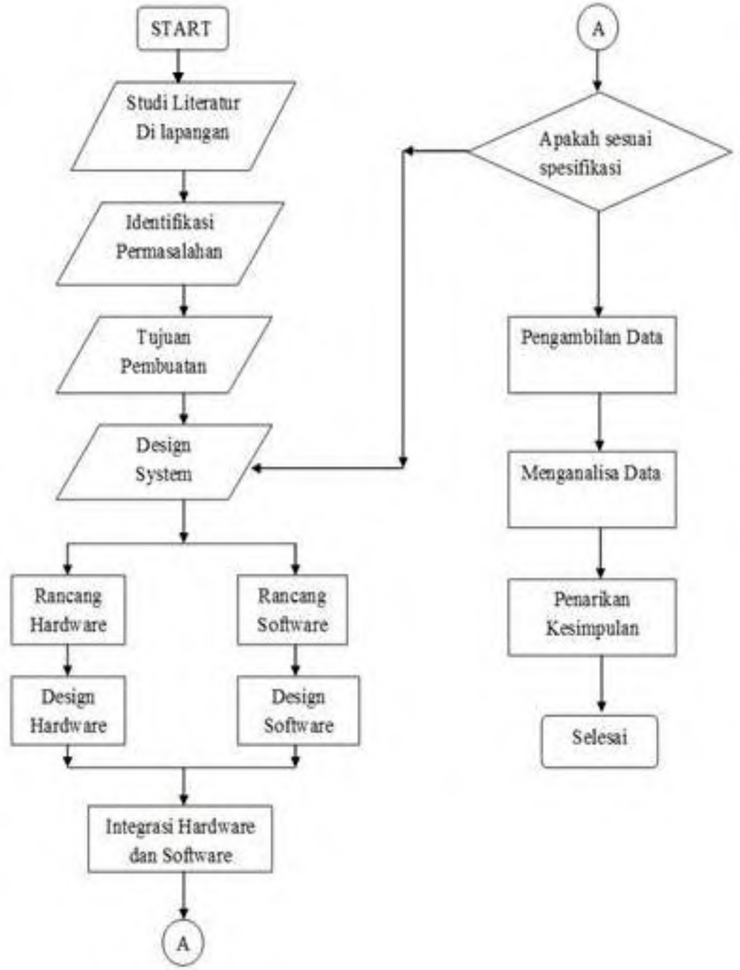
BAB III
PERANCANGAN DAN PEMBUATAN SISTEM

Tahapan-tahapan perancangan alat dalam tugas akhir ini digambarkan dalam *Flowchart* pada Gambar 3.1



Gambar 3.1 *Flowchart* Pengerjaan Tugas Akhir

3.1 Studi Literatur

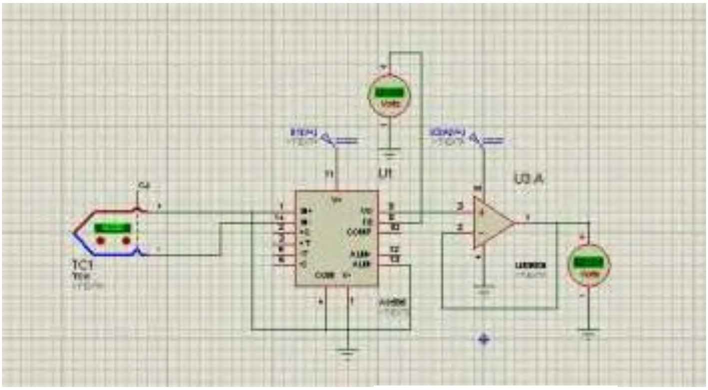
Dalam pembuatan alat eksperimen *blending* bioetanol dan premium, diawali dengan melakukan studi literatur mengenai perancangan alat eksperimen dan teori tentang temperatur liquid pada tangki yang tertutup, agar didapatkan pemahaman terhadap materi yang menunjang tugas akhir. Sumber literatur didapatkan dari buku-buku pendukung, *website*, dan jurnal ilmiah sebagai media informasi penunjang tugas akhir.

3.2 Perancangan Sistem dan Pembuatan Alat Eksperimen

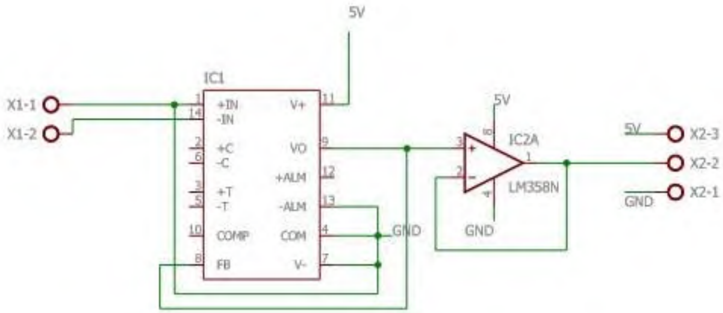
Perancangan sistem dan pembuatan alat eksperimen *blending* bioetanol dan premium terdiri dari pembuatan *hardware*, pembuatan *software*, serta pembuatan mekanik alat eksperimen *blending* bioetanol dan premium. *Hardware* dan *software* yang telah dibuat kemudian diintegrasikan melalui mikrokontroller Arduino Uno. Selanjutnya diintegrasikan dengan mekanik alat eksperimen *blending* bioetanol dan premium agar dapat bekerja.

3.2.1 Pembuatan *Hardware*

Pada pembuatan *hardware* dimulai dari mengintegrasikan sensor termokopel dan rangkaian penguat sinyal ke Arduiono Uno yang berfungsi sebagai kontroler. Kemudian *output* pembacaan termokopel ditampilkan pada *display* LCD dimana rangkaian LCD terhubung dengan Arduino Uno. Rangkaian penguat sinyal berfungsi untuk mengolah sinyal dari transduser termokopel berupa tegangan yang cukup kecil menjadi tegangan yang lebih besar, sehingga *output* dan rangkaian ini dapat dibaca oleh untai *Analog Digital Converter* (ADC).



Gambar 3.2 Rangkaian sensor termokopel



Gambar 3.3 Rangkaian AD595

Gambar 3.4 Bentuk Fisik Rangkaian AD595

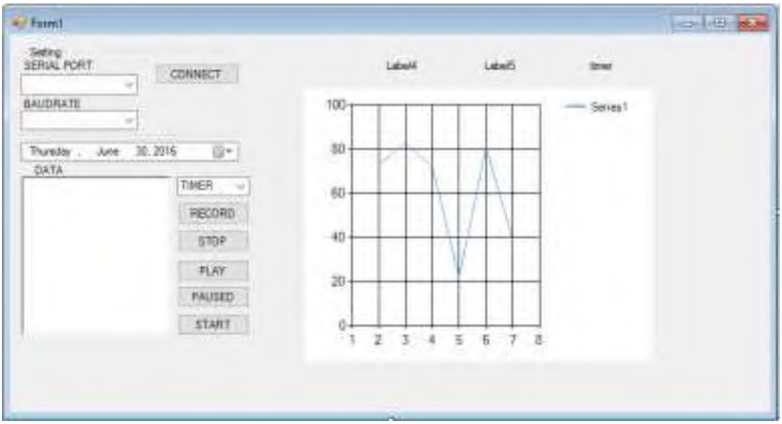
3.2.2 Pembuatan *Software*

Setelah melakukan perancangan dan pembuatan pada bagian perangkat keras, maka perlu dilakukan perancangan perangkat lunak yang terdiri dari dua tahap. Tahap pertama merupakan perancangan pernagkat lunak dari program kontroler agar pembacaan sensor dapat melakukan pembacaan atau sensing.

Perancangan program ini dilakukan pada software Arduino seperti pada gambar 3.5 di bawah ini. Software ini digunakan untuk memprogram mikrokontroler yang berfungsi untuk memproses data dari sensor-sensor. Dalam melakukan pemrograman arduino diperlukan penginisialisasian dari variabel-variabel yang akan digunakan.

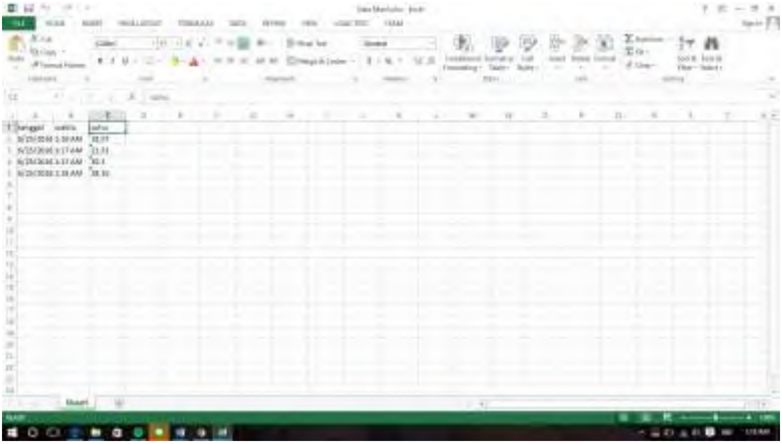
Gambar 3.5 *Software* Arduino Uno

Setelah menyelesaikan program pada mikrokontroler Arduino Uno, juga dilakukan perancangan perangkat lunak sebagai media interface data-data yang didapatkan. Dalam perancangan perangkat lunak ini digunakan software Visual Basic 2013 untuk melakukan perancangan software VB dilakukan dua tahap, yakni perancangan tampilan yang akan menunjukkan nilai-nilai variabel dan selanjutnya melakukan pemrograman agar VB dapat berkomunikasi dengan mikrokontroler, sehingga nilai yang diproses oleh mikrokontroler dapat ditampilkan pada VB. Selain itu juga dilakukan penyimpanan data-data di database melalui VB selama dilakukan running untuk dapat dipantau temperatur saat *blending* bioetanol dan premium setiap 30 detik selama 5 menit, 10 menit dan 15 menit.



Gambar 3.6 Tampilan Software Visual Basic .Net

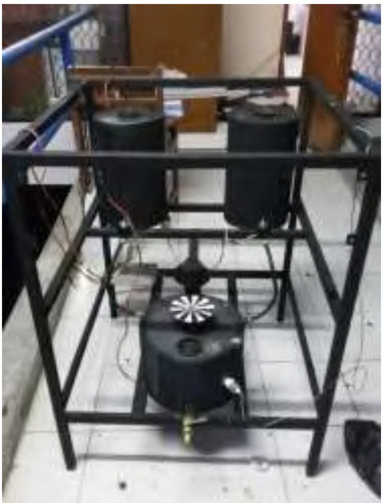
Pada tugas akhir ini proses penyimpanan data pada database Microsoft Excel menggunakan *Access Database Engine* yang telah diaktifkan terlebih dahulu. Data dari visual basic akan tersimpan otomatis pada Microsoft Excel. Berikut ini merupakan tampilan dari database Microsoft Excel:



Gambar 3.7 Tampilan *Software* Microsoft Excel

3.2.3 Perancangan Mekanik

Perancangan mekanik meliputi pembuatan sistem *blending* bioetanol dan premium serta pemasangan termokopel pada tangki *blending*.



Gambar 3.8 Mini Plant Sistem Blending Bioetanol dan Premium

Gambar 3.9 Letak Pemasangan Sensor Termokopel pada tangki

3.3 Integrasi

Pengintegrasian dilakukan agar antara hardware, software dan rancang bangun mekanik plant dapat menjadi satu kesatuan ketika alat difungsikan. Langkah awal yaitu dengan mengintegrasikan hardware yang berupa sensor Termokopel, rangkaian LCD dan juga arduino uno dengan mekanik yaitu berupa tangki untuk blending. Setelah itu, arduino akan dihubungkan dengan software visual basic 2013 untuk tampilan yang lebih mudah dimengerti oleh pengguna.

3.4 Pengujian Alat dan Sistem Monitoring

Pengujian dilakukan dengan memeriksa nilai keluaran pada serial monitor melalui software Arduino. Apabila terjadi kesalahan pembacaan atau data tidak muncul, maka dilakukan troubleshoot dengan melakukan pengecekan wiring dan listing program. Setelah melakukan pengujian dan troubleshoot pada program mikrokontroler, selanjutnya melakukan koneksi serial antara mikrokontroler dengan Visual Basic .Net sebagai media interface akuisisi data. Pengujian koneksi serial ini untuk mengetahui apakah VB telah menampilkan informasi yang diinginkan terhadap sistem *blending* bioetanol dan premium.

Pada sistem monitoring temperatur *blending* bioetanol dan premium diuji coba dengan cara mengisi tangki pertama premium dan tangki kedua bioetanol kemudian tangki ketiga yaitu campuran bioetanol dan premium dengan perbandingan bioetanol 15% dan premium 85%. Percobaan ini bertujuan untuk mengetahui perbandingan suhu yang terjadi ketika *blending* selama 5 menit, 10 menit dan 15 menit. Apabila semua sistem monitoring serta rangkaian mekanik dapat bekerja dengan baik, maka selanjutnya dilakukan pengambilan data monitoring temperatur.

3.5 Pengambilan Data Temperatur

Pada bagian ini dilakukan kalibrasi sebelum monitoring temperatur, setelah sensor terkalibrasi baru dilakukan pengambilan data monitoring temperatur pada saat *blending* untuk memperoleh data dari sensor yang telah terintegrasi..

3.6 Analisis Data dan Pembahasan

Setelah selesai pengambilan data dilakukan analisis data dengan mengolah data untuk mengetahui karakteristik dari sensor serta perbandingan suhu terhadap waktu dan pembahasannya

3.7 Penulisan Laporan

Setelah semua hasil yang diinginkan tercapai kemudian semua hasil mulai dari studi literatur sampai dengan analisa data dan kesimpulan dicantumkan dalam sebuah laporan.

BAB IV
ANALISIS DATA DAN PEMBAHASAN

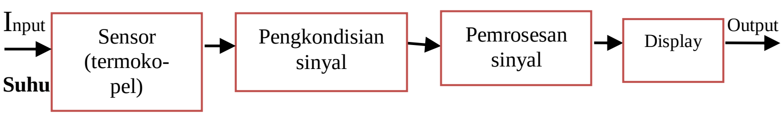
Pada bab ini dilakukan analisa dan pembahasan dari pengujian data. Analisa dan pembahasan dilakukan berdasarkan data yang diperoleh pada sistem monitoring temperatur sistem *blending* bioetanol dan premium. Data-data tersebut menunjukkan temperatur dari campuran bioetanol dan premium saat di *blending*.

4.1. Uji Komponen Sistem

Untuk mengetahui dan menganalisa sensor yang digunakan dan rangkaian yang telah dibuat agar dapat berfungsi dengan baik diperlukan adanya pengujian terhadap rangkaian yang telah dibuat. Berikut ini adalah pengujian yang dilakukan terhadap masing-masing komponen pendukung sistem monitoring temperatur

4.1.1 Sensor Termokopel Baut Tipe K

Pada perancangan sensor termokopel baut tipe k ini hendaknya sesuai dengan diagram blok pengukuran. Dimulai dari input sensor yang berupa tegangan (V) yang selanjutnya diolah menjadi data temperatur (°C). Rangkaian pengkondisian sinyal menggunakan AD595.



Gambar 4.1 Diagram Blok Sistem Monitoring

Untuk konfigurasi kaki AD595 dengan Arduino UNO yang digunakan adalah pin ground sebagai ground, pin vcc sebagai vcc, dan pin tengah sebagai *output*. Untuk lebih jelasnya dilihat pada tabel 4.1

Tabel 4.1 Konfigurasi AD595 dengan Arduino

Konfigurasi AD595 dengan Arduino	
Sensor Pin	Sensor Pin
GND	GND
VCC	VCC
TENGAH	A0

4.1.2 Konversi ADC pada sensor termokopel baut tipe K

Sensor termokopel baut tipe K merupakan tipe sensor analog. Sensor tersebut terlebih dahulu dikonversi dengan ADC agar dapat terbaca pada *display*. Output sensor termokopel masih sangat kecil yaitu dalam µV. Agar dapat terbaca maka perlu dikuatkan menggunakan rangkaian AD595. AD595 merupakan rangkaian yang berfungsi sebagai penguat sekaligus rangkaian ADC, output yang dikeluarkan berupa data voltase (V). Spesifikasi dari sensor termokopel baut tipe K yaitu 0-400^{o}C.

Sumber tegangan yang digunakan pada pengujian sensor ialah dari arduino uno sebesar 5V dan ADC 10 bit dari AD595. Output sensor berupa tegangan (V), kemudian dikonversi pada arduino agar keluarannya menjadi celcius (^{o}C), berikut rumus mengubah kedalam derajat celcius:

$$\mathrm{ADC} = \frac{5}{1023} \times 100$$

Dengan :

Vout = 10 mV/1^{o}C

Setiap suhu 1 ^{o}C akan menunjukan tegangan 10 mV

Artinya, jika terbaca tegangan Vout = 500 mV, maka temperaturnya = 500mV/10mV= 50^{o}C.

4.1.3 Uji Sensor

Pengujian alat ukur ini dilakukan dengan membandingkan alat ukur standard (sebagai kalibrator) dan alat ukur suhu yang digunakan. Alat ukur standard yang digunakan adalah Termometer yang sudah terkalibrasi. Dalam hal ini kedua alat ukur tersebut mempunyai fungsi yang sama yaitu untuk mengukur alat suhu. Berikut merupakan data uji sensor yang dikalibrasi:

Tabel 4.2 Data pembacaan hasil uji sensor

No.	Pembacaan Standard (t)	Pembacaan Alat					Rata-Rata Pemb.Alat (x)
		1	2	3	4	5	
1	10	10.26	10.26	10.75	10.75	10.26	10.456
2	15	15.15	15.64	15.66	15.15	15.64	15.448
3	20	20.04	20.04	20.53	20.51	20.53	20.33
4	25	25.55	25.53	25.63	25.63	25.53	25.574

Tabel 4.3 Data perhitungan hasil uji sensor

Koreksi (y)	ti^2	ti.yi	Yreg	Residu (R)	*Sum Square Residual* (SSR)
-0.456	100	-4.56	-0.4166	-0.0394	0.00155236
-0.448	225	-6.72	-0.4402	-0.0078	0.00006084
-0.33	400	-6.6	-0.4638	0.1338	0.01790244
-0.574	625	-14.35	-0.4874	-0.0866	0.00749956

Keterangan
1. yi : Koreksi
2. ti : Pembacaan standard ke-i
3. k : Didapat dari tabel student, dengan cl :95%, Veff:4,27

Perhitungan diatas menggunakan termometer standar yang kemudian dibandingkan dengan termokopel yang belum dikalibrasi.

Pengujian alat ukur ini bertujuan untuk mengetahui besar ketidakpastian alat ukur yang dibuat, sehingga dengan mengetahui hal tersebut bisa pula diketahui nilai ketidakpastian pengukuran (UA_1). Akan tetapi, sebelum menghitung nilai ketidakpastian dari alat ukur tersebut, maka perlu dketahui terlebih dahulu standard deviasi (δ) dari pengukuran tersebut. Adapun untuk menghitung standard deviasi (δ) sebagai berikut :

A. Standard deviasi koreksi:

$$\sigma = \sqrt{\frac{\sum(y_i - \bar{y})^2}{n-1}}$$

$$= 0{,}0997$$

Dimana :

X	:Data Uji
X	: Nilai rata-rata data uji
n	: Jumlah Pengukuran

Dari persamaan tersebut diketahui bahwa nilai dari standard deviasi koreksi sebesar 1,0829. Sehingga untuk menghitung nilai ketidakpastian pendekatan regresi (UA_2) dengan mengetahui persamaan regresi (Yreg = a+bx) dan *sum square residual* (SSR)

B. $$\boldsymbol{b = \frac{n.\sum ti.yi - \sum yi.\sum ti}{\left(\sum ti^2\right) - (\sum ti)^\wedge 2}}$$

$$= \frac{4\,(-32{,}23) - (-1{,}808)\,(70)}{4\,(1350) - (4900)}$$

= -0,00472

C. a = y – bx

= -0,452 – (-0,00472) (17.5)

= -0.3694

D. ***Sum Square Residual* (SSR)**

$$SSR = \sum(y_i - Yreg)^2$$
$$= 0{,}0270$$

E. **Ua_1**

$$Ua_1 = \frac{\sigma}{\sqrt{n}}$$

$$= \frac{0{,}0997}{2}$$
$$= 0{,}04983$$

F. **Ua2**

$$Ua2 = \sqrt{\frac{SSR}{n-2}}$$
$$= \sqrt{\frac{0{,}0270}{2}}$$
$$= 0{,}1162$$

G. **Ketidakpastian Tipe B**

Ub_1

$$Ub_1 = \frac{\frac{1}{2} x Resolusi}{\sqrt{3}}$$
$$= \frac{0{,}0005}{1{,}732}$$
$$= 0{,}00025$$

Ub2

$$Ub_2 = \frac{a}{k}$$
$$= \frac{-0{,}3694}{2{,}011232}$$
$$= -0{,}184$$

H. **Nilai ketidakpastian kombinasi U_c :**

$$U_c = \sqrt{U_{AI}{}^2 + U_{A2}{}^2 + U_{B1}{}^2 + U_{B2}{}^2}$$
$$= \sqrt{0{,}04983 + 0{,}1162 + 0{,}00025 +} \; (-0{,}184)$$
$$= 0.280162$$

I. Veff (Derajat Kebebaan Efektif)

$$\text{Veff} = \frac{Uc^4}{\frac{Ua_1{}^4}{V_1} + \frac{Ua_2{}^4}{V_2} + \frac{Ub_1{}^4}{V_3} + \frac{Ub_2{}^4}{V_4}}$$
$$= \frac{0{,}0062}{0{,}000128}$$
$$= 48{,}14$$

J. k, Faktor Cakupan

Veff = 48,14
k = 2,011232 (dari tabel T-Student)

K. Uexp, Ketidakpastian Diperluas

Uexp = k x Uc
Uexp = 2,011232 x 0,280162
Uexp = 0,563472

4.2 Karakteristik Statik Sensor Termokopel Baut Tipe K

Karakteristik statik adalah karakteristik yang harus diperhatikan apabila alat tersebut digunakan untuk mengukur suatu kondisi yang tidak berubah karena waktu atau hanya berubah secara lambat laun. Untuk itu perlu dilakukan perhitungan untuk mengetahui nilai karakteristik dari sensor termokopel baut tipe K diantaranya sebagai berikut :

Tabel 4.4 Data perhitungan karakteristik statik termokopel baut tipe k

Termometer	Data Naik		Data Turun		Oideal	O-Oideal	Beda Histeresis	Yn-Xn (data naik)	(Yn-Xn)/Yn
	std (In)	alat (Out)	std (In)	alat (Out)					
10	10	10.26	10	10.75	10.26	0.000	0.490	0.260	0.000
15	15	15.15	15	15.64	15.35667	-0.207	0.490	0.150	0.010
20	20	20.04	20	20.53	20.45333	-0.413	0.490	0.040	0.002
25	25	25.55	25	25.53	25.55	0.000	-0.020	0.550	0.022

a. Sensitivitas (dari data pengujian alat) $= \frac{\Delta O}{\Delta I}$

$$= \frac{25{,}550 - 10{,}260}{25 - 10} = 1{,}0193$$

b. Akurasi :

$A = 1 - \left|\frac{Y_n - X_n}{Y_n}\right|$, dengan Y_n = Pembacaan standar (I) dan X_n = Pembacaan alat (O)

$$A = 1 - |0{,}009|$$
$$= 0{,}9910$$
$$= 99{,}10\%$$

c. Error :

$$e = 1 - A$$
$$e = 1\text{-}99{,}10\%$$
$$e = 0{,}90\%$$

d. Histerisis

$H(I) = O(I)_{I\downarrow} - O(I)_{I\uparrow}, \widehat{H} = H(I)_{max}$ sehingga :

$$\%\ Maksimum\ histeresis = \frac{\widehat{H}}{O_{max} - O_{min}} x\ 100\%$$

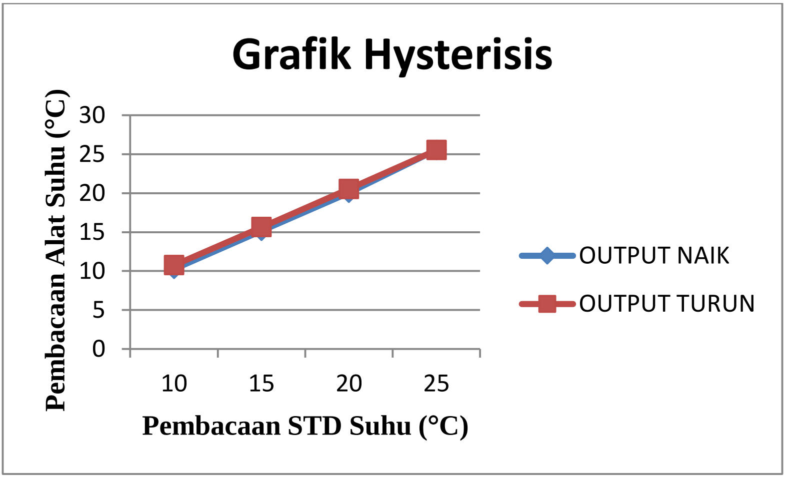
$$\%\ Maksimum\ histeresis = \frac{-0{,}020}{25{,}55 - 10{,}26} x\ 100\%$$

$$\%\ Maksimum\ histeresis = \frac{-0{,}020}{15{,}29} x\ 100\%$$

$$\%\ Maksimum\ histeresis = 0{,}13\%$$

Sehingga diperoleh nilai karakteristik statik dari sensor termokopel baut tipe K diantaranya :

a.	Range	: 10 ºC – 25ºC
b.	Span	: 15ºC
c.	Resolusi	: 0,01
d.	Sensitifivitas (K)	: 1,0193ºC (Dari data pengujian)
e.	Histerisis	: 0,13 %
f.	Akurasi	: 99,10%
g.	Kesalahan (*error*)	: 0,90%



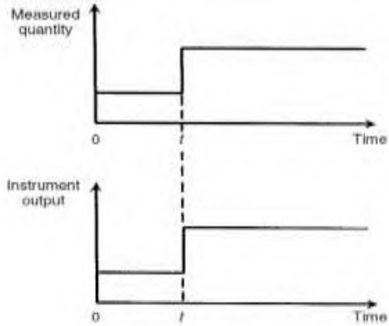
Gambar 4.2 Grafik Histerisis

4.3 Karakteristik Dinamik Sensor Termokopel Baut Tipe K

Karakteristik dinamik dari sebuah alat ukur menggambarkan perilakunya antara waktu yang terukur dengan perubahan nilai dan waktu ketika sebuah alat output mencapai nilai stabil. Nilai karakteristik dinamik dikutip dalam lembaran instrumen data hanya berlaku pada saat instrumen yang digunakan dalam kondisi lingkungan tertentu.

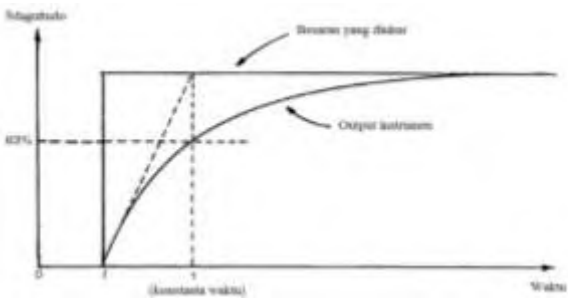
Karakteristik dinamik dikelompokkan menjadi tiga orde diantarnya:

1. Instrument orde nol
   Pada Instrument orde nol, ketika ada perubahan input pengukuran, output akan bergerak cepat menuju nilai baru sehingga mendekati respon *step.* Berikut ini merupakan respon output orde nol



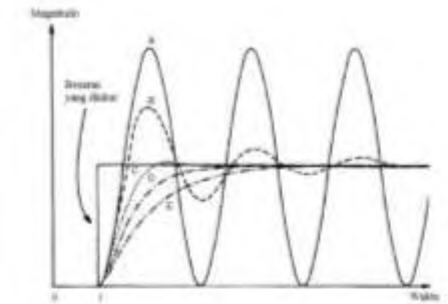
Gambar 4.3 Respon orde nol[12]

2. Instrument orde satu
   Pada instrument orde satu, saat ada perubahan step input pengukuran, output instrumen berubah secara gradual (tidak secara tiba-tiba seperti instrumen orde nol) dan membutuhkan waktu untuk mencapai kondisi yang sama dengan nilai besaran yang diukur. Pada orde ini nilainya dipengaruhi oleh karakteristik statik instrumen.



Gambar 4.4 Respon orde satu[12]

3. Instrument orde dua
   Pada instrument orde dua ini dipengaruhi oleh beberapa faktor diantaranya rasio redaman, sensitivitas statik, dan frekuensi natural tak teredam. Redaman sangat mempengaruhi respon terhadap perubahan step input. Bentuk respon step besaran output o yang diperoleh bergantung pada nilai parameter rasio redaman.



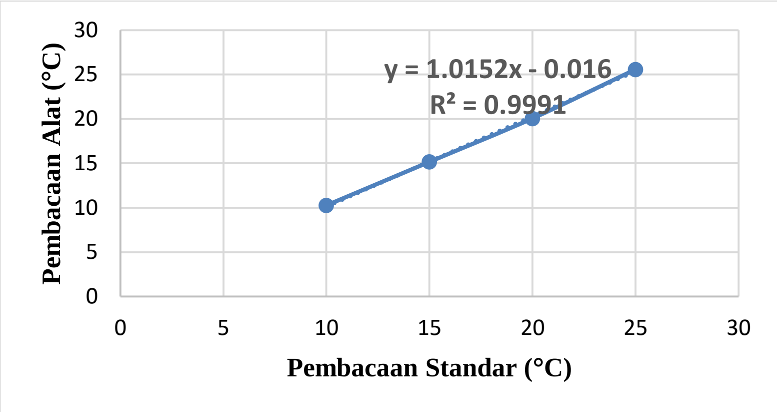
Gambar 4.5 Respon orde dua[12]

Termokopel baut tipe K termasuk instrument orde satu karena pada saat dilakukan pengukuran, nilai output yang dihasilkan membutuhkan waktu untuk mencapai besaran yang diinginkan dan dipengaruhi oleh nilai karakteristik statik.
Persamaan dalam instrument orde satu :

$$\frac{qo}{qi}(D) = \frac{\mathrm{K}}{\lambda S + 1}$$

Dimana:
K = Sensitivitas statik elemen pengukuran
λ = konstanta waktu elemen pengukuran

Dari data pada tabel 4.2 diperoleh grafik pembacaan alat dan pembacaan standar sebagai berikut:



Gambar 4.6 Grafik pembacaan alat dan pembacaan standar suhu

4.4 Pengambilan Data Monitoring Temperatur

Pada pengambilan data kondisi ini yaitu suhu awal tangki yang belum terisi apapun dan masih kosong adalah 27.37°C dan suhu awal campuran bioetanol dan premium sebelum di*blending* adalah 24.93°C.. Berikut ini merupakan hasil pengambilan data monitoring temperatur pada saat *blending* bioetanol dan premium metode 1 sampai 5, dimana data diambil setiap 30 detik.

Tabel 4.5 Pengambilan data monitoring temperatur

Metode	Waktu	Waktu (Per 30 Detik)	Suhu (°C)
1	2 Menit	07:45:35	25.42
		07:46:05	24.02
		07:46:35	24.51
		07:47:05	24.86
		Rata-Rata	24.70
2	4 Menit	08:07:01	25.42
		08:07:31	24.97
		08:08:01	25.93
		08:08:31	25.93

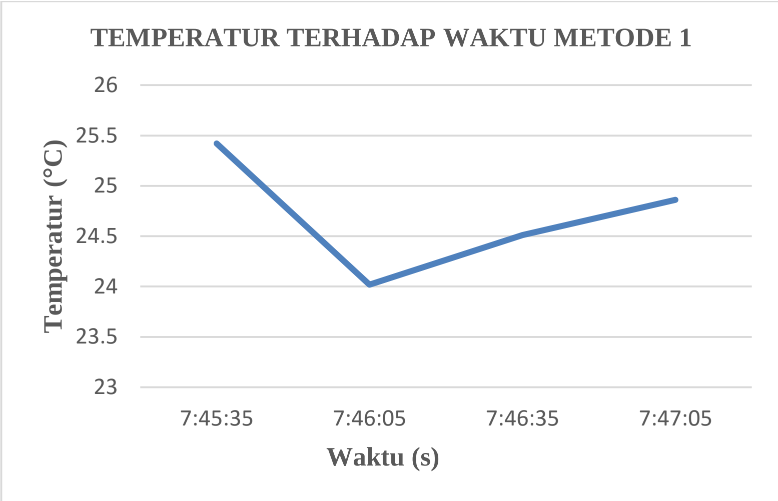
Tabel 4.5 Lanjutan

Metode	Waktu	Waktu (Per 30 Detik)	Suhu (ºC)
2	4 Menit	08:09:01	24.93
		08:09:31	24.93
		08:10:01	24.93
		08:10:31	25.42
		Rata-Rata	25.31
3	6 Menit	08:17:00	26.39
		08:17:30	25.90
		08:18:00	26.88
		08:18:30	26.39
		08:19:00	26.39
		08:19:30	25.90
		08:20:00	26.39
		08:20:30	25.90
		08:21:00	25.90
		08:21:30	26.39
		08:22:00	25.42
		08:22:30	25.90
		Rata-Rata	26.15
4	8 Menit	08:31:04	24.93
		08:31:34	26.88
		08:32:04	26.39
		08:32:34	25.9
		08:33:04	25.9
		08:33:34	25.51
		08:34:04	26.35
		08:34:34	28.84
		08:35:04	24.93
		08:35:34	25.9
		08:36:04	25.42
		08:36:34	25.9
		08:37:04	26.02
		08:37:34	25.9

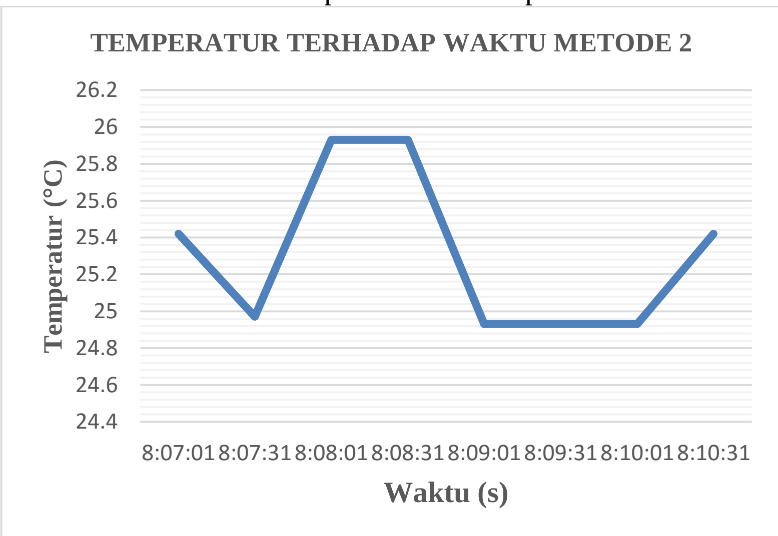
Tabel 4.5 Lanjutan

Metode	**Waktu**	**Waktu (Per 30 Detik)**	**Suhu (°C)**
4	8 Menit	08:38:04	26.88
		08:38:34	26.88
		Rata-Rata	26.16
5	10 Menit	08:51:12	25.9
		08:51:42	26.37
		08:52:12	25.90
		08:52:42	25.90
		08:53:12	26.88
		08:53:42	25.42
		08:54:12	26.86
		08:54:42	25.90
		08:55:12	26.88
		08:55:42	26.86
		08:56:12	26.39
		08:56:42	26.39
		08:57:12	26.88
		08:57:42	26.39
		08:58:12	26.37
		08:58:42	26.37
		08:59:12	26.86
		08:59:42	26.39
		09:00:12	26.39
		09:00:42	26.88
		Rata-Rata	26.41

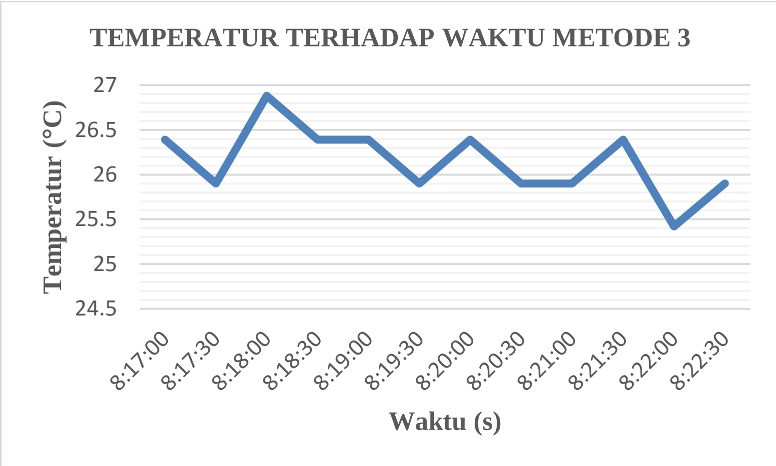
Tabel 4.5 merupakan hasil dari pengambilan data monitoring suhu saat *blending* selama 2 menit, 4 menit, 6 menit, 8 menit dan 10 menit. Berikut ini merupakan grafik respon suhu terhadap waktu metode satu sampai metode 5.



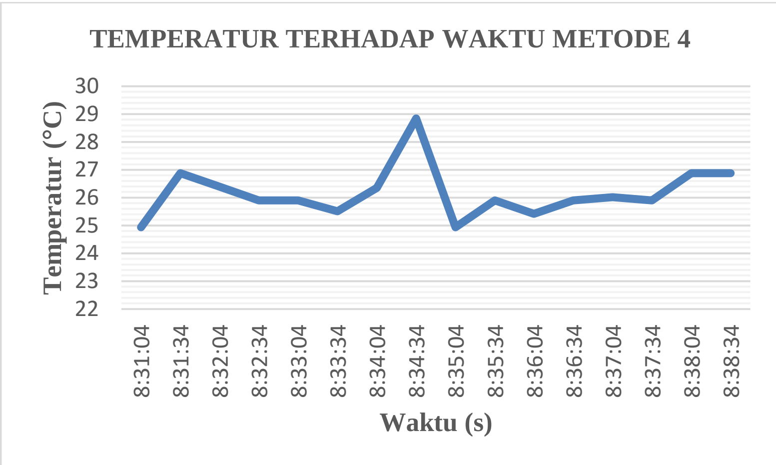
Gambar 4.7 Grafik respon suhu terhadap waktu metode 1



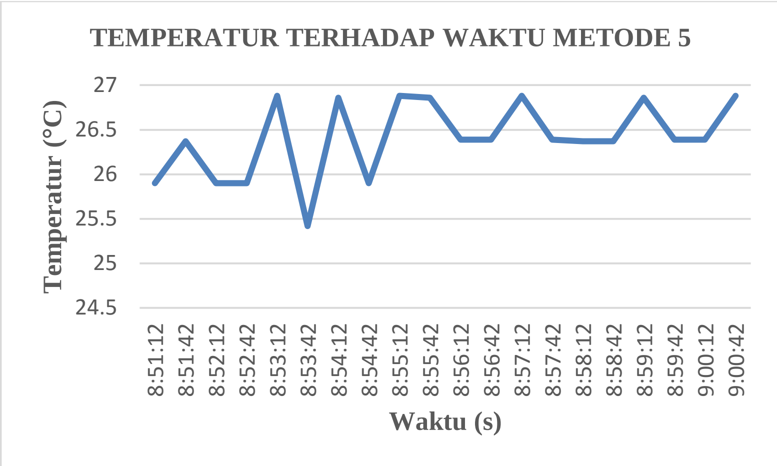
Gambar 4.8 Grafik respon suhu terhadap waktu metode 2



Gambar 4.9 Grafik respon suhu terhadap waktu metode 3



Gambar 4.10 Grafik respon suhu terhadap waktu metode 4



Gambar 4.11 Grafik respon suhu terhadap waktu metode 5

Pada gambar diatas menunjukkan sebuah grafik temperatur terhadap waktu dengan menggunakan metode 1 sampai metode 5 yaitu pengambilan data dilakukan pada saat *blending* selama 2 menit, 4 menit, 6 menit, 8 menit dan 10 menit. Pada grafik tersebut menunjukkan keadaan temperatur dari campuran bioetanol dan premium pada saat di *blending* selama 2, 4, 6, 8 dan 10 menit dan data diambil setiap 30 detik.

Pada Grafik diatas menunjukkan keadaan dimana keadaan temperatur awal campuran bioetanol dan premium adalah berkisar 24°C sampai 25°C . Kemudian pada saat di *blending* selama 6 menit suhu mulai mengalami kenaikan. Semakin lama proses *blending* suhu semakin tinggi, *blade* motor DC yang berputar mengaduk campuran bioetanol dan premium pada tangki tertutup memampatkan udara dan bahan bakar sehingga mengakibatkan suhu fluida naik dan tinggi. Pada saat *blending* suhu naik juga dipengaruhi oleh faktor lingkungan dimana tangki *blending* tidak diberi selimut atau pelindung agar suhu tidak terpengaruh oleh suhu udara luar.

Tabel 4.6 Hasil Uji Homogenitas

jumlah (waktu)	std	etanol	koreksi	std deviasi	Ua_1	Ua_2
2	15	16,77	-1,77	2,50315801	1,770	0,000
4	15	19,21	-4,21	2,80666667	1,251579	0,791
6	15	14,49	0,51	0,24984795	1,02191	0,505
8	15	20,25	-5,25	2,12132034	0,885	0,384
10	15	20,59	-5,59	1,96412579	0,791568	0,315

Tabel 4.6 merupakan hasil dari uji homogenitas pada eksperimen *blending* selama 2 menit, 4 menit, 6 menit, 8 menit dan 10 menit.

4.5 Pembahasan

Tugas akhir yang berjudul sistem monitoring temperatur pada mini plant sistem *blending* bioetanol dan premium untuk mengetahui pengaruh suhu terhadap waktu pada saat *blending*. Menggunakan sensor termokopel baut tipe K sebagai alat ukur temperatur dan AD595 sebagai rangkaian pengkondisian sinyal. Kemudian pemrosesan sinyal menggunakan mikrokontroller Arduino Uno.

Sebelum sensor ini digunakan perlu dilakukan kalibrasi untuk mengetahui performansi dari sensor tersebut. Kalibrasi sensor termokopel ini menggunakan Alat ukur standard yakni *Thermometer Digital* yang sudah terkalibrasi. Dilakukan pada *range* 10ºC hingga 25ºC. Kedua alat tersebut didinginkan dengan air es. Setelah dilakukan pengujian sensor yaitu dilakukan perhitungan kalibrasi. Setelah dilakukan kalibrasi didapatkan hasil pengukuran temperatur pada alat standar dan alat uji. Dari hasil pembacaan alat standard dan alat yang dikalibrasi dapat dicari nilai ketidakpastian pengukuran temperatur dengan hasil Ua_1 = 0,4983, Ua_2 = 0.1162, Ub_1 = 0.00025, Ub_2 = -0,184 Uc = 0,280162. Sehingga berdasarkan perhitungan ketidakpastian diperluas tersebut menghasilkan nilai Uexpand sebesar ± 0,563472 dengan tingkat kepercayaan 95% dari tabel *T-Student*. Hasil dari perhitungan ketidakpastian tersebut akan menjadi acuan dari sensor termokopel baut tipe K yang akan digunakan. Sensor tersebut memiliki karakteristik statik diantaranya resolusi sebesar 0.01, sensitivitas 1,0193^{o}C dan akurasi sebesar 0.99.

Monitoring temperatur menggunakan PC sebagai visualisasi data. Diantaranya menggunakan microsoft visual basic dan LCD 16x2 sebagai display data dan Microsoft Excel sebagai penyimpanan database monitoring. Pengambilan data sistem monitoring pada *blending* bioetanol dan premium dilakukan sebanyak lima kali yaitu selama 2 menit, 4 menit, 6 menit, 8 menit dan 10 menit dimana data diambil setiap 30 detik. Hasil data monitoring metode satu sampai lima bertujuan untuk membandingkan hasil dari kelima metode tersebut. Suhu yang dihasilkan pada campuran bioetanol dan premium yaitu berkisar 24^{o}C - 25^{o}C, namun pada saat di *blending* selama 6 menit suhu mulai mengalami kenaikan. Semakin lama proses *blending* suhu semakin tinggi, *blade* motor DC yang berputar mengaduk campuran bioetanol dan premium pada tangki tertutup memampatkan udara dan bahan bakar sehingga mengakibatkan suhu udara naik dan tinggi. Pada saat *blending* suhu naik juga dipengaruhi oleh faktor lingkungan dimana tangki *blending* tidak diberi selimut atau pelindung agar suhu tidak terpengaruh oleh suhu udara luar. Dari *blending* bioetanol dan premium dengan perbandingan bioetanol 15% dan premium 95% didapatkan tingkat homogenitasnya yaitu koreksi terhadap waktu *blending* 2 menit sebesar -1.771, 4 menit sebesar -4.21, 6 menit sebesar 0.51, 8 menit sebesar -5.25, dan 10 menit sebesar -5.59.

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LAMPIRAN A
(DATASHEET AD595)

1. *Datasheet* AD595

ANALOG DEVICES

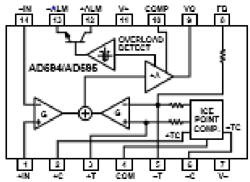
Monolithic Thermocouple Amplifiers with Cold Junction Compensation

AD594/AD595

FEATURES

- Pretrimmed for Type J (AD594) or Type K (AD595) Thermocouples
- Can Be Used with Type T Thermocouple Inputs
- Low Impedance Voltage Output: 10 mV/°C
- Built-In Ice Point Compensation
- Wide Power Supply Range: +5 V to ±15 V
- Low Power: <1 mW typical
- Thermocouple Failure Alarm
- Laser Wafer Trimmed to 1°C Calibration Accuracy
- Setpoint Mode Operation
- Self-Contained Celsius Thermometer Operation
- High Impedance Differential Input
- Side-Brazed DIP or Low Cost Cerdip

FUNCTIONAL BLOCK DIAGRAM



PRODUCT DESCRIPTION

The AD594/AD595 is a complete instrumentation amplifier and thermocouple cold junction compensator on a monolithic chip. It combines an ice point reference with a precalibrated amplifier to produce a high level (10 mV/°C) output directly from a thermocouple signal. Pin-strapping options allow it to be used as a linear amplifier-compensator or as a switched output setpoint controller using either fixed or remote setpoint control. It can be used to amplify its compensation voltage directly, thereby converting it to a stand-alone Celsius transducer with a low impedance voltage output.

The AD594/AD595 includes a thermocouple failure alarm that indicates if one or both thermocouple leads become open. The alarm output has a flexible format which includes TTL drive capability.

The AD594/AD595 can be powered from a single ended supply (including +5 V) and by including a negative supply, temperatures below 0°C can be measured. To minimize self-heating, an unloaded AD594/AD595 will typically operate with a total supply current 160 μA, but is also capable of delivering in excess of ±5 mA to a load.

The AD594 is precalibrated by laser wafer trimming to match the characteristic of type J (iron-constantan) thermocouples and the AD595 is laser trimmed for type K (chromel-alumel) inputs. The temperature transducer voltages and gain control resistors are available at the package pins so that the circuit can be recalibrated for the thermocouple types by the addition of two or three resistors. These terminals also allow more precise calibration for both thermocouple and thermometer applications.

The AD594/AD595 is available in two performance grades. The C and the A versions have calibration accuracies of ±1°C and ±3°C, respectively. Both are designed to be used from 0°C to +50°C, and are available in 14-pin, hermetically sealed, side-brazed ceramic DIPs as well as low cost cerdip packages.

PRODUCT HIGHLIGHTS

1. The AD594/AD595 provides cold junction compensation, amplification, and an output buffer in a single IC package.
2. Compensation, zero, and scale factor are all precalibrated by laser wafer trimming (LWT) of each IC chip.
3. Flexible pinout provides for operation as a setpoint controller or a stand-alone temperature transducer calibrated in degrees Celsius.
4. Operation at remote application sites is facilitated by low quiescent current and a wide supply voltage range +5 V to dual supplies spanning 30 V.
5. Differential input rejects common-mode noise voltage on the thermocouple leads.

REV. C

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781/329-4700 World Wide Web Site: http://www.analog.com
Fax: 781/326-8703

AD594/AD595–SPECIFICATIONS (@ +25°C and V_S = 5 V, Type J (AD594), Type K (AD595) Thermocouple, unless otherwise noted)

Model	AD594A			AD594C			AD595A			AD595C			
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Units
ABSOLUTE MAXIMUM RATING													
$+V_S$ to $-V_S$			36			36			36			36	Volts
Common-Mode Input Voltage	$-V_S - 0.15$		$+V_S$	$-V_S - 0.15$		$+V_S$	$-V_S - 0.15$		$+V_S$	$-V_S - 0.15$		$+V_S$	Volts
Differential Input Voltage	$-V_S$		$+V_S$	$-V_S$		$+V_S$	$-V_S$		$+V_S$	$-V_S$		$+V_S$	Volts
Alarm Voltages													
+ALM	$-V_S$		$-V_S + 36$	$-V_S$		$-V_S + 36$	$-V_S$		$-V_S + 36$	$-V_S$		$-V_S + 36$	Volts
–ALM	$-V_S$		$+V_S$	$-V_S$		$+V_S$	$-V_S$		$+V_S$	$-V_S$		$+V_S$	Volts
Operating Temperature Range	–55		+125	–55		+125	–55		+125	–55		+125	°C
Output Short Circuit to Common	Indefinite			Indefinite			Indefinite			Indefinite			
TEMPERATURE MEASUREMENT (Specified Temperature Range 0°C to +50°C)													
Calibration Error at +25°C[1]			±3			±1			±3			±1	°C
Stability vs. Temperature[2]			±0.05			±0.025			±0.05			±0.025	°C/°C
Gain Error			±1.5			±0.75			±1.5			±0.75	%
Nominal Transfer Function			10			10			10			10	mV/°C
AMPLIFIER CHARACTERISTICS													
Closed Loop Gain[3]		193.4				193.4			247.3			247.3	
Input Offset Voltage		(Temperature in °C) × 51.70 μV/°C			(Temperature in °C) × 51.70 μV/°C			(Temperature in °C) × 40.44 μV/°C			(Temperature in °C) × 40.44 μV/°C		μV
Input Bias Current		0.1			0.1			0.1			0.1		μA
Differential Input Range	–10		+50				–10		+50	–10		+50	mV
Common-Mode Range	$-V_S - 0.15$		$-V_S - 4$	$-V_S - 0.15$		$-V_S - 4$	$-V_S - 0.15$		$-V_S - 4$	$-V_S - 0.15$		$-V_S - 4$	Volts
Common-Mode Sensitivity – RTO			10			10			10			10	mV/V
Power Supply Sensitivity – RTO			10			10			10			10	mV/V
Output Voltage Range													
Dual Supply	$-V_S + 2.5$		$+V_S - 2$	$-V_S + 2.5$		$+V_S - 2$	$-V_S + 2.5$		$+V_S - 2$	$-V_S + 2.5$		$+V_S - 2$	Volts
Single Supply	0		$+V_S - 2$	0		$-V_S - 2$	0		$+V_S + 2$	0		$+V_S - 2$	Volts
Usable Output Current[4]		±5			±5			±5			±5		mA
3 dB Bandwidth		15			15			15			15		kHz
ALARM CHARACTERISTICS													
$V_{CE(SAT)}$ at 2 mA		0.3			0.3			0.3			0.3		Volts
Leakage Current			±1			±1			±1			±1	μA max
Operating Voltage at – ALM			$+V_S - 4$			$+V_S - 4$			$+V_S - 4$			$+V_S - 4$	Volts
Short Circuit Current		20			20			20			20		mA
POWER REQUIREMENTS													
Specified Performance		$+V_S = 5, -V_S = 0$			$+V_S = 5, -V_S = 0$			$+V_S = 5, -V_S = 0$			$+V_S = 5, -V_S = 0$		Volts
Operating[5]		$+V_S$ to $-V_S \le 30$			$+V_S$ to $-V_S \le 30$			$+V_S$ to $-V_S \le 30$			$+V_S$ to $-V_S \le 30$		Volts
Quiescent Current (No Load)													
$+V_S$		160	300		160	300		160	300		160	300	μA
$-V_S$		100			100			100			100		μA
PACKAGE OPTION													
TO-116 (D-14)		AD594AD			AD594CD			AD595AD			AD595CD		
Cerdip (Q-14)		AD594AQ			AD594CQ			AD595AQ			AD595CQ		

NOTES

[1] Calibrated for minimum error at +25°C using a thermocouple sensitivity of 51.7 μV/°C. Since a J type thermocouple deviates from this straight line approximation, the AD594 will normally read 3.1 mV when the measuring junction is at 0°C. The AD595 will similarly read 2.7 mV at 0°C.

[2] Defined as the slope of the line connecting the AD594/AD595 errors measured at 0°C and 50°C ambient temperature.

[3] Pin 8 shorted to Pin 9.

[4] Current Sink Capability in single supply configuration is limited to current drawn to ground through a 50 kΩ resistor at output voltages below 2.5 V.

[5] $-V_S$ must not exceed –16.5 V.

Specifications shown in boldface are tested on all production units at final electrical test. Results from those tests are used to calculate outgoing quality levels. All min and max specifications are guaranteed, although only those shown in boldface are tested on all production units.

Specifications subject to change without notice.

INTERPRETING AD594/AD595 OUTPUT VOLTAGES

To achieve a temperature proportional output of 10 mV/°C and accurately compensate for the reference junction over the rated operating range of the circuit, the AD594/AD595 is gain trimmed to match the transfer characteristic of J and K type thermocouples at 25°C. For a type J output in this temperature range the TC is 51.70 μV/°C, while for a type K it is 40.44 μV/°C. The resulting gain for the AD594 is 193.4 (10 mV/°C divided by 51.7 μV/°C) and for the AD595 is 247.3 (10 mV/°C divided by 40.44 μV/°C). In addition, an absolute accuracy trim induces an input offset to the output amplifier characteristic of 16 μV for the AD594 and 11 μV for the AD595. This offset arises because the AD594/AD595 is trimmed for a 250 mV output while applying a 25°C thermocouple input.

Because a thermocouple output voltage is nonlinear with respect to temperature, and the AD594/AD595 linearly amplifies the compensated signal, the following transfer functions should be used to determine the actual output voltages:

AD594 output = (Type J Voltage + 16 μV) × 193.4

AD595 output = (Type K Voltage + 11 μV) × 247.3 or conversely:

Type J voltage = (AD594 output/193.4) – 16 μV

Type K voltage = (AD595 output/247.3) – 11 μV

Table I lists the ideal AD594/AD595 output voltages as a function of Celsius temperature for type J and K ANSI standard thermocouples, with the package and reference junction at 25°C. As is normally the case, these outputs are subject to calibration, gain and temperature sensitivity errors. Output values for intermediate temperatures can be interpolated, or calculated using the output equations and ANSI thermocouple voltage tables referred to zero degrees Celsius. Due to a slight variation in alloy content between ANSI type J and DIN FE-CUNI

Table I. Output Voltage vs. Thermocouple Temperature (Ambient +25°C, V_S = –5 V, +15 V)

Thermocouple Temperature °C	Type J Voltage mV	AD594 Output mV	Type K Voltage mV	AD595 Output mV
–200	–7.890	–1523	–5.891	–1454
–180	–7.402	–1438	–5.550	–1370
–160	–6.821	–1316	–5.141	–1269
–140	–6.159	–1188	–4.669	–1152
–120	–5.426	–1046	–4.138	–1021
–100	–4.632	–893	–3.553	–876
–80	–3.785	–729	–2.920	–719
–60	–2.892	–556	–2.243	–552
–40	–1.960	–376	–1.527	–375
–20	–.995	–189	–.777	–189
–10	–.501	–94	–.392	–94
0	0	3.1	0	2.7
10	.507	101	.397	101
20	1.019	200	.798	200
25	1.277	250	1.000	250
30	1.536	300	1.203	300
40	2.058	401	1.611	401
50	2.585	503	2.022	503
60	3.115	606	2.436	605
80	4.186	813	3.266	810
100	5.268	1022	4.095	1015
120	6.359	1233	4.919	1219
140	7.457	1445	5.733	1420
160	8.560	1659	6.539	1620
180	9.667	1873	7.338	1817
200	10.777	2087	8.137	2015
220	11.887	2302	8.938	2213
240	12.998	2517	9.745	2413
260	14.108	2732	10.560	2614
280	15.217	2946	11.381	2817
300	16.325	3160	12.207	3022
320	17.432	3374	13.039	3227
340	18.537	3588	13.874	3434
360	19.640	3801	14.712	3641
380	20.743	4015	15.552	3849
400	21.846	4228	16.395	4057
420	22.949	4441	17.241	4266
440	24.054	4655	18.088	4476
460	25.161	4869	18.938	4686
480	26.273	5084	19.788	4896
500	27.388	5300	20.640	5107
520	28.511	5517	21.493	5318
540	29.642	5736	22.346	5529
560	30.782	5956	23.198	5740
580	31.933	6179	24.050	5950
600	33.096	6404	24.902	6161
620	34.273	6632	25.751	6371
640	35.464	6862	26.599	6581
660	36.671	7095	27.445	6790
680	37.893	7332	28.288	6998
700	39.130	7571	29.128	7206
720	40.382	7813	29.965	7413
740	41.647	8058	30.799	7619
750	42.283	8181	31.214	7722
760	–	–	31.629	7825
780	–	–	32.455	8029
800	–	–	33.277	8232
820	–	–	34.095	8434
840	–	–	34.909	8636
860	–	–	35.718	8836
880	–	–	36.524	9035
900	–	–	37.325	9233
920	–	–	38.122	9430
940	–	–	38.915	9626
960	–	–	39.703	9821
980	–	–	40.488	10015
1000	–	–	41.269	10209
1020	–	–	42.045	10400
1040	–	–	42.817	10591
1060	–	–	43.585	10781
1080	–	–	44.439	10970
1100	–	–	45.108	11158
1120	–	–	45.863	11345
1140	–	–	46.612	11530
1160	–	–	47.356	11714
1180	–	–	48.095	11897
1200	–	–	48.828	12078
1220	–	–	49.555	12258
1240	–	–	50.276	12436
1250	–	–	50.633	12524

thermocouples Table I should not be used in conjunction with European standard thermocouples. Instead the transfer function given previously and a DIN thermocouple table should be used. ANSI type K and DIN NiCr-Ni thermocouples are composed

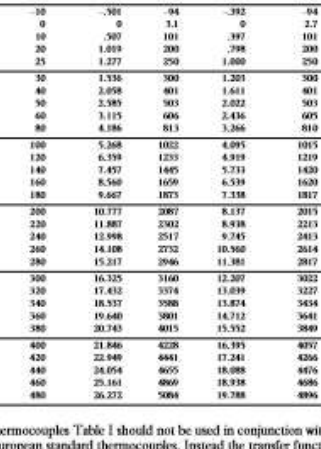


Figure 1. Basic Connection, Single Supply Operation

of identical alloys and exhibit similar behavior. The upper temperature limits in Table I are those recommended for type J and type K thermocouples by the majority of vendors.

SINGLE AND DUAL SUPPLY CONNECTIONS

The AD594/AD595 is a completely self-contained thermocouple conditioner. Using a single +5 V supply the interconnections shown in Figure 1 will provide a direct output from a type J thermocouple (AD594) or type K thermocouple (AD595) measuring from 0°C to +300°C.

Any convenient supply voltage from +5 V to +30 V may be used, with self-heating errors being minimized at lower supply levels. In the single supply configuration the +5 V supply connects to Pin 11 with the V– connection at Pin 7 strapped to power and signal common at Pin 4. The thermocouple wire inputs connect to Pins 1 and 14 either directly from the measuring point or through intervening connections of similar thermocouple wire type. When the alarm output at Pin 13 is not used it should be connected to common or –V. The precalibrated feedback network at Pin 8 is tied to the output at Pin 9 to provide a 10 mV/°C nominal temperature transfer characteristic.

By using a wider ranging dual supply, as shown in Figure 2, the AD594/AD595 can be interfaced to thermocouples measuring both negative and extended positive temperatures.

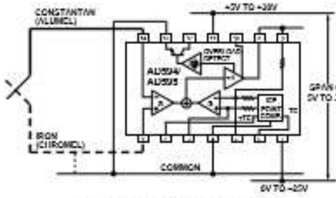


Figure 2. Dual Supply Operation

With a negative supply the output can indicate negative temperatures and drive grounded loads or loads returned to positive voltages. Increasing the positive supply from 5 V to 15 V extends the output voltage range well beyond the 750°C temperature limit recommended for type J thermocouples (AD594) and the 1250°C for type K thermocouples (AD595).

Common-mode voltages on the thermocouple inputs must remain within the common-mode range of the AD594/AD595, with a return path provided for the bias currents. If the thermocouple is not remotely grounded, then the dotted line connections in Figures 1 and 2 are recommended. A resistor may be needed in this connection to assure that common-mode voltages induced in the thermocouple loop are not converted to normal mode.

THERMOCOUPLE CONNECTIONS

The isothermal terminating connections of a pair of thermocouple wires forms an effective reference junction. This junction must be kept at the same temperature as the AD594/AD595 for the internal cold junction compensation to be effective.

A method that provides for thermal equilibrium is the printed circuit board connection layout illustrated in Figure 3.

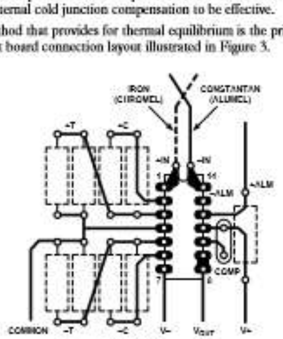


Figure 3. PCB Connections

Here the AD594/AD595 package temperature and circuit board are thermally contacted in the copper printed circuit board tracks under Pins 1 and 14. The reference junction is now composed of a copper-constantan (or copper-alumel) connection and copper-iron (or copper-chromel) connection, both of which are at the same temperature as the AD594/AD595.

The printed circuit board layout shown also provides for placement of optional alarm load resistors, recalibration resistors and a compensation capacitor to limit bandwidth.

To ensure secure bonding the thermocouple wire should be cleaned to remove oxidation prior to soldering. Noncorrosive rosin flux is effective with iron, constantan, chromel and alumel and the following solders: 95% tin-5% antimony, 95% tin-5% silver or 90% tin-10% lead.

FUNCTIONAL DESCRIPTION

The AD594 behaves like two differential amplifiers. The outputs are summed and used to control a high gain amplifier, as shown in Figure 4.

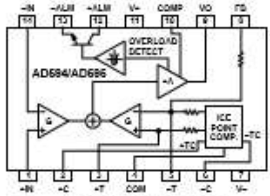


Figure 4. AD594/AD595 Block Diagram

In normal operation the main amplifier output, at Pin 9, is connected to the feedback network, at Pin 8. Thermocouple signals applied to the floating input stage, at Pins 1 and 14, are amplified by gain G of the differential amplifier and are then further amplified by gain A in the main amplifier. The output of the main amplifier is fed back to a second differential stage in an inverting connection. The feedback signal is amplified by this stage and is also applied to the main amplifier input through a summing circuit. Because of the inversion, the amplifier causes the feedback to be driven to reduce this difference signal to a small value. The two differential amplifiers are made to match and have identical gains, G. As a result, the feedback signal that must be applied to the right-hand differential amplifier will precisely match the thermocouple input signal when the difference signal has been reduced to zero. The feedback network is trimmed so that the effective gain to the output, at Pins 8 and 9, results in a voltage of 10 mV/°C of thermocouple excitation.

In addition to the feedback signal, a cold junction compensation voltage is applied to the right-hand differential amplifier. The compensation is a differential voltage proportional to the Celsius temperature of the AD594/AD595. This signal disturbs the differential input so that the amplifier output must adjust to restore the input to equal the applied thermocouple voltage.

The compensation is applied through the gain scaling resistors so that its effect on the main output is also 10 mV/°C. As a result, the compensation voltage adds to the effect of the thermocouple voltage a signal directly proportional to the difference between 0°C and the AD594/AD595 temperature. If the thermocouple reference junction is maintained at the AD594/AD595 temperature, the output of the AD594/AD595 will correspond to the reading that would have been obtained from amplification of a signal from a thermocouple referenced to an ice bath.

The AD594/AD595 also includes an input open circuit detector that switches on an alarm transistor. This transistor is actually a current-limited output buffer, but can be used up to the limit as a switch transistor for either pull-up or pull-down operation of external alarms.

The ice point compensation network has voltages available with positive and negative temperature coefficients. These voltages may be used with external resistors to modify the ice point compensation and recalibrate the AD594/AD595 as described in the next column.

The feedback resistor is separately pinned out so that its value can be padded with a series resistor, or replaced with an external resistor between Pins 5 and 9. External availability of the feedback resistor allows gain to be adjusted, and also permits the AD594/AD595 to operate in a switching mode for setpoint operation.

CAUTIONS:

The temperature compensation terminals (+C and –C) at Pins 2 and 6 are provided to supply small calibration currents only. The AD594/AD595 may be permanently damaged if they are grounded or connected to a low impedance.

The AD594/AD595 is internally frequency compensated for feedback ratios (corresponding to normal signal gain) of 75 or more. If a lower gain is desired, additional frequency compensation should be added in the form of a 300 pF capacitor from Pin 10 to the output at Pin 9. As shown in Figure 5 an additional 0.01 μF capacitor between Pins 10 and 11 is recommended.

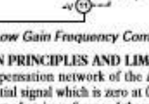


Figure 5. Low Gain Frequency Compensation

RECALIBRATION PRINCIPLES AND LIMITATIONS

The ice point compensation network of the AD594/AD595 produces a differential signal which is zero at 0°C and corresponds to the output of an ice referenced thermocouple at the temperature of the chip. The positive TC output of the circuit is proportional to Kelvin temperature and appears as a voltage at +T. It is possible to decrease this signal by loading it with a resistor from +T to COM, or increase it with a pull-up resistor from +T to the larger positive TC voltage at +C. Note that adjustments to +T should be made by measuring the voltage which tracks it at –T. To avoid destabilizing the feedback amplifier the measuring instrument should be isolated by a few thousand ohms in series with the lead connected to –T.

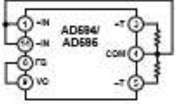


Figure 6. Decreased Sensitivity Adjustment

Changing the positive TC half of the differential output of the compensation scheme shifts the zero point away from 0°C. The zero can be restored by adjusting the current flow into the negative input of the feedback amplifier, the –T pin. A current into this terminal can be produced with a resistor between –C and –T to balance an increase in +T, or a resistor from –T to COM to offset a decrease in +T.

If the compensation is adjusted substantially to accommodate a different thermocouple type, its effect on the final output voltage will increase or decrease in proportion. To restore the nominal output to 10 mV/°C the gain may be adjusted to match the new compensation and thermocouple input characteristics. When reducing the compensation the resistance between –T and COM automatically increases the gain to within 0.5% of the correct value. If a smaller gain is required, however, the nominal 47 kΩ internal feedback resistor can be paralleled or replaced with an external resistor.

Fine calibration adjustments will require temperature response measurements of individual devices to assure accuracy. Major reconfigurations for other thermocouple types can be achieved without seriously compromising initial calibration accuracy, so long as the procedure is done at a fixed temperature using the factory calibration as a reference. It should be noted that intermediate recalibration conditions may require the use of a negative supply.

EXAMPLE: TYPE E RECALIBRATION—AD594/AD595

Both the AD594 and AD595 can be configured to condition the output of a type E (chromel-constantan) thermocouple. Temperature characteristics of type E thermocouples differ less from type J, than from type K, therefore the AD594 is preferred for recalibration.

While maintaining the device at a constant temperature follow the recalibration steps given here. First, measure the device temperature by tying both inputs to common (or a selected common-mode potential) and connecting FB to VO. The AD594 is now in the stand alone Celsius thermometer mode. For this example assume the ambient is 24°C and the initial output VO is 240 mV. Check the output at VO to verify that it corresponds to the temperature of the device.

Next, measure the voltage –T at Pin 5 with a high impedance DVM (capacitance should be isolated by a few thousand ohms of resistance at the measured terminals). At 24°C the –T voltage will be about 8.3 mV. To adjust the compensation of an AD594 to a type E thermocouple a resistor, R1, should be connected between +T and +C, Pins 2 and 3, to raise the voltage at –T by the ratio of thermocouple sensitivities. The ratio for converting a type J device to a type E characteristic is:

$$r\ (AD594) = (60.9\ \mu V/°C)/(51.7\ \mu V/°C) = 1.18$$

Thus, multiply the initial voltage measured at –T by r and experimentally determine the R1 value required to raise –T to that level. For the example the new –T voltage should be about 9.8 mV. The resistance value should be approximately 1.8 kΩ.

The zero differential point must now be shifted back to 0°C. This is accomplished by multiplying the original output voltage VO by r and adjusting the measured output voltage to this value by experimentally adding a resistor, R2, between –C and –T, Pins 5 and 6. The target output value in this case should be about 283 mV. The resistance value of R2 should be approximately 240 kΩ.

Finally, the gain must be recalibrated such that the output VO indicates the device's temperature once again. Do this by adding a third resistor, R3, between FB and –T, Pins 8 and 5. VO should now be back to the initial 240 mV reading. The resistance value of R3 should be approximately 280 kΩ. The final connection diagram is shown in Figure 7. An approximate verification of the effectiveness of recalibration is to measure the differential gain to the output. For type E it should be 164.2.

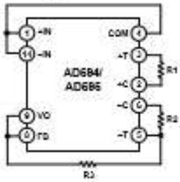


Figure 7. Type E Recalibration

When implementing a similar recalibration procedure for the AD595 the values for R1, R2, R3 and r will be approximately 650 Ω, 84 kΩ, 93 kΩ and 1.51, respectively. Power consumption will increase by about 50% when using the AD595 with type E inputs.

Note that during this procedure it is crucial to maintain the AD594/AD595 at a stable temperature because it is used as the temperature reference. Contact with fingers or any tools not at ambient temperature will quickly produce errors. Radiational heating from a change in lighting or approach of a soldering iron must also be guarded against.

USING TYPE T THERMOCOUPLES WITH THE AD595

Because of the similarity of thermal EMFs in the 0°C to +50°C range between type K and type T thermocouples, the AD595 can be directly used with both types of inputs. Within this ambient temperature range the AD595 should exhibit no more than an additional 0.2°C output calibration error when used with type T inputs. The error arises because the ice point compensator is trimmed to type K characteristics at 25°C. To calculate the AD595 output values over the recommended –200°C to +350°C range for type T thermocouples, simply use the ANSI thermocouple voltages referred to 0°C and the output equation given on page 2 for the AD595. Because of the relatively large nonlinearities associated with type T thermocouples the output will deviate widely from the nominal 10 mV/°C. However, cold junction compensation over the rated 0°C to +50°C ambient will remain accurate.

STABILITY OVER TEMPERATURE

Each AD594/AD595 is tested for error over temperature with the measuring thermocouple at 0°C. The combined effects of cold junction compensation error, amplifier offset drift and gain error determine the stability of the AD594/AD595 output over the rated ambient temperature range. Figure 8 shows an AD594/AD595 drift error envelope. The slope of this figure has units of °C/°C.

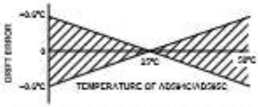


Figure 8. Drift Error vs. Temperature

THERMAL ENVIRONMENT EFFECTS

The inherent low power dissipation of the AD594/AD595 and the low thermal resistance of the package make self-heating errors almost negligible. For example, in still air the chip to ambient thermal resistance is about 80°C/watt (for the D package). At the nominal dissipation of 800 μW the self-heating in free air is less than 0.065°C. Submerged in fluorinert liquid (unstirred) the thermal resistance is about 40°C/watt, resulting in a self-heating error of about 0.032°C.

SETPOINT CONTROLLER

The AD594/AD595 can readily be connected as a setpoint controller as shown in Figure 9.

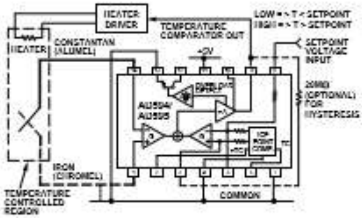


Figure 9. Setpoint Controller

The thermocouple is used to sense the unknown temperature and provide a thermal EMF to the input of the AD594/AD595. The signal is cold junction compensated, amplified to 10 mV/°C and compared to an external setpoint voltage applied by the user to the feedback at Pin 8. Table I lists the correspondence between setpoint voltage and temperature, accounting for the nonlinearity of the measurement thermocouple. If the setpoint temperature range is within the operating range (–55°C to +125°C) of the AD594/AD595, the chip can be used as the transducer for the circuit by shorting the inputs together and utilizing the nominal calibration of 10 mV/°C. This is the centigrade thermometer configuration as shown in Figure 13.

In operation if the setpoint voltage is above the voltage corresponding to the temperature being measured the output swings low to approximately zero volts. Conversely, when the temperature rises above the setpoint voltage the output switches to the positive limit of about 4 volts with a +5 V supply. Figure 9 shows the setpoint comparator configuration complete with a heater element driver circuit being controlled by the AD594/AD595 toggled output. Hysteresis can be introduced by injecting a current into the positive input of the feedback amplifier when the output is toggled high. With an AD594 about 200 nA into the +T terminal provides 1°C of hysteresis. When using a single 5 V supply with an AD594, a 20 MΩ resistor from V_O to +T will supply the 200 nA of current when the output is forced high (about 4 V). To widen the hysteresis band decrease the resistance connected from VO to +T.

ALARM CIRCUIT

In all applications of the AD594/AD595 the –ALM connection, Pin 13, should be constrained so that it is not more positive than (V+) – 4 V. This can be most easily achieved by connecting Pin 13 to either common at Pin 4 or V– at Pin 7. For most applications that use the alarm signal, Pin 13 will be grounded and the signal will be taken from +ALM on Pin 12. A typical application is shown in Figure 10.

In this configuration the alarm transistor will be off in normal operation and the 20 k pull up will cause the +ALM output on Pin 12 to go high. If one or both of the thermocouple leads are interrupted, the +ALM pin will be driven low. As shown in Figure 10 this signal is compatible with the input of a TTL gate which can be used as a buffer and/or inverter.

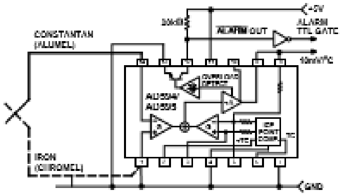


Figure 10. Using the Alarm to Drive a TTL Gate ("Grounded" Emitter Configuration)

Since the alarm is a high level output it may be used to directly drive an LED or other indicator as shown in Figure 11.

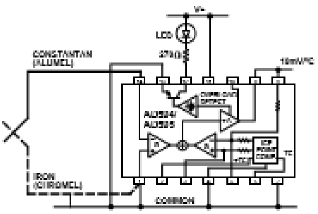


Figure 11. Alarm Directly Drives LED

A 270 Ω series resistor will limit current in the LED to 10 mA, but may be omitted since the alarm output transistor is current limited at about 20 mA. The transistor, however, will operate in a high dissipation mode and the temperature of the circuit will rise well above ambient. Note that the cold junction compensation will be affected whenever the alarm circuit is activated. The time required for the chip to return to ambient temperature will depend on the power dissipation of the alarm circuit, the nature of the thermal path to the environment and the alarm duration.

The alarm can be used with both single and dual supplies. It can be operated above or below ground. The collector and emitter of the output transistor can be used in any normal switch configuration. As an example a negative referenced load can be driven from –ALM as shown in Figure 12.

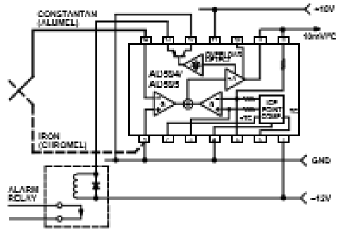


Figure 12. –ALM Driving A Negative Referenced Load

The collector (+ALM) should not be allowed to become more positive than (V–) +36 V, however, it may be permitted to be more positive than V+. The emitter voltage (–ALM) should be constrained so that it does not become more positive than 4 volts below the V+ applied to the circuit.

Additionally, the AD594/AD595 can be configured to produce an extreme upscale or downscale output in applications where an extra signal line for an alarm is inappropriate. By tying either of the thermocouple inputs to common most runaway control conditions can be automatically avoided. A +IN to common connection creates a downscale output if the thermocouple opens, while connecting –IN to common provides an upscale output.

CELSIUS THERMOMETER

The AD594/AD595 may be configured as a stand-alone Celsius thermometer as shown in Figure 13.

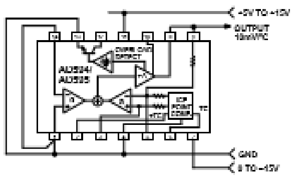


Figure 13. AD594/AD595 as a Stand-Alone Celsius Thermometer

Simply omit the thermocouple and connect the inputs (Pins 1 and 14) to common. The output now will reflect the compensation voltage and hence will indicate the AD594/AD595 temperature with a scale factor of 10 mV/°C. In this three terminal, voltage output, temperature sensing mode, the AD594/AD595 will operate over the full military –55°C to +125°C temperature range.

THERMOCOUPLE BASICS

Thermocouples are economical and rugged; they have reasonably good long-term stability. Because of their small size, they respond quickly and are good choices where fast response is important. They function over temperature ranges from cryogenics to jet-engine exhaust and have reasonable linearity and accuracy.

Because the number of free electrons in a piece of metal depends on both temperature and composition of the metal, two pieces of dissimilar metal in isothermal and contact will exhibit a potential difference that is a repeatable function of temperature, as shown in Figure 14. The resulting voltage depends on the temperatures, T1 and T2, in a repeatable way.

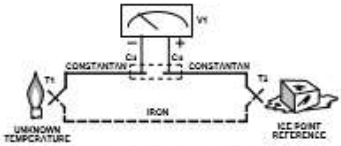


Figure 14. Thermocouple Voltage with 0°C Reference

Since the thermocouple is basically a differential rather than absolute measuring device, a know reference temperature is required for one of the junctions if the temperature of the other is to be inferred from the output voltage. Thermocouples made of specially selected materials have been exhaustively characterized in terms of voltage versus temperature compared to primary temperature standards. Most notably the water-ice point of 0°C is used for tables of standard thermocouple performance.

An alternative measurement technique, illustrated in Figure 15, is used in most practical applications where accuracy requirements do not warrant maintenance of primary standards. The reference junction temperature is allowed to change with the environment of the measurement system, but it is carefully measured by some type of absolute thermometer. A measurement of the thermocouple voltage combined with a knowledge of the reference temperature can be used to calculate the measurement junction temperature. Usual practice, however, is to use a convenient thermoelectric method to measure the reference temperature and to arrange its output voltage so that it corresponds to a thermocouple referred to 0°C. This voltage is simply added to the thermocouple voltage and the sum then corresponds to the standard voltage tabulated for an ice-point referenced thermocouple.

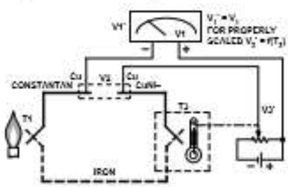


Figure 15. Substitution of Measured Reference Temperature for Ice Point Reference

The temperature sensitivity of silicon integrated circuit transistors is quite predictable and repeatable. This sensitivity is exploited in the AD594/AD595 to produce a temperature related voltage to compensate the reference of "cold" junction of a thermocouple as shown in Figure 16.

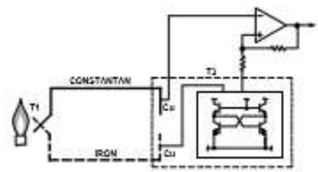


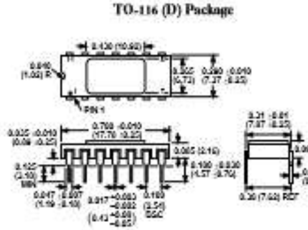
Figure 16. Connecting Isothermal Junctions

Since the compensation is at the reference junction temperature, it is often convenient to form the reference "junction" by connecting directly to the circuit wiring. So long as those connections and the compensation are at the same temperature no error will result.

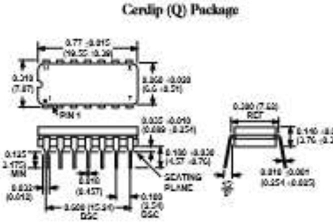
OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

TO-116 (D) Package



Cerdip (Q) Package



LAMPIRAN B
(*Listing Program* di Mikrokontroller dan Microsoft Visual Studio 2013)

2.1 Listing Program Ardunio Uno

```
#include <SPI.h>
#include <SD.h>
#include <LiquidCrystal.h>
int analogPin = 0,i;
float adc,adc_total,adc_total_fix, suhu, volt;

const int degreeSymbol = B11011111;
const int chipSelect = 7;
LiquidCrystal lcd(10, 9, 5, 4 , 3, 2);
void setup(){
 // put your setup code here, to run once:
Serial.begin(9600);
lcd.begin(16, 2);
lcd.setCursor(0,0);
lcd.print("FEBY JESSICA");
lcd.setCursor(0,1);
lcd.print("MONITORING SUHU");
delay(1500);
lcd.clear();

  while (!Serial) {
    ; // wait for serial port to connect. Needed for Leonardo only
  }
  Serial.print("Initializing SD card...");
  // see if the card is present and can be initialized:
  if (!SD.begin(chipSelect)) {
    Serial.println("Card failed, or not present");
    // don't do anything more:
    return;
  }
```

```
  Serial.println("card initialized.");
}

void loop(){
// put your main code here, to run repeatedly:
adc_total=0;
for(i=0;i<50;i++)
{
adc = analogRead(analogPin);
adc_total = adc_total+adc;
delay(0.04);
}
adc_total_fix = adc_total/50;
volt = (adc_total_fix*5)/1023;
suhu = volt*100;
  File dataFile = SD.open("datalog.txt", FILE_WRITE);
  if (dataFile) {
    dataFile.print(suhu);
dataFile.write(degreeSymbol);
dataFile.print("C");   //ke sdcard
    dataFile.close();
    Serial.print("suhu=");
    Serial.print(suhu, 2);   //Ke Visual studio 2k15
  Serial.write(degreeSymbol);
lcd.println("C");

  (Serial.available()>0);
lcd.setCursor(0,1);
lcd.print("Suhu :");
lcd.setCursor(7,1);
lcd.print(suhu);
lcd.write(degreeSymbol);

lcd.print("C");
    }
  else {
```

```
    Serial.println("error opening datalog.txt"); //bila error
  }
}
```

2.2 Listing program Visual Basic 2013

```
Imports System
Imports System.IO.Ports.SerialPort
Imports System.Data
Imports System.Data.OleDb
Public Class Form1
    Private myPortlist As String()
    Private baudlist As String() = {"300", "600",
"1200", "2400", "4800", "9600"}
    Private WithEvents myserial As New
IO.Ports.SerialPort
    Private timer, counter As Integer
    Private conString As String =
"Provider=Microsoft.ACE.OLEDB.12.0;Data
Source=E:\Feby\Kuliah\Tugas Akhir\TA FEBY\Data
Excel\Data MonSuhu.xlsx;Extended Properties = ""Excel
12.0 Xml;HDR=YES"""
    Private koneksi As
System.Data.OleDb.OleDbConnection
    Private perintah As System.Data.OleDb.OleDbCommand
    Private recording As Boolean = False
    Private suhu As Double

    Private Sub Form1_Load(sender As Object, e As
EventArgs) Handles MyBase.Load
        findPort()
        Label5.Text = Date.Now.ToShortDateString
        Label4.Text = Date.Now.ToShortTimeString
        If (myPortlist.Count >= 1) Then
           ComboBox1.Items.AddRange(myPortlist)
          ComboBox1.SelectedIndex = myPortlist.Count -1
        End If

        ComboBox2.Items.AddRange(baudlist)
        ComboBox2.SelectedIndex = 5
        Button5.Enabled = False
```

```
        Button2.Enabled = False


    End Sub
    Sub findPort()
        Dim i As Integer = 0
        For Each myport As String In
My.Computer.Ports.SerialPortNames
            ReDim Preserve myPortlist(i)
            myPortlist(i) = myport
            i += i
        Next

    End Sub

    Private Sub ComboBox1_SelectedIndexChanged(sender
As Object, e As EventArgs) Handles ComboBox1.Click
       findPort()
       ComboBox1.Items.Clear()
        If (Not myPortlist Is Nothing) Then
          ComboBox1.Items.AddRange(myPortlist)
          ComboBox1.SelectedIndex = myPortlist.Count -1
        End If

    End Sub

    Private Sub Button1_Click(sender As Object, e As
EventArgs) Handles Button1.Click

        If (Not myserial.IsOpen) Then
            myserial.PortName = ComboBox1.Text
            myserial.BaudRate = CInt(ComboBox2.Text)
            Try
                myserial.Open()

            Catch ex As Exception
                MsgBox(ex.Message)
            End Try
            If myserial.IsOpen Then
                MsgBox("Opened")
                Button1.Text = "DISCONNECTED"
            End If
```

```
        ElseIf myserial.IsOpen Then
            myserial.Close()
            If Not myserial.IsOpen Then
                Button1.Text = "CONNECT"
                MsgBox("Closed")
            End If

        End If

    End Sub
    Private Sub Timer1_Tick_1(sender As Object, e As
EventArgs) Handles Timer1.Tick
        timer += 1
        Label6.Text = timer.ToString
        Label5.Text = Date.Now.ToShortDateString
        Label4.Text = Date.Now.ToShortTimeString
        Dim per30 As Integer = timer Mod 30

        If per30 = 0 Then
            If recording = True Then
                simpan_data(suhu.ToString)
            End If
        End If
        Select Case ComboBox1.Text
            Case "2 menit"
                If timer = 120 Then
                    stop_recording()
                End If

        End Select
    End Sub
Sub stop_recording()
    Timer1.Stop()
    koneksi.Close()
    recording = False
End Sub
Private Sub myserial_dataReceive(sender As Object, e As
IO.Ports.SerialDataReceivedEventArgs)
    Dim dataReceive As String = myserial.ReadLine
    Me.Invoke(New oper(AddressOf olahdata),
dataReceive)
End Sub
```

```
Delegate Sub oper(ByVal [data] As String)
Sub olahdata(ByVal dataIn As String)
    counter += 1
    RichTextBox1.AppendText(dataIn)
        RichTextBox1.ScrollToCaret()
        Dim strTnd As Integer = InStr(dataIn, "=")
        If strTnd <> 0 Then
            Dim pisahtls As String() =
dataIn.Split("=")
            suhu = CDbl(pisahtls(pisahtls.Length - 1))
            Chart1.ChartAreas(0).RecalculateAxesScale()
            Try

Chart1.Series("Series1").Points.AddXY(counter, suhu)

            Catch ex As Exception

            End Try
        End If
    End Sub

Private Sub simpan_data(dataIn As String)
    perintah = New OleDb.OleDbCommand
    With perintah
        .Connection = koneksi
            .CommandText = "INSERT INTO [Sheet1$]
([Tanggal], [Waktu], [Suhu]) VALUES ('" +
Date.Now.ToShortDateString + "', '" +
Date.Now.ToShortTimeString + "', '" + dataIn + "')"
    End With
    Try
        perintah.ExecuteNonQuery()
    Catch ex As Exception
        MsgBox(ex.Message)
    End Try
End Sub


Private Sub Button6_Click(sender As Object, e As
EventArgs) Handles Button6.Click
    AddHandler myserial.DataReceived, AddressOf
myserial_dataReceive
```

```
    Button5.Enabled = True
    Button6.Enabled = False
End Sub

Private Sub Button5_Click(sender As Object, e As
EventArgs) Handles Button5.Click
    RemoveHandler myserial.DataReceived, AddressOf
myserial_dataReceive
    Button5.Enabled = False
    Button6.Enabled = True
End Sub

    Private Sub Button2_Click(sender As Object, e As
EventArgs) Handles Button2.Click
        koneksi = New OleDbConnection
        koneksi.ConnectionString = conString
        Try
            koneksi.Open()
        Catch ex As Exception
            MsgBox(ex.Message)
        End Try
        recording = True
        Timer1.Interval = 1000
        Timer1.Start()
        Button2.Enabled = False
    End Sub
    Private Sub ComboBox3_SelectedIndexChanged(sender
As Object, e As EventArgs) Handles
ComboBox3.SelectedIndexChanged
        Button2.Enabled = True


    End Sub

    Private Sub Button3_Click(sender As Object, e As
EventArgs) Handles Button3.Click
        stop_recording()
        Button3.Enabled = False
        Button2.Enabled = True
    End Sub
End Class
```

LAMPIRAN C
(Hasil Pengujian Tingkat Homogenitas)

1. Hasil Uji Homogenitas

enero

	PT. ENERGI AGRO NUSANTARA a subsidiary of PTPN X	No. Dokumen	ENR FM 11 44
		No. Revisi	00
		Tanggal	27 Oktober 2015

FORMULIR
REPORT OF ANALYSIS (RoA)

BB-ROA-16007/rev0

Sample Name	Gasohol
Sample Date	June 27th, 2016
Sample Time	16 : 00
Test Date	June 27th, 2016
Sampling Point	-

ANALYSIS RESULT :

No	Parameter	Unit	2 Menit	4 Menit	6 Menit	8 Menit	10 Menit
1	Ethanol Content	% v/v	16.77	19.21	19.49	20.55	20.59
2	Impurities :						
	Isobutanol	% v/v	2.43	2.16	4.18	3.23	2.67

Approved By :
Supervisor of Quality Control : Anggreini Fajar PL

Known By :
Directo : Dimas Eko Prasetyo

LAMPIRAN A
(DATASHEET AD595)

1. *Datasheet* AD595

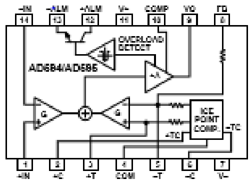
ANALOG DEVICES

Monolithic Thermocouple Amplifiers with Cold Junction Compensation

AD594/AD595

FEATURES
Pretrimmed for Type J (AD594) or
Type K (AD595) Thermocouples
Can Be Used with Type T Thermocouple Inputs
Low Impedance Voltage Output: 10 mV/°C
Built-In Ice Point Compensation
Wide Power Supply Range: +5 V to ±15 V
Low Power: <1 mW typical
Thermocouple Failure Alarm
Laser Wafer Trimmed to 1°C Calibration Accuracy
Setpoint Mode Operation
Self-Contained Celsius Thermometer Operation
High Impedance Differential Input
Side-Brazed DIP or Low Cost Cerdip

FUNCTIONAL BLOCK DIAGRAM



PRODUCT DESCRIPTION

The AD594/AD595 is a complete instrumentation amplifier and thermocouple cold junction compensator on a monolithic chip. It combines an ice point reference with a precalibrated amplifier to produce a high level (10 mV/°C) output directly from a thermocouple signal. Pin-strapping options allow it to be used as a linear amplifier-compensator or as a switched output setpoint controller using either fixed or remote setpoint control. It can be used to amplify its compensation voltage directly, thereby converting it to a stand-alone Celsius transducer with a low impedance voltage output.

The AD594/AD595 includes a thermocouple failure alarm that indicates if one or both thermocouple leads become open. The alarm output has a flexible format which includes TTL drive capability.

The AD594/AD595 can be powered from a single ended supply (including +5 V) and by including a negative supply, temperatures below 0°C can be measured. To minimize self-heating, an unloaded AD594/AD595 will typically operate with a total supply current 160 μA, but is also capable of delivering in excess of ±5 mA to a load.

The AD594 is precalibrated by laser wafer trimming to match the characteristic of type J (iron-constantan) thermocouples and the AD595 is laser trimmed for type K (chromel-alumel) inputs. The temperature transducer voltages and gain control resistors are available at the package pins so that the circuit can be recalibrated for the thermocouple types by the addition of two or three resistors. These terminals also allow more precise calibration for both thermocouple and thermometer applications.

The AD594/AD595 is available in two performance grades. The C and the A versions have calibration accuracies of ±1°C and ±3°C, respectively. Both are designed to be used from 0°C to +50°C, and are available in 14-pin, hermetically sealed, side-brazed ceramic DIPs as well as low cost cerdip packages.

PRODUCT HIGHLIGHTS

1. The AD594/AD595 provides cold junction compensation, amplification, and an output buffer in a single IC package.
2. Compensation, zero, and scale factor are all precalibrated by laser wafer trimming (LWT) of each IC chip.
3. Flexible pinout provides for operation as a setpoint controller or a stand-alone temperature transducer calibrated in degrees Celsius.
4. Operation at remote application sites is facilitated by low quiescent current and a wide supply voltage range +5 V to dual supplies spanning 30 V.
5. Differential input rejects common-mode noise voltage on the thermocouple leads.

REV. C

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781/329-4700 World Wide Web Site: http://www.analog.com
Fax: 781/326-8703

AD594/AD595–SPECIFICATIONS (@ +25°C and V_S = 5 V, Type J (AD594), Type K (AD595) Thermocouple, unless otherwise noted)

Model	AD594A Min	AD594A Typ	AD594A Max	AD594C Min	AD594C Typ	AD594C Max	AD595A Min	AD595A Typ	AD595A Max	AD595C Min	AD595C Typ	AD595C Max	Units
ABSOLUTE MAXIMUM RATING													
$+V_S$ to $-V_S$			36			36			36			36	Volts
Common-Mode Input Voltage	$-V_S - 0.15$		$+V_S$	$-V_S - 0.15$		$+V_S$	$-V_S - 0.15$		$+V_S$	$-V_S - 0.15$		$+V_S$	Volts
Differential Input Voltage	$-V_S$		$+V_S$	$-V_S$		$+V_S$	$-V_S$		$+V_S$	$-V_S$		$+V_S$	Volts
Alarm Voltages													
+ALM	$-V_S$		$-V_S + 36$	$-V_S$		$-V_S + 36$	$-V_S$		$-V_S + 36$	$-V_S$		$-V_S + 36$	Volts
–ALM	$-V_S$		$+V_S$	$-V_S$		$+V_S$	$-V_S$		$+V_S$	$-V_S$		$+V_S$	Volts
Operating Temperature Range	–55		+125	–55		+125	–55		+125	–55		+125	°C
Output Short Circuit to Common	Indefinite			Indefinite			Indefinite			Indefinite			
TEMPERATURE MEASUREMENT (Specified Temperature Range 0°C to +50°C)													
Calibration Error at +25°C[1]			±3			±1			±3			±1	°C
Stability vs. Temperature[2]			±0.05			±0.025			±0.05			±0.025	°C/°C
Gain Error			±1.5			±0.75			±1.5			±0.75	%
Nominal Transfer Function			10			10			10			10	mV/°C
AMPLIFIER CHARACTERISTICS													
Closed Loop Gain[3]		193.4			193.4			247.3			247.3		
Input Offset Voltage		(Temperature in °C) × 51.70 µV/°C			(Temperature in °C) × 51.70 µV/°C			(Temperature in °C) × 40.44 µV/°C			(Temperature in °C) × 40.44 µV/°C		µV
Input Bias Current		0.1			0.1			0.1			0.1		µA
Differential Input Range	–10		+50				–10		+50	–10		+50	mV
Common-Mode Range	$-V_S - 0.15$		$-V_S - 4$	$-V_S - 0.15$		$-V_S - 4$	$-V_S - 0.15$		$-V_S - 4$	$-V_S - 0.15$		$-V_S - 4$	Volts
Common-Mode Sensitivity – RTO			10			10			10			10	mV/V
Power Supply Sensitivity – RTO			10			10			10			10	mV/V
Output Voltage Range													
Dual Supply	$-V_S + 2.5$		$+V_S - 2$	$-V_S + 2.5$		$+V_S - 2$	$-V_S + 2.5$		$+V_S - 2$	$-V_S + 2.5$		$+V_S - 2$	Volts
Single Supply	0		$+V_S - 2$	0		$-V_S - 2$	0		$+V_S + 2$	0		$+V_S - 2$	Volts
Usable Output Current[4]		±5			±5			±5			±5		mA
3 dB Bandwidth		15			15			15			15		kHz
ALARM CHARACTERISTICS													
$V_{CE(SAT)}$ at 2 mA		0.3			0.3			0.3			0.3		Volts
Leakage Current			±1			±1			±1			±1	µA max
Operating Voltage at – ALM			$+V_S - 4$			$+V_S - 4$			$+V_S - 4$			$+V_S - 4$	Volts
Short Circuit Current		20			20			20			20		mA
POWER REQUIREMENTS													
Specified Performance		$+V_S = 5, -V_S = 0$			$+V_S = 5, -V_S = 0$			$+V_S = 5, -V_S = 0$			$+V_S = 5, -V_S = 0$		Volts
Operating[5]		$+V_S$ to $-V_S \leq 30$			$+V_S$ to $-V_S \leq 30$			$+V_S$ to $-V_S \leq 30$			$+V_S$ to $-V_S \leq 30$		Volts
Quiescent Current (No Load)													
$+V_S$		160	300		160	300		160	300		160	300	µA
$-V_S$		100			100			100			100		µA
PACKAGE OPTION													
TO-116 (D-14)		AD594AD			AD594CD			AD595AD			AD595CD		
Cerdip (Q-14)		AD594AQ			AD594CQ			AD595AQ			AD595CQ		

NOTES
[1]Calibrated for minimum error at +25°C using a thermocouple sensitivity of 51.7 µV/°C. Since a J type thermocouple deviates from this straight line approximation, the AD594 will normally read 3.1 mV when the measuring junction is at 0°C. The AD595 will similarly read 2.7 mV at 0°C.
[2]Defined as the slope of the line connecting the AD594/AD595 errors measured at 0°C and 50°C ambient temperature.
[3]Pin 8 shorted to Pin 9.
[4]Current Sink Capability in single supply configuration is limited to current drawn to ground through a 50 kΩ resistor at output voltages below 2.5 V.
[5]$-V_S$ must not exceed –16.5 V.

Specifications shown in boldface are tested on all production units at final electrical test. Results from those tests are used to calculate outgoing quality levels. All min and max specifications are guaranteed, although only those shown in boldface are tested on all production units.
Specifications subject to change without notice.

INTERPRETING AD594/AD595 OUTPUT VOLTAGES

To achieve a temperature proportional output of 10 mV/°C and accurately compensate for the reference junction over the rated operating range of the circuit, the AD594/AD595 is gain trimmed to match the transfer characteristic of J and K type thermocouples at 25°C. For a type J output in this temperature range the TC is 51.70 µV/°C, while for a type K it is 40.44 µV/°C. The resulting gain for the AD594 is 193.4 (10 mV/°C divided by 51.7 µV/°C) and for the AD595 is 247.3 (10 mV/°C divided by 40.44 µV/°C). In addition, an absolute accuracy trim induces an input offset to the output amplifier characteristic of 16 µV for the AD594 and 11 µV for the AD595. This offset arises because the AD594/AD595 is trimmed for a 250 mV output while applying a 25°C thermocouple input.

Because a thermocouple output voltage is nonlinear with respect to temperature, and the AD594/AD595 linearly amplifies the compensated signal, the following transfer functions should be used to determine the actual output voltages:

AD594 output = (Type J Voltage + 16 µV) × 193.4

AD595 output = (Type K Voltage + 11 µV) × 247.3 or conversely:

Type J voltage = (AD594 output/193.4) – 16 µV

Type K voltage = (AD595 output/247.3) – 11 µV

Table I lists the ideal AD594/AD595 output voltages as a function of Celsius temperature for type J and K ANSI standard thermocouples, with the package and reference junction at 25°C. As is normally the case, these outputs are subject to calibration, gain and temperature sensitivity errors. Output values for intermediate temperatures can be interpolated, or calculated using the output equations and ANSI thermocouple voltage tables referred to zero degrees Celsius. Due to a slight variation in alloy content between ANSI type J and DIN Fe-CuNi

Table I. Output Voltage vs. Thermocouple Temperature (Ambient +25°C, V_S = –5 V, +15 V)

Thermocouple Temperature °C	Type J Voltage mV	AD594 Output mV	Type K Voltage mV	AD595 Output mV
–200	–7.890	–1523	–5.891	–1454
–180	–7.402	–1428	–5.550	–1370
–160	–6.821	–1316	–5.141	–1269
–140	–6.159	–1188	–4.669	–1152
–120	–5.426	–1046	–4.138	–1021
–100	–4.632	–893	–3.553	–876
–80	–3.785	–729	–2.920	–719
–60	–2.892	–556	–2.243	–552
–40	–1.960	–376	–1.527	–375
–20	–.995	–189	–.777	–189
–10	–.501	–94	–.392	–94
0	0	3.1	0	2.7
10	.507	101	.397	101
20	1.019	200	.798	200
25	1.277	250	1.000	250
30	1.536	300	1.203	300
40	2.058	401	1.611	401
50	2.585	503	2.022	503
60	3.115	606	2.436	605
80	4.186	813	3.266	810
100	5.268	1022	4.095	1015
120	6.359	1233	4.919	1219
140	7.457	1445	5.733	1420
160	8.560	1659	6.539	1620
180	9.667	1873	7.338	1817
200	10.777	2087	8.137	2015
220	11.887	2302	8.938	2213
240	12.998	2517	9.745	2413
260	14.108	2732	10.560	2614
280	15.217	2946	11.381	2817
300	16.325	3160	12.207	3022
320	17.432	3374	13.039	3227
340	18.537	3588	13.874	3434
360	19.640	3801	14.712	3641
380	20.743	4015	15.552	3849
400	21.846	4228	16.395	4057
420	22.949	4441	17.241	4266
440	24.054	4655	18.088	4476
460	25.161	4869	18.938	4686
480	26.273	5084	19.788	4896
500	27.388	5300	20.640	5107
520	28.511	5517	21.493	5318
540	29.642	5736	22.346	5529
560	30.782	5956	23.198	5740
580	31.933	6179	24.050	5950
600	33.096	6404	24.902	6161
620	34.273	6632	25.751	6371
640	35.464	6862	26.599	6581
660	36.671	7095	27.445	6790
680	37.893	7332	28.288	6998
700	39.130	7571	29.128	7206
720	40.382	7813	29.965	7413
740	41.647	8058	30.799	7619
750	42.283	8181	31.214	7722
760	–	–	31.628	7825
780	–	–	32.455	8029
800	–	–	33.277	8232
820	–	–	34.095	8434
840	–	–	34.909	8636
860	–	–	35.718	8836
880	–	–	36.524	9035
900	–	–	37.325	9233
920	–	–	38.122	9430
940	–	–	38.915	9626
960	–	–	39.703	9821
980	–	–	40.488	10015
1000	–	–	41.269	10209
1020	–	–	42.045	10400
1040	–	–	42.817	10591
1060	–	–	43.585	10781
1080	–	–	44.439	10970
1100	–	–	45.108	11158
1120	–	–	45.863	11345
1140	–	–	46.612	11530
1160	–	–	47.356	11714
1180	–	–	48.095	11897
1200	–	–	48.828	12078
1220	–	–	49.555	12258
1240	–	–	50.276	12436
1250	–	–	50.633	12524

thermocouples Table I should not be used in conjunction with European standard thermocouples. Instead the transfer function given previously and a DIN thermocouple table should be used. ANSI type K and DIN NiCr-Ni thermocouples are composed

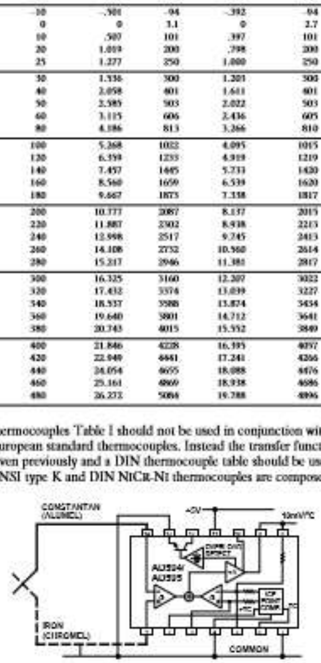


Figure 1. Basic Connection, Single Supply Operation

of identical alloys and exhibit similar behavior. The upper temperature limits in Table I are those recommended for type J and type K thermocouples by the majority of vendors.

SINGLE AND DUAL SUPPLY CONNECTIONS

The AD594/AD595 is a completely self-contained thermocouple conditioner. Using a single +5 V supply the interconnections shown in Figure 1 will provide a direct output from a type J thermocouple (AD594) or type K thermocouple (AD595) measuring from 0°C to +300°C.

Any convenient supply voltage from +5 V to +30 V may be used, with self-heating errors being minimized at lower supply levels. In the single supply configuration the +5 V supply connects to Pin 11 with the V– connection at Pin 7 strapped to power and signal common at Pin 4. The thermocouple wire inputs connect to Pins 1 and 14 either directly from the measuring point or through intervening connections of similar thermocouple wire type. When the alarm output at Pin 13 is not used it should be connected to common or –V. The precalibrated feedback network at Pin 8 is tied to the output at Pin 9 to provide a 10 mV/°C nominal temperature transfer characteristic.

By using a wider ranging dual supply, as shown in Figure 2, the AD594/AD595 can be interfaced to thermocouples measuring both negative and extended positive temperatures.

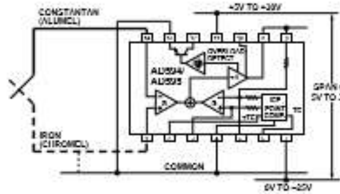


Figure 2. Dual Supply Operation

With a negative supply the output can indicate negative temperatures and drive grounded loads or loads returned to positive voltages. Increasing the positive supply from 5 V to 15 V extends the output voltage range well beyond the 750°C temperature limit recommended for type J thermocouples (AD594) and the 1250°C for type K thermocouples (AD595).

Common-mode voltages on the thermocouple inputs must remain within the common-mode range of the AD594/AD595, with a return path provided for the bias currents. If the thermocouple is not remotely grounded, then the dotted line connections in Figures 1 and 2 are recommended. A resistor may be needed in this connection to assure that common-mode voltages induced in the thermocouple loop are not converted to normal mode.

THERMOCOUPLE CONNECTIONS

The isothermal terminating connections of a pair of thermocouple wires forms an effective reference junction. This junction must be kept at the same temperature as the AD594/AD595 for the internal cold junction compensation to be effective.

A method that provides for thermal equilibrium is the printed circuit board connection layout illustrated in Figure 3.

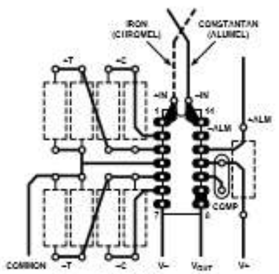


Figure 3. PCB Connections

Here the AD594/AD595 package temperature and circuit board are thermally contacted in the copper printed circuit board tracks under Pins 1 and 14. The reference junction is now composed of a copper-constantan (or copper-alumel) connection and copper-iron (or copper-chromel) connection, both of which are at the same temperature as the AD594/AD595.

The printed circuit board layout shown also provides for placement of optional alarm load resistors, recalibration resistors and a compensation capacitor to limit bandwidth.

To ensure secure bonding the thermocouple wire should be cleaned to remove oxidation prior to soldering. Noncorrosive rosin flux is effective with iron, constantan, chromel and alumel and the following solders: 95% tin-5% antimony, 95% tin-5% silver or 90% tin-10% lead.

FUNCTIONAL DESCRIPTION

The AD594 behaves like two differential amplifiers. The outputs are summed and used to control a high gain amplifier, as shown in Figure 4.

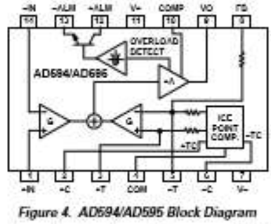


Figure 4. AD594/AD595 Block Diagram

In normal operation the main amplifier output, at Pin 9, is connected to the feedback network, at Pin 8. Thermocouple signals applied to the floating input stage, at Pins 1 and 14, are amplified by gain G of the differential amplifier and are then further amplified by gain A in the main amplifier. The output of the main amplifier is fed back to a second differential stage in an inverting connection. The feedback signal is amplified by this stage and is also applied to the main amplifier input through a summing circuit. Because of the inversion, the amplifier causes the feedback to be driven to reduce this difference signal to a small value. The two differential amplifiers are made to match and have identical gains, G. As a result, the feedback signal that must be applied to the right-hand differential amplifier will precisely match the thermocouple input signal when the difference signal has been reduced to zero. The feedback network is trimmed so that the effective gain to the output, at Pins 8 and 9, results in a voltage of 10 mV/°C of thermocouple excitation.

In addition to the feedback signal, a cold junction compensation voltage is applied to the right-hand differential amplifier. The compensation is a differential voltage proportional to the Celsius temperature of the AD594/AD595. This signal disturbs the differential input so that the amplifier output must adjust to restore the input to equal the applied thermocouple voltage.

The compensation is applied through the gain scaling resistors so that its effect on the main output is also 10 mV/°C. As a result, the compensation voltage adds to the effect of the thermocouple voltage a signal directly proportional to the difference between 0°C and the AD594/AD595 temperature. If the thermocouple reference junction is maintained at the AD594/AD595 temperature, the output of the AD594/AD595 will correspond to the reading that would have been obtained from amplification of a signal from a thermocouple referenced to an ice bath.

The AD594/AD595 also includes an input open circuit detector that switches on an alarm transistor. This transistor is actually a current-limited output buffer, but can be used up to the limit as a switch transistor for either pull-up or pull-down operation of external alarms.

The ice point compensation network has voltages available with positive and negative temperature coefficients. These voltages may be used with external resistors to modify the ice point compensation and recalibrate the AD594/AD595 as described in the next column.

The feedback resistor is separately pinned out so that its value can be padded with a series resistor, or replaced with an external resistor between Pins 5 and 9. External availability of the feedback resistor allows gain to be adjusted, and also permits the AD594/AD595 to operate in a switching mode for setpoint operation.

CAUTIONS:

The temperature compensation terminals (+C and –C) at Pins 2 and 6 are provided to supply small calibration currents only. The AD594/AD595 may be permanently damaged if they are grounded or connected to a low impedance.

The AD594/AD595 is internally frequency compensated for feedback ratios (corresponding to normal signal gain) of 75 or more. If a lower gain is desired, additional frequency compensation should be added in the form of a 300 pF capacitor from Pin 10 to the output at Pin 9. As shown in Figure 5 an additional 0.01 µF capacitor between Pins 10 and 11 is recommended.

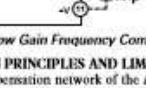


Figure 5. Low Gain Frequency Compensation

RECALIBRATION PRINCIPLES AND LIMITATIONS

The ice point compensation network of the AD594/AD595 produces a differential signal which is zero at 0°C and corresponds to the output of an ice referenced thermocouple at the temperature of the chip. The positive TC output of the circuit is proportional to Kelvin temperature and appears as a voltage at +T. It is possible to decrease this signal by loading it with a resistor from +T to COM, or increase it with a pull-up resistor from +T to the larger positive TC voltage at +C. Note that adjustments to +T should be made by measuring the voltage which tracks it at –T. To avoid destabilizing the feedback amplifier the measuring instrument should be isolated by a few thousand ohms in series with the lead connected to –T.

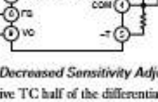


Figure 6. Decreased Sensitivity Adjustment

Changing the positive TC half of the differential output of the compensation scheme shifts the zero point away from 0°C. The zero can be restored by adjusting the current flow into the negative input of the feedback amplifier, the –T pin. A current into this terminal can be produced with a resistor between –C and –T to balance an increase in +T, or a resistor from –T to COM to offset a decrease in +T.

If the compensation is adjusted substantially to accommodate a different thermocouple type, its effect on the final output voltage will increase or decrease in proportion. To restore the nominal output to 10 mV/°C the gain may be adjusted to match the new compensation and thermocouple input characteristics. When reducing the compensation the resistance between –T and COM automatically increases the gain to within 0.5% of the correct value. If a smaller gain is required, however, the nominal 47 kΩ internal feedback resistor can be paralleled or replaced with an external resistor.

Fine calibration adjustments will require temperature response measurements of individual devices to assure accuracy. Major reconfigurations for other thermocouple types can be achieved without seriously compromising initial calibration accuracy, so long as the procedure is done at a fixed temperature using the factory calibration as a reference. It should be noted that intermediate recalibration conditions may require the use of a negative supply.

EXAMPLE: TYPE E RECALIBRATION—AD594/AD595

Both the AD594 and AD595 can be configured to condition the output of a type E (chromel-constantan) thermocouple. Temperature characteristics of type E thermocouples differ less from type J, than from type K, therefore the AD594 is preferred for recalibration.

While maintaining the device at a constant temperature follow the recalibration steps given here. First, measure the device temperature by tying both inputs to common (or a selected common-mode potential) and connecting FB to VO. The AD594 is now in the stand alone Celsius thermometer mode. For this example assume the ambient is 24°C and the initial output VO is 240 mV. Check the output at VO to verify that it corresponds to the temperature of the device.

Next, measure the voltage –T at Pin 5 with a high impedance DVM (capacitance should be isolated by a few thousand ohms of resistance at the measured terminals). At 24°C the –T voltage will be about 8.3 mV. To adjust the compensation of an AD594 to a type E thermocouple a resistor, R1, should be connected between +T and +C, Pins 2 and 3, to raise the voltage at –T by the ratio of thermocouple sensitivities. The ratio for converting a type J device to a type E characteristic is:

$$r\ (AD594) = (60.9\ \mu V/°C)/(51.7\ \mu V/°C) = 1.18$$

Thus, multiply the initial voltage measured at –T by r and experimentally determine the R1 value required to raise –T to that level. For the example the new –T voltage should be about 9.8 mV. The resistance value should be approximately 1.8 kΩ.

The zero differential point must now be shifted back to 0°C. This is accomplished by multiplying the original output voltage VO by r and adjusting the measured output voltage to this value by experimentally adding a resistor, R2, between –C and –T, Pins 5 and 6. The target output value in this case should be about 283 mV. The resistance value of R2 should be approximately 240 kΩ.

Finally, the gain must be recalibrated such that the output VO indicates the device's temperature once again. Do this by adding a third resistor, R3, between FB and –T, Pins 8 and 5. VO should now be back to the initial 240 mV reading. The resistance value of R3 should be approximately 280 kΩ. The final connection diagram is shown in Figure 7. An approximate verification of the effectiveness of recalibration is to measure the differential gain to the output. For type E it should be 164.2.

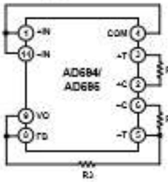


Figure 7. Type E Recalibration

When implementing a similar recalibration procedure for the AD595 the values for R1, R2, R3 and r will be approximately 650 Ω, 84 kΩ, 93 kΩ and 1.51, respectively. Power consumption will increase by about 50% when using the AD595 with type E inputs.

Note that during this procedure it is crucial to maintain the AD594/AD595 at a stable temperature because it is used as the temperature reference. Contact with fingers or any tools not at ambient temperature will quickly produce errors. Radiational heating from a change in lighting or approach of a soldering iron must also be guarded against.

USING TYPE T THERMOCOUPLES WITH THE AD595

Because of the similarity of thermal EMFs in the 0°C to +50°C range between type K and type T thermocouples, the AD595 can be directly used with both types of inputs. Within this ambient temperature range the AD595 should exhibit no more than an additional 0.2°C output calibration error when used with type T inputs. The error arises because the ice point compensator is trimmed to type K characteristics at 25°C. To calculate the AD595 output values over the recommended –200°C to +350°C range for type T thermocouples, simply use the ANSI thermocouple voltages referred to 0°C and the output equation given on page 2 for the AD595. Because of the relatively large nonlinearities associated with type T thermocouples the output will deviate widely from the nominal 10 mV/°C. However, cold junction compensation over the rated 0°C to +50°C ambient will remain accurate.

STABILITY OVER TEMPERATURE

Each AD594/AD595 is tested for error over temperature with the measuring thermocouple at 0°C. The combined effects of cold junction compensation error, amplifier offset drift and gain error determine the stability of the AD594/AD595 output over the rated ambient temperature range. Figure 8 shows an AD594/AD595 drift error envelope. The slope of this figure has units of °C/°C.

Figure 8. Drift Error vs. Temperature

THERMAL ENVIRONMENT EFFECTS

The inherent low power dissipation of the AD594/AD595 and the low thermal resistance of the package make self-heating errors almost negligible. For example, in still air the chip to ambient thermal resistance is about 80°C/watt (for the D package). At the nominal dissipation of 800 μW the self-heating in free air is less than 0.065°C. Submerged in fluorinert liquid (unstirred) the thermal resistance is about 40°C/watt, resulting in a self-heating error of about 0.032°C.

SETPOINT CONTROLLER

The AD594/AD595 can readily be connected as a setpoint controller as shown in Figure 9.

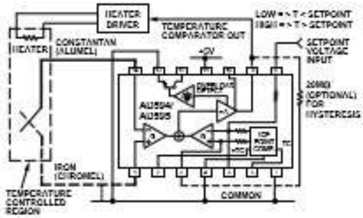


Figure 9. Setpoint Controller

The thermocouple is used to sense the unknown temperature and provide a thermal EMF to the input of the AD594/AD595. The signal is cold junction compensated, amplified to 10 mV/°C and compared to an external setpoint voltage applied by the user to the feedback at Pin 8. Table I lists the correspondence between setpoint voltage and temperature, accounting for the nonlinearity of the measurement thermocouple. If the setpoint temperature range is within the operating range (–55°C to +125°C) of the AD594/AD595, the chip can be used as the transducer for the circuit by shorting the inputs together and utilizing the nominal calibration of 10 mV/°C. This is the centigrade thermometer configuration as shown in Figure 13.

In operation if the setpoint voltage is above the voltage corresponding to the temperature being measured the output swings low to approximately zero volts. Conversely, when the temperature rises above the setpoint voltage the output switches to the positive limit of about 4 volts with a +5 V supply. Figure 9 shows the setpoint comparator configuration complete with a heater element driver circuit being controlled by the AD594/AD595 toggled output. Hysteresis can be introduced by injecting a current into the positive input of the feedback amplifier when the output is toggled high. With an AD594 about 200 nA into the +T terminal provides 1°C of hysteresis. When using a single 5 V supply with an AD594, a 20 MΩ resistor from V_O to +T will supply the 200 nA of current when the output is forced high (about 4 V). To widen the hysteresis band decrease the resistance connected from VO to +T.

ALARM CIRCUIT

In all applications of the AD594/AD595 the –ALM connection, Pin 13, should be constrained so that it is not more positive than (V+) – 4 V. This can be most easily achieved by connecting Pin 13 to either common at Pin 4 or V– at Pin 7. For most applications that use the alarm signal, Pin 13 will be grounded and the signal will be taken from +ALM on Pin 12. A typical application is shown in Figure 10.

In this configuration the alarm transistor will be off in normal operation and the 20 k pull up will cause the +ALM output on Pin 12 to go high. If one or both of the thermocouple leads are interrupted, the +ALM pin will be driven low. As shown in Figure 10 this signal is compatible with the input of a TTL gate which can be used as a buffer and/or inverter.

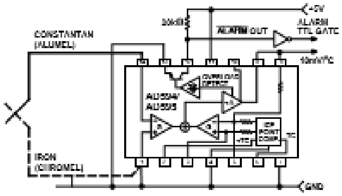


Figure 10. Using the Alarm to Drive a TTL Gate ("Grounded" Emitter Configuration)

Since the alarm is a high level output it may be used to directly drive an LED or other indicator as shown in Figure 11.

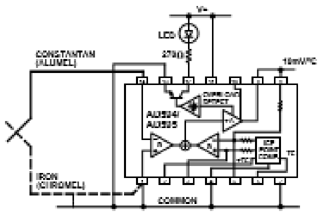


Figure 11. Alarm Directly Drives LED

A 270 Ω series resistor will limit current in the LED to 10 mA, but may be omitted since the alarm output transistor is current limited at about 20 mA. The transistor, however, will operate in a high dissipation mode and the temperature of the circuit will rise well above ambient. Note that the cold junction compensation will be affected whenever the alarm circuit is activated. The time required for the chip to return to ambient temperature will depend on the power dissipation of the alarm circuit, the nature of the thermal path to the environment and the alarm duration.

The alarm can be used with both single and dual supplies. It can be operated above or below ground. The collector and emitter of the output transistor can be used in any normal switch configuration. As an example a negative referenced load can be driven from –ALM as shown in Figure 12.

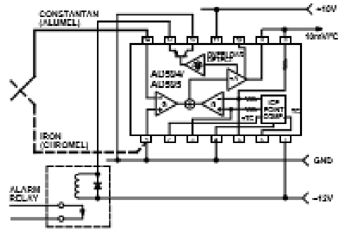


Figure 12. –ALM Driving A Negative Referenced Load

The collector (+ALM) should not be allowed to become more positive than (V–) +36 V, however, it may be permitted to be more positive than V+. The emitter voltage (–ALM) should be constrained so that it does not become more positive than 4 volts below the V+ applied to the circuit.

Additionally, the AD594/AD595 can be configured to produce an extreme upscale or downscale output in applications where an extra signal line for an alarm is inappropriate. By tying either of the thermocouple inputs to common most runaway control conditions can be automatically avoided. A +IN to common connection creates a downscale output if the thermocouple opens, while connecting –IN to common provides an upscale output.

CELSIUS THERMOMETER

The AD594/AD595 may be configured as a stand-alone Celsius thermometer as shown in Figure 13.

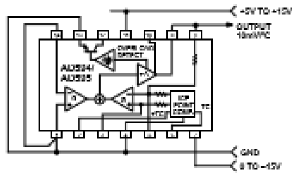


Figure 13. AD594/AD595 as a Stand-Alone Celsius Thermometer

Simply omit the thermocouple and connect the inputs (Pins 1 and 14) to common. The output now will reflect the compensation voltage and hence will indicate the AD594/AD595 temperature with a scale factor of 10 mV/°C. In this three terminal, voltage output, temperature sensing mode, the AD594/AD595 will operate over the full military –55°C to +125°C temperature range.

THERMOCOUPLE BASICS

Thermocouples are economical and rugged; they have reasonably good long-term stability. Because of their small size, they respond quickly and are good choices where fast response is important. They function over temperature ranges from cryogenics to jet-engine exhaust and have reasonable linearity and accuracy.

Because the number of free electrons in a piece of metal depends on both temperature and composition of the metal, two pieces of dissimilar metal in isothermal and contact will exhibit a potential difference that is a repeatable function of temperature, as shown in Figure 14. The resulting voltage depends on the temperatures, T1 and T2, in a repeatable way.

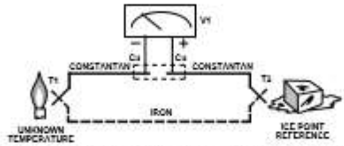


Figure 14. Thermocouple Voltage with 0°C Reference

Since the thermocouple is basically a differential rather than absolute measuring device, a know reference temperature is required for one of the junctions if the temperature of the other is to be inferred from the output voltage. Thermocouples made of specially selected materials have been exhaustively characterized in terms of voltage versus temperature compared to primary temperature standards. Most notably the water-ice point of 0°C is used for tables of standard thermocouple performance.

An alternative measurement technique, illustrated in Figure 15, is used in most practical applications where accuracy requirements do not warrant maintenance of primary standards. The reference junction temperature is allowed to change with the environment of the measurement system, but it is carefully measured by some type of absolute thermometer. A measurement of the thermocouple voltage combined with a knowledge of the reference temperature can be used to calculate the measurement junction temperature. Usual practice, however, is to use a convenient thermoelectric method to measure the reference temperature and to arrange its output voltage so that it corresponds to a thermocouple referred to 0°C. This voltage is simply added to the thermocouple voltage and the sum then corresponds to the standard voltage tabulated for an ice-point referenced thermocouple.

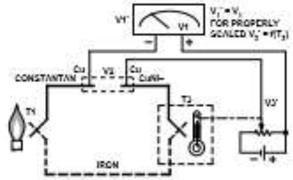


Figure 15. Substitution of Measured Reference Temperature for Ice Point Reference

The temperature sensitivity of silicon integrated circuit transistors is quite predictable and repeatable. This sensitivity is exploited in the AD594/AD595 to produce a temperature related voltage to compensate the reference of "cold" junction of a thermocouple as shown in Figure 16.

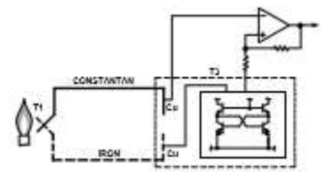


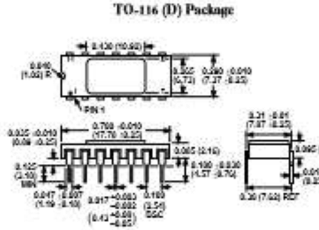
Figure 16. Connecting Isothermal Junctions

Since the compensation is at the reference junction temperature, it is often convenient to form the reference "junction" by connecting directly to the circuit wiring. So long as these connections and the compensation are at the same temperature no error will result.

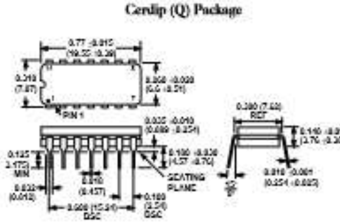
OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

TO-116 (D) Package



Cerdip (Q) Package



LAMPIRAN B
(*Listing Program* di Mikrokontroller dan Microsoft Visual Studio 2013)

2.1 Listing Program Ardunio Uno

```
#include <SPI.h>
#include <SD.h>
#include <LiquidCrystal.h>
int analogPin = 0,i;
float adc,adc_total,adc_total_fix, suhu, volt;

const int degreeSymbol = B11011111;
const int chipSelect = 7;
LiquidCrystal lcd(10, 9, 5, 4 , 3, 2);
void setup(){
 // put your setup code here, to run once:
Serial.begin(9600);
lcd.begin(16, 2);
lcd.setCursor(0,0);
lcd.print("FEBY JESSICA");
lcd.setCursor(0,1);
lcd.print("MONITORING SUHU");
delay(1500);
lcd.clear();

  while (!Serial) {
    ; // wait for serial port to connect. Needed for Leonardo only
  }
  Serial.print("Initializing SD card...");
  // see if the card is present and can be initialized:
  if (!SD.begin(chipSelect)) {
    Serial.println("Card failed, or not present");
    // don't do anything more:
    return;
  }
```

```
  Serial.println("card initialized.");
}

void loop(){
// put your main code here, to run repeatedly:
adc_total=0;
for(i=0;i<50;i++)
{
adc = analogRead(analogPin);
adc_total = adc_total+adc;
delay(0.04);
}
adc_total_fix = adc_total/50;
volt = (adc_total_fix*5)/1023;
suhu = volt*100;
  File dataFile = SD.open("datalog.txt", FILE_WRITE);
  if (dataFile) {
    dataFile.print(suhu);
dataFile.write(degreeSymbol);
dataFile.print("C");   //ke sdcard
    dataFile.close();
    Serial.print("suhu=");
    Serial.print(suhu, 2);   //Ke Visual studio 2k15
  Serial.write(degreeSymbol);
lcd.println("C");

  (Serial.available()>0);
lcd.setCursor(0,1);
lcd.print("Suhu :");
lcd.setCursor(7,1);
lcd.print(suhu);
lcd.write(degreeSymbol);

lcd.print("C");
    }
  else {
```

```
  Serial.println("error opening datalog.txt"); //bila error
 }
}
```

2.2 Listing program Visual Basic 2013

```
Imports System
Imports System.IO.Ports.SerialPort
Imports System.Data
Imports System.Data.OleDb
Public Class Form1
    Private myPortlist As String()
    Private baudlist As String() = {"300", "600",
"1200", "2400", "4800", "9600"}
    Private WithEvents myserial As New
IO.Ports.SerialPort
    Private timer, counter As Integer
    Private conString As String =
"Provider=Microsoft.ACE.OLEDB.12.0;Data
Source=E:\Feby\Kuliah\Tugas Akhir\TA FEBY\Data
Excel\Data MonSuhu.xlsx;Extended Properties = ""Excel
12.0 Xml;HDR=YES"""
    Private koneksi As
System.Data.OleDb.OleDbConnection
    Private perintah As System.Data.OleDb.OleDbCommand
    Private recording As Boolean = False
    Private suhu As Double

    Private Sub Form1_Load(sender As Object, e As
EventArgs) Handles MyBase.Load
        findPort()
        Label5.Text = Date.Now.ToShortDateString
        Label4.Text = Date.Now.ToShortTimeString
        If (myPortlist.Count >= 1) Then
           ComboBox1.Items.AddRange(myPortlist)
          ComboBox1.SelectedIndex = myPortlist.Count -1
        End If

        ComboBox2.Items.AddRange(baudlist)
        ComboBox2.SelectedIndex = 5
        Button5.Enabled = False
```

```
        Button2.Enabled = False


    End Sub
    Sub findPort()
        Dim i As Integer = 0
        For Each myport As String In
My.Computer.Ports.SerialPortNames
            ReDim Preserve myPortlist(i)
            myPortlist(i) = myport
            i += i
        Next

    End Sub

    Private Sub ComboBox1_SelectedIndexChanged(sender
As Object, e As EventArgs) Handles ComboBox1.Click
       findPort()
       ComboBox1.Items.Clear()
        If (Not myPortlist Is Nothing) Then
          ComboBox1.Items.AddRange(myPortlist)
          ComboBox1.SelectedIndex = myPortlist.Count -1
        End If

    End Sub

    Private Sub Button1_Click(sender As Object, e As
EventArgs) Handles Button1.Click

        If (Not myserial.IsOpen) Then
            myserial.PortName = ComboBox1.Text
            myserial.BaudRate = CInt(ComboBox2.Text)
            Try
                myserial.Open()

            Catch ex As Exception
                MsgBox(ex.Message)
            End Try
            If myserial.IsOpen Then
                MsgBox("Opened")
                Button1.Text = "DISCONNECTED"
            End If
```

```
        ElseIf myserial.IsOpen Then
            myserial.Close()
            If Not myserial.IsOpen Then
                Button1.Text = "CONNECT"
                MsgBox("Closed")
            End If

        End If

    End Sub
    Private Sub Timer1_Tick_1(sender As Object, e As
EventArgs) Handles Timer1.Tick
        timer += 1
        Label6.Text = timer.ToString
        Label5.Text = Date.Now.ToShortDateString
        Label4.Text = Date.Now.ToShortTimeString
        Dim per30 As Integer = timer Mod 30

        If per30 = 0 Then
            If recording = True Then
                simpan_data(suhu.ToString)
            End If
        End If
        Select Case ComboBox1.Text
            Case "2 menit"
                If timer = 120 Then
                    stop_recording()
                End If

        End Select
    End Sub
Sub stop_recording()
    Timer1.Stop()
    koneksi.Close()
    recording = False
End Sub
Private Sub myserial_dataReceive(sender As Object, e As
IO.Ports.SerialDataReceivedEventArgs)
    Dim dataReceive As String = myserial.ReadLine
    Me.Invoke(New oper(AddressOf olahdata),
dataReceive)
End Sub
```

```
Delegate Sub oper(ByVal [data] As String)
Sub olahdata(ByVal dataIn As String)
    counter += 1
    RichTextBox1.AppendText(dataIn)
        RichTextBox1.ScrollToCaret()
        Dim strTnd As Integer = InStr(dataIn, "=")
        If strTnd <> 0 Then
            Dim pisahtls As String() =
dataIn.Split("=")
            suhu = CDbl(pisahtls(pisahtls.Length - 1))
            Chart1.ChartAreas(0).RecalculateAxesScale()
            Try

Chart1.Series("Series1").Points.AddXY(counter, suhu)

            Catch ex As Exception

            End Try
        End If
    End Sub

Private Sub simpan_data(dataIn As String)
    perintah = New OleDb.OleDbCommand
    With perintah
        .Connection = koneksi
            .CommandText = "INSERT INTO [Sheet1$]
([Tanggal], [Waktu], [Suhu]) VALUES ('" +
Date.Now.ToShortDateString + "', '" +
Date.Now.ToShortTimeString + "', '" + dataIn + "')"
    End With
    Try
        perintah.ExecuteNonQuery()
    Catch ex As Exception
        MsgBox(ex.Message)
    End Try
End Sub


Private Sub Button6_Click(sender As Object, e As
EventArgs) Handles Button6.Click
    AddHandler myserial.DataReceived, AddressOf
myserial_dataReceive
```

```
    Button5.Enabled = True
    Button6.Enabled = False
End Sub

Private Sub Button5_Click(sender As Object, e As
EventArgs) Handles Button5.Click
    RemoveHandler myserial.DataReceived, AddressOf
myserial_dataReceive
    Button5.Enabled = False
    Button6.Enabled = True
End Sub

    Private Sub Button2_Click(sender As Object, e As
EventArgs) Handles Button2.Click
        koneksi = New OleDbConnection
        koneksi.ConnectionString = conString
        Try
            koneksi.Open()
        Catch ex As Exception
            MsgBox(ex.Message)
        End Try
        recording = True
        Timer1.Interval = 1000
        Timer1.Start()
        Button2.Enabled = False
    End Sub
    Private Sub ComboBox3_SelectedIndexChanged(sender
As Object, e As EventArgs) Handles
ComboBox3.SelectedIndexChanged
        Button2.Enabled = True


    End Sub

    Private Sub Button3_Click(sender As Object, e As
EventArgs) Handles Button3.Click
        stop_recording()
        Button3.Enabled = False
        Button2.Enabled = True
    End Sub
End Class
```

LAMPIRAN C
(Hasil Pengujian Tingkat Homogenitas)

1. Hasil Uji Homogenitas

enero

	PT. ENERGI AGRO NUSANTARA a subsidiary of PTPN X	No. Dokumen	ENR FM 11 44
		No. Revisi	00
		Tanggal	27 Oktober 2015
FORMULIR REPORT OF ANALYSIS (RoA)			

BB-ROA-16007/rev0

Sample Name	Gasohol
Sample Date	June 27th, 2016
Sample Time	16 : 00
Test Date	June 27th, 2016
Sampling Point	-

ANALYSIS RESULT :

No	Parameter	Unit	2 Menit	4 Menit	6 Menit	8 Menit	10 Menit
1	Ethanol Content	% v/v	16.77	19.21	19.49	20.55	20.59
2	Impurities :						
	Isobutanol	% v/v	2.43	2.16	4.18	3.23	2.67

Approved By :
Supervisor of Quality Control : Anggreini Fajar PL

Known By :
Directo : Dimas Eko Prasetyo

BAB V
PENUTUP

5.1 Kesimpulan

Telah dibuat alat eksperimen sistem monitoring temperatur pada mini plant sistem *blending* bioetanol dan dan dari kegiatan monitoring temperatur dapat disimpulkan bahwa :

- Telah dibuat alat eksperimen rancang bangun sistem monitoring temperatur pada sistem *blending* bioetanol dan premium dengan menggunakan sensor termokopel serta rangkaian AD595 sebagai penguat sinyal yang telah diintegrasikan dengan mikrokontroler *arduino uno*.
- Dari hasil monitoring temperatur didapatkan hasil pengambilan data temperatur setiap 30 detik sebanyak lima kali metode pengambilan rata-rata temperaturnya selama 2 menit sebesar 24,70^oC, 4 menit sebesar 25,31^oC, 6 menit 26,15^oC, 8 menit 26,16^oC dan 10 sebesar 26,41^oC menit, sebelum monitoring temperatur dilakukan kalibrasi pada sensor dan didapatkan nilai ketidakpastian diperluas sebesar 0,563472. Nilai karakteristik statik dari sensor termokopel baut tipe K diantaranya Range sebesar 10 ^oC – 25^oC, Span sebesar 15^oC, Resolusi sebesar 0,01, Sensitifivitas (K) sebesar 1,0193^oC, Histerisis sebesar 0,13 %, Akurasi sebesar 99,10% dan *Error* sebesar 0,90%
- Pada saat di *blending* semakin lama proses *blending* rata-rata suhu semakin tinggi. Pada saat *blending* suhu naik dipengaruhi oleh tangki tertutup yang memampatkan udara dan bahan bakar serta faktor lingkungan dimana tangki *blending* tidak diberi selimut atau pelindung agar suhu tidak terpengaruh oleh suhu udara luar.

5.2 Rekomendasi

Adapun saran yang disampaikan untuk melengkapi atau melanjutkan penelitian ini agar monitoring temperatur pada sistem *blending* bioetanol dan premium semakin sempurna, yaitu:

- Sebaiknya tangki diberi selimut atau pelindung tangki agar suhu tangki tidak terpengaruh oleh faktor suhu dari luar tangki.
- Sebaiknya sensor termokopel diberi isolator agar suhu tetap stabil ketika monitoring temperatur saat proses *blending*

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BIODATA PENULIS

FEBY JESSICA AYU atau biasa akrab dipanggil Feby, lahir di Madiun 04 November 1994 dari ayah bernama Henri Yuli Hartanto dan ibu bernama Retno Indari P.D. Penulis merupakan Anak kedua dari tiga bersaudara. Mahasiswa Jurusan Teknik Fisika Prodi D3 Metrologi dan Instrumentasi Fakultas Teknologi Industri, Institut Teknologi Sepuluh Nopember Surabaya. Penulis berasal dari kota madiun, alamat Perumahan Bumimas Blok J No 11 Madiun. Pada tahun 2007, penulis menyelesaikan pendidikan tingkat dasar di SDN 01 Kartoharjo Madiun. Pada tahun 2010 penulis menyelesaikan pendidikan tingkat menengah di SMPN 04 Madiun. Tahun 2013 berhasil menyelesaikan pendidikan tingkat menengah atas di SMAN 2 Madiun. Dan pada tahun 2016 ini, penulis mampu menyelesaikan gelar ahli madya di Program Studi DIII-Metrologi dan Instrumentasi, Jurusan Teknik Fisika Institut Teknologi Sepuluh Nopember Surabaya. Penulis berhasil menyelesaikan Tugas Akhir dengan judul “RANCANG BANGUN SISTEM MONITORING TEMPERATUR PADA MINI PLANT SISTEM *BLENDING* BIOETANOL DAN PREMIUM”. Bagi pembaca yang memiliki kritik, saran, atau ingin berdiskusi lebih lanjut mengenai Tugas Akhir ini maka dapat menghubungi penulis melalui email febyjessica@yahoo.com