PERANCANGAN DAN PEMBUATAN SISTEM KONTROL TEMPERATUR UNTUK ALAT DESTILASI ETANOL BERBASIS ARDUINO

SKRIPSI

Disusun Oleh :

LUTFI ROZAQI

14.12.902

JURUSAN TEKNIK ELEKTRO S-1

KONSENTRASI TEKNIK ELEKTRONIKA

FAKULTAS TEKNOLOGI INDUSTRI

INSTITUT TEKNOLOGI NASIONAL MALANG

2016

LEMBAR PERSETUJUAN

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SKRIPSI

Disusun dan Diajukan Untuk Melengkapi dan Memenuhi Persyaratan
Guna Mencapai Gelar Sarjana Teknik

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Lutfi Rozaqi

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ABSTRAK

Etanol memiliki banyak manfaat, misalnya digunakan pada kosmetik, kesehatan, bahan baku industri, dan sumber bahan bakar alternatif. Tingkat konsentrasi etanol yang dimanfaatkan berbeda-beda sesuai dengan penggunaannya. Untuk memperoleh etanol dengan konsentrasi yang tinggi dapat dilakukan proses destilasi untuk memisahkan etanol dengan larutan lain. Proses destilasi merupakan proses pemisahan suatu campuran menjadi dua atau lebih produk dengan memanfaatkan perbedaaan suhu penguapan komponen campuran. Untuk melakukan penguapan cairan perlu dilakukan pemanasan dengan suhu yang tepat, di mana suhu penguapan dari etanol adalah antara 78°C hingga 80°C.

Pada umumnya proses untuk menjaga kondisi temperatur pemanasan pada destilasi etanol masih dilakukan secara manual, untuk itu dalam perancangan alat ini diimplementasikan sistem kontrol suhu otomatis untuk pemanasan pada proses destilasi etanol. Dalam perancangan sistem digunakan arduino sebagai kontroler utama dengan heater sebagai aktuator untuk pemanas. Suhu pemanasan heater dikendalikan oleh arduino berdasarkan pembacaan oleh sensor suhu DS18B20. Suhu pemanasan heater ditentukan oleh besar input tegangan yang diberikan. Sehingga digunakan rangkaian kontrol pemicuan sudut fasa untuk mengendalikan input tegangan AC dari heater.

Berdasarkan hasil pengujian dapat diketahui bahwa dengan menggunakan sampel berupa etanol 70% dengan volume 3.5 liter dan set point suhu 78°C serta waktu kerja selama 3 jam diperoleh etanol yang memiliki volume sebesar 66 ml dengan konsentrasi 88% di mana durasi waktu agar suhu dapat mencapai set point adalah 1 jam 5 menit, dengan error pengontrolan suhu pemanasan sebesar 1.39% dan error pembacaan sensor suhu sebesar 0.285%.

Kata Kunci *:Etanol, Destilasi, Kontrol Suhu, Arduino*

DESIGN AND MANUFACTURE OF ARDUINO BASED TEMPERATURE CONTROL SYSTEM FOR ETHANOL DISTILLATION DEVICE

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ABSTRACT

Ethanol has many purpose, for example, used in cosmetics, healthcare, industrial raw materials, and alternative fuel sources. The degree of concentration from ethanol which is used varies according to its use. To obtain higher ethanol concentrations, may do a distillation process to separate ethanol with other components of liquid. The distillation process is the process of separating a mixture of liquid into two or more components by utilizing temperature differences for vaporization between each components. For the vaporation of some mixture fluid, warming process needs to be done with the correct temperature, where the degree temperature for vaporization of ethanol is between 78°C to 80°C.

Generally, the process to maintain the condition of the heating temperature in the distillation of ethanol is still done manually, therefore in the design of the device, implemented an automatic temperature control system for heating in the ethanol distillation process. The system designed using arduino as the main controller with heater as the actuator for heating. Heating temperature of the heater is controlled by arduino based on a sensing by the DS18B20 temperature sensor. Heater temperature is determined by the input voltage applied to the device. Hence the phase-fired controller circuit is used to control AC voltage input from the heater.

Based on the test results, it can be seen that by using a sample of 70% ethanol with a volume of 3.5 liters and a temperature set point of 78°C and working time of device for 3 hours, obtained ethanol which has a volume of 66 ml with a concentration of 88% where the duration of time for the temperature to reach the set point is 1 hour 5 minutes, with the error of temperature heating control is 1.39% and the sensing error of temperature sensor is 0.285%.

***Keywords** :Ethanol, Distillation, Temperature Control, Arduino*

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Adapun maksud dan tujuan dari penulisan laporan ini merupakan salah satu syarat untuk dapat menyelesaikan studi dan mendapatkan gelar Sarjana Jurusan Teknik Elektro S-1, Konsentrasi Teknik Elektronika ITN Malang.

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Malang, Agustus 2016

Penulis

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BAB I
PENDAHULUAN

1.1. Latar Belakang Masalah

Etanol memiliki banyak manfaat, misalnya digunakan pada kosmetik yaitu sebagai bahan untuk parfum, di mana etanol digunakan untuk pelarut karena aromanya yang sedap. Di bidang kesehatan etanol banyak dimanfaatkan sebagai zat antiseptik. Etanol juga dapat digunakan untuk *solvent*, serta sebagai bahan baku industri. Manfaat lain dari etanol yaitu sebagai salah satu sumber energi alternatif yang mempunyai beberapa kelebihan, diantaranya sifat etanol yang dapat diperbarui dan ramah lingkungan karena memiliki emisi karbondioksida yang rendah.[1]

Grade atau tingkat konsentrasi etanol yang dimanfaatkan berbeda-beda sesuai dengan penggunaannya. Untuk etanol yang mempunyai tingkat konsentrasi 90-96,5% dapat digunakan pada industri, sedangkan etanol yang mempunyai tingkat konsentrasi 96-99,5% dapat digunakan sebagai campuran untuk bahan dasar industri farmasi. Tingkat konsentrasi etanol yang dapat dimanfaatkan unutk campuran bahan bakar untuk kendaraan sebesar 99,5-100%. [2]

Untuk memperoleh etanol dengan konsentrasi yang tinggi dapat dilakukan proses destilasi. Destilasi dilakukan untuk memisahkan etanol dengan larutan lain.[2] Pada dasarnya pada proses ini terjadi pemisahan suatu campuran menjadi dua atau lebih produk lewat pengeksploitasian perbedaan kemampuan menguap komponen-komponen campuran pada suatu cairan.[3] Untuk meningkatkan kadar etanol dapat dilakukan dengan proses destilasi dengan suhu terkontrol antara 78°C hingga 80°C.[4] Dengan memanaskan larutan pada suhu tersebut akan mengakibatkan sebagian besar etanol menguap, dan melalui unit kondensasi dapat dihasilkan etanol dengan konsentrasi yang lebih tinggi. [2]

Pada umumnya proses untuk menjaga kondisi temperatur pemanasan pada destilasi etanol masih dilakukan secara manual, padahal seperti yang diketahui proses destilasi etanol membutuhkan temperatur yang konstan agar etanol dan air dapat terpisah. Dengan berkembangnya teknologi yang cukup pesat muncul berbagai solusi dari permasalahan tersebut, salah satuya adalah dengan pembuatan sistem kontrol otomatis berbasis *board* arduino. *Board* arduino dapat diaplikasikan untuk mengontrol otomasi dari proses pemanasan pada destilasi etanol. Untuk pengaplikasiannya, *board* arduino perlu mengetahui suhu dari cairan yang memiliki etanol sebagai *feedback* untuk kontrol suhu pemanasan dari *heater* agar tetap bernilai konstan.

1.2. Rumusan Masalah

Rumusan masalah yang akan dibahas pada penelitian adalah pada proses destilasi etanol diperlukan suhu yang konstan antara 78°C hingga 80°C yang di mana apabila berubah-ubah maka konsentrasi etanol akan berkurang disebabkan kandungan lain pada cairan yang akan didestilasi juga ikut terbawa. Sehingga muncul permasalahan sebagai berikut :

1. Bagaimana cara merancang dan membuat suatu aplikasi kontrol untuk pemanasan untuk alat destilasi dengan suhu pemanasan konstan antara 78°C hingga 80°C?

1.3. Tujuan Penelitian

Tujuan dari penelitian ini adalah untuk merancang dan membuat aplikasi kontrol untuk pemanasan pada alat destilasi etanol agar pemanas dapat menghasilkan suhu konstan antara 78°C hingga 80°C sehingga proses destilasi etanol dapat berjalan dengan baik.

1.4. Batasan Masalah

Masalah yang akan dibatasi pada pembahasan dari penelitian ini adalah :

1. Menggunakan Arduino sebagai kontroler.
2. Menggunakan sensor suhu untuk benda cair.
3. Alat destilasi berkapasitas maksimal 4 liter disebabkan digunakan sebagai *prototype*.
4. Hanya membahas kontrol suhu untuk pemanasan pada proses destilasi etanol.
5. Sampel etanol mengunakan etanol 70%
6. Suhu pemanasan yang dikontrol untuk sampel adalah 78°C.
7. Volume sampel yang digunakan adalah 3.5 liter.
8. Waktu pengujian dibatasi hingga 3 jam.

1.5. Metodologi Masalah

Dalam pelakasanaan penelitian, penulis menggunakan metode penelitian terapan. Penelitian dan pengembangan dilakukan untuk menyelesaikan permasalahan yang akan dibahas. Pada pengumpulan data, dilakukan studi literatur yang ditujukan untuk menemukan konsep-konsep atau landasan-landasan teoretis untuk pelaksanaan penelitian. Kemudian konsep tersebut memunculkan suatu ide perancangan suatu metode bentuk penyelesaian yang biasanya dapat berupa suatu aplikasi suatu sistem maupun sebuah alat unutuk menyelesakan masalah.

Hasil perancangan aplikasi suatu sistem atau alat tersebut divalidasi melalui diskusi dengan pakar dan para ahli lainnya sehingga dapat diketahui kekurangan dari hasil penelitian tersebut. Selanjutnya hasil rancangan direalisasikan dengan membuat aplikasi suatu sistem atau alat tersebut.

Untuk mengetahui kinerja dari aplikasi suatu sistem atau alat tersebut perlu dilakukan pengujian dan pengamatan secara langsung terhadap hasil penelitian. Hasil pengujian dibandingkan dengan konsep-konsep atau landasan-landasan teoretis sehingga dapat diperoleh data untuk dianalisis bagaimana kinerja dari aplikasi suatu sistem atau alat tersebut dapat mempengaruhi dan menyelesaikan permasalahan dan dapat ditarik suatu kesimpulan dari metode penyelesaian tersebut.

1.6. Sistematika Penulisan

Untuk mempermudah dan memahami pembahasan penulisanskripsi ini, sistematika penulisan disusun sebagai berikut:

BAB I : PENDAHULUAN

Bab ini meliputi latar belakang masalah, rumusan masalah, tujuan, batasan masalah, metodologi, dan sistematika penulisan dari penelitian.

BAB II : KAJIAN PUSTAKA

Dalam bab ini memuat tentang kajian teori dan data-data referensi yang akan digunakan di dalam penelitian.

BAB III : PERANCANGAN DAN PEMBUATAN

Bab ini berisikan tentang desain untuk perancangan dan pembuatan aplikasi atau alat.

BAB IV : PENGUJIAN DAN ANALISA

Bab ini berisikan tentang langkah-langkah pengujian terhadap aplikasi atau alat beserta analisa dari hasil pengujian.

BAB V : PENUTUP

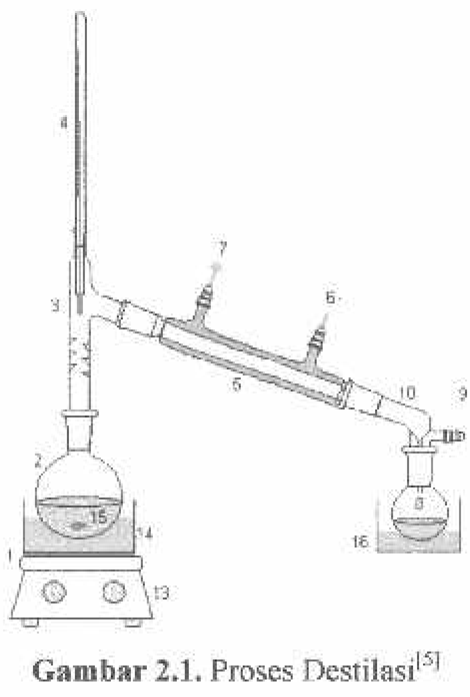
Bab ini berisikan tentang kesimpulan dari penelitan dan saran yang digunakan sebagai pertimbangan untuk pengembangan dari penelitian.

BAB II
KAJIAN PUSTAKA

2.1. Destilasi

Proses destilasi merupakan proses pemisahan dua zat atau lebih yang mempunyai perbedaan titik didih. Jika zat-zat yang dipisahkan mempunyai perbedaan titik didih yang jauh berbeda, dapat digunakan metode isolasi biasa. Zat yang memiliki titik didih rendah akan cepat menguap dari pada zat yang bertitik didih tinggi. Uap dari bahan yang memiliki titik didih rendah akan mudah menguap masuk ke dalam pipa-pipa kondensor serta mengalami proses terjadi proses pendinginan, sehingga akan turun berupa tetesan-tetesan yang turun ke dalam penampung atau disebut juga destilat. Proses destilasi adalah proses pengolahan sudah ratusan tahun diaplikasikan secara luas.

Pada dasarnya pada proses ini terjadi pemisahan suatu campuran menjadi dua atau lebih produk lewat eksploitasi perbedaan kemampuan menguap komponen-komponen dalam campuran.[3]



Gambar 2.1. Proses Destilasi[5]

Gambar di atas menunjukkan contoh proses destilasi, di mana suatu campuran yang berupa cairan (nomor 15) dimasukkan ke dalam labu (nomor 2) yang dipanaskan melalui penangas (nomor 14) dengan *heater* (nomor 13). Suhu pemanasan dapat diatur dengan mengamati termometer (nomor 4). Pada saat dipanaskan, sedikit demi sedikit campuran akan menguap. Uap kemudian naik melalui pipa (nomor 3) dan mengalir menuju pendingin atau kondensor (nomor 5). Pendinginan uap adalah dengan cara mengalirkan air melalui dinding pendingin. Setelah melalui pendingin, uap akan mengembun membentuk cairan kembali dan melaju ke adaptor (10) dan menetes ke labu destilat (8).[5]

2.2. Etanol

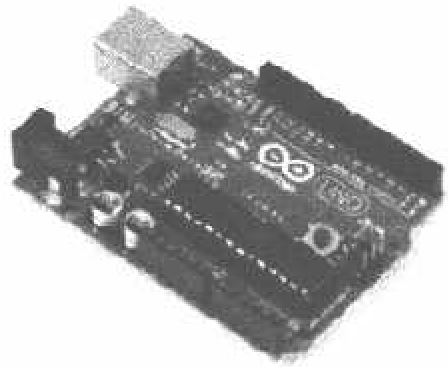
Alkohol adalah senyawa hidrokarbon berupa gugus hydroksil (-OH) dengan 2 atom karbon (C). Spesies alkohol yang banyak digunakan adalah CH_3CH_2OH yang disebut metil alkohol (metanol), C_2H_5OH yang diberi nama etil alkohol (etanol), dan C_3H_7OH yang disebut isopropil alkohol (IPA) atau propanol-2. Dalam dunia perdagangan yang disebut alkohol adalah etanol atau etil alkohol atau metil karbinol dengan rumus kimia C_2H_5OH.[6] Etanol disebut juga etil alkohol dengan rumus kimia C_2H_5OH atau CH_3CH_2OH. Etanol memiliki sifat tidak berwarna, volatil dan dapat bercampur dengan air.[7]

Destilasi dilakukan untuk memisahkan etanol dengan air. Untuk meningkatkan kadar etanol dapat dilakukan dengan proses destilasi dengan suhu terkontrol antara 78°C hingga 80°C.[4] Dengan memanaskan larutan pada suhu tersebut akan mengakibatkan sebagian besar etanol menguap, dan melalui unit kondensasi dapat dihasilkan etanol dengan konsentrasi yang lebih tinggi.

Mengingat pemanfaatan bioetanol atau etanol beraneka ragam, sehingga *grade* tingkat konsentrasi etanol yang dimanfaatkan harus berbeda sesuai dengan penggunaannya. Untuk etanol yang mempunyai tingkat konsentrasi 90-96,5% dapat digunakan pada industri, sedangkan etanol yang mempunyai tingkat konsentrasi 96-99,5% dapat digunakan sebagai campuran untuk bahan dasar industri farmasi. Besarnya tingkat konsentrasi etanol yang dimanfaatkan sebagai campuran bahan bakar untuk kendaraan sebesar 99,5-100%.[1]

2.3. Arduino

Arduino sebagai sebuah *platform* komputasi fisik yang bersifat *open source* pada papan (*board*) I/O yang sederhana. Arduino terdiri dari dua bagian utama yaitu *hardware* berupa papan Arduino dan Arduino IDE sebagai *software* untuk membuat *sketch* program untuk di-*upload* pada papan Arduino.[8]



Gambar 2.2. Bentuk Fisik Arduino Uno[8]

Mikrokontroler yang digunakan pada Arduino adalah mikrokontroler jenis Atmel AVR. Atmel AVR adalah keluarga mikrokontroler dengan arsitektur RISC (*Reduce Instruction Set Computing*) 8-bit. Mikrokontroler Atmel AVR memiliki fitur yang lengkap, di antaranya Port I/O, ADC, Timer/Counter, PWM, komunikasi serial, komunikasi I2C, *watchdog*, dan lain sebagainya.[9]

2.4. Sensor Suhu DS18B20

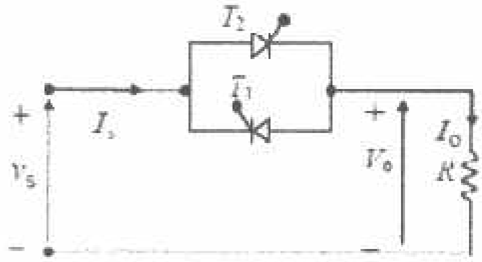
Gambar 2.3. Bentuk Fisik Sensor Suhu DS18B20[10]

Sensor suhu DS18B20 merupakan thermometer digital yang dapat melakukan pengukuran suhu skala Celsius dengan resolusi ketelitia 9-bit hingga 12-bit. Sensor DS18B20 menggunakan komunikasi antarmuka 1-Wire bus di mana pada devais yang *support* dengan antarmuka ini, cukup membutuhkan satu jalur data untuk berkomunikasi dengan devais lain misalnya mikroprosessor. Tiap sensor DS18B20 memiliki kode serial unik 64-bit sebagai alamat sehingga dalam satu jalur data dapat difungsikan beberapa sensor DS18B20. Sensor ini dapat mengukur temperatur dari -55°C hingga +125°C.[11]

2.5. Pengontrol Tegangan AC

Untuk transfer energi, dua jenis pengontrol yang biasa digunakan yaitu kontrol *on-off* dan kontrol sudut fasa. Pada kontrol *on-off*, saklar thyristor menghubungkan beban dengan sumber AC selama beberapa putaran tegangan masukan dan diputus selama beberapa putaran yang lain. Pada kontrol sudut fasa, saklar thyristor menghubungkan beban dengan sumber ac untuk setiap bagian dari putaran tegangan masukan. Sehingga bila dibandingkan dengan kontrol *on-off*, kontrol sudut fasa dapat memberikan *range* pengaturan tegangan secara penuh.[12]

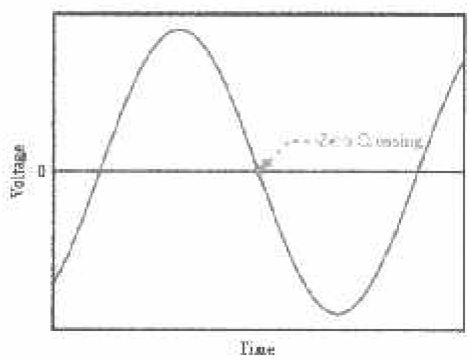
2.5.1. Prinsip Kontrol Sudut Fasa



Gambar 2.4. Rangkaian Pengontrol Gelombang Penuh Satu Fasa[12]

Prinsip dari kontrol sudut fasa untuk gelombang penuh satu fasa dapat dijelaskan berdasarkan rangkaian pada gambar di atas. Energi mengalir ke beban dikontrol dengan menunda sudut pemicuan (*firing angle*) thyristor *T1* dan sudut pemicuan thyristor *T2*.[12]

2.5.2. Rangkaian *Zero Crossing Detector*



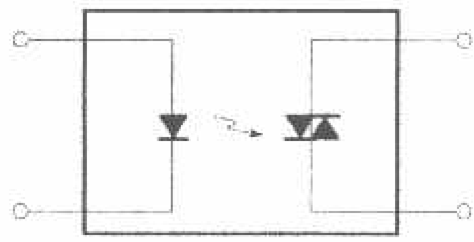
Gambar 2.5. *Zero Crossing*[13]

Rangkaian *zero crossing detector* adalah rangkaian yang digunakan untuk mendeteksi gelombang sinus AC 220V saat melewati titik tegangan nol. Titik nol yang dideteksi merupakan titik peralihan antar siklus.[14]

2.5.3. TRIAC

TRIAC dapat bersifat konduktif dalam dua arah. Dalam hal ini dapat dianggap sebagai dua buah thyristor tersambung secara antiparalel. Karena TRIAC merupakan komponen bidirectional, terminalnya tidak dapat ditentukan sebagai anode atau katode. Tiap koneksi kaki dari TRIAC diberi nama *main terminal 1* (MT1), *main terminal 2* (MT2) dan *gate* atau gerbang (G).[12]

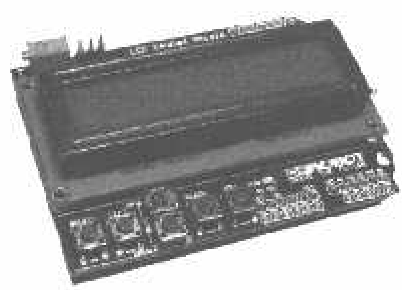
2.5.4. MOC Opto Isolator



Gambar 2.6. MOC Opto Isolator[15]

MOC merupakan driver TRIAC untuk sudut fasa yang bersifat acak yang terdiri atas LED alumunium gallium arsenide yang dipasangkan dengan chip detektor berbahan silikon. Terdapat sekat antara LED dengan output yang didesain sebagai driver kontrol TRIAC untuk beban AC. Output MOC akan mengeluarkan sinyal untuk mendriver TRIAC yang lebih besar.[15]

2.6. DFR0009 Arduino LCD *Keypad Shield*

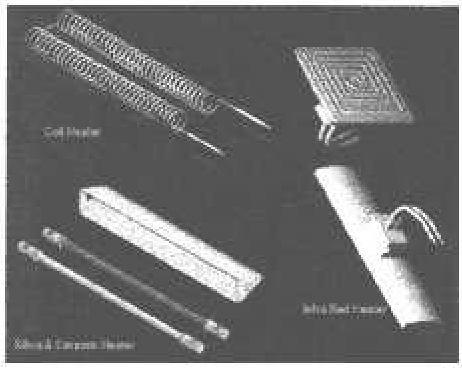


Gambar 2.7. DFR0009 Arduino LCD *Keypad Shield*[16]

DFR0009 Arduino LCD *keypad shield* dirancang bagi *board* Arduino, untuk menyediakan antarmuka bersifat *user-friendly* yang memiliki fitur sebagai *display* yang dilengkapi dengan *keypad* sehingga pengguna dapat melakukan pemilihan menu atau perintah beserta tampilannya dengan hanya satu buah *shield*.

Shield ini terdiri atas LCD karakter 16x2 dan keypad yang terdiri atas 5 buah *button* yaitu *select*, *up*, *down*, *right*, dan *left*. Untuk menghemat pin, antarmuka *keypad* menggunakan 1 buah pin ADC (A0).[16]

2.7. Elemen *Heater*



Gambar 2.8. Contoh Elemen Heater[17]

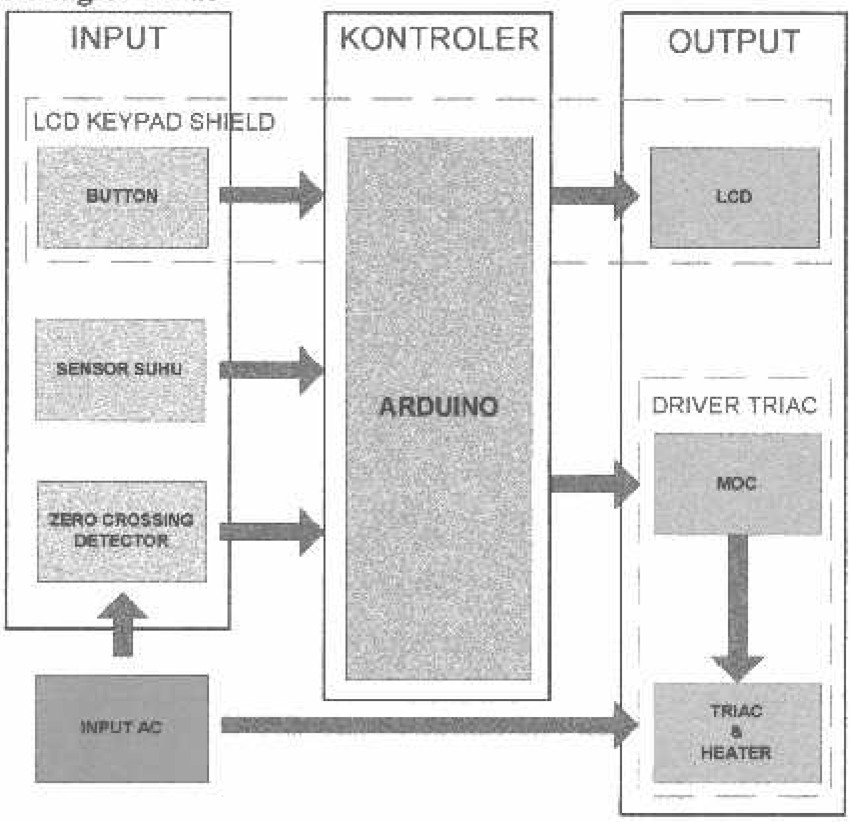
Elemen pemanas listrik ini bersumber dari kawat yang memiliki tahanan listrik tinggi (*resistance wire)*, sehingga ketika terjadi panas maka kawat tersebut tidak leleh atau terbakar. Bahan yang sering dipakai adalah nikelin yang dialiri arus listrik. Selanjutnya dilapisi oleh bahan isolasi yang dapat meneruskan panas dan aman untuk dapat digunakan. Menurut bentuknya terbagi menjadi dua jenis elemen pemanas listrik yaitu, elemen pemanas listrik bentuk dasar yaitu elemen pemanas dimana *resistance wire* hanya dilapisi oleh isolator listrik. Kedua, elemen pemanas listrik bentuk lanjut merupakan elemen pemanas dari bentuk dasar yang dilapisi oleh pipa atau lembaran plat logam untuk maksud sebagai penyesuaian terhadap penggunaan dari elemen pemanas tersebut.[17]

BAB III

PERANCANGAN DAN PEMBUATAN

Pada bab ini dibahas mengenai perancangan dari sistem yang dibagi atas blok diagram alat, prinsip kerja alat, perancangan perangkat keras, dan perancangan perangkat lunak

3.1. Blok Diagram Alat



Gambar 3.1. Blok Diagram Alat

Uraian

- Sensor Suhu

  Sebagai detektor nilai suhu pada cairan yang akan didestilasi.

- Rangkaian ZCD (*Zero Crossing Detector*)

  Sebagai pendeteksi titik nol atau titik sudut fasa pada gelombang AC.

- Arduino.

  Sebagai kontroler utama untuk kontrol suhu pada proses pemanasan pada saat destilasi.

- LCD Keypad Shield
  a. LCD

     Sebagai penampil nilai suhu pada cairan yang akan didestilasi.

  b. Button

     Sebagai devais untuk menginputkan nilai *set point* suhu.
- Driver TRIAC
  a. MOC (Opto-Isolator)

     Sebagai penyekat dan kopling antara output DC sebagai sinyal kendali waktu pemicuan dari arduino dengan input AC untuk pemicuan TRIAC.

  b. TRIAC

     Sebagai driver untuk input tegangan AC untuk AC dari *heater*.
- *Heater*

  Sebagai pemanas untuk cairan yang akan didestilasi.

3.2. Prinsip Kerja Alat

Prinsip kerja dari alat adalah:

- Nilai suhu dari cairan yang akan didestilasi akan ditampilkan dalam display berupa LCD secara *realtime*.
- Setelah sensor suhu mendeteksi nilai suhu pada cairan yang akan didestiasi, kemudian nilai deteksi akan dibandingkan dengan nilai *set point* suhu yang diinputkan. Nilai hasil perbandingan merupakan nilai yang menentukan bagaimana tingkat pemanasan pada *heater*, apabila telah mendekati suhu yang diinginkan maka *heater* akan mengurangi suhu pemanasan dan *heater* akan berhenti bekerja bila suhu telah mencapai nilai set point. Seperti yang diketahui bahwa nilai suhu pemanasan oleh *heater* ditentukan oleh besar tegangan yang disalurkan pada elemen dari *heater*. Untuk mengatur input tegangan tersebut digunakan rangkaian pemicu sudut fasa yang terdiri atas rangkaian *Zero-Crossing Detector* sebagai sinkronisasi dengan arduino untuk mengendalikan sinyal pemicuan sudut fasa pada rangkaian *driver* TRIAC yang digunakan untuk mengendalikan tegangan input AC dari *heater*.
- Rangkaian *Zero-Crossing Detector* yang diinputkan pada arduino digunakan sebagai deteksi titik sudut fasa dari input AC. Rangkaian ini digunakan untuk sinkronisasi fasa pemicuan agar tidak terjadi pergeseran fasa pada arduino

untuk sinyal kendali input AC pada *heater* menggunakan rangkaian driver TRIAC. Rangkaian *Zero-Crossing Detector* bekerja dengan memberi sinyal acuan kapan waktu titik sudut fasa tegangan AC sehingga waktu pemicuan sinyal dari arduino ke driver TRIAC dapat diketahui.

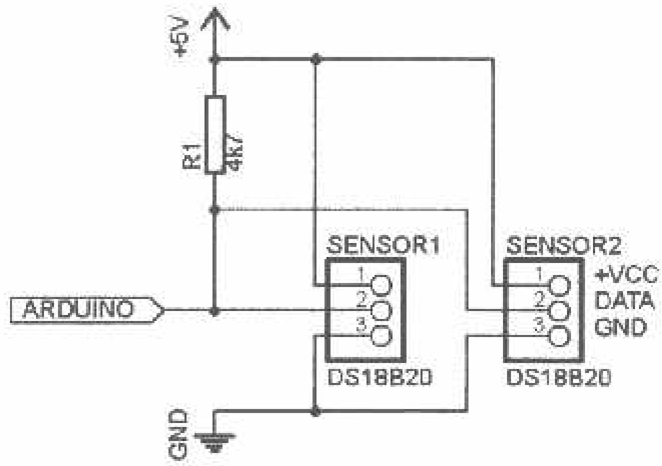
- Arduino mengirimkan sinyal pemicuan pada rangkaian driver TRIAC. Pada rangkaian terdapat komponen MOC sebelum ke TRIAC karena sinyal dari arduino merupakan sinyal DC sehingga perlu diberikan kopling untuk memicu *gate* dari TRIAC yang memerlukan sinyal AC sebagai sinyal picu. Lama penundaan dari pengiriman sinyal oleh arduino pada driver TRIAC menentukan lama waktu on dari tegangan input untuk *heater* sebagai pemanas cairan destilasi. Apabila waktu penundaan semakin lama, maka nilai tegangan input akan semakin turun karena waktu on untuk input tegangan semakin pendek sehingga suhu pemanasan *heater* akan berkurang. Seperti yang diketahui bahwa *heater* terdiri atas kawat nikelin di mana apabila terdapat tegangan melewati kawat maka kawat akan muncul dissipasi daya sehingga menimbulkan panas, bila nilai tegangan yang lewat pada kawat nikelin semakin besar maka dissipasi daya juga meningkat sehingga suhu pemanasan juga ikut meningkat.

3.3. Perancangan Alat

Pada bab ini dibahas mengenai perancangan sistem dari alat yang terdiri atas perancangan perangkat keras dan perancangan perangkat lunak.

3.3.1. Perancangan Perangkat Keras

a. Rangkaian Sensor DS18B20

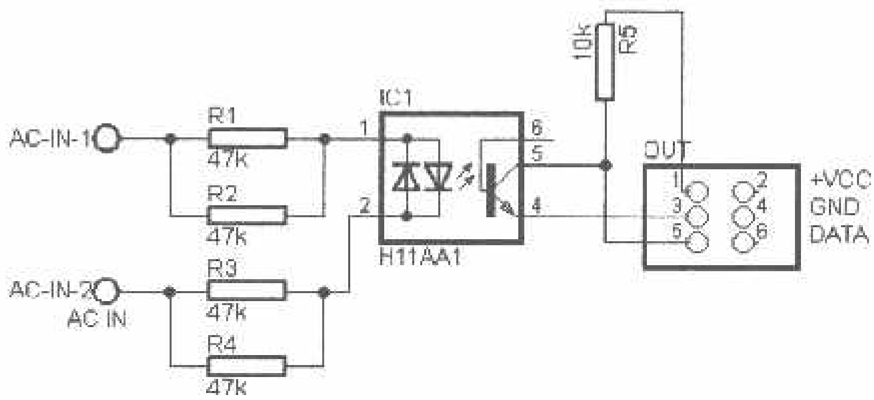


Gambar 3.2. Rangkaian Sensor Suhu DS18B20

Pada perancangan rangkaian di atas digunakan dua buah sensor suhu DS18B20. Seperti yang diketahui bahwa sensor suhu DS18B20 menggunakan komunikasi dengan protokol 1-Wire, di mana untuk komunikasi melalui protokol ini cukup menggunakan satu buah jalur untuk beberapa devais, sehingga kedua kaki data dari sensor ditempatkan pada jalur yang sama. Pada komunikasi 1-Wire, jalur data perlu diberi resistor pull-up sebesar 4k7Ω.

Digunakan dua buah sensor suhu agar area deteksi untuk cairan yang akan didestilasi lebih luas yaitu di bagian bawah tungku destilasi dan bagian atas tungku destilasi. Hasil pembacaan kedua sensor lalu diakumulasi dan digunakan sebagai acuan untuk kontrol suhu pada proses destilasi.

b. Rangkaian *Zero-Crossing Detector*



Gambar 3.3. Rangkaian *Zero-Crossing Detector*

Pada perancangan rangkaian di atas dipilih nilai resistor untuk input pada IC optocoupler H11AA1 adalah 47kΩ agar nilai arus untuk LED pada IC H11AA1 diharapkan bernilai 5mA. Resistor disusun sedemikian rupa dengan menyusun paralel dua buah resistor 47kΩ lalu disusun seri dengan dua buah resistor 47kΩ yang juga di paralel, sehingga nilai resistansi dari empat resistor tersebut tetap 47kΩ. Hal ini dilakukan agar disipasi daya dibagi pada keempat resistor sehingga memperpanjang umur pemakaian resistor. Apabila telah diketahui bahwa nilai drop tegangan pada LED dari IC H11AA1 adalah 1.5V, maka perhitungan untuk mencari nilai R_1 adalah sebagai berikut :

$$R_{total} = \frac{V_{AC}-V_{LED}}{I_{LED}} \quad (3.1)$$

$$R_{total} = \frac{230V - 1.5V}{5mA}$$

$$R_{total} = \frac{228.5V}{5 \times 10^{-3}A}$$

$$R_{total} = 45700\Omega \approx 47k\Omega$$

di mana :

R_{total} = nilai resistansi total dari semua resistor R_1, R_2, R_3, dan R_4 (Ω)

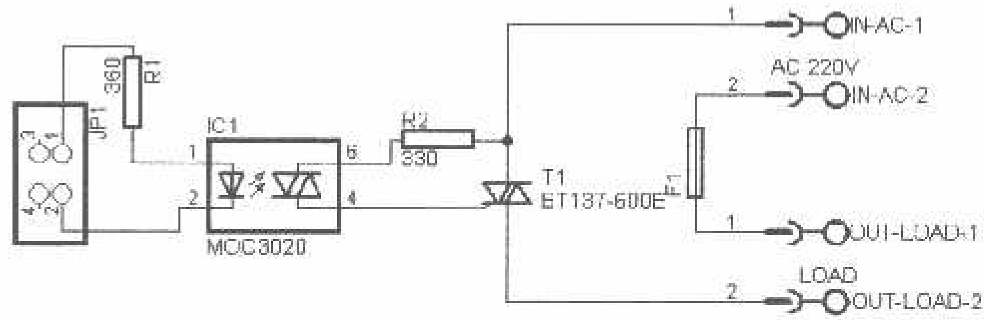
V_A = nilai input tegangan AC (V)

V_{LED} = nilai drop tegangan pada LED (V)

I_{LED} = nilai arus pada LED (A)

Disebabkan nilai resistor sebesar 45700Ω tidak ada di pasaran maka digunakan nilai terdekat yaitu 47kΩ.

c. Rangkaian Driver TRIAC



Gambar 3.4. Rangkaian Driver TRIAC

Pada perancangan rangkaian di atas dipilih nilai resistor R_2 adalah 330Ω. Hal ini disebabkan nilai I_{TMS} dari IC MOC3020 adalah 1.2A dan tegangan input AC adalah 220V (digunakan 230V untuk kemungkinan terburuk). Berikut perhitungannya :

Sebelumnya perlu dicari nilai dari V_{pk} :

$$V_{Pk} = V_{AC} \times 1.414 \quad (3.2)$$

$$V_{Pk} = 230V \times 1.414$$

$$V_{Pk} = 325.22V$$

di mana :

V_{pk} = nilai input tegangan AC peak (V)

V_{AC} = nilai input tegangan AC rms (V)

$$R_2 = \frac{V_{Pk}}{I_{TMS}} \quad (3.3)$$

$$R_2 = \frac{325.22V}{1.2A}$$

$$R_2 = 271.0166\ldots\Omega \approx 270\sim330\Omega$$

di mana :

R_2 = nilai resistansi R_2 (Ω)

V_{pk} = nilai input tegangan AC peak (V)

I_{TMS} = nilai arus tertinggi output driver pada MOC3020 pada kondisi *nonrepetitive peak on state* (A)

Disebabkan nilai resistor sebesar 271.0166...Ω tidak ada di pasaran maka digunakan niai terdekat yang ada di atasnya yaitu 330Ω.

Selain itu, pada perancangan rangkaian di atas dipilih nilai resistor R_1 yang digunakan untuk menyalakan LED pada IC MOC3020 adalah 360Ω. Hal ini disebabkan nilai arus yang direkomendasikan untuk melewati pin arduino adalah 20mA, sehingga penulis menentukan nilai arus untuk menyalakan LED adalah 10mA. Berikut perhitungannya:

$$R_1 = \frac{V_{DC} - V_{LED}}{I_{LED}} \quad (3.4)$$

$$R_1 = \frac{5V - 1.5V}{10mA}$$

$$R_1 = \frac{3.5V}{10 \times 10^{-3}A}$$

$$R_1 = 350\Omega \approx 360\Omega$$

di mana :

R_1 = nilai resistansi R_1 (Ω)

V_{DC} = nilai input tegangan DC (V)

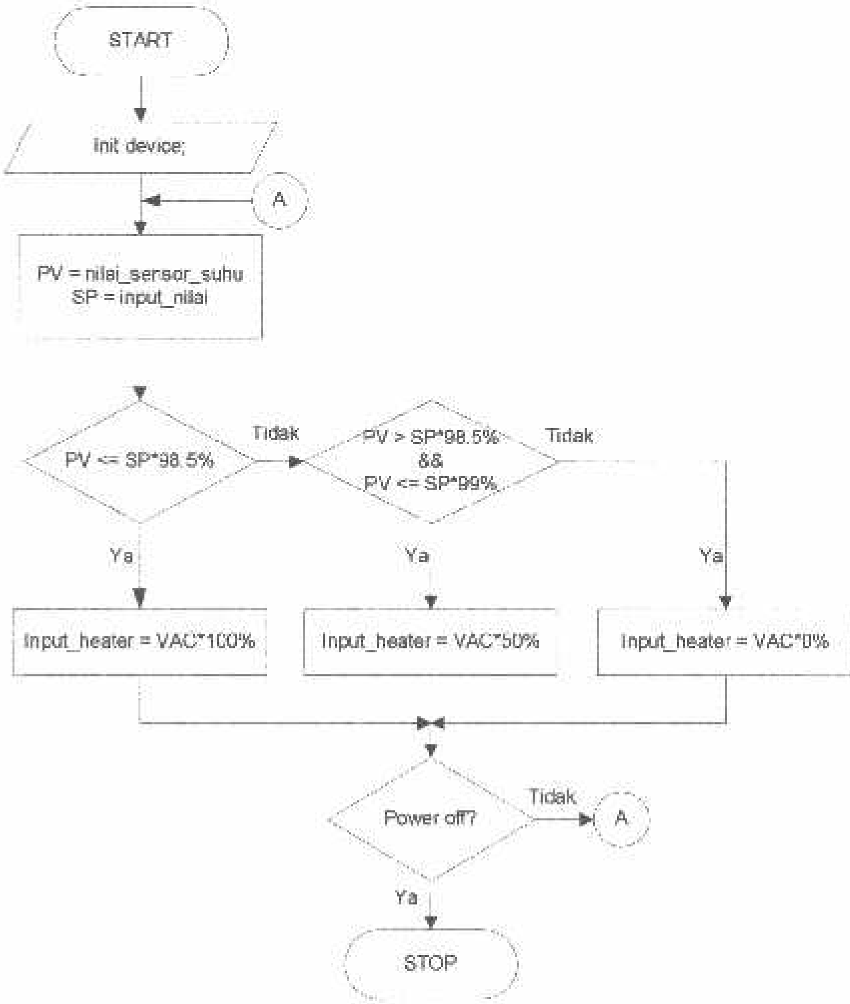
V_{LED} = nilai drop tegangan pada LED (V)

I_{LED} = nilai arus untuk LED pada MOC3020 (A)

Disebabkan nilai resistor sebesar 350Ω tidak ada di pasaran maka digunakan nilai terdekat yang ada di atasnya yaitu 360Ω.

3.3.2. Perancangan Perangkat Lunak

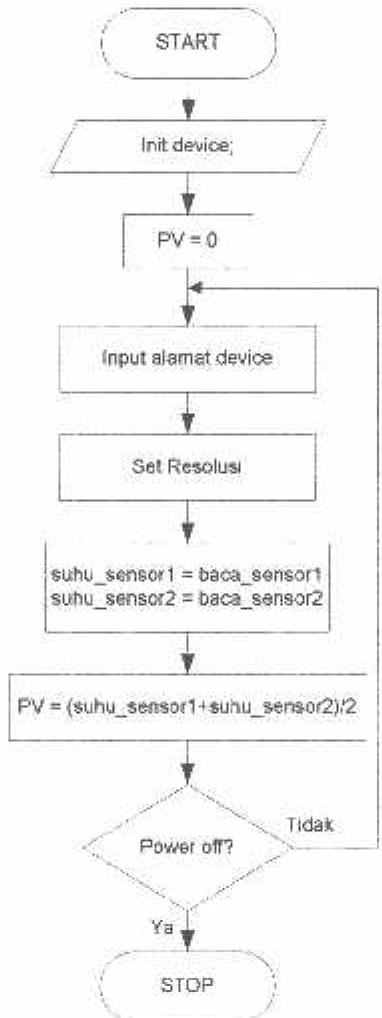
a. Program Kontrol Utama



Gambar 3.5. *Flowchart* Program Kontrol Utama

Pada gambar di atas ditunjukkan *flowchart* dari program kontrol utama. Program akan ditanam pada arduino sebagai kontroler untuk menentukan keputusan berdasarkan input data yang diperoleh dan dibandingkan dengan nilai dari set point (SP), di mana input data (PV) diperoleh dari sensor suhu DS18B20. Ketika nilai PV kurang dari sama dengan 98.5% dari nilai SP maka arduino memerintahkan driver TRIAC untuk memberi input pada *heater* sebesar 100% dari 220VAC atau *heater* bekerja 100%. Dan seterusnya, ketika PV lebih dari 98.5% dan kurang dari sama dengan 99% dari nilai SP maka *heater* bekerja 50%, dan bila PV lebih dari 99% maka *heater* bekerja 0% atau dengan kata lain *heater* dalam keadaan mati. Pengurangan nilai input yang bertahap pada *heater* bertujuan untuk memperlambat pemanasan ketika suhu telah mendekati nilai SP sehingga diharapkan nilai suhu tidak terlampau jauh rentangnya dari nilai SP.

b. Program Sensor DS18B20



Gambar 3.6. *Flowchart* Program Sensor DS18B20

Pada gambar di atas ditunjukkan *flowchart* dari program untuk pembacaan suhu sensor DS18B20. Terdapat dua buah sensor suhu yang digunakan agar area deteksi lebih luas. Hasil pembacaan kedua sensor dirata-rata dan digunakan untuk acuan untuk kontrol suhu pada proses pemanasan pada saat destilasi. PV atau *Point Value* merupakan nilai deteksi sensor yang digunakan sebagai acuan kontrol. Untuk membaca suhu, sebelumnya perlu diinputkan alamat dari sensor agar devais sensor dapat dikenali oleh arduino. Seperti yang diketahui sensor DS18B20 merupakan devais yang memanfaatkan protokol komunikasi 1-Wire, di mana tiap devais yang menggunakan protokol ini hanya menggunakan satu buah jalur saja sehingga untuk membedakan pembacaan pada tiap devais dengan protokol ini perlu diinputkan alamat unik dari tiap devais pada kontroler utama yaitu Arduino. Alamat untuk sensor 1 adalah 0x28, 0x76, 0x1D, 0x5B, 0x07, 0x00, 0x00, 0x92 dan untuk sensor 2 adalah 0x28, 0x17, 0xB8, 0x58, 0x07, 0x00, 0x00, 0x0F. Kemudian set resolusi pembacaan sensor di mana pada perancangan alat ini digunakan resolusi sebesar 11 bit. Resolusi 11 bit dipilih disebabkan agar tingkat ketelitian pembacaan sensor diharapkan cukup tinggi dengan kecepatan pembacaan yang juga cukup cepat. Setelah itu baca nilai suhu dari kedua sensor dan selanjutnya diakumulasikan dan dirata-rata kedua hasil pembacaan sensor tersebut agar menjadi nilai PV yang digunakan sebagai suhu acuan untuk pengontrolan suhu pada proses destilasi. Berikut rumus yang digunakan untuk menentukan nilai PV :

$$PV = \frac{suhu\ sensor\ 1 + suhu\ sensor\ 2}{2} \quad \text{..........} \quad (3.5)$$

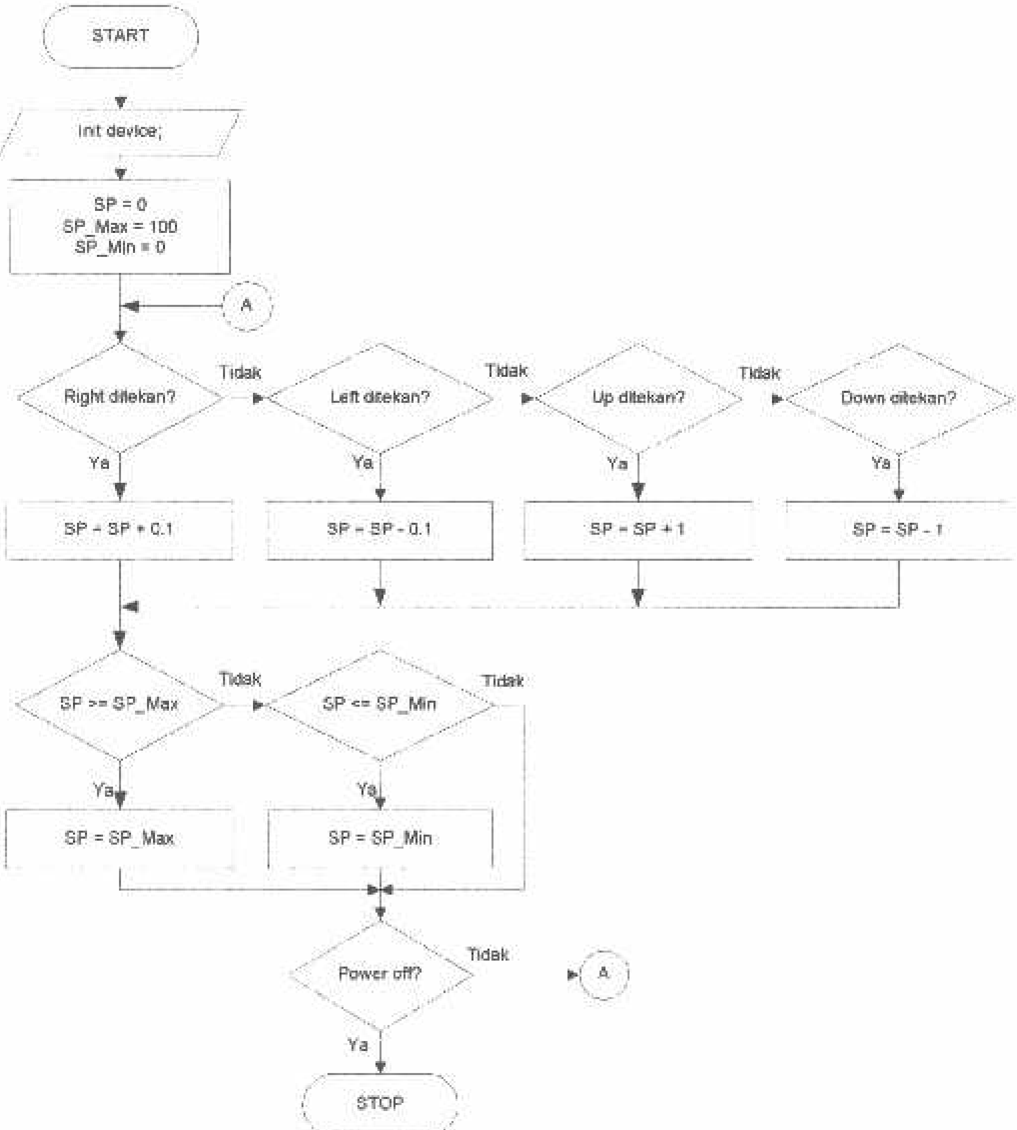
di mana :

PV = nilai suhu aktual dari cairan destilasi (°C)

suhu sensor 1 = nilai pembacaan suhu pada sensor 1 (°C)

suhu sensor 2 = nilai pembacaan suhu pada sensor 2 (°C)

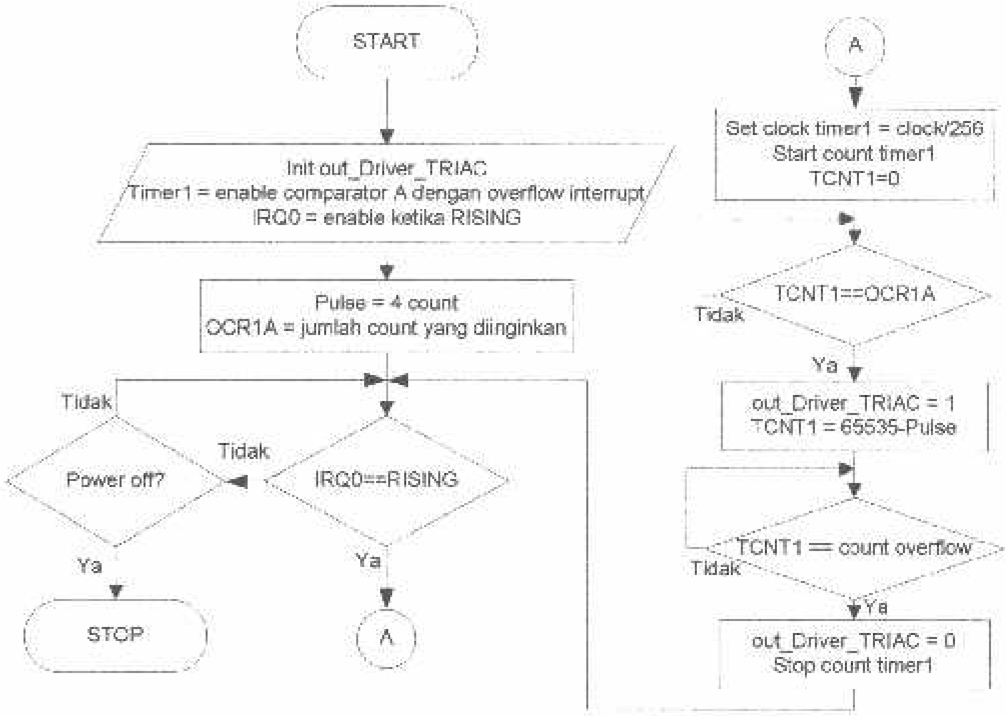
c. Program Button



Gambar 3.7. *Flowchart* Program Button

Pada gambar di atas ditunjukkan *flowchart* dari program untuk fungsi tiap button pada alat. Button digunakan untuk menentukan nilai SP atau *Set Point* dari suhu pemanasan yang diinginkan. Nilai SP dibatasi antara 0 hingga 100. Terdapat 4 buah button yang digunakan, yaitu button "Right" digunakan untuk menambah nilai SP sebesar 0.1, button "Left" digunakan untuk mengurangi nilai SP sebesar 0.1, button "Up" digunakan untuk menambah nilai SP sebesar 1, dan button "Right" digunakan untuk mengurangi nilai SP sebesar 1.

d. Program Kontrol Pemicuan Sudut Fasa



Gambar 3.8. *Flowchart* Program Kontrol Pemicuan Sudut Fasa

Pada gambar di atas ditunjukkan *flowchart* dari program kontrol untuk pemicuan sudut fasa sebagai kontrol tegangan untuk *heater*. Program memanfaatkan timer1 sebagai pewaktu penyalaan trigger untuk MOC pada driver TRIAC dan interrupt0 atau IRQ0 pada pin 2 sebagai input sinyal *Zero-Crossing Detector*. Pada timer1 dikonfigurasi dengan menyalakan fungsi comparator A dengan interrupt yang aktif pada saat timer telah mencacah atau *counting* hingga overflow. Comparator A pada timer1 akan mengkomparasi nilai dari cacahan timer1 dengan nilai OCR1A. Konfigurasi interrupt0 adalah akan mengaktifkan routine ISR (*Interrupt Service Routine*) pada saat menerima sinyal tepi naik (RISING).

Pulse menentukan lama sinyal trigger untuk MOC driver TRIAC. Sebelumnya perlu diketahui bahwa satuan pulse merupakan count atau cacahan tiap kali timer menghitung. Untuk mencari nilai 1 count sebelumnya perlu ditentukan nilai resolusi sumber clock dan nilai maksimal cacahan dari timer. Pada timer1 dari arduino nilai maksimal counter atau timer mengalami overflow pada saat cacahan mencapai 2^{16}-1 atau 65535 dan sumber clock pada program disetting dengan nilai clock dari arduino yaitu 16MHz dibagi 256.

Dengan nilai tersebut dapat dicari nilai resolusi, yaitu :

$$resolusi = \frac{1}{CLK/256} \quad \text{.........} (3.6)$$

$$resolusi = \frac{1}{16.10^6/256}$$

$$resolusi = \frac{256}{16 \times 10^6} = 0.000016\, s = 16\, \mu s$$

di mana :

resolusi = nilai resolusi waktu tiap satu kali pencacahan pada timer (s)

CLK = sumber clock dari arduino (Hz)

Setelah diketahui nilai resolusi dapat dicari lama waktu sinyal trigger untuk driver TRIAC, yaitu :

$$Pulse\ time = resolusi \times pulse \quad \text{.........} (3.7)$$

$$Pulse\ time = 16\, \mu s \times 4$$

$$Pulse\ time = 64\, \mu s$$

di mana :

Pulse time = lama waktu dari sinyal on untuk trigger driver TRIAC (s)

Pulse = jumlah cacahan sinyal pulse (count)

Jadi sinyal trigger on yang diberikan untuk driver TRIAC adalah selama 64 μs. Sedangkan nilai count atau cacahan pembanding timer1 yaitu OCR1A menentukan lama *delay* atau penundaan sebelum memulai untuk memicu driver TRIAC dengan sinyal pulse, semakin lama nilai delay maka semakin sempit waktu on untuk driver TRIAC sehingga tegangan kerja semakin rendah karena waktu kerja driver TRIAC berkurang. Nilai maksimal dari nilai count dari OCR1A dapat dicari dengan cara membagi nilai periode dari ½ gelombang pada frekuensi AC dengan nilai resolusi clock. Nilai periode dari ½ gelombang pada frekuensi AC perlu diketahui disebabkan penggeseran fasa tegangan untuk output *heater* dilakukan tiap ½ dari gelombang AC penuh.

Berikut perhitungan nilai periode :

$$T_{half} = \frac{1}{50} \times \frac{1}{2} \quad \text{.........} (3.8)$$

$$T_{half} = \frac{1}{100}$$

$$T_{half} = 0.01\, s = 10 \times 10^3\, \mu s$$

BAB IV
PENGUJIAN DAN ANALISA

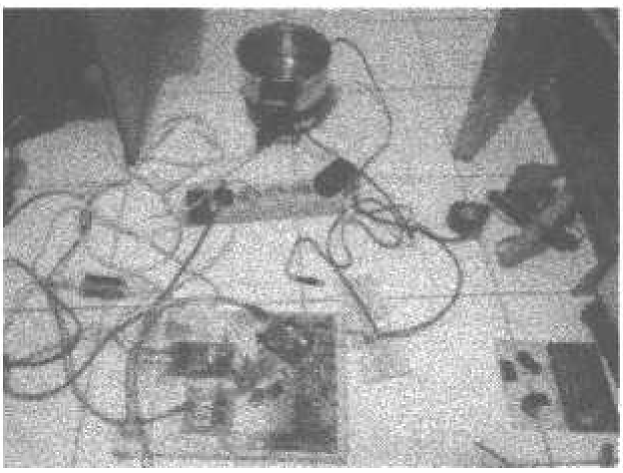
Pada bab ini dibahas mengenai pengujian serta analisa dari hasil perancangan sistem yang bertujuan untuk mengetahui apakah sistem telah bekerja dengan baik.

4.1. Pengujian Tiap Blok

Pengujian dilakukan untuk mengetahui kondisi kerja dari tiap blok pada alat. Bagian yang diuji adalah :

1. Sensor Suhu DS18B20.
2. LCD Keypad Shield.
3. Rangkaian *Zero-Crossing Detector* dan rangkaian Driver TRIAC

4.1.1. Sensor Suhu DS18B20

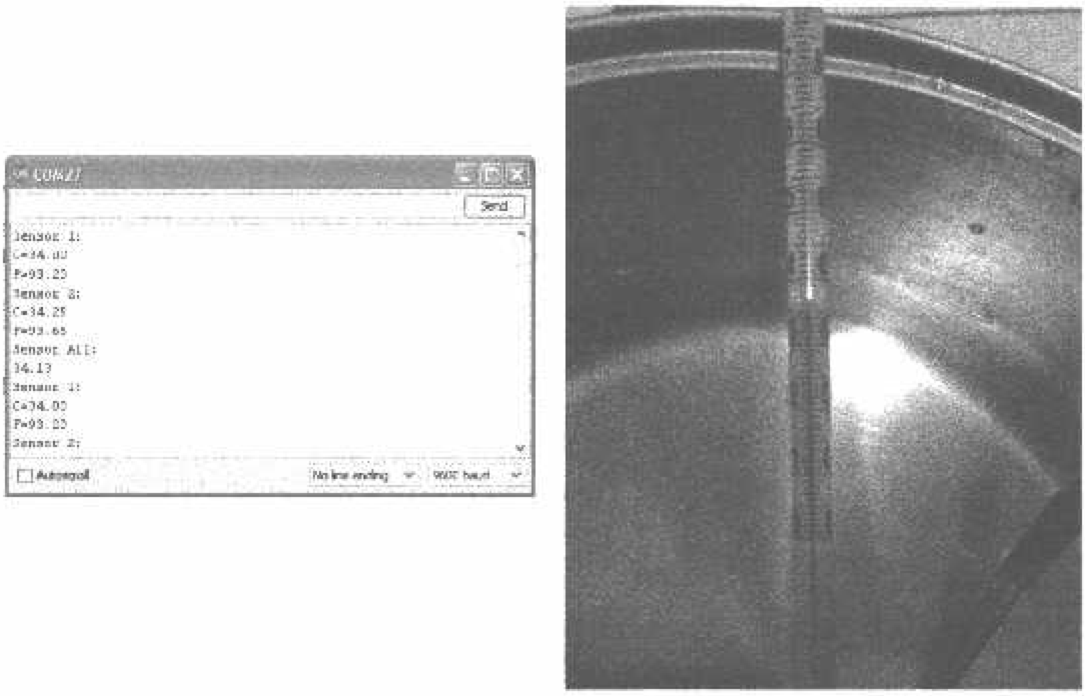


Gambar 4.1. Proses Pengujian Sensor Suhu DS18B20

Pengujian sensor suhu DS18B20 dilakukan dengan membandingkan nilai sensor dengan thermometer. Nilai pembacaan sensor dilihat melalui serial monitor dari software Arduino IDE di komputer. Berikut hasil pembacaaan dari sensor:

Tabel 4.1. Hasil Pengujian Sensor Suhu DS18B20

Suhu(°C)			Error (%)	
Thermometer	**Sensor 1**	**Sensor 2**	**Sensor 1**	**Sensor 2**
28	27.88	28.13	0.43%	0.46%
29	29	29.13	0.00%	0.45%
30	30	30.13	0.00%	0.43%
31	30.88	31.13	0.39%	0.42%
32	32	32.13	0.00%	0.41%
33	33	33.13	0.00%	0.39%
34	34	34.25	0.00%	0.74%
35	34.88	35.13	0.34%	0.37%
36	35.88	36.13	0.33%	0.36%
37	36.88	37.13	0.32%	0.35%
38	37.88	38.13	0.32%	0.34%
39	38.88	39.25	0.31%	0.64%
40	39.88	40.25	0.30%	0.63%
41	40.88	41.13	0.29%	0.32%
42	42	42.13	0.00%	0.31%
43	42.88	43.13	0.28%	0.30%
44	44	44.13	0.00%	0.30%
45	45	45.25	0.00%	0.56%
46	45.88	46.25	0.26%	0.54%
47	47	47.25	0.00%	0.53%
48	47.88	48.25	0.25%	0.52%
49	48.75	49	0.51%	0.00%
50	50	50.25	0.00%	0.50%
51	51	51.13	0.00%	0.25%
52	52	52.13	0.00%	0.25%
53	53	53.13	0.00%	0.25%
54	54	54.13	0.00%	0.24%
55	55	55.13	0.00%	0.24%
56	56	56.13	0.00%	0.23%
57	57	57.38	0.00%	0.67%
58	58	58.38	0.00%	0.66%
59	59	59.25	0.00%	0.42%
60	60.13	60.38	0.22%	0.63%
61	61.13	61.38	0.21%	0.62%
62	62.13	62.38	0.21%	0.61%
Rata-rata Error Tiap Sensor			0.14%	0.43%
Error Keseluruhan			0.285%	



(a) (b)

Gambar 4.2. (a)Contoh Hasil Pembacaan Sensor DS18B20 pada Komputer melalui Serial Monitor di Software Arduino IDE, (b)Contoh Hasil Pembacaan Suhu Menggunakan Thermometer

Untuk perhitungan error pembacaan sensor digunakan rumus berikut :

$$Error\ (\%) = \frac{|Suhu_{Sensor} - Suhu_{Thermometer}|}{Suhu_{Thermometer}} \times 100\% \quad \ldots\ldots (4.1)$$

di mana :

Error (%) = nilai error pembacaan sensor (%)

$Suhu_{Sensor}$ = nilai suhu pada sensor (^{0}C)

$Suhu_{Thermometer}$ = nilai suhu pada thermometer (^{0}C)

Berikut contoh bentuk perhitungan error data pembacaan sensor menggunakan rumus 4.1 di atas berdasarkan data pertama dari sensor 1:

$$Error\ (\%) = \frac{|Suhu_{Sensor} - Suhu_{Thermometer}|}{Suhu_{Thermometer}} \times 100\%$$

$$Error\ (\%) = \frac{|27.88\ ^0C - 28\ ^0C|}{28^0C} \times 100\%$$

$$Error\ (\%) = \frac{0.12^0C}{28^0C} \times 100\%$$

$$Error\ (\%) = 0.48\%$$

Untuk perhitungan rata-rata error dari pembacaan tiap sensor digunakan rumus berikut:

$$Error_{Sensor\ n}\ (\%) = \frac{|\sum Error_{Sensor\ n}|}{Jumlah\ Pengukuran} \times 100\% \quad \text{...} (4.2)$$

di mana :

$Error_{Sensor\ n}(\%)$ = rata rata nilai error pembacaan sensor n (%)

$\sum Error_{Sensor\ n}$ = total nilai error pada tiap pengukuran suhu pada sensor n (%)

Jumlah Pengukuran = jumlah pengukuran suhu pada sensor n

Untuk perhitungan error keseluruhan pembacaan dari kedua sensor digunakan rumus berikut :

$$Error\ Keseluruhan\ (\%) = \frac{Error_{Sensor\ 1} + Error_{Sensor\ 2}}{2} \quad \text{....................................} (4.3)$$

$$Error\ Keseluruhan\ (\%) = \frac{0.14\% + 0.43\%}{2}$$

$$Error\ Keseluruhan\ (\%) = \frac{0.57\%}{2} = 0.285\%$$

di mana :

Error Keseluruhan (%) = nilai error pembacaan semua sensor (%)

$Error_{Sensor\ 1}$ = nilai error rata-rata pembacaan sensor 1 (%)

$Error_{Sensor\ 2}$ = nilai error rata-rata pembacaan sensor 2 (%)

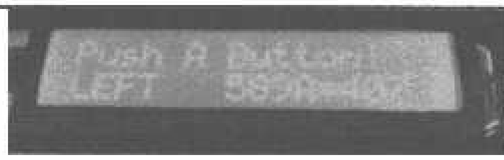
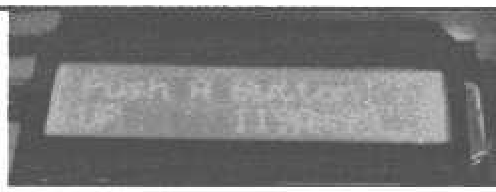
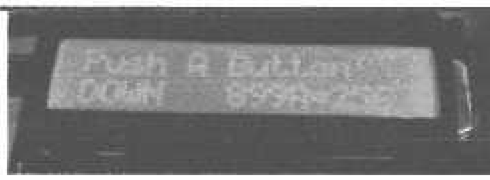
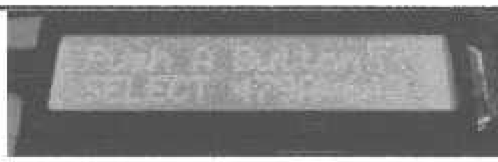
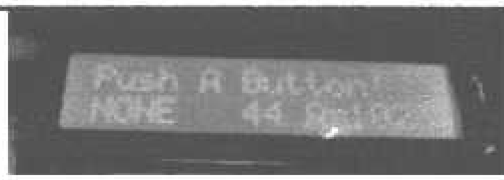
Dari data hasil perbandingan pengukuran suhu pada tabel di atas diperoleh nilai error pada sensor 1 adalah 0.14% dan error pada sensor 2 adalah 0.42%. Nilai error keseluruhan sensor adalah 0.285%.

4.1.2. LCD Keypad Shield

Pengujian LCD Keypad Shield dilakukan dengan menekan tiap *button* dari shield. Berikut gambar dari tiap pengujian :

Tabel 4.2. Hasil Pengujian LCD Keypad Shield

Tombol yang Ditekan	**Gambar**
Right	

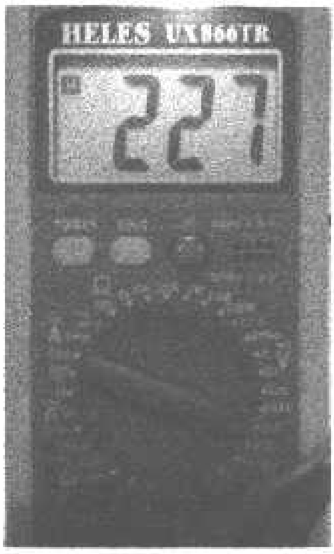
Left	
Up	
Down	
Select	
Tidak Ada	

Berdasarkan hasil percobaan di atas dapat diketahui bahwa LCD Keypad Shield dapat bekerja dengan baik.

4.1.3. Rangkaian *Zero-Crossing Detector* dan Rangkaian Driver TRIAC

Percobaan ini dilakukan untuk mengetahui kinerja dari rangkaian *Zero-Crossing Detector* dan rangkaian Driver TRIAC yang merupakan bagian dari rangkaian kontrol pemicuan sudut fasa sebagai kontrol beban *heater*. Pada percobaan ini digunakan alat berupa osiloskop untuk melihat bentuk gelombang dari rangkaian *Zero-Crosing Detector* dan rangkaian driver TRIAC. Osiloskop yang digunakan adalah Osiloskop Pintek PS-401 dengan nomer seri 11.01.08.01 di Laboratorium Pengukuran di lantai 2 Gedung Laboratorium Elektro ITN Malang. Dengan alasan keamanan, maka pada percobaan tegangan sumber yang digunakan adalah 12VAC yang diperoleh dengan menurunkan tegangan jala-jala 220VAC menggunakan transformator *step-down*.

Agar dapat diperoleh perbandingan yang tepat output 12VAC dari transformator antara dengan tegangan jala-jala maka sebelumnya dilakukan pengukuran tegangan pada terminal AC dan pada output 12VAC dari transformator.



(a)

(b)

Gambar 4.3. (a)Hasil Pengukuran Tegangan Jala-Jala pada Terminal AC Menggunakan Multimeter, (b)Hasil Pengukuran Tegangan Output 12VAC dari Transformator Menggunakan Multimeter

Berikut tabel hasil pengukuran :

Tabel 4.3. Hasil Pengukuran Tegangan Jala-Jala dan Transformator

Objek Pengukuran	**Hasil Pengukuran**
Terminal AC	227VAC
Output 12VAC transformator	11.82VAC

Sehingga diperoleh hasil perbandingan berikut :

$$Nilai\ perbandingan = \frac{Nilai\ Output\ 12VAC}{Nilai\ Terminal\ AC} \quad (4.4)$$

$$Nilai\ perbandingan = \frac{11.82\ VAC}{227\ VAC}$$

$$Nilai\ perbandingan = \frac{1}{19.204737\ ...}$$

$$\approx \frac{1}{19.205} = 1{:}\,19.205$$

di mana :

Nilai perbandingan = nilai perbandingan

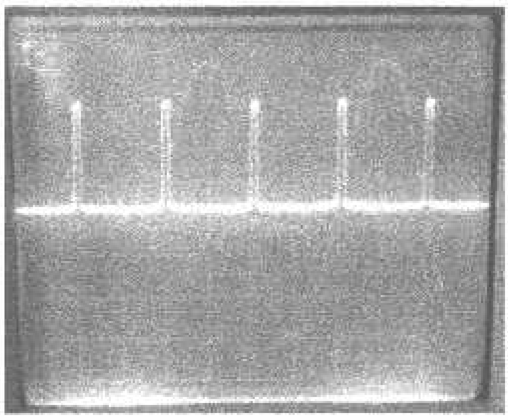
Nilai Output 12VAC = nilai pada output 12VAC dari transformator (VAC)

Nilai Terminal AC = nilai pada terminal AC (VAC)

Dengan acuan perbandingan di atas maka dapat dihitung berapa nilai yang diwakilkan oleh pengukuran pada percobaan dari kedua rangkaian. Percobaan dibagi menjadi dua bagian yaitu pada input dan output dari rangkaian *Zero-Crossing Detector* dan pada output dari rangkaian driver TRIAC.

1. Percobaan rangkaian *Zero-Crossing Detector*:

Pengukuran gelombang pada rangkaian *Zero-Crossing Detector* menggunakan osiloskop, di mana Ch. 1 merupakan input dari rangkaian *Zero-Crossing Detector* berupa arus AC dan Ch. 2 merupakan output dari rangkaian *Zero-Crossing Detector* berupa arus DC. Pengaturan pada osiloskop dilakukan dengan rincian yaitu pada Ch. 1, V/div = 5x di input AC dan pada Ch. 2, V/div = 2x di input DC serta T/div = 5 ms. Berikut hasil pengukuran gelombang :

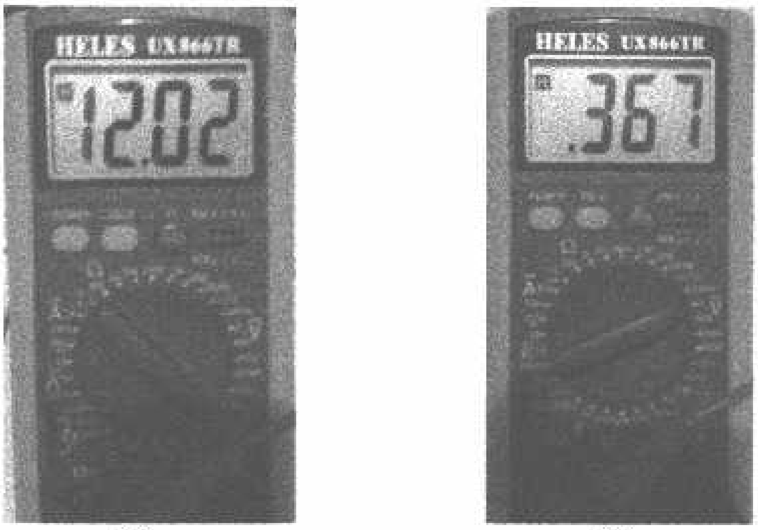


Gambar 4.4. Bentuk Gelombang Input dan Output Rangkaian *Zero-Crossing Detector*

Berikut keterangan dari hasil pengukuran rangkaian *zero-crossing detector* menggunakan osiloskop untuk V_{peak} dan multimeter untuk V_{rms} :

Tabel 4.4. Hasil Pengukuran Amplitudo Rangkaian *Zero-Crossing Detector*

Ch.	Jml. kotak vertikal (div)	V_{peak} (V)	V_{rms} (V)
Ch. 1	3.4	17 V	12.02 V
Ch. 2	2.6	5.2 V	0.367 V



(a) (b)

Gambar 4.5. (a)Hasil Pengukuran Amplitudo Rangkaian *Zero-Crossing Detector* pada Ch. 1 Menggunakan Multimeter, (b)Hasil Pengukuran Amplitudo Rangkaian *Zero-Crossing Detector* pada Ch. 2 Menggunakan Multimeter

Tabel 4.5. Hasil Pengukuran Periode Rangkaian *Zero-Crossing Detector* Menggunakan Osiloskop

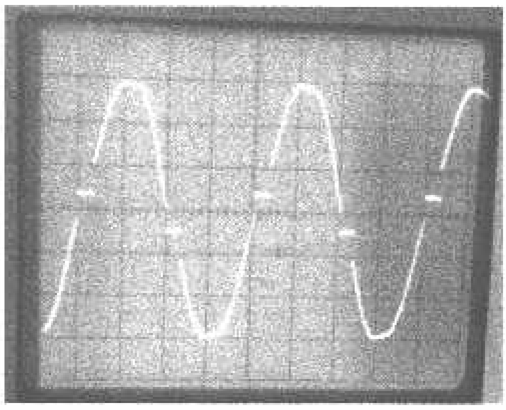
Ch.	**Jml. kotak horizontal (div)**	**T (ms)**	**f (Hz)**
Ch. 1	4	20 ms	50 Hz
Ch. 2 (jarak antar pulsa)	2	10 ms	100 Hz
Ch. 2 (lebar pulsa)	0.15	T = 0.75 ms	

Dari hasil pengukuran di atas dapat diketahui bahwa rangkaian *Zero-Crossing Detector* telah bekerja dengan baik. Hal ini ditunjukkan dengan munculnya pulsa pada output rangkaian *Zero-Crossing Detector* setiap terjadi peralihan fasa atau pada kondisi *Zero-Crossing* dari input AC.

2. Percobaan rangkaian driver TRIAC :

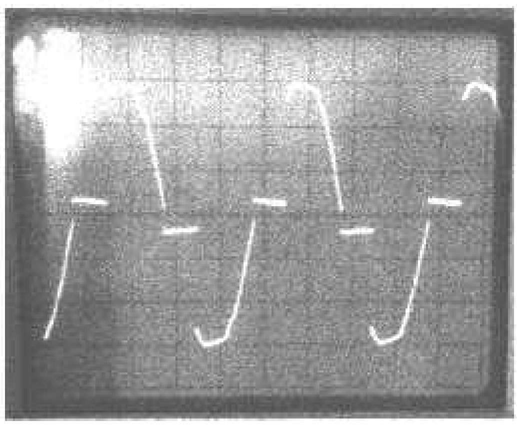
Berikut hasil pengukuran pada rangkaian driver TRIAC menggunakan osiloskop dengan pengaturan V/div = 5x dan T/div = 5 ms :

1. Kondisi output 80% dari input VAC :



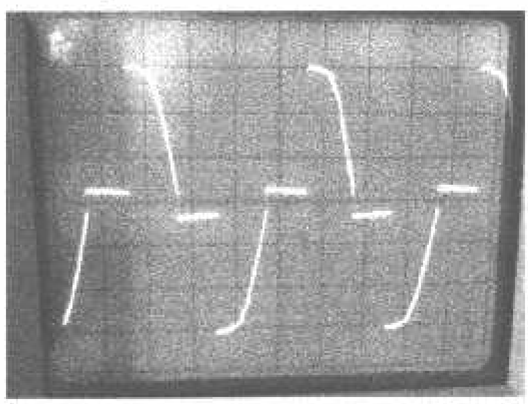
Gambar 4.6. Bentuk Gelombang Output Rangkaian driver TRIAC dengan Kondisi Output 80% dari Input VAC

2. Kondisi output 75% dari input VAC :



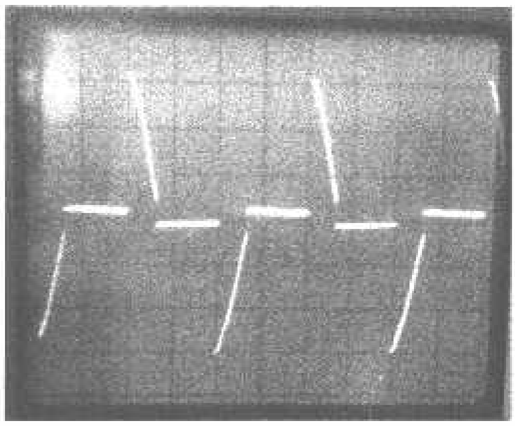
Gambar 4.7. Bentuk Gelombang Output Rangkaian driver TRIAC dengan Kondisi Output 75% dari Input VAC

3. Kondisi output 50% dari input VAC :



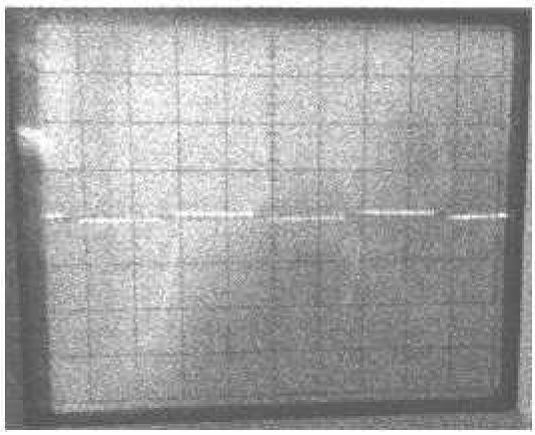
Gambar 4.8. Bentuk Gelombang Output Rangkaian driver TRIAC dengan Kondisi Output 50% dari Input VAC

4. Kondisi output 30% dari input VAC :



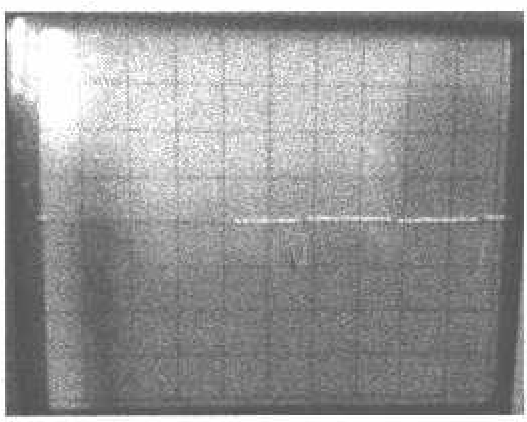
Gambar 4.9. Bentuk Gelombang Output Rangkaian driver TRIAC dengan Kondisi Output 30% dari Input VAC

5. Kondisi output 10% dari input VAC :



Gambar 4.10. Bentuk Gelombang Output Rangkaian driver TRIAC dengan Kondisi Output 10% dari Input VAC

6. Kondisi output 5% dari input VAC :



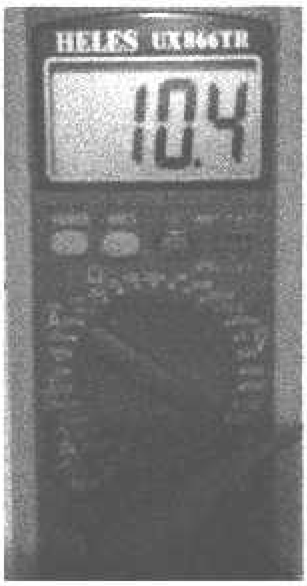
Gambar 4.11. Bentuk Gelombang Output Rangkaian driver TRIAC dengan Kondisi Output 5% dari Input VAC

Berikut keterangan dari hasil pengukuran rangkaian driver TRIAC :

Tabel 4.6. Hasil Pengukuran Rangkaian Driver TRIAC

Kondisi Output	Jml. kotak horizontal$_{total}$ (div)	Jml. kotak horizontal$_{on}$ (div)	V_{rms} (V)
80% dari input	4	3.2	10.4 V
75% dari input	4	3	9.1 V
50% dari input	4	2	6.75 V
30% dari input	4	1.2	4.01 V
10% dari input	4	0.4	1.38 V
5% dari input	4	0.2	0.359 V

Dari hasil pengukuran di atas dapat diketahui bahwa rangkaian driver TRIAC telah bekerja dengan baik. Hal ini ditunjukkan dengan waktu sudut pemicuan yang berubah sehingga waktu ON dari TRIAC dapat diubah sesuai keinginan, di mana semakin lama *delay* waktu pemicuan maka waktu ON dari TRIAC akan semakin pendek sehingga tegangan kerja juga semakin berkurang. Pada percobaan ini tegangan diukur menggunakan multimeter digital jenis Heles UX-866TR, sehingga nilai tegangan pengukuran berupa tegangan rms.



Gambar 4.12. Contoh Hasil Pengukuran Amplitudo Rangkaian Driver TRIAC Menggunakan Multimeter

4.2. Pengujian Keseluruhan Sistem

Pada tahap ini, tiap blok dirangkai menjadi satu sehingga membentuk suatu sistem. Setelah sistem terbentuk maka dilakukan pengujian dari keseluruhan sistem untuk mengetahui kinerja dari sistem atau alat yang telah dirancang dan dibuat.

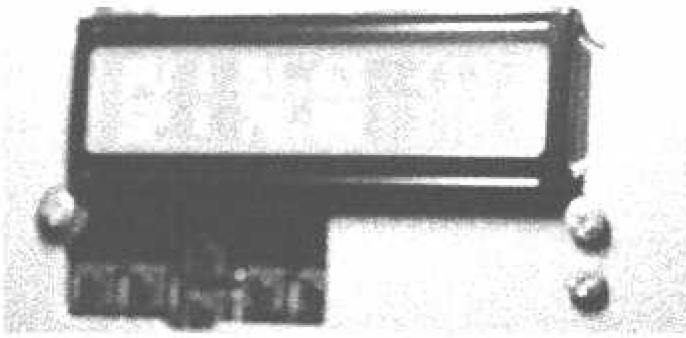
Pada pengujian ini digunakan sampel berupa etanol 70% dengan volume 3.5 liter. Set point yang diharapkan untuk suhu pemanasan adalah 78°C dengan durasi waktu kerja alat selama 3 jam. Berikut hasil dari pengukuran suhu dari pemanasan sampel untuk proses destilasi :

Tabel 4.7. Tabel Suhu Pemanasan Sampel untuk Proses Destilasi

Menit ke	Suhu (°C)
0	26.87
5	27
10	28.44
15	31.06
20	36.25
25	41.31
30	46.5
35	51.63
40	56.63
45	61.44
50	66.19
55	70.75
60	75.12
65	78.94
70	81
75	81.12
80	80.56
85	79.44
90	78.12
95	76.81
100	75.87
105	77.25
110	78.5
115	78.75
120	78.19
125	77.25
130	76.19
135	76.81

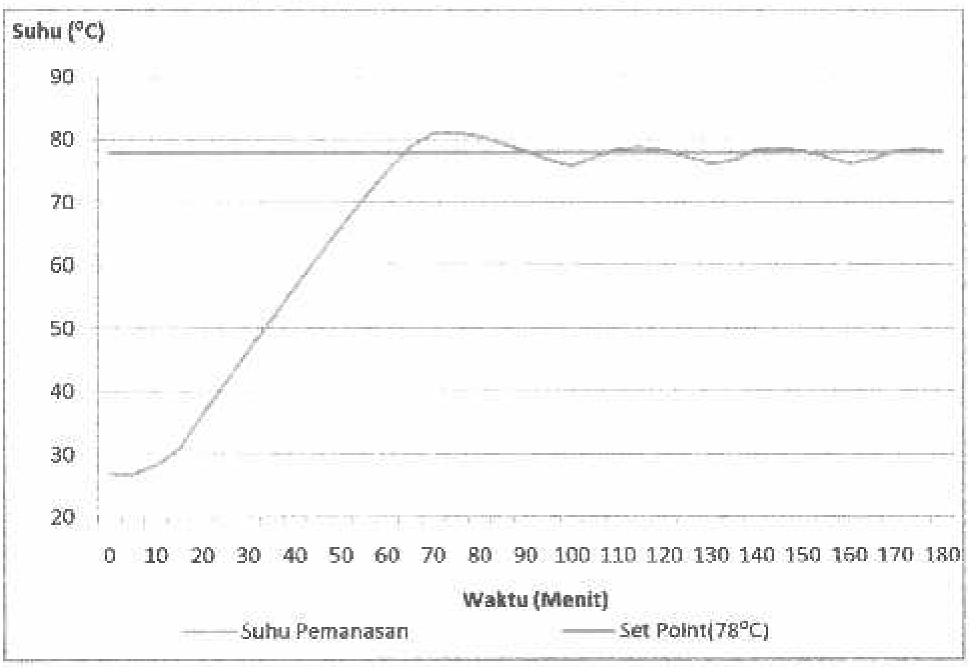
140	78.4
145	78.62
150	78.12
155	77.25
160	76.19
165	76.94
170	78.19
175	78.44
180	78.12

Pada tabel di atas disajikan hasil pengukuran suhu pemanasan sampel, di mana data suhu pengukuran di ambil tiap 5 menit. Data suhu diambil mulai dari menit ke 0 hingga menit ke 180. Berikut contoh gambar tampilan suhu pemanasan yang ditampilkan oleh LCD :



Gambar 4.13. Contoh Tampilan Suhu Pemanasan yang Ditampilkan oleh LCD

Berikut bentuk penyajian data dalam bentuk grafik :



Grafik 4.1. Grafik Suhu Pemanasan Sampel untuk Proses Destilasi

Dari grafik di atas dapat diketahui respon pemanasan sampel untuk destilasi, di mana data suhu pemanasan disajikan dengan garis warna biru dan set point disajikan denagn garis warna merah. Berdasarkan dari tabel dan grafik di atas, suhu pemanasan dari *heater* mencapai set point 78°C ketika mencapai menit ke-65 atau sekitar 1 jam 5 menit dari waktu awal pemanasan. Pada titik ini sistem kontrol suhu mulai bekerja di mana nilai suhu pemanasan akan terus mendekati nilai set point. Durasi waktu kontrol suhu dimulai dari menit ke-65 hingga waktu pengujian selesai yaitu pada menit ke 180 atau dengan durasi sekitar 1 jam 55 menit. Untuk mengetahui kinerja dari sistem kontrol pemanasan dapat dihitung error dari suhu pemanasan ketika sistem kontrol suhu mulai bekerja terhadap set point yaitu dengan rumus berikut :

$$Error\ (\%) = \frac{|Suhu_{Pemanasan} - Suhu_{Set\ Point}|}{Suhu_{Set\ Point}} \times 100\% \quad (4.5)$$

di mana :

Error (%) = nilai error suhu pemasan (%)

$Suhu_{Pemanasan}$ = nilai suhu pemanasan (°C)

$Suhu_{Set\ Point}$ = nilai suhu set point (°C)

Berikut contoh bentuk perhitungan error suhu pemanasan dengan menggunakan rumus 4.5 di atas berdasarkan data suhu pada menit ke-65:

$$Error\ (\%) = \frac{|Suhu_{Pemanasan} - Suhu_{Set\ Point}|}{Suhu_{Set\ Point}} \times 100\%$$

$$Error\ (\%) = \frac{|78.94^{0}C - 78^{0}C|}{78^{0}C} \times 100\%$$

$$Error\ (\%) = \frac{0.94^{0}C}{78^{0}C} \times 100\% = 1.21\%$$

Untuk perhitungan error suhu pemanasan selanjutnya hingga menit ke-180 dapat dilihat pada tabel berikut :

Tabel 4.8. Tabel Error Kontrol Suhu Pemanasan Sampel untuk Proses Destilasi

Suhu (°C)	Error (%)
78.94	1.21%
81	3.85%
81.12	4.00%
80.56	3.28%
79.44	1.85%
78.12	0.15%

76.81	1.53%
75.87	2.73%
77.25	0.96%
78.5	0.64%
78.75	0.96%
78.19	0.24%
77.25	0.96%
76.19	2.32%
76.81	1.53%
78.4	0.51%
78.62	0.79%
78.12	0.15%
77.25	0.96%
76.19	2.32%
76.94	1.36%
78.19	0.24%
78.44	0.56%
78.12	0.15%
Error Rata-Rata	1.39%

Untuk perhitungan rata-rata error dari suhu pemanasan digunakan rumus berikut:

$$Error\ (\%) = \frac{|\Sigma Error_{Suhu\ Pemansasan}|}{Jumlah\ Pengukuran} \times 100\% \qquad (4.6)$$

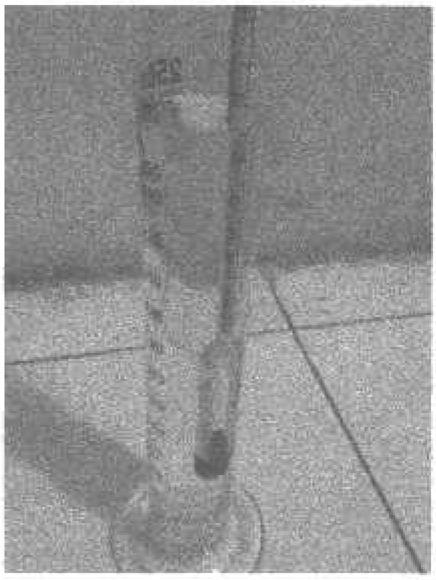
di mana :

Error (%) = rata rata nilai error kontrol suhu pemanasan (%)

$\sum Error_{Suhu\ Pemanasan}$ = total nilai error pada tiap nilai suhu pemanasan ketika kontrol suhu dimulai (%)

Jumlah Pengukuran = jumlah pengukuran

Berdasarkan hasil analisa pada tabel di atas diperoleh error kontrol suhu pemanasan untuk proses destilasi yang dilakukan menggunakan alat ini adalah 1.39%.



Gambar 4.14. Pengukuran Konsentrasi Cairan Hasil Destilasi Menggunakan Alkoholmeter

Dari proses destilasi yang dilakukan ketika dilakukan proses pengujian diperoleh hasil cairan destilasi berupa etanol dengan volume sebesar 66 ml dengan konsentrasi 88% yang masing-masing diukur dengan gelas ukur 250 ml dan alkoholmeter.

BAB V
PENUTUP

5.1. Kesimpulan

Setelah dilakukan serangkaian proses perancangan, pembuatan, pengujian, serta analisa di atas dapat diperoleh kesimpulan sebagai berikut :

1. Pengendalian suhu dari beban *heater* dapat dilakukan dengan mengubah-ubah nilai input tegangannya, sehingga dapat digunakan rangkaian kontrol pemicuan sudut fasa untuk kontrol input tegangan dari *heater*, di mana pada sistem ini *heater* berfungsi sebagai pemanas untuk proses destilasi.
2. Berdasarkan hasil pengujian sensor suhu DS18B20 dengan thermometer didapatkan error sebesar 0.14% pada sensor 1 dan error sebesar 0.43% pada sensor 2 sehingga diperoleh error keseluruhan sensor yaitu 0.285%.
3. Error pengontrolan suhu pemanasan suhu destilasi menggunakan alat ini adalah 1.39%.
4. Dengan menggunakan sampel berupa etanol 70% dengan volume 3.5 liter dan set point suhu 78°C serta waktu kerja selama 3 jam diperoleh etanol dengan volume sebesar 66 ml dengan konsentrasi 88% dengan waktu pemanasan hingga suhu mencapai set point adalah 1 jam 5 menit.

5.2. Saran

Pada proses pengerjaan alat ini masih terdapat berbagai macam kekurangan yang sekiranya dapat disempurnakan sehingga menjadi lebih baik lagi. Untuk perbaikan dan pengembangan dari alat dapat dilakukan berbagai hal berikut, di antaranya :

1. Pengkabelan harus dilakukan dengan rapi agar tidak sering terjadi error pada sistem.
2. Pada desain mekanik sebaiknya diminimalisir potensi kebocoran disebabkan dapat memperlambat proses pemanasan dan mengurangi hasil dari cairan destilasi.

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LAMPIRAN

RIWAYAT HIDUP

Data Pribadi

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TTL	: Malang, 7 Agustus 1992
Alamat	: Jl. Danau Dibaruh. Blok F1 A-9. Perumahan Sawojajar. RT 02/RW 12. Kelurahan Sawojajar. Kecamatan Kedung Kandang. Kota Malang. Jawa Timur
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Pendidikan

1998 - 2004	: SD Negeri Madyopuro IV Malang
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2007 - 2010	: SMK Negeri I Singosari, Malang. Jurusan Teknik Elektronika Industri
2010 - 2013	: Ahli Madya (D3). Politeknik Negeri Malang. Jurusan Teknik Elektro. Program Studi Elektronika
2014 - 2016	: Sarjana Teknik Strata-1 (S1). Institut Teknologi Nasional Malang. Jurusan Teknik Elektro S-1. Konsentrasi Teknik Elektronika

LISTING PROGRAM

```
#include <avr/io.h>
#include <avr/interrupt.h>

#include <OneWire.h>
#include <DallasTemperature.h>

#include <LiquidCrystal.h>

//LiquidCrystal lcd(8, 9, 4, 5, 6, 7);//Shield Pin
LiquidCrystal lcd(7, 8, 3, 4, 5, 6);//Shield Pin

#define btnINCR10     0
#define btnINCR       1
#define btnDECR10     2
#define btnDECR       3
#define btnSELECT     4
#define btnNONE       5
#define setPMAX       100    //Maximal set point value
#define setPMIN       0      //Minimal set point value
#define btnDlay       100    //Speed for button to change set point value (lower the delay,
faster the speed)

#define DETECT 2         //zero cross detect pin
#define GATE 9           //triac gate pin
#define PULSE 4          //trigger pulse width (counts)

#define ONE_WIRE_BUS 12 //sensor ds18b20 pin

#define BP1    0.985    //Break Point 1 for SP
#define BP2    0.99     //Break Point 2 for SP

#define ValBP1 60;       //OCR1A Value for BP1
#define ValBP2 320;      //OCR1A Value for BP2
#define ValBP3 630;      //OCR1A Value for BP3

OneWire oneWire(ONE_WIRE_BUS);
DallasTemperature sensors(&oneWire);
DeviceAddress Probe01 = { 0x28, 0x76, 0x1D, 0x5B, 0x07, 0x00, 0x00, 0x92 }; // "Sensor 1"
DeviceAddress Probe02 = { 0x28, 0x17, 0xB8, 0x58, 0x07, 0x00, 0x00, 0x0F }; // "Sensor 2"

int lcd_key       = 0;
int adc_key_in    = 0;
int startControl  = 0;
float set_point   = 0;
void setup(){
  //Serial.begin(9600);

  //AC Control
  pinMode(DETECT, INPUT);      //zero cross detect
  digitalWrite(DETECT, HIGH); //enable pull-up resistor
  pinMode(GATE, OUTPUT);      //triac gate control
  // set up Timer1
  OCR1A = 100;      //initialize the comparator
  TIMSK1 = 0x03;    //enable comparator A and overflow interrupts
  TCCR1A = 0x00;    //timer control registers set for
  TCCR1B = 0x00;    //normal operation, timer disabled
  // set up zero crossing interrupt
  attachInterrupt(0,zeroCrossingInterrupt, RISING);
  //IRQ0 is pin 2. Call zeroCrossingInterrupt on rising signal

  //LCD
  lcd.begin(16, 2);

  //Sensor
  sensors.begin();
  sensors.setResolution(Probe01, 11);
  sensors.setResolution(Probe02, 11);

}

void zeroCrossingInterrupt(){ //zero cross detect
  TCCR1B=0x04; //start timer with divide by 256 input
  TCNT1 = 0;   //reset timer - count from zero
}
```

```
ISR(TIMER1_COMPA_vect){ //comparator match
  digitalWrite(GATE,HIGH);  //set triac gate to high
  TCNT1 = 65536-PULSE;      //trigger pulse width
}

ISR(TIMER1_OVF_vect){ //timer1 overflow
  digitalWrite(GATE,LOW); //turn off triac gate
  TCCR1B = 0x00;          //disable timer stop unintended triggers
}

void loop(){
  sensors.requestTemperatures(); // Send the command to get temperatures

  //Temperature Value variable
  float temp1 = sensors.getTempC(Probe01);
  float temp2 = sensors.getTempC(Probe02);
  float tempAll = (temp1+temp2)/2;

  //Break Point variable
  float SetBP1= set_point*BP1;
  float SetBP2= set_point*BP2;

  //Display
  lcd.setCursor(0,0);
  lcd.print("PV :");
  lcd.setCursor(5,0);
  lcd.print(tempAll);//Point Value of Temperature Sensor

  lcd.setCursor(0,1);
  lcd.print("SP :");
  lcd.setCursor(5,1);
  lcd.print(set_point);//Set Point

  lcd.setCursor(12,1);
  lcd.print("ITN");

  //Keypad Control
  lcd_key = read_LCD_buttons();
  switch (lcd_key)
  {
  case btnINCR10:
    {
      //lcd.print("INCR10");
      delay(btnDlay);
      set_point=set_point+0.1;
      if (set_point>=setPMAX) {set_point=setPMAX;}
      break;
    }
  case btnDECR10:
    {
      //lcd.print("DECR10");
      delay(btnDlay);
      set_point=set_point-0.1;
      if (set_point<=setPMIN) {set_point=setPMIN;}
      break;
    }
  case btnINCR:
    {
      //lcd.print("INCR");
      delay(btnDlay);
      set_point++;
      if (set_point>=setPMAX) {set_point=setPMAX;}
      break;
    }
  case btnDECR:
    {
      //lcd.print("DECR");
      delay(btnDlay);
      set_point--;
      if (set_point<=setPMIN) {set_point=setPMIN;}
      break;
    }
  case btnSELECT:{
    startControl=1;
    break;}
  case btnNONE:{break;}
  }
```

```
  //Temperature Control
  if (startControl==0) {
    //Control Condition OFF
    OCR1A=ValBP3;
    lcd.setCursor(12,0);
    lcd.print("<0>");
    }
  if (startControl==1) {
    //Control Condition ON
    lcd.setCursor(12,0);
    lcd.print("<1>");

    if (tempAll<=SetBP1) {OCR1A=ValBP1;}
    if (tempAll>SetBP1&&tempAll<=SetBP2) {OCR1A=ValBP2;}
    if (tempAll>SetBP2)  {OCR1A=ValBP3;}
  }

  //Try
  //OCR1A = 500;

  //delay(2000);
  //lcd.clear();
}
int read_LCD_buttons()
{
  adc_key_in = analogRead(0);
  delay(5);
  int k = (analogRead(0) - adc_key_in);
  if (5 < abs(k)) return btnNONE;
  if (adc_key_in > 1000) return btnNONE;
  if (adc_key_in < 50)   return btnINCR10;
  if (adc_key_in < 195)  return btnINCR;
  if (adc_key_in < 380)  return btnDECR;
  if (adc_key_in < 555)  return btnDECR10;
  if (adc_key_in < 790)  return btnSELECT;
  return btnNONE;  // when all others fail, return this...
}
```

FORM-FORM

BERITA ACARA RAPAT PERSETUJUAN JUDUL/PROPOSAL SKRIPSI

PROGRAM STUDI TEKNIK ELEKTRO S-1

Konsentrasi : T. ELKA S1

Tanggal : 29 - 2 - 2016

1.	NIM	4112902
2.	Nama	LUTFI ROZAQI
3.	Judul yang diajukan	Perancangan dan Pembuatan Sistem Kontrol Temperatur untuk Alat Destilasi Etanol Berbasis Arduino
4.	**Disetujui/~~Ditolak~~** *	
5.	Catatan:	
6.	Pembimbing yang diusulkan: 1. Dr. Eng. Kony S. ST, MT 2. Ir. Eko Muroedy, MT	

Menyetujui

1. Koordinator Dosen Kelompok Keahlian

(Dr. F. Endi L, ST. MT)

* : Coret yang tidak perlu

PERKUMPULAN PENGELOLA PENDIDIKAN UMUM DAN TEKNOLOGI NASIONAL MALANG

INSTITUT TEKNOLOGI NASIONAL MALANG

FAKULTAS TEKNOLOGI INDUSTRI
FAKULTAS TEKNIK SIPIL DAN PERENCANAAN
PROGRAM PASCASARJANA MAGISTER TEKNIK

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Kampus II : Jl. Raya Karanglo Km 2 Telp. (0341) 417636 Fax. (0341) 417634 Malang

Nomor Surat : ITN-177/EL-FTI/2015 8 Maret 2016
Lampiran : -
Perihal : BIMBINGAN SKRIPSI (**Baru**)

Kepada : Yth. Bapak/Ibu **DR.Eng.Komang Somawirata.ST,MT**
Dosen Teknik Elektro S-1
ITN MALANG

Dengan Hormat
Sesuai dengan permohonan dan persetujuan dalam Proposal Skripsi untuk mahasiswa:

Nama	: Lutfi Rozaqi
Nim	: 1412902
Fakultas	: **Teknologi Industri**
Program Studi	: **Teknik Elektro S-1**
Konsentrasi	: Teknik Elektronika

Maka dengan ini pembimbingan tersebut kami serahkan sepenuhnya kepada Saudara/i selama masa waktu :

" Semester Genap Tahun Akademik 2015-2016 "

Demikian atas perhatian serta bantuannya kami sampaikan terima kasih.

Mengetahui
Ketua Program Studi Teknik Elektro S-1

INSTITUT TEKNOLOGI NASIONAL MALANG FAKULTAS TEKNOLOGI INDUSTRI JURUSAN TEKNIK ELEKTRO

M. Ibrahim Ashari, ST, MT
NIP.P. 1030100358

PERKUMPULAN PENGELOLA PENDIDIKAN UMUM DAN TEKNOLOGI NASIONAL MALANG

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FAKULTAS TEKNOLOGI INDUSTRI
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Nomor Surat : ITN-177/EL-FTI/2015 8 Maret 2016
Lampiran : -
Perihal : BIMBINGAN SKRIPSI (**Baru**)

Kepada : Yth. Bapak/Ibu **Ir. Eko Nurcahyo.MT**
Dosen Teknik Elektro S-1
ITN MALANG

Dengan Hormat
Sesuai dengan permohonan dan persetujuan dalam Proposal Skripsi untuk mahasiswa:

Nama	: Lutfi Rozaqi
Nim	: 1412902
Fakultas	: **Teknologi Industri**
Program Studi	: **Teknik Elektro S-1**
Konsentrasi	: Teknik Elektronika

Maka dengan ini pembimbingan tersebut kami serahkan sepenuhnya kepada Saudara/i selama masa waktu :

" Semester Genap Tahun Akademik 2015-2016"

Demikian atas perhatian serta bantuannya kami sampaikan terima kasih.

Mengetahui
Ketua Program Studi Teknik Elektro S-1

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JURUSAN TEKNIK ELEKTRO S-1
FAKULTAS TEKNOLOGI INDUSTRI
INSTITUT TEKNOLOGI NASIONAL MALANG

BERITA ACARA SEMINAR PROPOSAL SKRIPSI
PROGRAM STUDI TEKNIK ELEKTRO S1

KONSENTRASI	T. ELEKTRONIKA S1

1.	Nama Mahasiswa	Lutfi Rozaqi			NIM	1412902
2.	Keterangan	Tanggal		Waktu		Tempat / Ruang
	Pelaksanaan	17 Maret 2016				
3.	Spesifikasi Judul (berilah tanda silang) *)					
	a. Sistem Tenaga Elektrik		e. Embbeded System		i. Sistem Informasi	
	b. Konversi Energi		f. Antar Muka		j. Jaringan Komputer	
	c. Sistem Kendali		g. Elektronika Telekomunikasi		k. Web	
	d. Tegangan Tinggi		h. Elektronika Instrumentasi		l. Algoritma Cerdas	
4.	Judul Proposal yang diseminarkan Mahasiswa	Perancangan dan Pembuatan Sistem Kontrol Temperatur Untuk Alat Destilasi Etanol Berbasis Arduino				
5.	Perubahan Judul yang diusulkan oleh Kelompok Dosen Keahlian	....				
6.	Catatan :					
	Catatan :					
7.	Persetujuan Judul Skripsi					
	Disetujui, Dosen Keahlian I M. Ibrahim A.ST.MT			Disetujui, Dosen Keahlian II		
	Mengetahui, Ketua Jurusan. M. Ibrahim Ashari,ST,MT NIP. P. 1030100358		Disetujui, Calon Dosen Pembimbing Pembimbing I DR.Eng.Komang Somawirata.ST,MT			Pembimbing II Ir. Eko Nurcahyo.MT

PROGRAM STUDI TEKNIK ELEKTRO S-1
FAKULTAS TEKNOLOGI INDUSTRI
INSTITUT TEKNOLOGI NASIONAL MALANG
Kampus II . Jl. Raya Karanglo Km. 2 Malang

MONITORING BIMBINGAN SKRIPSI

SEMESTER GENAP TAHUN AKADEMIK 2015-2016

Nama Mahasiswa : Lutfi Rozaqi
NIM : 1412902
Nama Pembimbing : Dr. Eng. I Komang Somawirata, ST, MT
Judul Skripsi : PERANCANGAN DAN PEMBUATAN SISTEM KONTROL TEMPERATUR UNTUK ALAT DESTILASI ETANOL BERBASIS ARDUINO

Minggu Ke-	Hari, Tanggal	Waktu Bimbingan	Materi Bimbingan	Paraf
1	Senin 21/3 2016	13.00 - 14.00	Pendahuluan dan Dasar Teori	[signature]
2	Senin 28/3 2016	12.30 - 13.00	Mekanik	[signature]
3	Senin 4/4 2016	13.00 - 14.00	Rangkaian Driver TRIAC dan ZCD	[signature]
4	Selasa 12/4 2016	14.00	[illegible]	[signature]
5	[illegible] 23/5 2016	14.00	Lanjut ke makalah seminar	[signature]
6				
7				

Malang, 8 Agustus 2016
Pembimbing

[signature]

Dr. Eng. I Komang Somawirata, ST, MT
NIP. P. 1030100361

PROGRAM STUDI TEKNIK ELEKTRO S-1
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MONITORING BIMBINGAN SKRIPSI

SEMESTER GENAP TAHUN AKADEMIK 2015-2016

Nama Mahasiswa : Lutfi Rozaqi
NIM : 1412902
Nama Pembimbing : Ir. Eko Nurcahyo, MT
Judul Skripsi : PERANCANGAN DAN PEMBUATAN SISTEM KONTROL TEMPERATUR UNTUK ALAT DESTILASI ETANOL BERBASIS ARDUINO

Minggu Ke-	Hari, Tanggal	Waktu Bimbingan	Materi Bimbingan	Paraf
1	Senin 21/3 2016	14.00-15.00	Pendahuluan dan Prinsip Kerja	Eof
2	Senin 28/3 2016	13.00-14.30	Rangkaian driver TRIAC dan ZCD	Eof
3	Senin 4/4 2016	12.00-13.00	Mekanik	Eof
4	Senin 11/4 2016	13.00-14.30	Revisi Rancangan Alat	Eof
5	Senin 23/5 2016	12.00-13.00	Acc maju SEMPRO	Eof
6	Senin 30/5 2016	10.00-11.00	Revisi Letak Sensor + Program	Eof
7	Senin 1/8 2016	10.00-11.00	Acc maju Kompre	Eof

Malang, 3 Agustus 2016
Pembimbing

Ir. Eko Nurcahyo, MT
NIP. Y. 1028700172

JURUSAN TEKNIK ELEKTRO S-1
FAKULTAS TEKNOLOGI INDUSTRI
INSTITUT TEKNOLOGI NASIONAL MALANG

BERITA ACARA SEMINAR PROGRESS SKRIPSI
PROGRAM STUDI TEKNIK ELEKTRO S1

KONSENTRASI	T. Elektronika

1.	Nama Mahasiswa	Lutfi Rozaqi		NIM	1412902
2.	Keterangan Pelaksanaan	Tanggal	Waktu		Tempat / Ruang
3.	Judul Skripsi	Perancangan dan Pembuatan Sistem Kontrol Temperatur Untuk Alat Destilasi Etanol Berbasis Arduino			
4.	Perubahan Judul	Perancangan dan Pembuatan sistem kontrol temperatur untuk Destilasi Etanol Berbasis Arduino			
5.	Catatan :				
6.	Mengetahui, Ketua Jurusan. M. Ibrahim Ashari, ST, MT	Disetujui, Dosen Pembimbing — Pembimbing I: Dr. Eng. I Komang Somawirata, ST, MT		Pembimbing II: Ir. Eko Nurcahyo, MT	

PERKUMPULAN PENGELOLA PENDIDIKAN UMUM DAN TEKNOLOGI NASIONAL MALANG
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BERITA ACARA UJIAN SKRIPSI
FAKULTAS TEKNOLOGI INDUSTRI

NAMA : LUTFI ROZAQI
NIM : 14.12.902
JURUSAN : Teknik Elektro S-1
KONSENTRASI : Teknik Elektronika
MASA BIMBINGAN : SEMESTER GENAP 2015/2016
JUDUL : ***PERANCANGAN DAN PEMBUATAN SISTEM KONTROL TEMPERATUR UNTUK ALAT DESTILASI ETANOL BERBASIS ARDUINO***

Dipertahankan dihadapan Majelis Penguji Skripsi Jenjang Strata Satu (S-1) pada :

Hari : Kamis
Tanggal : 4 Agustus 2016
Dengan Nilai : 86,7 (A)

PANITIA UJIAN SKRIPSI

Ketua Majelis Penguji

M. Ibrahim Ashari, ST, MT
NIP.P. 1030100358

Sekretaris Majelis Penguji

Dr. Eng. I Komang Somawirata, ST, MT
NIP.P. 1030100361

ANGGOTA PENGUJI

Dosen Penguji I

Dr. F. Yudi Limpraptono, ST, MT
NIP. Y. 1039500274

Dosen Penguji II

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INSTITUT TEKNOLOGI NASIONAL MALANG
FAKULTAS TEKNOLOGI INDUSTRI
PROGRAM STUDI TEKNIK ELEKTRO S-1
KONSENTRASI TEKNIK ELEKTRONIKA

PERSETUJUAN PERBAIKAN SKRIPSI

Dari hasil ujian skripsi Program Studi Teknik Elektro jenjang strata satu (S-1) yang diselenggarakan pada :

Hari : Kamis
Tanggal : 4 Agustus 2016

Telah dilakukan perbaikan skripsi oleh :

Nama : Lutfi Rozaqi
NIM : 1412902
Program Studi : Teknik Elektro S-1
Konsentrasi : Teknik Elektronika
Judul Skripsi : **Perancangan dan Pembuatan Sistem Kontrol Temperatur untuk Alat Destilasi Etanol Berbasis Arduino**

No	Materi Perbaikan	Keterangan
1.	–	

Dosen Penguji I

Dr. F. Yudi Limpraptono, ST, MT
NIP. Y. 1039500274

Dosen Pembimbing I

Dr. Eng. I Komang Somawirata, ST, MT
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INSTITUT TEKNOLOGI NASIONAL MALANG
FAKULTAS TEKNOLOGI INDUSTRI
PROGRAM STUDI TEKNIK ELEKTRO S-1
KONSENTRASI TEKNIK ELEKTRONIKA

PERSETUJUAN PERBAIKAN SKRIPSI

Dari hasil ujian skripsi Program Studi Teknik Elektro jenjang strata satu (S-1) yang diselenggarakan pada :

Hari : Kamis

Tanggal : 4 Agustus 2016

Telah dilakukan perbaikan skripsi oleh :

Nama : Lutfi Rozaqi

NIM : 1412902

Program Studi : Teknik Elektro S-1

Konsentrasi : Teknik Elektronika

Judul Skripsi : **Perancangan dan Pembuatan Sistem Kontrol Temperatur untuk Alat Destilasi Etanol Berbasis Arduino**

No	Materi Perbaikan	Keterangan
1.		

Dosen Penguji II

M. IbrahimAshari, ST, MT
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Dosen Pembimbing I

Dr. Eng. I Komang Somawirata, ST, MT
NIP.P. 1030100361

Dosen Pembimbing II

Ir. Eko Nurcahyo, MT
NIP. Y. 1028700172

SURAT PERNYATAAN ORISINALITAS

Yang bertandatangan di bawah ini :

Nama	: Lutfi Rozaqi
NIM	: 14.12.902
Program Studi	: T.Elektro S-1
Konsentrasi	: Teknik Elektronika

Dengan ini menyatakan bahwa Skripsi yang saya buat adalah hasil karya sendiri, tidak merupakan plagiasi dari karya orang lain. Dalam skripsi ini tidak memuat karya orang lain, kecuali dicantumkan sumbernya sesuai dengan ketentuan yang berlaku.

Demikian surat pernyataan ini saya buat, dan apabila di kemudian hari ada pelanggaran atas surat pernyataan ini, saya bersedia menerima sangsinya.

Malang, Agustus 2016

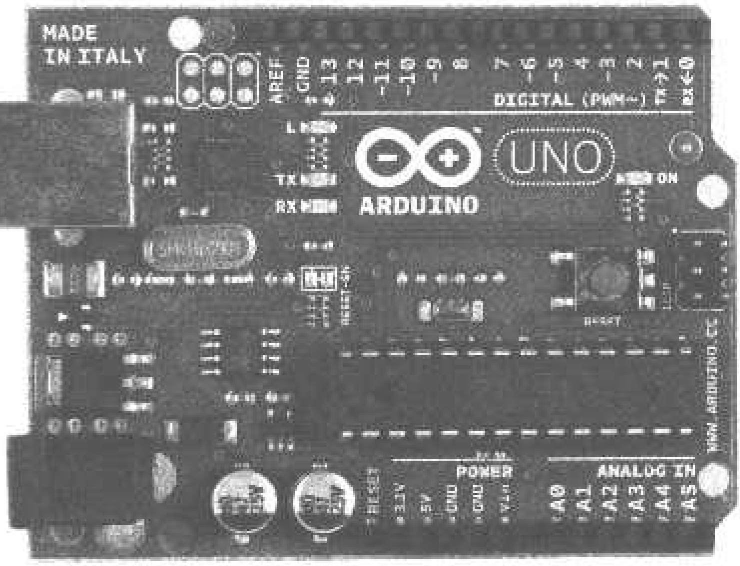
Yang membuat Pernyataan,

Lutfi Rozaqi

NIM. 1412902

DATASHEET

Arduino UNO



Product Overview

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter.

"Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduno, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions, see the index of Arduino boards.

Index

radiospares RADIONICS

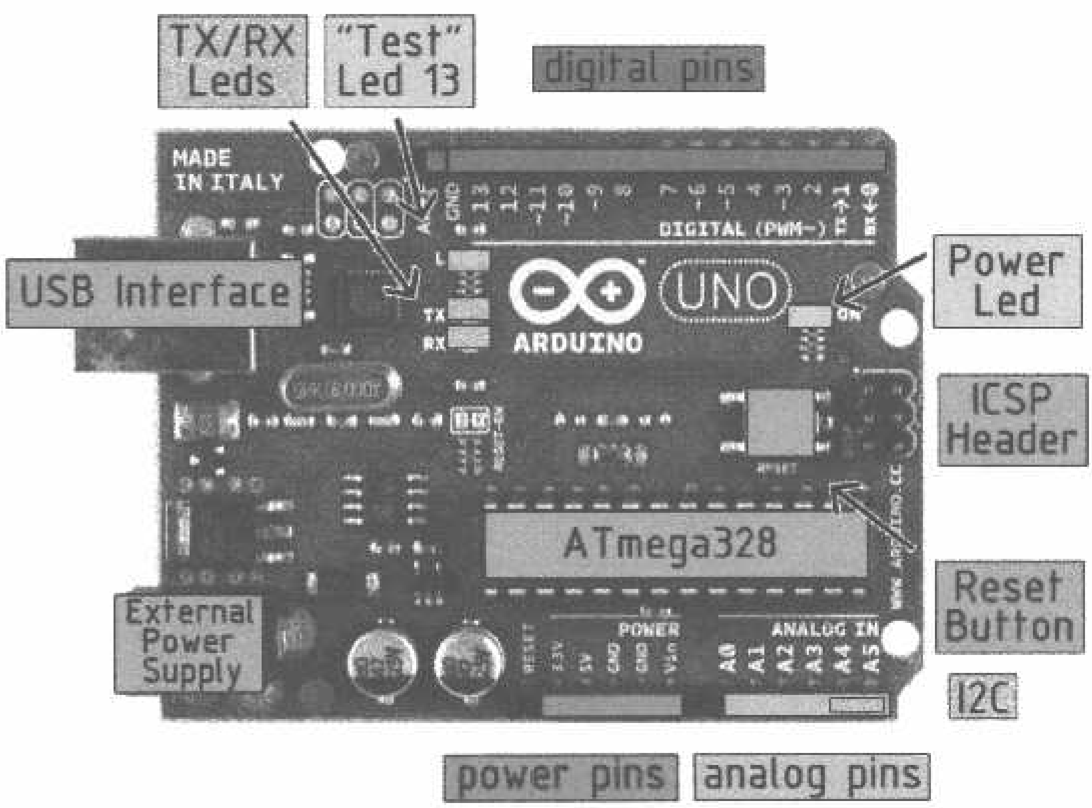
Technical Specification

EAGLE files: arduino-duemilanove-uno-design.zip Schematic: arduino-uno-schematic.pdf

Summary

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB of which 0.5 KB used by bootloader
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz

the board



Power

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically.

External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The power pins are as follows:

- **VIN.** The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- **5V.** The regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated 5V supply.
- **3V3.** A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- **GND.** Ground pins.

Memory

The Atmega328 has 32 KB of flash memory for storing code (of which 0,5 KB is used for the bootloader); It has also 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the EEPROM library).

Input and Output

Each of the 14 digital pins on the Uno can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

- **Serial: 0 (RX) and 1 (TX).** Used to receive (RX) and transmit (TX) TTL serial data. TThese pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip .
- **External Interrupts: 2 and 3.** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.
- **PWM: 3, 5, 6, 9, 10, and 11.** Provide 8-bit PWM output with the analogWrite() function.
- **SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK).** These pins support SPI communication, which, although provided by the underlying hardware, is not currently included in the Arduino language.

- **LED: 13.** There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

The Uno has 6 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and the analogReference() function. Additionally, some pins have specialized functionality:

- **I^2C: 4 (SDA) and 5 (SCL).** Support I^2C (TWI) communication using the Wire library.

There are a couple of other pins on the board:

- **AREF.** Reference voltage for the analog inputs. Used with analogReference().
- **Reset.** Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

See also the mapping between Arduino pins and Atmega328 ports.

Communication

The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega8U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '8U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, an *.inf file is required..

The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (but not for serial communication on pins 0 and 1).

A SoftwareSerial library allows for serial communication on any of the Uno's digital pins.

The ATmega328 also support I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the documentation for details. To use the SPI communication, please see the ATmega328 datasheet.

Programming

The Arduino Uno can be programmed with the Arduino software (download). Select "Arduino Uno w/ ATmega328" from the **Tools > Board** menu (according to the microcontroller on your board). For details, see the reference and tutorials.

The ATmega328 on the Arduino Uno comes preburned with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files).

You can also bypass the bootloader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header; see these instructions for details.

The ATmega8U2 firmware source code is available . The ATmega8U2 is loaded with a DFU bootloader, which can be activated by connecting the solder jumper on the back of the board (near the map of Italy) and then resetting the 8U2. You can then use Atmel's FLIP software (Windows) or the DFU programmer (Mac OS X and Linux) to load a new firmware. Or you can use the ISP header with an external programmer (overwriting the DFU bootloader).

Automatic (Software) Reset

Rather than requiring a physical press of the reset button before an upload, the Arduino Uno is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the ATmega8U2 is connected to the reset line of the ATmega328 via a 100 nanofarad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino software uses this capability to allow you to upload code by simply pressing the upload button in the Arduino environment. This means that the bootloader can have a shorter timeout, as the lowering of DTR can be well-coordinated with the start of the upload.

This setup has other implications. When the Uno is connected to either a computer running Mac OS X or Linux, it resets each time a connection is made to it from software (via USB). For the following half-second or so, the bootloader is running on the Uno. While it is programmed to ignore malformed data (i.e. anything besides an upload of new code), it will intercept the first few bytes of data sent to the board after a connection is opened. If a sketch running on the board receives one-time configuration or other data when it first starts, make sure that the software with which it communicates waits a second after opening the connection and before sending this data.

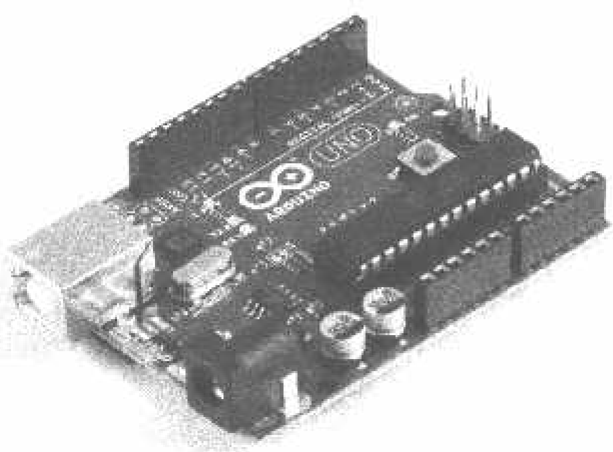
The Uno contains a trace that can be cut to disable the auto-reset. The pads on either side of the trace can be soldered together to re-enable it. It's labeled "RESET-EN". You may also be able to disable the auto-reset by connecting a 110 ohm resistor from 5V to the reset line; see this forum thread for details.

USB Overcurrent Protection

The Arduino Uno has a resettable polyfuse that protects your computer's USB ports from shorts and overcurrent. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed.

Physical Characteristics

The maximum length and width of the Uno PCB are 2.7 and 2.1 inches respectively, with the USB connector and power jack extending beyond the former dimension. Three screw holes allow the board to be attached to a surface or case. Note that the distance between digital pins 7 and 8 is 160 mil (0.16"), not an even multiple of the 100 mil spacing of the other pins.



How to use Arduino

Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller on the board is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). Arduino projects can be stand-alone or they can communicate with software on running on a computer (e.g. Flash, Processing, MaxMSP).

Arduino is a cross-platoform program. You'll have to follow different instructions for your personal OS. Check on the Arduino site for the latest instructions. *http://arduino.cc/en/Guide/HomePage*

Linux Install | Windows Install | Mac Install

Once you have downloaded/unzipped the arduino IDE, you can Plug the Arduino to your PC via USB cable.

Blink led

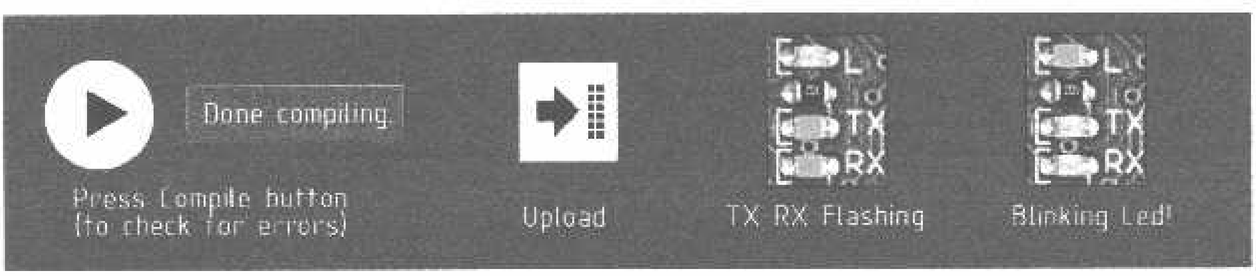
Now you're actually ready to "burn" your first program on the arduino board. To select "blink led", the physical translation of the well known programming "hello world", select

File>Sketchbook>
Arduino-0017>Examples>
Digital>Blink

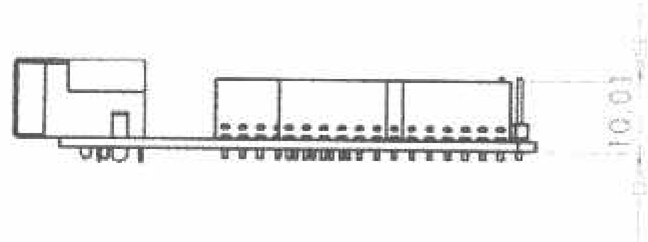
Once you have your skecth you'll see something very close to the screenshot on the right.

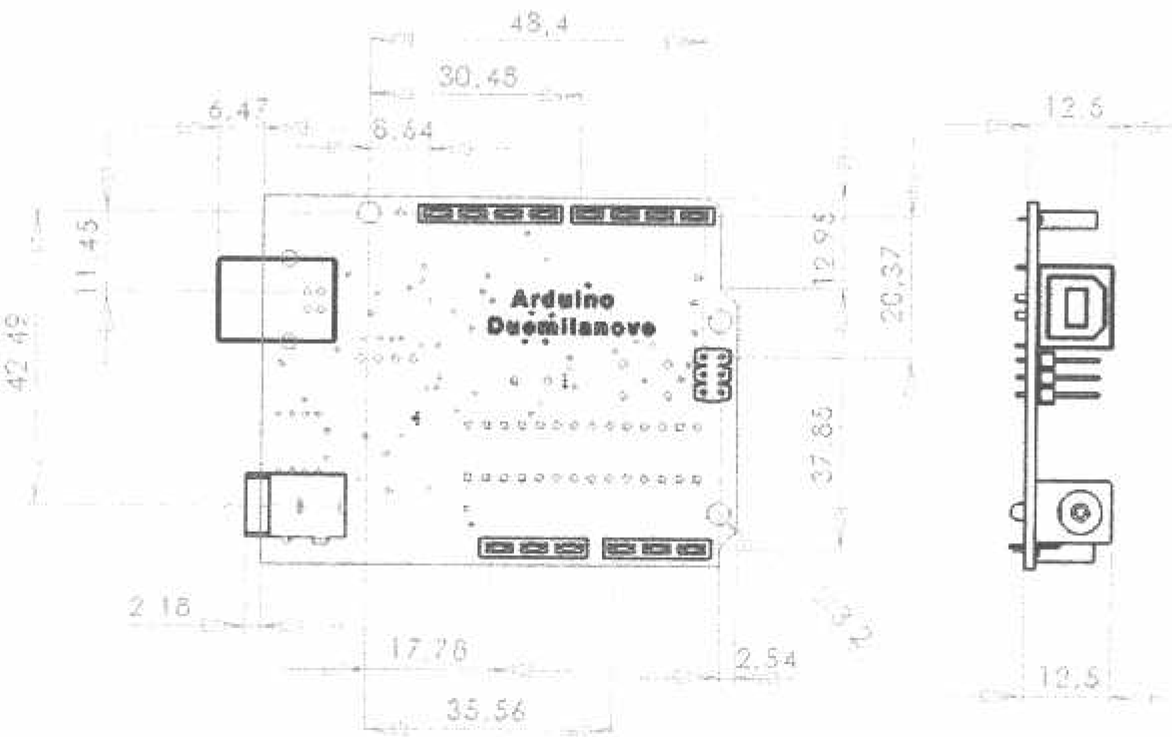
In **Tools>Board** select

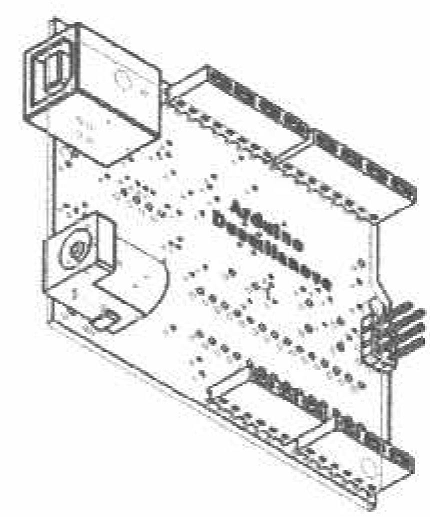
Now you have to go to
Tools>SerialPort
and select the right serial port, the one arduino is attached to.



Dimensioned Drawing







radiospares RADIONICS

maxim integrated™

DS18B20
Programmable Resolution 1-Wire Digital Thermometer

ESCRIPTION

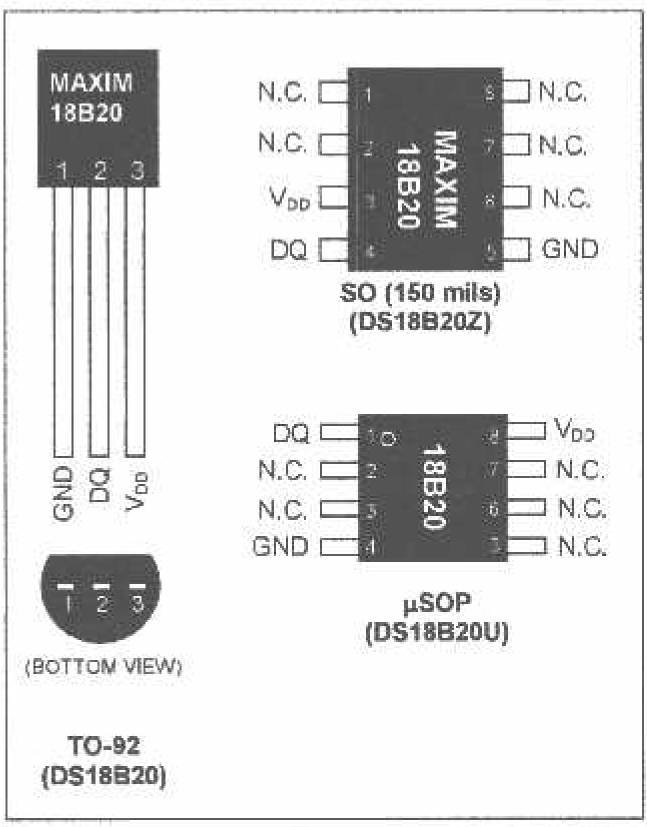
e DS18B20 digital thermometer provides 9-bit 12-bit Celsius temperature measurements and ; an alarm function with nonvolatile user-grammable upper and lower trigger points. e DS18B20 communicates over a 1-Wire bus t by definition requires only one data line (and und) for communication with a central croprocessor. It has an operating temperature ge of -55°C to +125°C and is accurate to 5°C over the range of -10°C to +85°C. In lition, the DS18B20 can derive power directly m the data line ("parasite power"), eliminating need for an external power supply.

ch DS18B20 has a unique 64-bit serial code, ich allows multiple DS18B20s to function on same 1-Wire bus. Thus, it is simple to use one croprocessor to control many DS18B20s tributed over a large area. Applications that benefit from this feature include HVAC ironmental controls, temperature monitoring tems inside buildings, equipment, or chinery, and process monitoring and control tems.

ATURES

- Unique 1-Wire® Interface Requires Only One Port Pin for Communication
- Each Device has a Unique 64-Bit Serial Code Stored in an On-Board ROM
- Multidrop Capability Simplifies Distributed Temperature-Sensing Applications
- Requires No External Components
- Can Be Powered from Data Line; Power Supply Range is 3.0V to 5.5V
- Measures Temperatures from -55°C to +125°C (-67°F to +257°F)
- ±0.5°C Accuracy from -10°C to +85°C
- Thermometer Resolution is User Selectable from 9 to 12 Bits
- Converts Temperature to 12-Bit Digital Word in 750ms (Max)
- User-Definable Nonvolatile (NV) Alarm Settings
- Alarm Search Command Identifies and Addresses Devices Whose Temperature is Outside Programmed Limits (Temperature Alarm Condition)
- Available in 8-Pin SO (150 mils), 8-Pin µSOP, and 3-Pin TO-92 Packages
- Software Compatible with the DS1822
- Applications Include Thermostatic Controls, Industrial Systems, Consumer Products, Thermometers, or Any Thermally Sensitive System

PIN CONFIGURATIONS



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· pricing, delivery, and ordering information, please contact Maxim Direct -888-629-4642, or visit Maxim's website at www.maximintegrated.com.

REV: 042208

RDERING INFORMATION

PART	TEMP RANGE	PIN-PACKAGE	TOP MARK
18B20	-55°C to +125°C	3 TO-92	18B20
18B20+	-55°C to +125°C	3 TO-92	18B20
18B20/T&R	-55°C to +125°C	3 TO-92 (2000 Piece)	18B20
18B20+T&R	-55°C to +125°C	3 TO-92 (2000 Piece)	18B20
18B20-SL/T&R	-55°C to +125°C	3 TO-92 (2000 Piece)*	18B20
18B20-SL+T&R	-55°C to +125°C	3 TO-92 (2000 Piece)*	18B20
18B20U	-55°C to +125°C	8 μSOP	18B20
18B20U+	-55°C to +125°C	8 μSOP	18B20
18B20U/T&R	-55°C to +125°C	8 μSOP (3000 Piece)	18B20
18B20U+T&R	-55°C to +125°C	8 μSOP (3000 Piece)	18B20
18B20Z	-55°C to +125°C	8 SO	DS18B20
18B20Z+	-55°C to +125°C	8 SO	DS18B20
18B20Z/T&R	-55°C to +125°C	8 SO (2500 Piece)	DS18B20
18B20Z+T&R	-55°C to +125°C	8 SO (2500 Piece)	DS18B20

notes a lead-free package. A "+" will appear on the top mark of lead-free packages.
= Tape and reel.
-92 packages in tape and reel can be ordered with straight or formed leads. Choose "SL" for straight leads. Bulk TO-92 orders are straight s only.

N DESCRIPTION

PIN			NAME	FUNCTION
SO	μSOP	TO-92		
, 2, 6, 7, 8	2, 3, 5, 6, 7	—	N.C.	No Connection
3	8	3	V_{DD}	Optional V_{DD}. V_{DD} must be grounded for operation in parasite power mode.
4	1	2	DQ	Data Input/Output. Open-drain 1-Wire interface pin. Also provides power to the device when used in parasite power mode (see the *Powering the DS18B20* section.)
5	4	1	GND	Ground

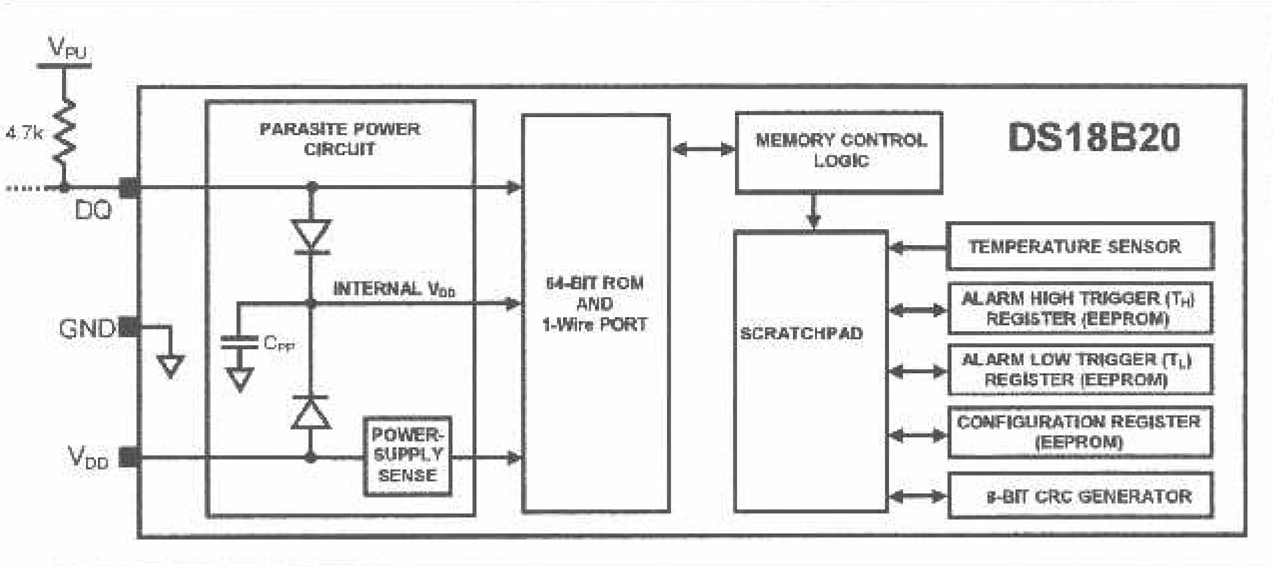
/ERVIEW

ure 1 shows a block diagram of the DS18B20, and pin descriptions are given in the *Pin Description* le. The 64-bit ROM stores the device's unique serial code. The scratchpad memory contains the 2-byte perature register that stores the digital output from the temperature sensor. In addition, the scratchpad vides access to the 1-byte upper and lower alarm trigger registers (T_H and T_L) and the 1-byte figuration register. The configuration register allows the user to set the resolution of the temperature-ligital conversion to 9, 10, 11, or 12 bits. The T_H, T_L, and configuration registers are nonvolatile PROM), so they will retain data when the device is powered down.

DS18B20 uses Maxim's exclusive 1-Wire bus protocol that implements bus communication using control signal. The control line requires a weak pullup resistor since all devices are linked to the bus a 3-state or open-drain port (the DQ pin in the case of the DS18B20). In this bus system, the roprocessor (the master device) identifies and addresses devices on the bus using each device's unique bit code. Because each device has a unique code, the number of devices that can be addressed on one s is virtually unlimited. The 1-Wire bus protocol, including detailed explanations of the commands and ime slots," is covered in the *1-Wire Bus System* section.

nother feature of the DS18B20 is the ability to operate without an external power supply. Power is tead supplied through the 1-Wire pullup resistor via the DQ pin when the bus is high. The high bus nal also charges an internal capacitor (C_{PP}), which then supplies power to the device when the bus is v. This method of deriving power from the 1-Wire bus is referred to as "parasite power." As an ernative, the DS18B20 may also be powered by an external supply on V_{DD}.

gure 1. DS18B20 Block Diagram



ERATION—MEASURING TEMPERATURE

e core functionality of the DS18B20 is its direct-to-digital temperature sensor. The resolution of the nperature sensor is user-configurable to 9, 10, 11, or 12 bits, corresponding to increments of 0.5°C, 5°C, 0.125°C, and 0.0625°C, respectively. The default resolution at power-up is 12-bit. The DS18B20 vers up in a low-power idle state. To initiate a temperature measurement and A-to-D conversion, the ster must issue a Convert T [44h] command. Following the conversion, the resulting thermal data is ed in the 2-byte temperature register in the scratchpad memory and the DS18B20 returns to its idle e. If the DS18B20 is powered by an external supply, the master can issue "read time slots" (see the *Vire Bus System* section) after the Convert T command and the DS18B20 will respond by transmitting hile the temperature conversion is in progress and 1 when the conversion is done. If the DS18B20 is vered with parasite power, this notification technique cannot be used since the bus must be pulled high a strong pullup during the entire temperature conversion. The bus requirements for parasite power are lained in detail in the *Powering the DS18B20* section.

e DS18B20 output temperature data is calibrated in degrees Celsius; for Fahrenheit applications, a kup table or conversion routine must be used. The temperature data is stored as a 16-bit sign-extended 's complement number in the temperature register (see Figure 2). The sign bits (S) indicate if the nperature is positive or negative: for positive numbers S = 0 and for negative numbers S = 1. If the 18B20 is configured for 12-bit resolution, all bits in the temperature register will contain valid data. 11-bit resolution, bit 0 is undefined. For 10-bit resolution, bits 1 and 0 are undefined, and for 9-bit olution bits 2, 1, and 0 are undefined. Table 1 gives examples of digital output data and the responding temperature reading for 12-bit resolution conversions.

ƺure 2. Temperature Register Format

	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
S BYTE	2^3	2^2	2^1	2^0	2^{-1}	2^{-2}	2^{-3}	2^{-4}
	BIT 15	BIT 14	BIT 13	BIT 12	BIT 11	BIT 10	BIT 9	BIT 8
S BYTE	S	S	S	S	S	2^6	2^5	2^4

SIGN

ble 1. Temperature/Data Relationship

EMPERATURE (°C)	DIGITAL OUTPUT (BINARY)	DIGITAL OUTPUT (HEX)
+125	0000 0111 1101 0000	07D0h
+85*	0000 0101 0101 0000	0550h
+25.0625	0000 0001 1001 0001	0191h
+10.125	0000 0000 1010 0010	00A2h
+0.5	0000 0000 0000 1000	0008h
0	0000 0000 0000 0000	0000h
-0.5	1111 1111 1111 1000	FFF8h
-10.125	1111 1111 0101 1110	FF5Eh
-25.0625	1111 1110 0110 1111	FE6Fh
-55	1111 1100 1001 0000	FC90h

power-on reset value of the temperature register is +85°C.

ERATION—ALARM SIGNALING

er the DS18B20 performs a temperature conversion, the temperature value is compared to the user-ined two's complement alarm trigger values stored in the 1-byte T_H and T_L registers (see Figure 3). : sign bit (S) indicates if the value is positive or negative: for positive numbers S = 0 and for negative nbers S = 1. The T_H and T_L registers are nonvolatile (EEPROM) so they will retain data when the ice is powered down. T_H and T_L can be accessed through bytes 2 and 3 of the scratchpad as explained he *Memory* section.

ure 3. T_H and T_L Register Format

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
S	2^6	2^5	2^4	2^3	2^2	2^1	2^0

ly bits 11 through 4 of the temperature register are used in the T_H and T_L comparison since T_H and T_L 8-bit registers. If the measured temperature is lower than or equal to T_L or higher than or equal to T_H, alarm condition exists and an alarm flag is set inside the DS18B20. This flag is updated after every iperature measurement; therefore, if the alarm condition goes away, the flag will be turned off after the t temperature conversion.

e master device can check the alarm flag status of all DS18B20s on the bus by issuing an Alarm Search Ch] command. Any DS18B20s with a set alarm flag will respond to the command, so the master can ermine exactly which DS18B20s have experienced an alarm condition. If an alarm condition exists l the T_H or T_L settings have changed, another temperature conversion should be done to validate the rm condition.

WERING THE DS18B20

e DS18B20 can be powered by an external supply on the V_{DD} pin, or it can operate in "parasite power" de, which allows the DS18B20 to function without a local external supply. Parasite power is very ful for applications that require remote temperature sensing or that are very space constrained. ure 1 shows the DS18B20's parasite-power control circuitry, which "steals" power from the 1-Wire via the DQ pin when the bus is high. The stolen charge powers the DS18B20 while the bus is high, l some of the charge is stored on the parasite power capacitor (C_{PP}) to provide power when the bus is . When the DS18B20 is used in parasite power mode, the V_{DD} pin must be connected to ground.

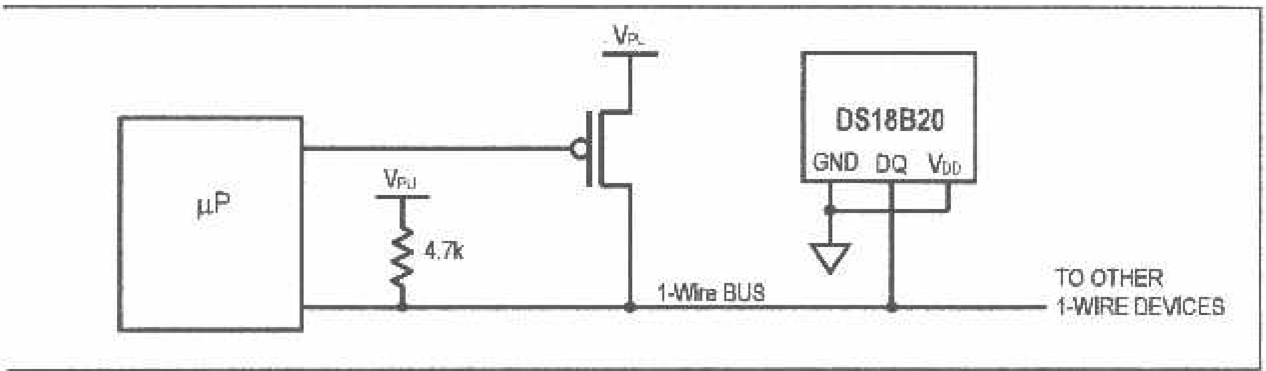
parasite power mode, the 1-Wire bus and C_{PP} can provide sufficient current to the DS18B20 for most rations as long as the specified timing and voltage requirements are met (see the *DC Electrical aracteristics* and *AC Electrical Characteristics*). However, when the DS18B20 is performing perature conversions or copying data from the scratchpad memory to EEPROM, the operating current be as high as 1.5mA. This current can cause an unacceptable voltage drop across the weak 1-Wire lup resistor and is more current than can be supplied by C_{PP}. To assure that the DS18B20 has sufficient pply current, it is necessary to provide a strong pullup on the 1-Wire bus whenever temperature versions are taking place or data is being copied from the scratchpad to EEPROM. This can be omplished by using a MOSFET to pull the bus directly to the rail as shown in Figure 4. The 1-Wire must be switched to the strong pullup within 10µs (max) after a Convert T [44h] or Copy Scratchpad h] command is issued, and the bus must be held high by the pullup for the duration of the conversion $_{NV}$) or data transfer (t_{WR} = 10ms). No other activity can take place on the 1-Wire bus while the pullup nabled.

DS18B20 can also be powered by the conventional method of connecting an external power supply he V_{DD} pin, as shown in Figure 5. The advantage of this method is that the MOSFET pullup is not uired, and the 1-Wire bus is free to carry other traffic during the temperature conversion time.

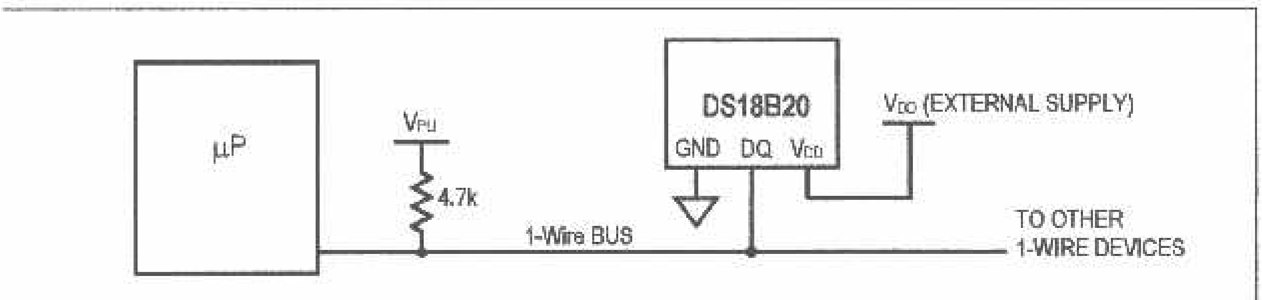
use of parasite power is not recommended for temperatures above +100°C since the DS18B20 may be able to sustain communications due to the higher leakage currents that can exist at these peratures. For applications in which such temperatures are likely, it is strongly recommended that the 18B20 be powered by an external power supply.

ome situations the bus master may not know whether the DS18B20s on the bus are parasite powered owered by external supplies. The master needs this information to determine if the strong bus pullup uld be used during temperature conversions. To get this information, the master can issue a Skip ROM Ch] command followed by a Read Power Supply [B4h] command followed by a "read time slot". ing the read time slot, parasite powered DS18B20s will pull the bus low, and externally powered 18B20s will let the bus remain high. If the bus is pulled low, the master knows that it must supply the ng pullup on the 1-Wire bus during temperature conversions.

jure 4. Supplying the Parasite-Powered DS18B20 During Temperature Conversions



jure 5. Powering the DS18B20 with an External Supply



-BIT LASERED ROM CODE

:h DS18B20 contains a unique 64–bit code (see Figure 6) stored in ROM. The least significant 8 bits :he ROM code contain the DS18B20's 1-Wire family code: 28h. The next 48 bits contain a unique al number. The most significant 8 bits contain a cyclic redundancy check (CRC) byte that is :ulated from the first 56 bits of the ROM code. A detailed explanation of the CRC bits is provided in *CRC Generation* section. The 64-bit ROM code and associated ROM function control logic allow the 18B20 to operate as a 1-Wire device using the protocol detailed in the *1-Wire Bus System* section.

jure 6. 64-Bit Lasered ROM Code

8-BIT CRC		48-BIT SERIAL NUMBER		8-BIT FAMILY CODE (28h)	
;B	LSB	MSB	LSB	MSB	LSB

EMORY

e DS18B20's memory is organized as shown in Figure 7. The memory consists of an SRAM atchpad with nonvolatile EEPROM storage for the high and low alarm trigger registers (T_H and T_L) l configuration register. Note that if the DS18B20 alarm function is not used, the T_H and T_L registers ı serve as general-purpose memory. All memory commands are described in detail in the *DS18B20 nction Commands* section.

te 0 and byte 1 of the scratchpad contain the LSB and the MSB of the temperature register, pectively. These bytes are read-only. Bytes 2 and 3 provide access to T_H and T_L registers. Byte 4 ıtains the configuration register data, which is explained in detail in the *Configuration Register* section. tes 5, 6, and 7 are reserved for internal use by the device and cannot be overwritten.

te 8 of the scratchpad is read-only and contains the CRC code for bytes 0 through 7 of the scratchpad. e DS18B20 generates this CRC using the method described in the *CRC Generation* section.

ta is written to bytes 2, 3, and 4 of the scratchpad using the Write Scratchpad [4Eh] command; the data st be transmitted to the DS18B20 starting with the least significant bit of byte 2. To verify data egrity, the scratchpad can be read (using the Read Scratchpad [BEh] command) after the data is tten. When reading the scratchpad, data is transferred over the 1-Wire bus starting with the least nificant bit of byte 0. To transfer the T_H, T_L and configuration data from the scratchpad to EEPROM, master must issue the Copy Scratchpad [48h] command.

ta in the EEPROM registers is retained when the device is powered down; at power-up the EEPROM a is reloaded into the corresponding scratchpad locations. Data can also be reloaded from EEPROM to scratchpad at any time using the Recall E^2 [B8h] command. The master can issue read time slots owing the Recall E^2 command and the DS18B20 will indicate the status of the recall by transmitting 0 ile the recall is in progress and 1 when the recall is done.

ure 7. DS18B20 Memory Map

	SCRATCHPAD (POWER-UP STATE)		EEPROM
Byte 0	Temperature LSB (50h) } (85°C)		
Byte 1	Temperature MSB (05h) } (85°C)		
Byte 2	T_H Register or User Byte 1*	↔	T_H Register or User Byte 1
Byte 3	T_L Register or User Byte 2*	↔	T_L Register or User Byte 2
Byte 4	Configuration Register*	↔	Configuration Register
Byte 5	Reserved (FFh)		
Byte 6	Reserved		
Byte 7	Reserved (10h)		
Byte 8	CRC*		

**Power-up state depends on value(s) stored in EEPROM.*

ƆNFIGURATION REGISTER

te 4 of the scratchpad memory contains the configuration register, which is organized as illustrated in ;ure 8. The user can set the conversion resolution of the DS18B20 using the R0 and R1 bits in this ;ister as shown in Table 2. The power-up default of these bits is R0 = 1 and R1 = 1 (12-bit resolution). te that there is a direct tradeoff between resolution and conversion time. Bit 7 and bits 0 to 4 in the ıfiguration register are reserved for internal use by the device and cannot be overwritten.

ɟure 8. Configuration Register

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
0	R1	R0	1	1	1	1	1

ble 2. Thermometer Resolution Configuration

R1	R0	RESOLUTION (BITS)	MAX CONVERSION TIME	
0	0	9	93.75ms	($t_{CONV}/8$)
0	1	10	187.5ms	($t_{CONV}/4$)
1	0	11	375ms	($t_{CONV}/2$)
1	1	12	750ms	(t_{CONV})

ꝛC GENERATION

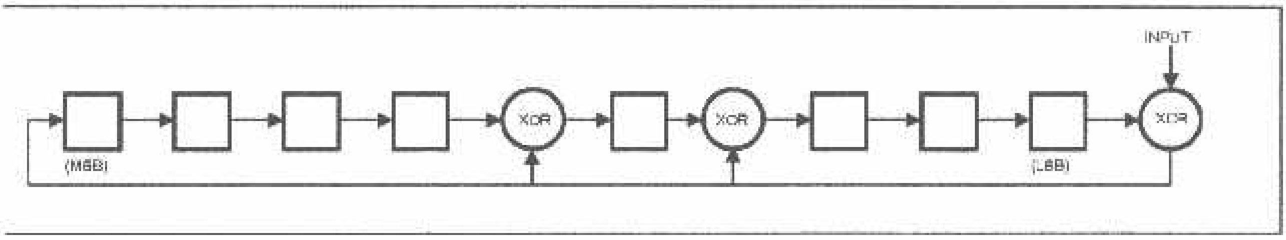
C bytes are provided as part of the DS18B20's 64-bit ROM code and in the 9th byte of the scratchpad ɪnory. The ROM code CRC is calculated from the first 56 bits of the ROM code and is contained in the st significant byte of the ROM. The scratchpad CRC is calculated from the data stored in the ɪtchpad, and therefore it changes when the data in the scratchpad changes. The CRCs provide the bus ɜter with a method of data validation when data is read from the DS18B20. To verify that data has n read correctly, the bus master must re-calculate the CRC from the received data and then compare value to either the ROM code CRC (for ROM reads) or to the scratchpad CRC (for scratchpad reads). he calculated CRC matches the read CRC, the data has been received error free. The comparison of C values and the decision to continue with an operation are determined entirely by the bus master. ɜre is no circuitry inside the DS18B20 that prevents a command sequence from proceeding if the 18B20 CRC (ROM or scratchpad) does not match the value generated by the bus master.

: equivalent polynomial function of the CRC (ROM or scratchpad) is:

$$CRC = X^8 + X^5 + X^4 + 1$$

: bus master can re-calculate the CRC and compare it to the CRC values from the DS18B20 using the ynomial generator shown in Figure 9. This circuit consists of a shift register and XOR gates, and the ɫ register bits are initialized to 0. Starting with the least significant bit of the ROM code or the least ıificant bit of byte 0 in the scratchpad, one bit at a time should shifted into the shift register. After ɫing in the 56th bit from the ROM or the most significant bit of byte 7 from the scratchpad, the ynomial generator will contain the re-calculated CRC. Next, the 8-bit ROM code or scratchpad CRC n the DS18B20 must be shifted into the circuit. At this point, if the re-calculated CRC was correct, the ɫ register will contain all 0s. Additional information about the Maxim 1-Wire cyclic redundancy check ıvailable in *Application Note 27: Understanding and Using Cyclic Redundancy Checks with Maxim ıtton Products.*

ȷure 9. CRC Generator



ΝIRE BUS SYSTEM

ɛ 1-Wire bus system uses a single bus master to control one or more slave devices. The DS18B20 is 'ays a slave. When there is only one slave on the bus, the system is referred to as a "single-drop" tem; the system is "multidrop" if there are multiple slaves on the bus.

data and commands are transmitted least significant bit first over the 1-Wire bus.

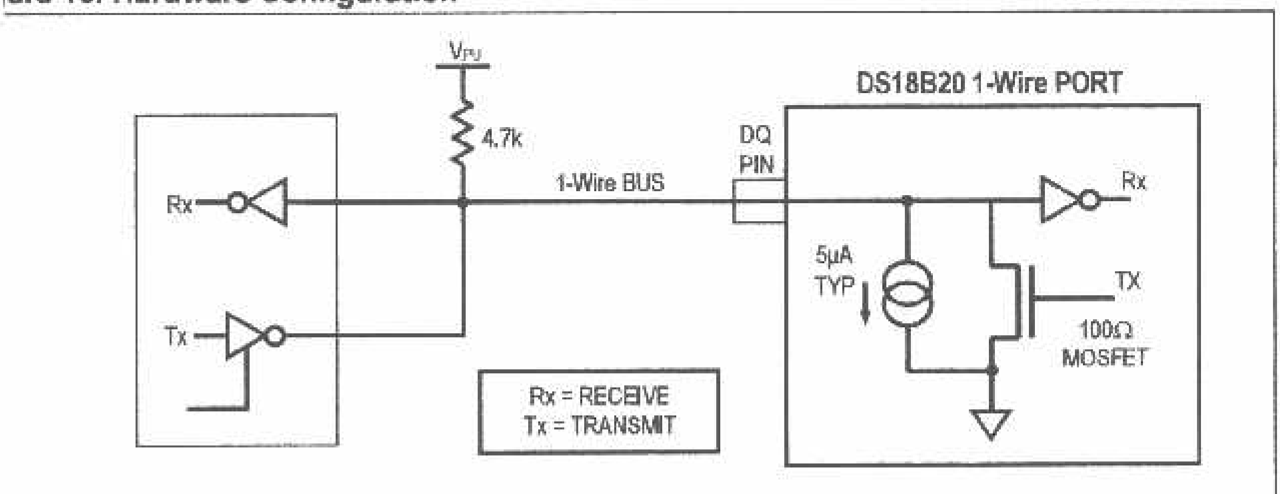
: following discussion of the 1-Wire bus system is broken down into three topics: hardware ıfiguration, transaction sequence, and 1-Wire signaling (signal types and timing).

ꓠRDWARE CONFIGURATION

: 1-Wire bus has by definition only a single data line. Each device (master or slave) interfaces to the a line via an open-drain or 3-state port. This allows each device to "release" the data line when the ice is not transmitting data so the bus is available for use by another device. The 1-Wire port of the 18B20 (the DQ pin) is open drain with an internal circuit equivalent to that shown in Figure 10.

: 1-Wire bus requires an external pullup resistor of approximately 5kΩ; thus, the idle state for the Vire bus is high. If for any reason a transaction needs to be suspended, the bus MUST be left in the idle e if the transaction is to resume. Infinite recovery time can occur between bits so long as the 1-Wire is in the inactive (high) state during the recovery period. If the bus is held low for more than 480µs, components on the bus will be reset.

ıure 10. Hardware Configuration



?ANSACTION SEQUENCE

e transaction sequence for accessing the DS18B20 is as follows:

Step 1. Initialization

Step 2. ROM Command (followed by any required data exchange)

Step 3. DS18B20 Function Command (followed by any required data exchange)

s very important to follow this sequence every time the DS18B20 is accessed, as the DS18B20 will not pond if any steps in the sequence are missing or out of order. Exceptions to this rule are the Search ᴵM [F0h] and Alarm Search [ECh] commands. After issuing either of these ROM commands, the ster must return to Step 1 in the sequence.

ITIALIZATION

transactions on the 1-Wire bus begin with an initialization sequence. The initialization sequence ısists of a reset pulse transmitted by the bus master followed by presence pulse(s) transmitted by the ve(s). The presence pulse lets the bus master know that slave devices (such as the DS18B20) are on the and are ready to operate. Timing for the reset and presence pulses is detailed in the *1-Wire Signaling* tion.

)M COMMANDS

er the bus master has detected a presence pulse, it can issue a ROM command. These commands :rate on the unique 64-bit ROM codes of each slave device and allow the master to single out a specific ice if many are present on the 1-Wire bus. These commands also allow the master to determine how ıy and what types of devices are present on the bus or if any device has experienced an alarm dition. There are five ROM commands, and each command is 8 bits long. The master device must ıe an appropriate ROM command before issuing a DS18B20 function command. A flowchart for :ration of the ROM commands is shown in Figure 11.

ARCH ROM [F0h]

en a system is initially powered up, the master must identify the ROM codes of all slave devices on bus, which allows the master to determine the number of slaves and their device types. The master ns the ROM codes through a process of elimination that requires the master to perform a Search ROM le (i.e., Search ROM command followed by data exchange) as many times as necessary to identify all he slave devices. If there is only one slave on the bus, the simpler Read ROM command (see below) be used in place of the Search ROM process. For a detailed explanation of the Search ROM cedure, refer to the *iButton® Book of Standards* at www.maxim-ic.com/ibuttonbook. After every rch ROM cycle, the bus master must return to Step 1 (Initialization) in the transaction sequence.

AD ROM [33h]

s command can only be used when there is one slave on the bus. It allows the bus master to read the /e's 64-bit ROM code without using the Search ROM procedure. If this command is used when there nore than one slave present on the bus, a data collision will occur when all the slaves attempt to ›ond at the same time.

TCH ROM [55h]

: match ROM command followed by a 64-bit ROM code sequence allows the bus master to address a :ific slave device on a multidrop or single-drop bus. Only the slave that exactly matches the 64-bit M code sequence will respond to the function command issued by the master; all other slaves on the will wait for a reset pulse.

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⟨IP ROM [CCh]

e master can use this command to address all devices on the bus simultaneously without sending out / ROM code information. For example, the master can make all DS18B20s on the bus perform ıultaneous temperature conversions by issuing a Skip ROM command followed by a Convert T [44h] nmand.

te that the Read Scratchpad [BEh] command can follow the Skip ROM command only if there is a gle slave device on the bus. In this case, time is saved by allowing the master to read from the slave hout sending the device's 64-bit ROM code. A Skip ROM command followed by a Read Scratchpad nmand will cause a data collision on the bus if there is more than one slave since multiple devices will empt to transmit data simultaneously.

ARM SEARCH [ECh]

e operation of this command is identical to the operation of the Search ROM command except that y slaves with a set alarm flag will respond. This command allows the master device to determine if ' DS18B20s experienced an alarm condition during the most recent temperature conversion. After ry Alarm Search cycle (i.e., Alarm Search command followed by data exchange), the bus master must urn to Step 1 (Initialization) in the transaction sequence. See the *Operation—Alarm Signaling* section an explanation of alarm flag operation.

518B20 FUNCTION COMMANDS

er the bus master has used a ROM command to address the DS18B20 with which it wishes to nmunicate, the master can issue one of the DS18B20 function commands. These commands allow the ster to write to and read from the DS18B20's scratchpad memory, initiate temperature conversions and ermine the power supply mode. The DS18B20 function commands, which are described below, are nmarized in Table 3 and illustrated by the flowchart in Figure 12.

)NVERT T [44h]

s command initiates a single temperature conversion. Following the conversion, the resulting thermal a is stored in the 2-byte temperature register in the scratchpad memory and the DS18B20 returns to its -power idle state. If the device is being used in parasite power mode, within 10µs (max) after this nmand is issued the master must enable a strong pullup on the 1-Wire bus for the duration of the version (t_{CONV}) as described in the *Powering the DS18B20* section. If the DS18B20 is powered by an ernal supply, the master can issue read time slots after the Convert T command and the DS18B20 will ɔond by transmitting a 0 while the temperature conversion is in progress and a 1 when the conversion one. In parasite power mode this notification technique cannot be used since the bus is pulled high by strong pullup during the conversion.

ꞮITE SCRATCHPAD [4Eh]

s command allows the master to write 3 bytes of data to the DS18B20's scratchpad. The first data byte vritten into the T_H register (byte 2 of the scratchpad), the second byte is written into the T_L register :e 3), and the third byte is written into the configuration register (byte 4). Data must be transmitted ;t significant bit first. All three bytes MUST be written before the master issues a reset, or the data / be corrupted.

AD SCRATCHPAD [BEh]

s command allows the master to read the contents of the scratchpad. The data transfer starts with the ;t significant bit of byte 0 and continues through the scratchpad until the 9th byte (byte 8 – CRC) is 1. The master may issue a reset to terminate reading at any time if only part of the scratchpad data is ded.

)PY SCRATCHPAD [48h]

is command copies the contents of the scratchpad T_H, T_L and configuration registers (bytes 2, 3 and 4) EEPROM. If the device is being used in parasite power mode, within 10µs (max) after this command is ued the master must enable a strong pullup on the 1-Wire bus for at least 10ms as described in the *wering the DS18B20* section.

:CALL E^2 [B8h]

is command recalls the alarm trigger values (T_H and T_L) and configuration data from EEPROM and ces the data in bytes 2, 3, and 4, respectively, in the scratchpad memory. The master device can issue d time slots following the Recall E^2 command and the DS18B20 will indicate the status of the recall by ısmitting 0 while the recall is in progress and 1 when the recall is done. The recall operation happens omatically at power-up, so valid data is available in the scratchpad as soon as power is applied to the 'ice.

AD POWER SUPPLY [B4h]

: master device issues this command followed by a read time slot to determine if any DS18B20s on the are using parasite power. During the read time slot, parasite powered DS18B20s will pull the bus ', and externally powered DS18B20s will let the bus remain high. See the *Powering the DS18B20* tion for usage information for this command.

ble 3. DS18B20 Function Command Set

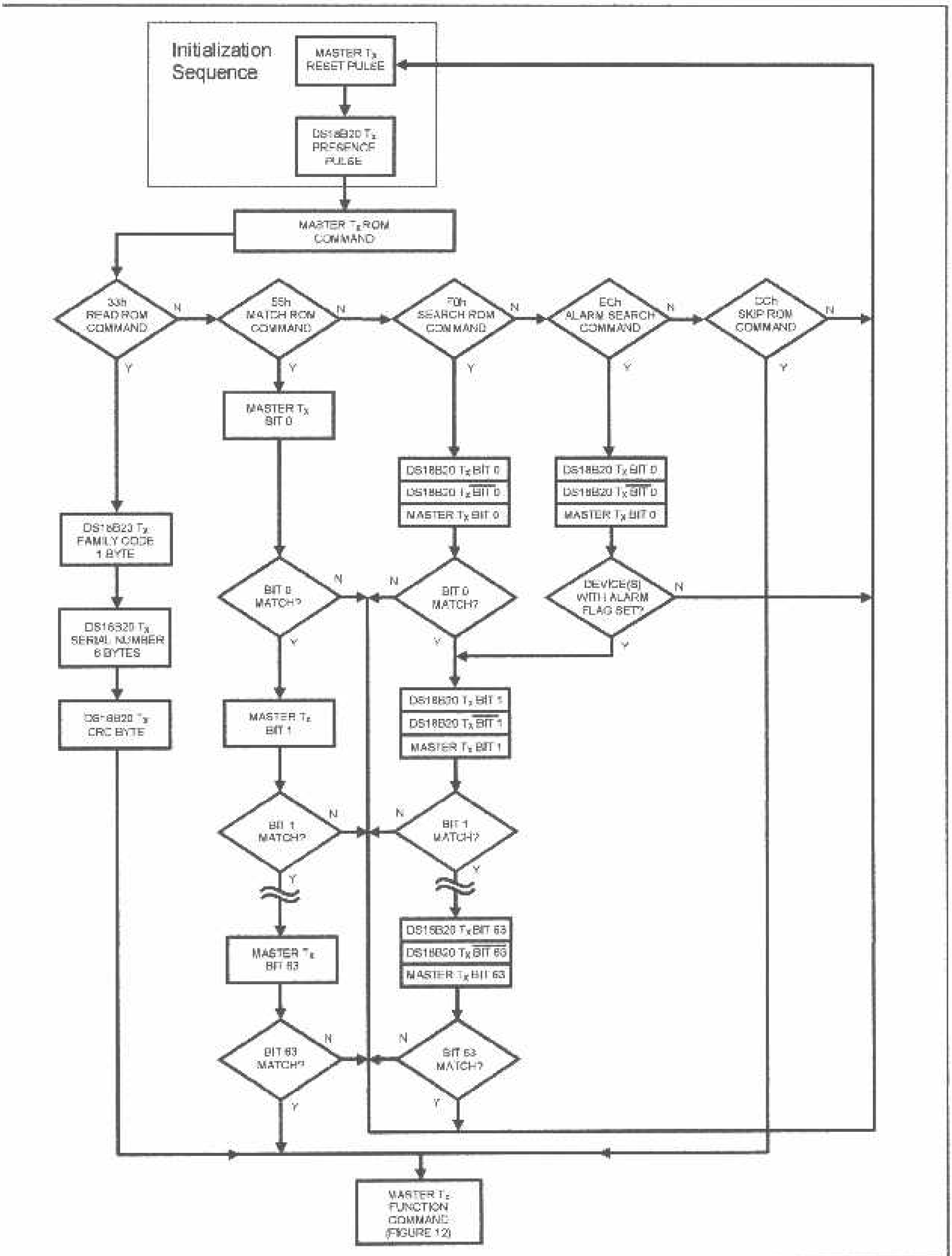
OMMAND	DESCRIPTION	PROTOCOL	1-Wire BUS ACTIVITY AFTER COMMAND IS ISSUED	NOTES
TEMPERATURE CONVERSION COMMANDS				
nvert T	Initiates temperature conversion.	44h	DS18B20 transmits conversion status to master (not applicable for parasite-powered DS18B20s).	1
MEMORY COMMANDS				
:ad ratchpad	Reads the entire scratchpad including the CRC byte.	BEh	DS18B20 transmits up to 9 data bytes to master.	2
rite ratchpad	Writes data into scratchpad bytes 2, 3, and 4 (T_H, T_L, and configuration registers).	4Eh	Master transmits 3 data bytes to DS18B20.	3
)py ratchpad	Copies T_H, T_L, and configuration register data from the scratchpad to EEPROM.	48h	None	1
:call E^2	Recalls T_H, T_L, and configuration register data from EEPROM to the scratchpad.	B8h	DS18B20 transmits recall status to master.	
:ad Power pply	Signals DS18B20 power supply mode to the master.	B4h	DS18B20 transmits supply status to master.	

: 1: For parasite-powered DS18B20s, the master must enable a strong pullup on the 1-Wire bus during temperature conversions and copies from the scratchpad to EEPROM. No other bus activity may take place during this time.

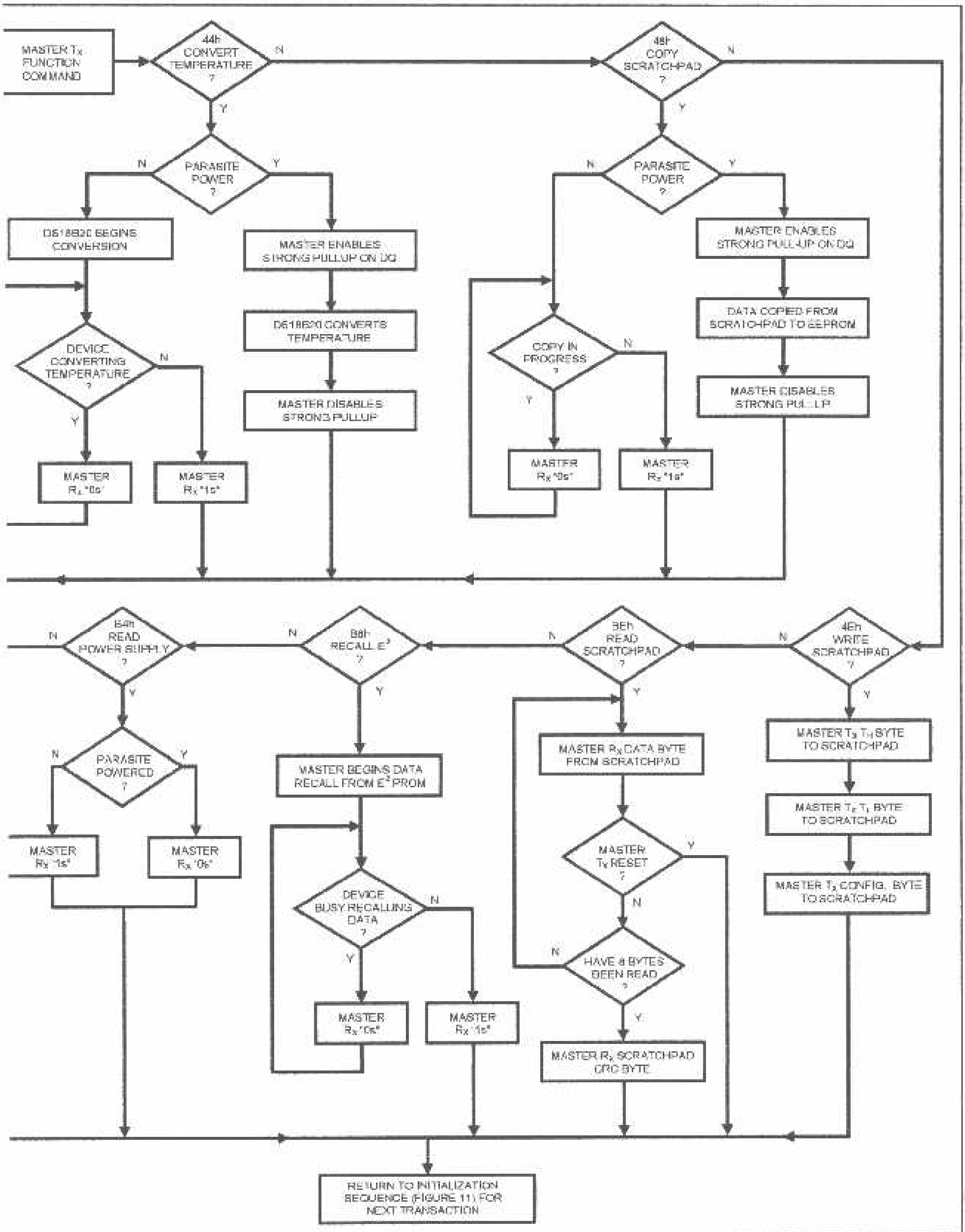
: 2: The master can interrupt the transmission of data at any time by issuing a reset.

: 3: All three bytes must be written before a reset is issued.

Figure 11. ROM Commands Flowchart



ıure 12. DS18B20 Function Commands Flowchart



WIRE SIGNALING

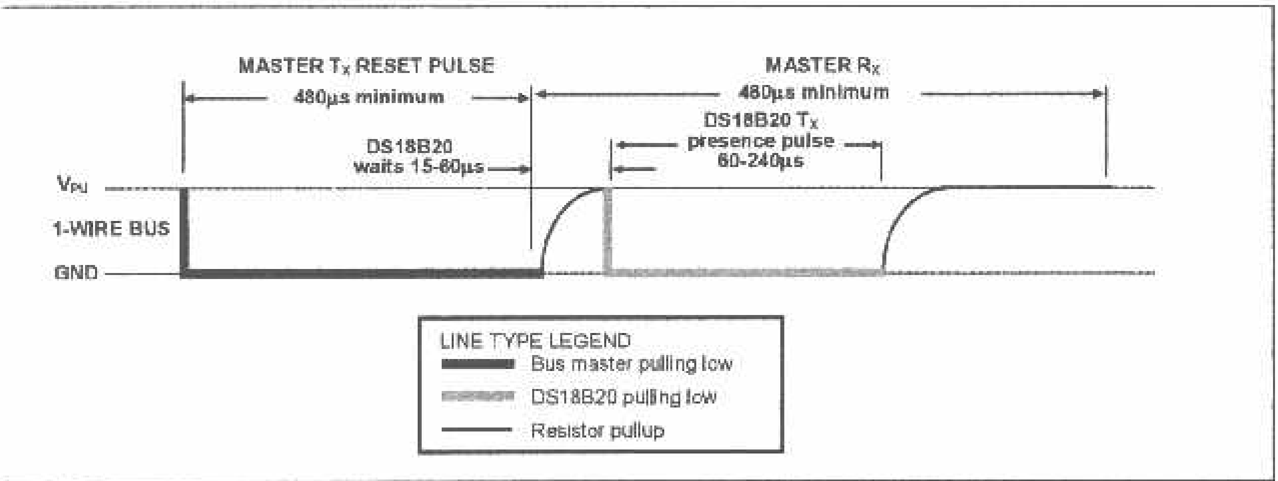
e DS18B20 uses a strict 1-Wire communication protocol to ensure data integrity. Several signal types defined by this protocol: reset pulse, presence pulse, write 0, write 1, read 0, and read 1. The bus ster initiates all these signals, with the exception of the presence pulse.

ITIALIZATION PROCEDURE—RESET AND PRESENCE PULSES

communication with the DS18B20 begins with an initialization sequence that consists of a reset pulse m the master followed by a presence pulse from the DS18B20. This is illustrated in Figure 13. When DS18B20 sends the presence pulse in response to the reset, it is indicating to the master that it is on bus and ready to operate.

ring the initialization sequence the bus master transmits (T_X) the reset pulse by pulling the 1-Wire bus for a minimum of 480µs. The bus master then releases the bus and goes into receive mode (R_X). en the bus is released, the 5kΩ pullup resistor pulls the 1-Wire bus high. When the DS18B20 detects rising edge, it waits 15µs to 60µs and then transmits a presence pulse by pulling the 1-Wire bus low 60µs to 240µs.

ure 13. Initialization Timing



AD/WRITE TIME SLOTS

bus master writes data to the DS18B20 during write time slots and reads data from the DS18B20 ng read time slots. One bit of data is transmitted over the 1-Wire bus per time slot.

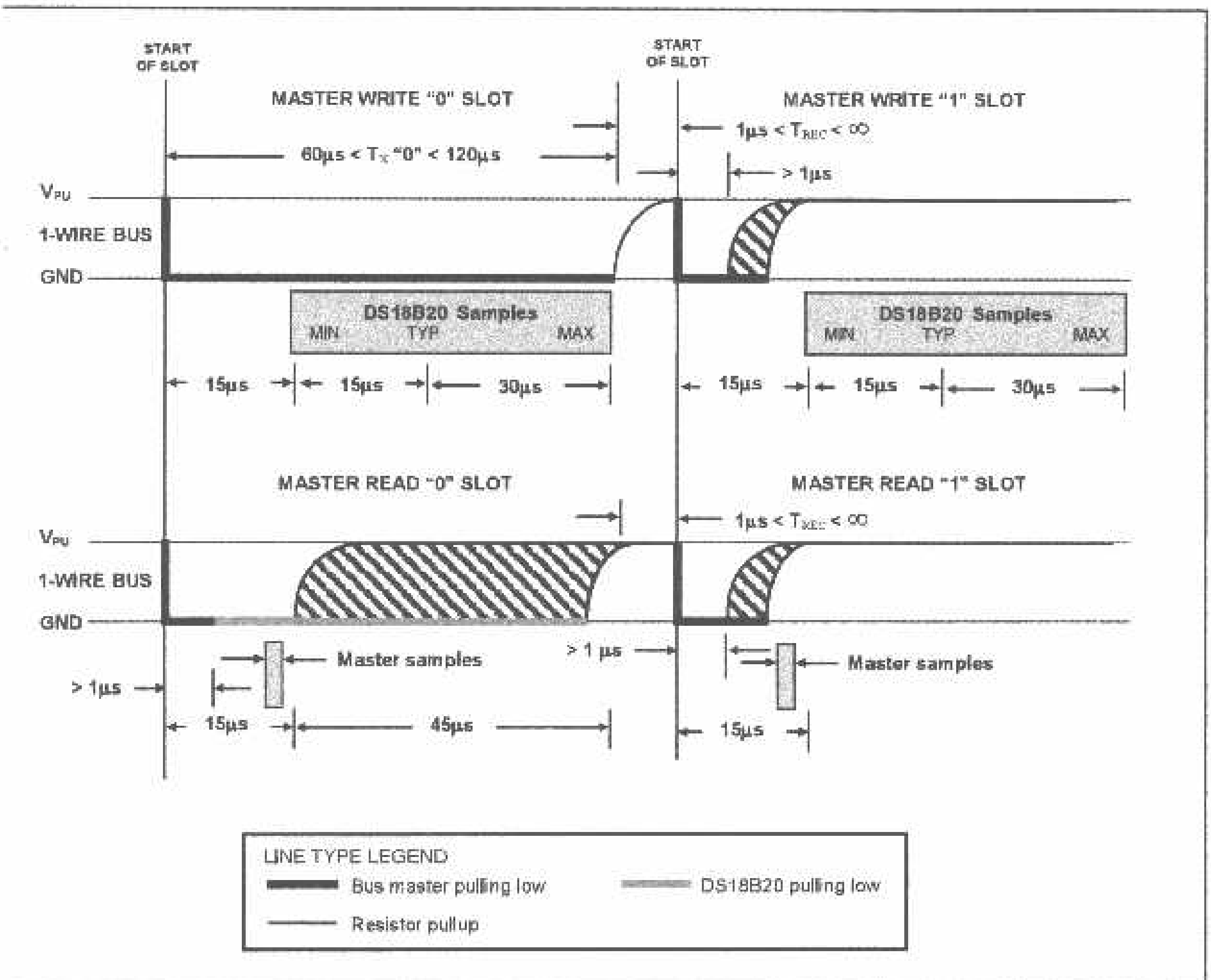
RITE TIME SLOTS

re are two types of write time slots: "Write 1" time slots and "Write 0" time slots. The bus master s a Write 1 time slot to write a logic 1 to the DS18B20 and a Write 0 time slot to write a logic 0 to the 18B20. All write time slots must be a minimum of 60µs in duration with a minimum of a 1µs recovery e between individual write slots. Both types of write time slots are initiated by the master pulling the Vire bus low (see Figure 14).

generate a Write 1 time slot, after pulling the 1-Wire bus low, the bus master must release the 1-Wire within 15µs. When the bus is released, the 5kΩ pullup resistor will pull the bus high. To generate a te 0 time slot, after pulling the 1-Wire bus low, the bus master must continue to hold the bus low for duration of the time slot (at least 60µs).

e DS18B20 samples the 1-Wire bus during a window that lasts from 15µs to 60µs after the master iates the write time slot. If the bus is high during the sampling window, a 1 is written to the DS18B20, he line is low, a 0 is written to the DS18B20.

jure 14. Read/Write Time Slot Timing Diagram



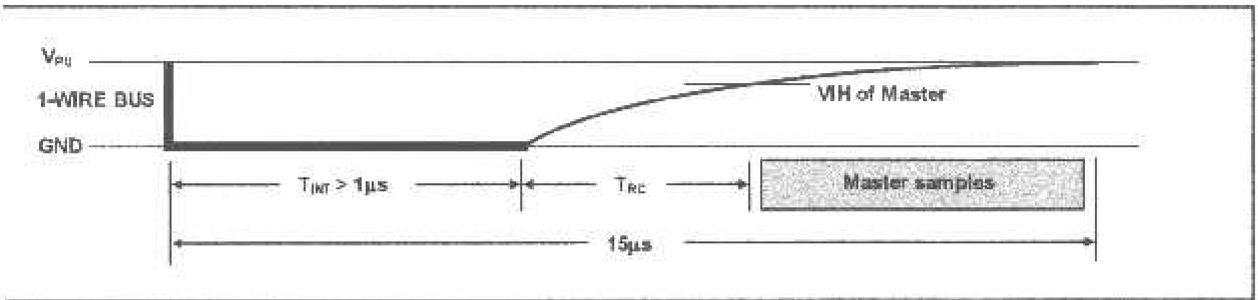
AD TIME SLOTS

DS18B20 can only transmit data to the master when the master issues read time slots. Therefore, the ter must generate read time slots immediately after issuing a Read Scratchpad [BEh] or Read Power ply [B4h] command, so that the DS18B20 can provide the requested data. In addition, the master can erate read time slots after issuing Convert T [44h] or Recall E^2 [B8h] commands to find out the status ne operation as explained in the *DS18B20 Function Commands* section.

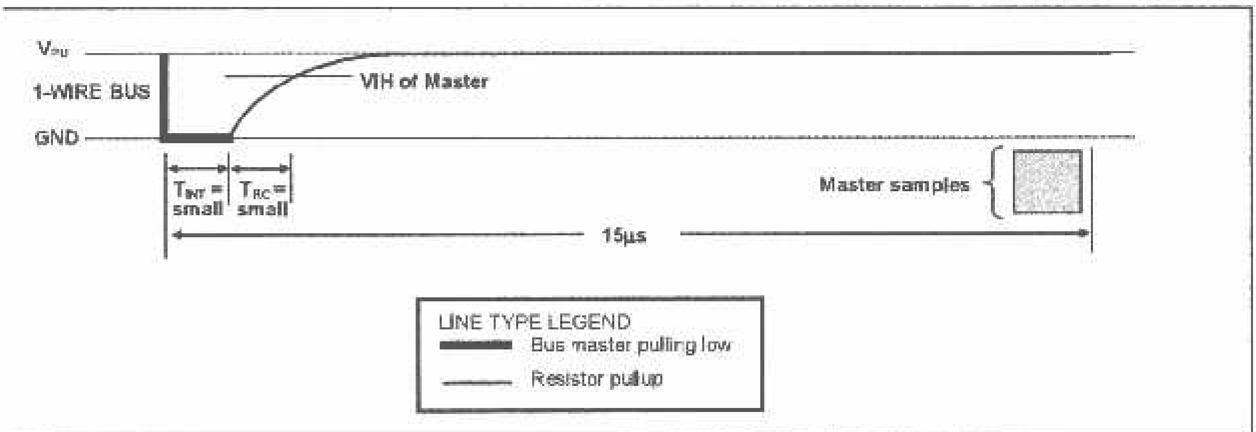
read time slots must be a minimum of 60µs in duration with a minimum of a 1µs recovery time veen slots. A read time slot is initiated by the master device pulling the 1-Wire bus low for a imum of 1µs and then releasing the bus (see Figure 14). After the master initiates the read time slot, DS18B20 will begin transmitting a 1 or 0 on bus. The DS18B20 transmits a 1 by leaving the bus high transmits a 0 by pulling the bus low. When transmitting a 0, the DS18B20 will release the bus by the of the time slot, and the bus will be pulled back to its high idle state by the pullup resister. Output a from the DS18B20 is valid for 15µs after the falling edge that initiated the read time slot. Therefore, master must release the bus and then sample the bus state within 15µs from the start of the slot.

ure 15 illustrates that the sum of T_{INIT}, T_{RC}, and T_{SAMPLE} must be less than 15µs for a read time slot. ure 16 shows that system timing margin is maximized by keeping T_{INIT} and T_{RC} as short as possible l by locating the master sample time during read time slots towards the end of the 15µs period.

jure 15. Detailed Master Read 1 Timing



jure 16. Recommended Master Read 1 Timing



LATED APPLICATION NOTES

following application notes can be applied to the DS18B20 and are available on our website at w.maxim-ic.com.

lication Note 27: Understanding and Using Cyclic Redundancy Checks with Maxim iButton Products
lication Note 122: Using Dallas' 1-Wire ICs in 1-Cell Li-Ion Battery Packs with Low-Side N-Channel ety FETs Master
lication Note 126: 1-Wire Communication Through Software
lication Note 162: Interfacing the DS18x20/DS1822 1-Wire Temperature Sensor in a Microcontroller ironment
lication Note 208: Curve Fitting the Error of a Bandgap-Based Digital Temperature Sensor
lication Note 2420: 1-Wire Communication with a Microchip PICmicro Microcontroller
lication Note 3754: Single-Wire Serial Bus Carries Isolated Power and Data

nple 1-Wire subroutines that can be used in conjunction with *Application Note 74: Reading and ting iButtons via Serial Interfaces* can be downloaded from the Maxim website.

18B20 OPERATION EXAMPLE 1

this example there are multiple DS18B20s on the bus and they are using parasite power. The bus ster initiates a temperature conversion in a specific DS18B20 and then reads its scratchpad and alculates the CRC to verify the data.

IASTER MODE	DATA (LSB FIRST)	COMMENTS
Tx	Reset	Master issues reset pulse.
Rx	Presence	DS18B20s respond with presence pulse.
Tx	55h	Master issues Match ROM command.
Tx	64-bit ROM code	Master sends DS18B20 ROM code.
Tx	44h	Master issues Convert T command.
Tx	DQ line held high by strong pullup	Master applies strong pullup to DQ for the duration of the conversion (t_{CONV}).
Tx	Reset	Master issues reset pulse.
Rx	Presence	DS18B20s respond with presence pulse.
Tx	55h	Master issues Match ROM command.
Tx	64-bit ROM code	Master sends DS18B20 ROM code.
Tx	BEh	Master issues Read Scratchpad command.
Rx	9 data bytes	Master reads entire scratchpad including CRC. The master then recalculates the CRC of the first eight data bytes from the scratchpad and compares the calculated CRC with the read CRC (byte 9). If they match, the master continues; if not, the read operation is repeated.

18B20 OPERATION EXAMPLE 2

his example there is only one DS18B20 on the bus and it is using parasite power. The master writes to T_H, T_L, and configuration registers in the DS18B20 scratchpad and then reads the scratchpad and ilculates the CRC to verify the data. The master then copies the scratchpad contents to EEPROM.

IASTER MODE	DATA (LSB FIRST)	COMMENTS
Tx	Reset	Master issues reset pulse.
Rx	Presence	DS18B20 responds with presence pulse.
Tx	CCh	Master issues Skip ROM command.
Tx	4Eh	Master issues Write Scratchpad command.
Tx	3 data bytes	Master sends three data bytes to scratchpad (T_H, T_L, and config).
Tx	Reset	Master issues reset pulse.
Rx	Presence	DS18B20 responds with presence pulse.
Tx	CCh	Master issues Skip ROM command.
Tx	BEh	Master issues Read Scratchpad command.
Rx	9 data bytes	Master reads entire scratchpad including CRC. The master then recalculates the CRC of the first eight data bytes from the scratchpad and compares the calculated CRC with the read CRC (byte 9). If they match, the master continues; if not, the read operation is repeated.
Tx	Reset	Master issues reset pulse.
Rx	Presence	DS18B20 responds with presence pulse.
Tx	CCh	Master issues Skip ROM command.
Tx	48h	Master issues Copy Scratchpad command.
Tx	DQ line held high by strong pullup	Master applies strong pullup to DQ for at least 10ms while copy operation is in progress.

ɜSOLUTE MAXIMUM RATINGS

ltage Range on Any Pin Relative to Ground ....-0.5V to +6.0V
erating Temperature Range ....-55°C to +125°C
rage Temperature Range...-55°C to +125°C
der Temperature ....Refer to the IPC/JEDEC J-STD-020 Specification.

ɜse are stress ratings only and functional operation of the device at these or any other conditions ɔve those indicated in the operation sections of this specification is not implied. Exposure to absolute ximum rating conditions for extended periods of time may affect reliability.

; ELECTRICAL CHARACTERISTICS (-55°C to +125°C; V_{DD}=3.0V to 5.5V)

'ARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
ıpply Voltage	V_{DD}	Local Power	+3.0		+5.5	V	1
ıllup Supply ɔltage	V_{PU}	Parasite Power	+3.0		+5.5	V	1,2
		Local Power	+3.0		V_{DD}		
ıermometer ror	t_{ERR}	-10°C to +85°C			±0.5	°C	3
		-55°C to +125°C			±2		
ɔut Logic-Low	V_{IL}		-0.3		+0.8	V	1,4,5
ɔut Logic-High	V_{IH}	Local Power	+2.2		The lower of 5.5 or V_{DD} + 0.3	V	1, 6
		Parasite Power	+3.0				
ık Current	I_L	$V_{I/O}$ = 0.4V	4.0			mA	1
andby Current	I_{DDS}			750	1000	nA	7,8
:tive Current	I_{DD}	V_{DD} = 5V		1	1.5	mA	9
Ͻ Input Current	I_{DQ}			5		µA	10
ift				±0.2		°C	11

ɪTES:

All voltages are referenced to ground.

The Pullup Supply Voltage specification assumes that the pullup device is ideal, and therefore the high level of the pullup is equal to V_{PU}. In order to meet the V_{IH} spec of the DS18B20, the actual supply rail for the strong pullup transistor must include margin for the voltage drop across the transistor when it is turned on; thus: $V_{PU\_ACTUAL} = V_{PU\_IDEAL} + V_{TRANSISTOR}$.

See typical performance curve in Figure 17.

Logic-low voltages are specified at a sink current of 4mA.

To guarantee a presence pulse under low voltage parasite power conditions, V_{ILMAX} may have to be reduced to as low as 0.5V.

Logic-high voltages are specified at a source current of 1mA.

Standby current specified up to +70°C. Standby current typically is 3µA at +125°C.

To minimize I_{DDS}, DQ should be within the following ranges: GND ≤ DQ ≤ GND + 0.3V or V_{DD} – 0.3V ≤ DQ ≤ V_{DD}.

Active current refers to supply current during active temperature conversions or EEPROM writes.

DQ line is high ("high-Z" state).

Drift data is based on a 1000-hour stress test at +125°C with V_{DD} = 5.5V.

: ELECTRICAL CHARACTERISTICS—NV MEMORY

(-55°C to +100°C; V_{DD} = 3.0V to 5.5V)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
V Write Cycle Time	t_{WR}			2	10	ms
:PROM Writes	N_{EEWR}	-55°C to +55°C	50k			writes
:PROM Data Retention	t_{EEDR}	-55°C to +55°C	10			years

: ELECTRICAL CHARACTERISTICS (-55°C to +125°C; V_{DD} = 3.0V to 5.5V)

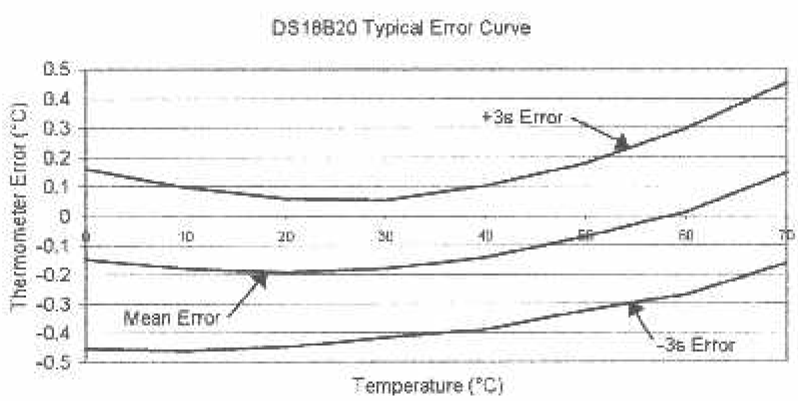
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
:mperature Conversion ime	t_{CONV}	9-bit resolution			93.75	ms	1
		10-bit resolution			187.5		
		11-bit resolution			375		
		12-bit resolution			750		
me to Strong Pullup On	t_{SPON}	Start Convert T Command Issued			10	µs	
me Slot	t_{SLOT}		60		120	µs	1
:covery Time	t_{REC}		1			µs	1
rite 0 Low Time	t_{LOW0}		60		120	µs	1
rite 1 Low Time	t_{LOW1}		1		15	µs	1
:ad Data Valid	t_{RDV}				15	µs	1
set Time High	t_{RSTH}		480			µs	1
set Time Low	t_{RSTL}		480			µs	1,2
:sence-Detect High	t_{PDHIGH}		15		60	µs	1
:sence-Detect Low	t_{PDLOW}		60		240	µs	1
pacitance	$C_{IN/OUT}$				25	pF	

)TES:

See the timing diagrams in Figure 18.

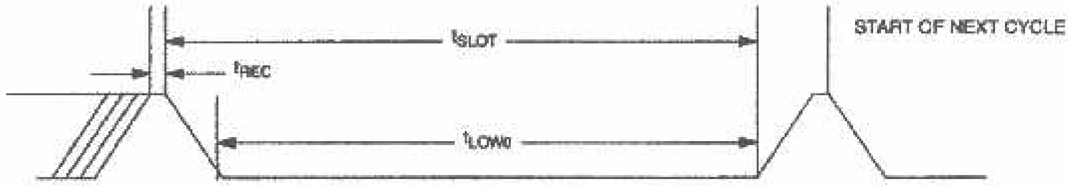
Under parasite power, if t_{RSTL} > 960µs, a power-on reset may occur.

ure 17. Typical Performance Curve

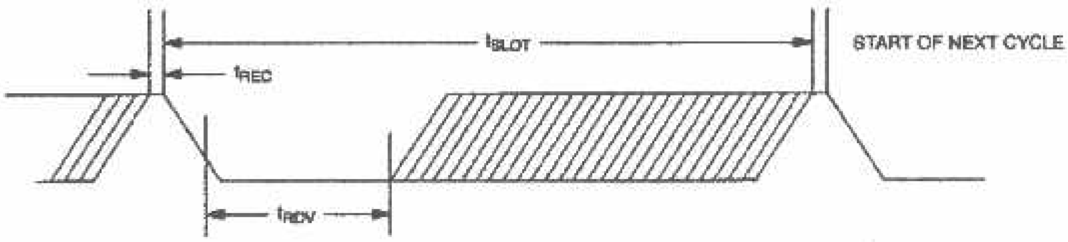


ıure 18. Timing Diagrams

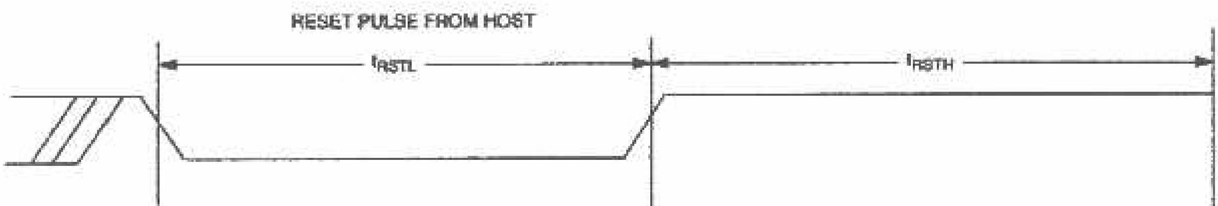
–WIRE WRITE ZERO TIME SLOT



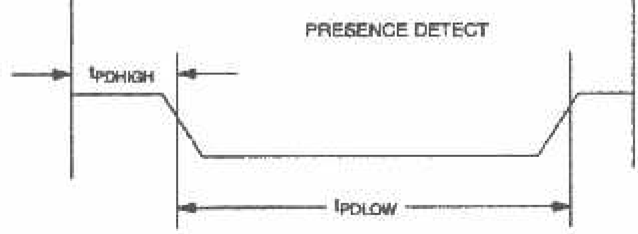
-WIRE READ ZERO TIME SLOT



-WIRE RESET PULSE



-WIRE PRESENCE DETECT



Infineon technologies

H11AA1

Bidirectional Input Optocoupler

ATURES

- **;urrent Transfer Ratio, 20% Min.**
- **C or Polarity Insensitive Input**
- **3uilt-in Reverse Polarity Input 'rotection**
- **O Compatible with Integrated Circuits**
- **ndustry Standard DIP Package**
- **Inderwriters Lab File #E52744**
- **VDE Approval #0884 (Available with ption 1)**

SCRIPTION

H11AA1 is a bi-directional input optically cou- d isolator consisting of two Gallium Arsenide ared LEDs coupled to a silicon NPN phototrans- r in a 6-pin DIP package. The H11AA1 has a imum CTR of 20% and a CTR symmetry of 1:3 is designed for applications requiring detection nonitoring of AC signals.

ximum Ratings

itter

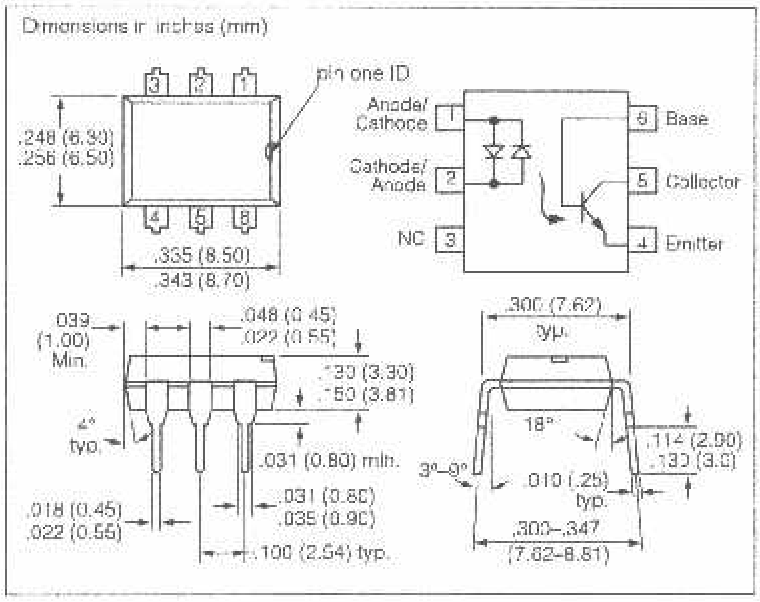
ntinuous Forward Current .... 60 mA
ver Dissipation at 25°C .... 100 mW
ate Linearly from 25°C .... 1.3 mW/°C

ector

ver Dissipation at 25°C Ambient .... 200 mW
ate Linearly from 25°C .... 2.6 mW/°C
ector-Emitter Breakdown Voltage, BV_{CEO} ... 30 V
tter-Base Breakdown Voltage, BV_{EBO} .... 5.0 V
ector-Base Breakdown Voltage, BV_{CBO} ...... 70 V

kage

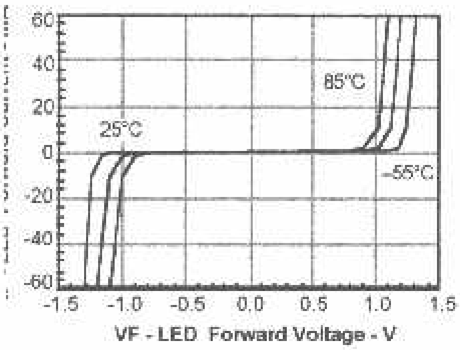
ation Test Voltage (between nitter and detector referred to andard climate 23°C/50%RH, IN 50014) .... 5300 V_{RMS}
epage .... min. 7.0 mm
arance .... min. 7 mm
nparative Tracking Index per IN IEC 112/VDE 0303, part 1 175
ation Resistance
$_O$=500 V, T_A=25°C .... ≥10^{12} Ω
$_O$=500 V, T_A=100°C .... ≥10^{11} Ω
age Temperature .... –55°C to +150°C
rating Temperature .... –55°C to +100°C
d Soldering Time at 260°C .... 10 sec.



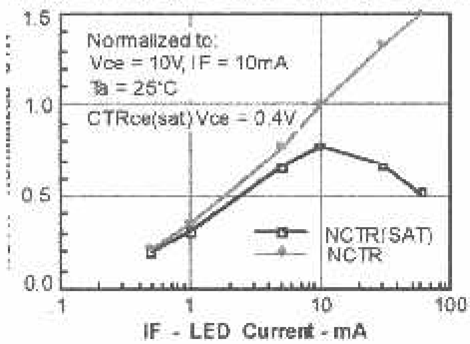
Electrical Characteristics T_A=25°C

Parameter	Min.	Typ.	Max.	Unit	Condition
Emitter					
Forward Voltage, V_F	—	1.2	1.5	V	I_F=±10 mA
Detector					
Breakdown Voltage	—	—	—	—	—
BV_{CEO}	30	—	—	V	I_C=1.0 mA
BV_{EBO}	7.0	—	—		I_E=100 µA
BV_{CBO}	70	—	—		I_C=100 µA
I_{CEO}	—	5.0	100	nA	V_{CE}=10 V
Package					
V_{CEsat}	—	—	0.4	V	I_F=±10 mA, I_C=0.5 mA
DC Current Transfer Ratio	20	—	—	%	I_F=±10 mA, V_{CE}=10 V
Symmetry CTR at + 10 mA / CTR at - 10 mA	0.33	1.0	3.0	—	—

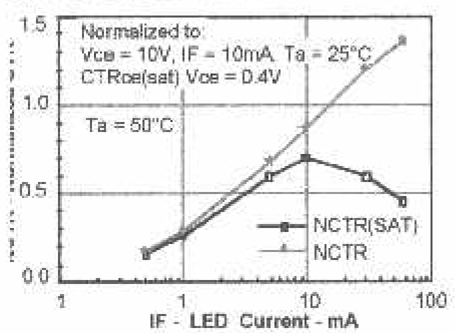
ure 1. LED forward current versus forward voltage



ure 2. Normalized non-saturated and ırated CTR at T_A=25°C versus LED current



ıre 3. Normalized non-saturated and saturated CTR at 50°C versus LED current



ıre 4. Normalized non-saturated and ırated CTR at T_A=70°C versus LED current

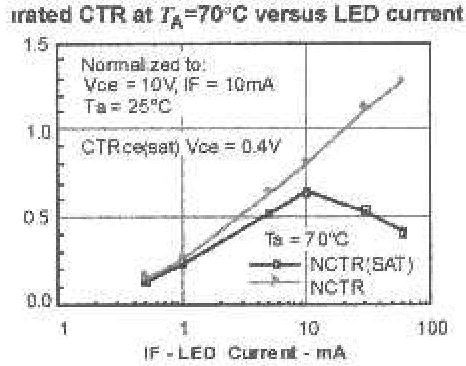


Figure 5. Normalized non-saturated and saturated CTR at T_A=85°C versus LED current

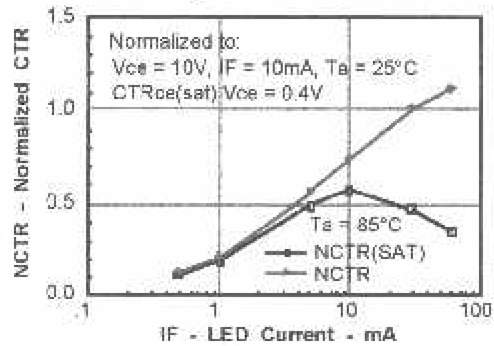


Figure 6. Collector-emitter current versus temperature and LED current

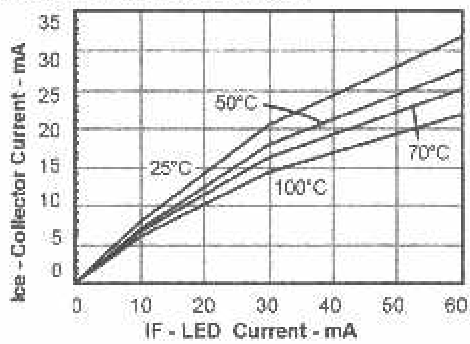


Figure 7. Collector-emitter leakage current versus temperature

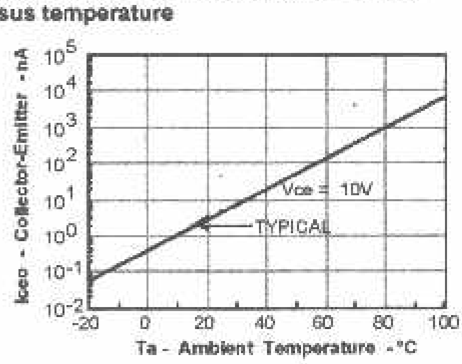
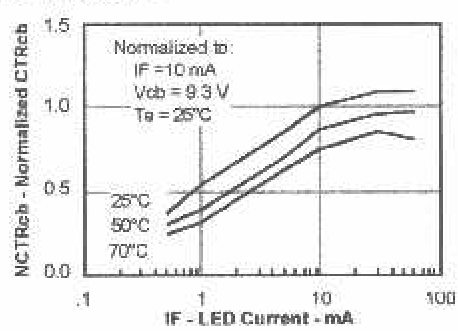
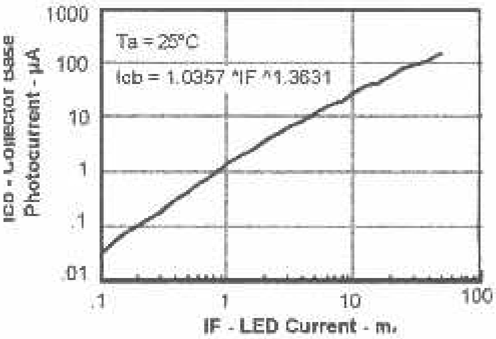


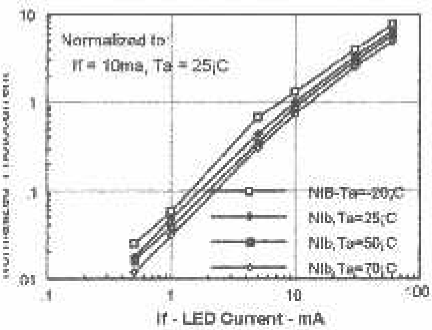
Figure 8. Normalized CTR_{cb} versus LED current and temperature



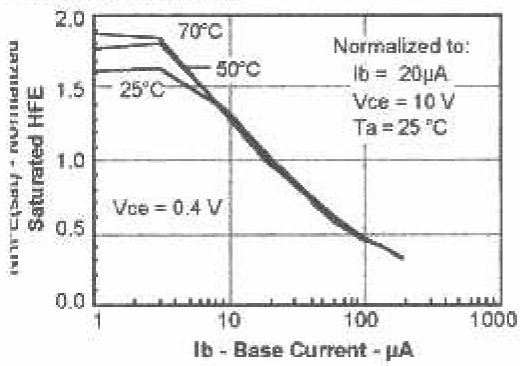
jure 9. Collector base photocurrent versus LED rrent



:ure 10. Normalized photocurrent versus D current



ure 11. Normalized saturated HFE versus base rent and temperature



ure 12. Normalized saturated HFE versus base rent and temperature

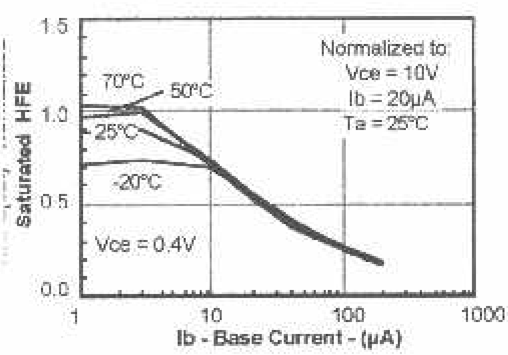


Figure 13. Propagation delay versus collector load resistor

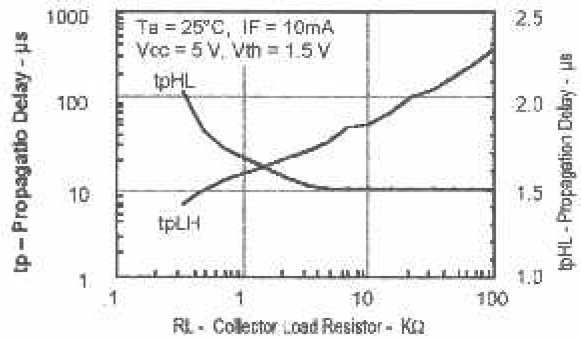


Figure 14. Switching waveform

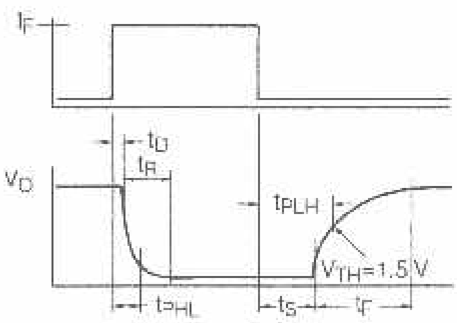
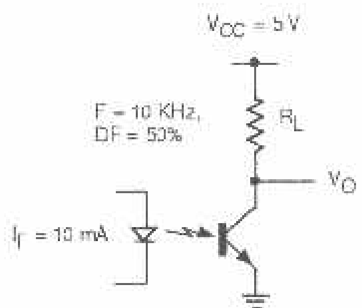


Figure 15. Switching schematic

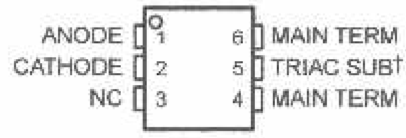


- 400 V Phototriac Driver Output
- Gallium-Arsenide-Diode Infrared Source and Optically-Coupled Silicon Traic Driver (Bilateral Switch)
- UL Recognized . . . File Number E65085
- High Isolation . . . 7500 V Peak
- Output Driver Designed for 220 Vac
- Standard 6-Terminal Plastic DIP
- Directly Interchangeable with Motorola MOC3020, MOC3021, MOC3022, and MOC3023

typical 115/240 Vac(rms) applications

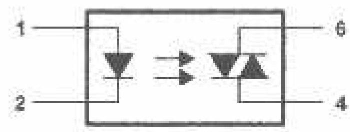
- Solenoid/Valve Controls
- Lamp Ballasts
- Interfacing Microprocessors to 115/240 Vac Peripherals
- Motor Controls
- Incandescent Lamp Dimmers

MOC3020 – MOC3023 . . . PACKAGE
(TOP VIEW)



† Do not connect this terminal
NC – No internal connection

logic diagram



absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)†

Input-to-output peak voltage, 5 s maximum duration, 60 Hz (see Note 1)	7.5 kV
Input diode reverse voltage	3 V
Input diode forward current, continuous	50 mA
Output repetitive peak off-state voltage	400 V
Output on-state current, total rms value (50-60 Hz, full sine wave): T_A = 25°C	100 mA
T_A = 70°C	50 mA
Output driver nonrepetitive peak on-state current (t_w = 10 ms, duty cycle = 10%, see Figure 7)	1.2 A
Continuous power dissipation at (or below) 25°C free-air temperature:	
Infrared-emitting diode (see Note 2)	100 mW
Phototriac (see Note 3)	300 mW
Total device (see Note 4)	330 mW
Operating junction temperature range, T_J	−40°C to 100°C
Storage temperature range, T_{stg}	−40°C to 150°C
Lead temperature 1,6 (1/16 inch) from case for 10 seconds	260°C

† Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

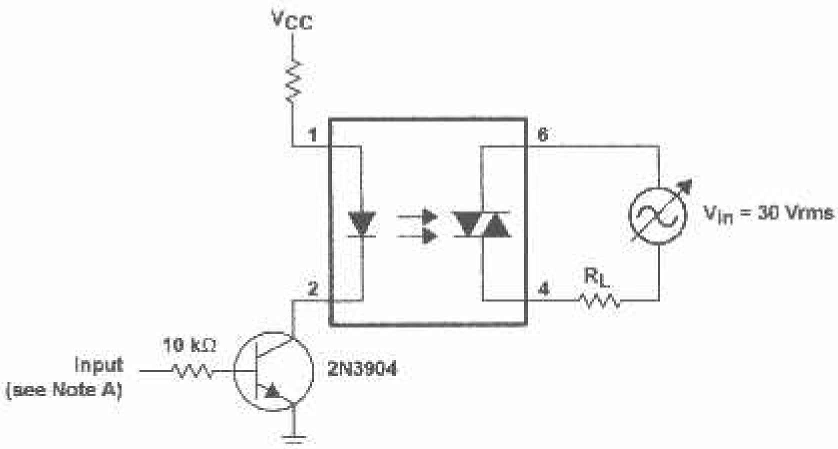
NOTES: 1. Input-to-output peak voltage is the internal device dielectric breakdown rating.
2. Derate linearly to 100°C free-air temperature at the rate of 1.33 mW/°C.
3. Derate linearly to 100°C free-air temperature at the rate of 4 mW/°C.
4. Derate linearly to 100°C free-air temperature at the rate of 4.4 mW/°C.

ctrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER			TEST CONDITIONS		MIN	TYP	MAX	UNIT
	Static reverse current		V_R = 3 V			0.05	100	μA
	Static forward voltage		I_F = 10 mA			1.2	1.5	V
RM)	Repetitive off-state current, either direction		$V_{(DRM)}$ = 400 V,	See Note 5		10	100	nA
dt	Critical rate of rise of off-state voltage		See Figure 1			100		V/μs
dt(c)	Critical rate of rise of commutating voltage		I_O = 15 mA,	See Figure 1		0.15		V/μs
	Input trigger current, either direction	MOC3020	Output supply voltage = 3 V			15	30	mA
		MOC3021				8	15	
		MOC3022				5	10	
		MOC3023				3	5	
M	Peak on-state voltage, either direction		I_{TM} = 100 mA			1.4	3	V
	Holding current, either direction					100		μA

'E 5: Test voltage must be applied at a rate no higher than 12 V/μs.

PARAMETER MEASUREMENT INFORMATION



TE A. The critical rate of rise of off-state voltage, dv/dt, is measured with the input at 0 V. The frequency of V_{in} is increased until the phototriac turns on. This frequency is then used to calculate the dv/dt according to the formula:

$$dv/dt = 2\sqrt{2}\pi f V_{in}$$

The critical rate of rise of commutating voltage, dv/dt(c), is measured by applying occasional 5-V pulses to the input and increasing the frequency of V_{in} until the phototriac stays on (latches) after the input pulse has ceased. With no further input pulses, the frequency of V_{in} is then gradually decreased until the phototriac turns off. The frequency at which turn–off occurs may then be used to calculate the dv/dt(c) according to the formula shown above.

Figure 1. Critical Rate of Rise Test Circuit

TYPICAL CHARACTERISTICS

EMITTING-DIODE TRIGGER CURRENT (NORMALIZED)
vs
FREE-AIR TEMPERATURE

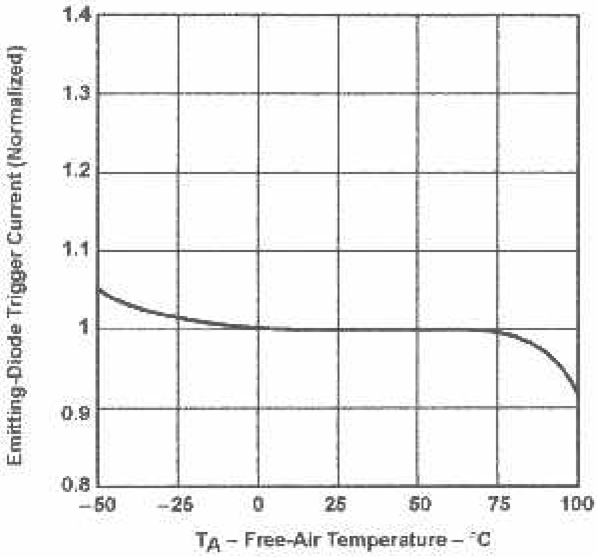


Figure 2

ON-STATE CHARACTERISTICS

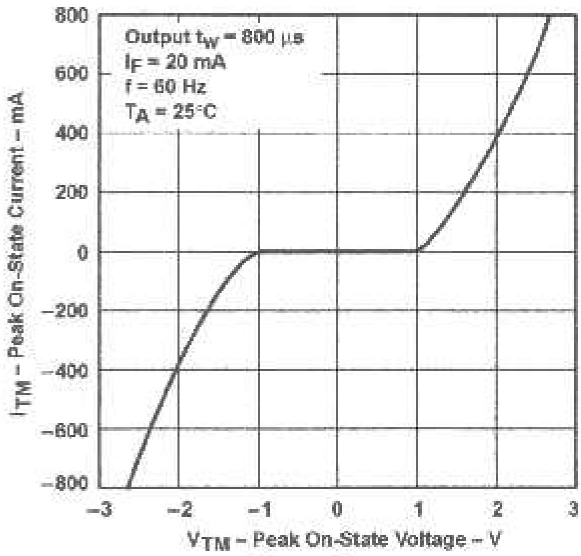


Figure 3

NONREPETITIVE PEAK ON-STATE CURRENT
vs
PULSE DURATION

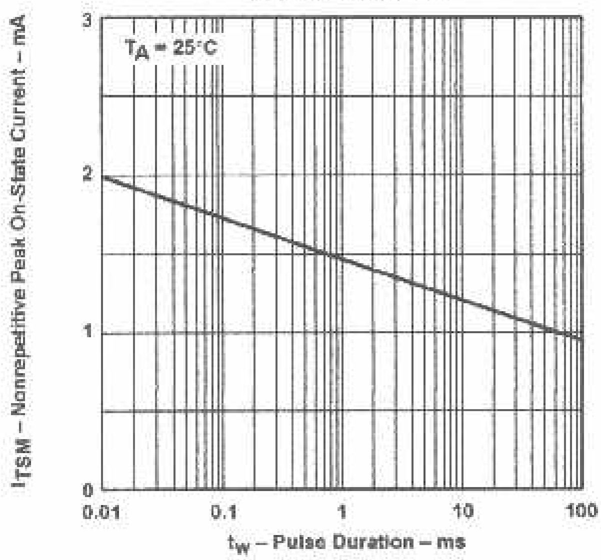


Figure 4

APPLICATIONS INFORMATION

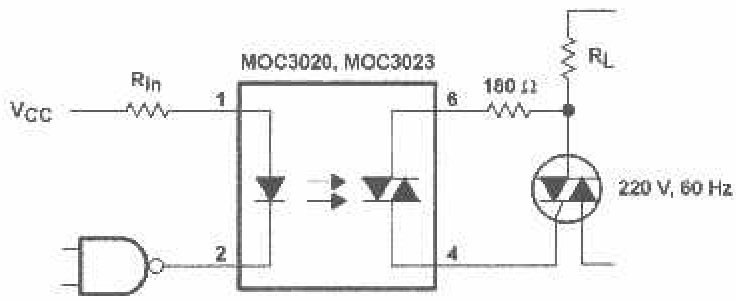


Figure 5. Resistive Load

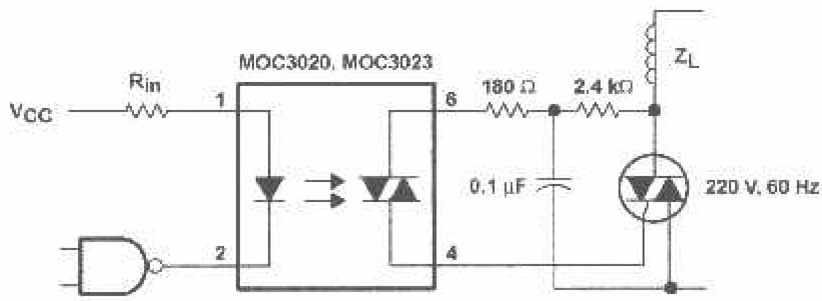


Figure 6. Inductive Load With Sensitive-Gate Triac

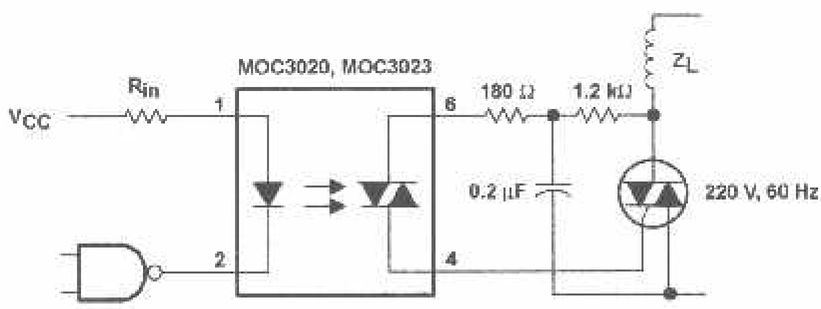
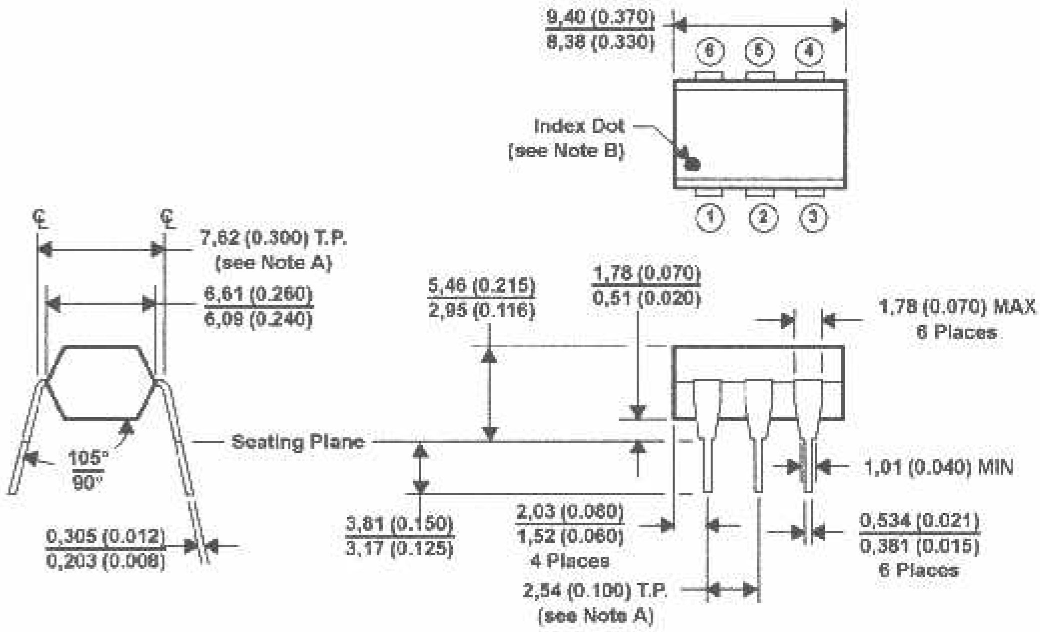


Figure 7. Inductive Load With Nonsensitive-Gate Triac

MECHANICAL INFORMATION

Each device consists of a gallium-arsenide infrared-emitting diode optically coupled to a silicon phototriac mounted on a 6-terminal lead frame encapsulated within an electrically nonconductive plastic compound. The case can withstand soldering temperature with no deformation and device performance characteristics remain stable when operated in high-humidity conditions.



NOTES: A. Leads are within 0,13 (0.005) radius of true position (T.P.) with maximum material condition and unit installed.
B. Pin 1 identified by index dot.
C. The dimensions given fall within JEDEC MO-001 AM dimensions.
D. All linear dimensions are given in millimeters and parenthetically given in inches.

Figure 8. Packaging Specifications

PACKAGING INFORMATION

Orderable Device	Status [1]	Package Type	Package Drawing	Pins	Package Qty	Eco Plan [2]	Lead/Ball Finish	MSL Peak Temp [3]
MOC3020	OBSOLETE	PDIP	N	6		TBD	Call TI	Call TI
MOC3021	OBSOLETE	PDIP	N	6		TBD	Call TI	Call TI
MOC3022	OBSOLETE	PDIP	N	6		TBD	Call TI	Call TI
MOC3023	OBSOLETE	PDIP	N	6		TBD	Call TI	Call TI

[1] The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

[2] Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS) or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

[3] MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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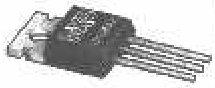


BT137-600E

4Q Triac

12 June 2014 Product data sheet

. General description

Planar passivated sensitive gate four quadrant triac in a SOT78 plastic package intended for use in general purpose bidirectional switching and phase control applications. This sensitive gate "series E" triac is intended to be interfaced directly to microcontrollers, logic integrated circuits and other low power gate trigger circuits.

. Features and benefits

- Direct triggering from low power drivers and logic ICs
- High blocking voltage capability
- Low holding current for low current loads and lowest EMI at commutation
- Planar passivated for voltage ruggedness and reliability
- Sensitive gate
- Triggering in all four quadrants

. Applications

- General purpose motor control
- General purpose switching

. Quick reference data

ble 1. Quick reference data

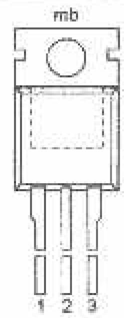
ymbol	Parameter	Conditions	Min	Typ	Max	Unit
DRM	repetitive peak off-state voltage		-	-	600	V
SM	non-repetitive peak on-state current	full sine wave; $T_{j(init)}$ = 25 °C; t_p = 20 ms; Fig. 4; Fig. 5	-	-	65	A
(RMS)	RMS on-state current	full sine wave; T_{mb} ≤ 102 °C; Fig. 1; Fig. 2; Fig. 3	-	-	8	A
tatic characteristics						
T	gate trigger current	V_D = 12 V; I_T = 0.1 A; T2+ G+; T_j = 25 °C; Fig. 7	-	2.5	10	mA
		V_D = 12 V; I_T = 0.1 A; T2+ G-; T_j = 25 °C; Fig. 7	-	4	10	mA
		V_D = 12 V; I_T = 0.1 A; T2- G-; T_j = 25 °C; Fig. 7	-	5	10	mA

or click this QR code to view the latest information for this product

ymbol	Parameter	Conditions	Min	Typ	Max	Unit
		V_D = 12 V; I_T = 0.1 A; T2- G+; T_j = 25 °C; Fig. 7	-	11	25	mA
I	holding current	V_D = 12 V; T_j = 25 °C; Fig. 9	-	2.5	20	mA

. Pinning information

ble 2. Pinning information

n	Symbol	Description	Simplified outline	Graphic symbol
	T1	main terminal 1	 TO-220AB (SOT78)	
	T2	main terminal 2		
	G	gate		
ıb	T2	mounting base; main terminal 2		

. Ordering information

ble 3. Ordering information

ype number	Package		
	Name	Description	Version
T137-600E	TO-220AB	plastic single-ended package; heatsink mounted; 1 mounting hole; 3-lead TO-220AB	SOT78
T137-600E/DG	TO-220AB	plastic single-ended package; heatsink mounted; 1 mounting hole; 3-lead TO-220AB	SOT78
T137-600E/L01	TO-220AB	plastic single-ended package; heatsink mounted; 1 mounting hole; 3-lead TO-220AB	SOT78

Marking

ble 4. Marking codes

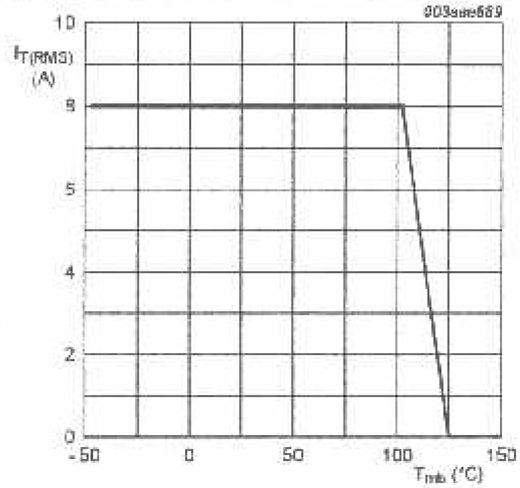
ype number	Marking code
T137-600E	
T137-600E/DG	BT137-600E/DG
T137-600E/L01	

. Limiting values

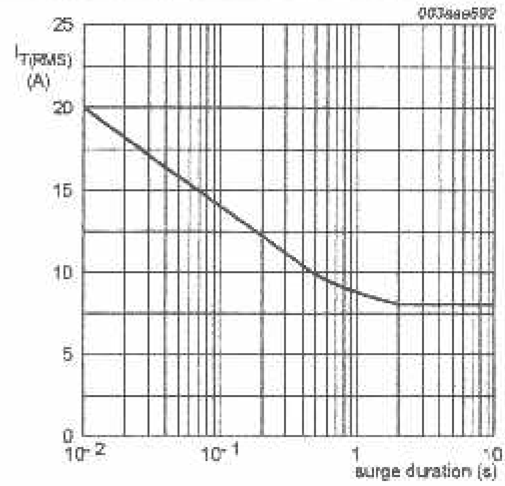
ble 5. Limiting values

accordance with the Absolute Maximum Rating System (IEC 60134).

ymbol	Parameter	Conditions	Min	Max	Unit
$'_{DRM}$	repetitive peak off-state voltage		-	600	V
$_{T(RMS)}$	RMS on-state current	full sine wave; $T_{mb} \leq 102$ °C; Fig. 1; Fig. 2; Fig. 3	-	8	A
$_{TSM}$	non-repetitive peak on-state current	full sine wave; $T_{j(init)} = 25$ °C; $t_p = 20$ ms; Fig. 4; Fig. 5	-	65	A
		full sine wave; $T_{j(init)} = 25$ °C; $t_p = 16.7$ ms	-	71	A
t	I^2t for fusing	$t_p = 10$ ms; SIN	-	21	A^2s
I_T/dt	rate of rise of on-state current	$I_T = 12$ A; $I_G = 0.2$ A; $dI_G/dt = 0.2$ A/μs; T2+ G+	-	50	A/μs
		$I_T = 12$ A; $I_G = 0.2$ A; $dI_G/dt = 0.2$ A/μs; T2+ G-	-	50	A/μs
		$I_T = 12$ A; $I_G = 0.2$ A; $dI_G/dt = 0.2$ A/μs; T2- G-	-	50	A/μs
		$I_T = 12$ A; $I_G = 0.2$ A; $dI_G/dt = 0.2$ A/μs; T2- G+	-	10	A/μs
$_{GM}$	peak gate current		-	2	A
$_{GM}$	peak gate power		-	5	W
$_{G(AV)}$	average gate power	over any 20 ms period	-	0.5	W
$_{stg}$	storage temperature		-40	150	°C
	junction temperature		-	125	°C



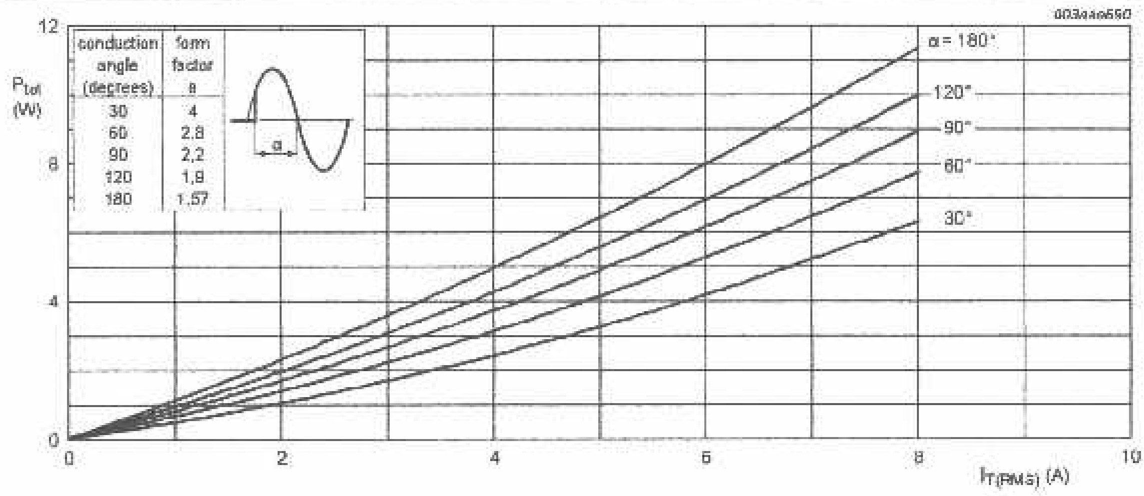
g. 1. **RMS on-state current as a function of mounting base temperature; maximum values**



f = 50 Hz

T_{mb} ≤ 102 °C

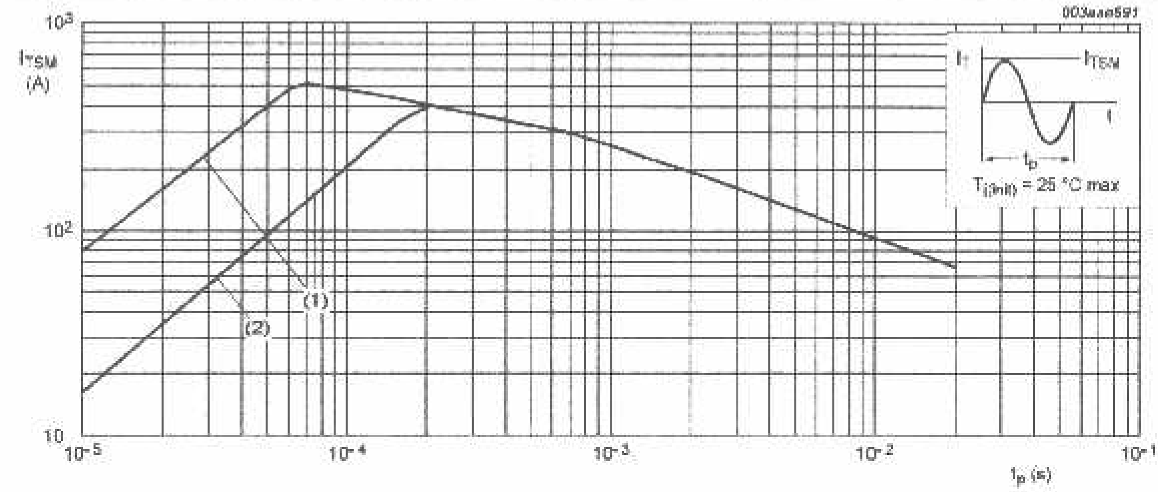
Fig. 2. RMS on-state current as a function of surge duration; maximum values



α = conduction angle

a = form factor = $I_{T(RMS)}/I_{T(AV)}$

g. 3. **Total power dissipation as a function of RMS on-state current; maximum values**

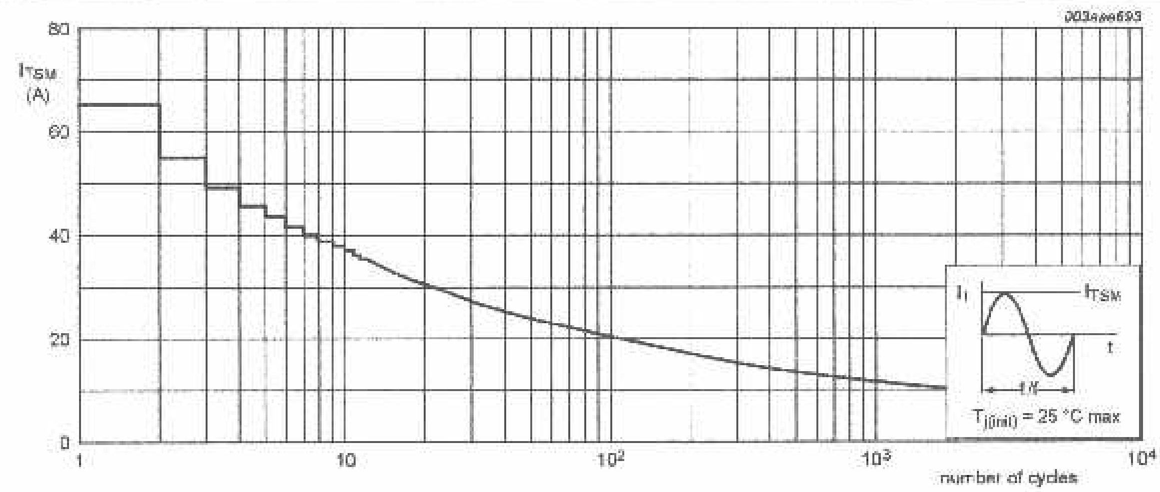


$t_p \leq 20$ ms

(1) dI_T/dt limit

(2) T2- G+ quadrant limit

g. 4. Non-repetitive peak on-state current as a function of pulse width; maximum values



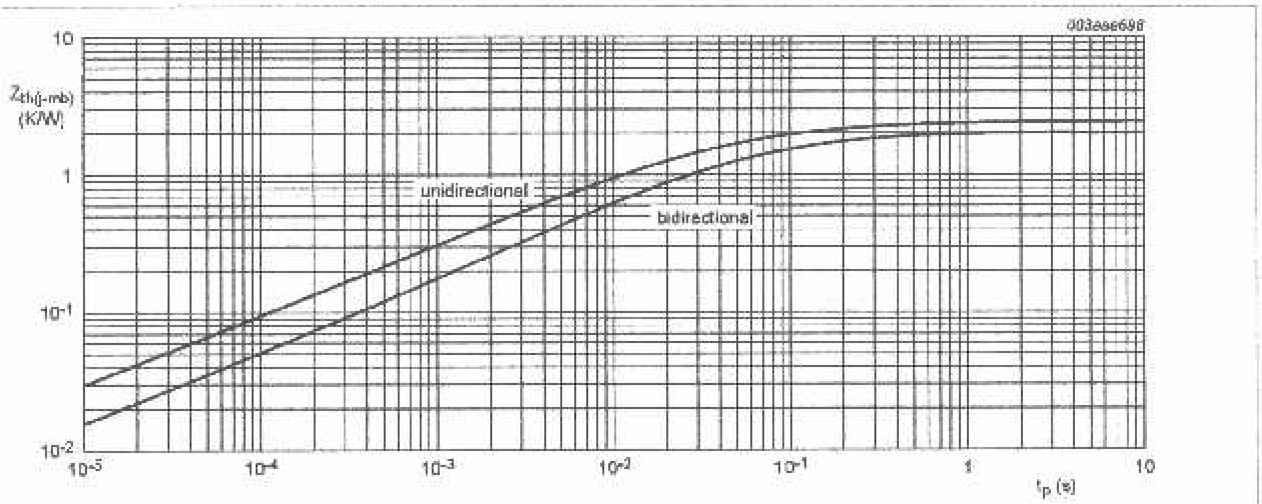
f = 50 Hz

g. 5. Non-repetitive peak on-state current as a function of the number of sinusoidal current cycles; maximum values

Thermal characteristics

ble 6. Thermal characteristics

ymbol	Parameter	Conditions		Min	Typ	Max	Unit
th(j-mb)	thermal resistance from junction to mounting base	half cycle; Fig. 6		-	-	2.4	K/W
		full cycle; Fig. 6		-	-	2	K/W
th(j-a)	thermal resistance from junction to ambient	in free air		-	60	-	K/W

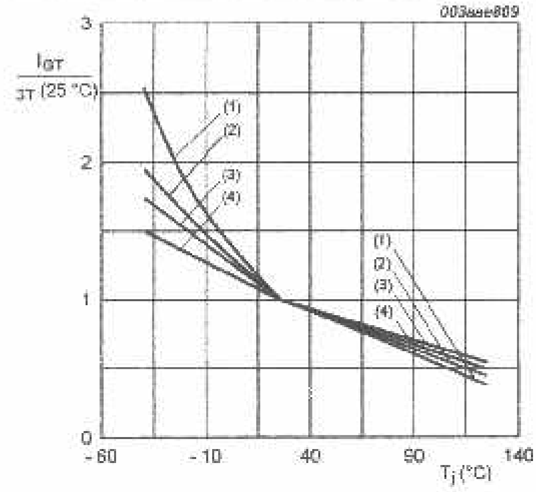


g. 6. Transient thermal impedance from junction to mounting base as a function of pulse width

). Characteristics

ɔle 7. Characteristics

ımbol	Parameter	Conditions	Min	Typ	Max	Unit
tatic characteristics						
ıT	gate trigger current	V_D = 12 V; I_T = 0.1 A; T2+ G+; T_j = 25 °C; Fig. 7	-	2.5	10	mA
		V_D = 12 V; I_T = 0.1 A; T2+ G-; T_j = 25 °C; Fig. 7	-	4	10	mA
		V_D = 12 V; I_T = 0.1 A; T2- G-; T_j = 25 °C; Fig. 7	-	5	10	mA
		V_D = 12 V; I_T = 0.1 A; T2- G+; T_j = 25 °C; Fig. 7	-	11	25	mA
	latching current	V_D = 12 V; I_G = 0.1 A; T2+ G+; T_j = 25 °C; Fig. 8	-	3	25	mA
		V_D = 12 V; I_G = 0.1 A; T2+ G-; T_j = 25 °C; Fig. 8	-	14	35	mA
		V_D = 12 V; I_G = 0.1 A; T2- G-; T_j = 25 °C; Fig. 8	-	3	25	mA
		V_D = 12 V; I_G = 0.1 A; T2- G+; T_j = 25 °C; Fig. 8	-	4	35	mA
ı	holding current	V_D = 12 V; T_j = 25 °C; Fig. 9	-	2.5	20	mA
т	on-state voltage	I_T = 10 A; T_j = 25 °C; Fig. 10	-	1.3	1.65	V
GT	gate trigger voltage	V_D = 12 V; I_T = 0.1 A; T_j = 25 °C; Fig. 11	-	0.7	1	V
		V_D = 400 V; I_T = 0.1 A; T_j = 125 °C; Fig. 11	0.25	0.4	-	V
ı	off-state current	V_D = 600 V; T_j = 125 °C	-	0.1	0.5	mA
ynamic characteristics						
V_D/dt	rate of rise of off-state voltage	V_{DM} = 402 V; T_j = 125 °C; (V_{DM} = 67% of V_{DRM}); exponential waveform; gate open circuit	-	50	-	V/µs
ı	gate-controlled turn-on time	I_{TM} = 12 A; V_D = 600 V; I_G = 0.1 A; dI_G/dt = 5 A/µs	-	2	-	µs



(1) T2- G+

(2) T2- G-

(3) T2+ G-

(4) T2+ G+

g. 7. Normalized gate trigger current as a function of junction temperature

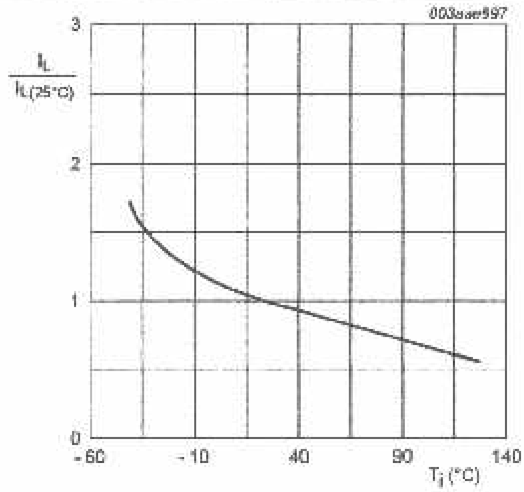
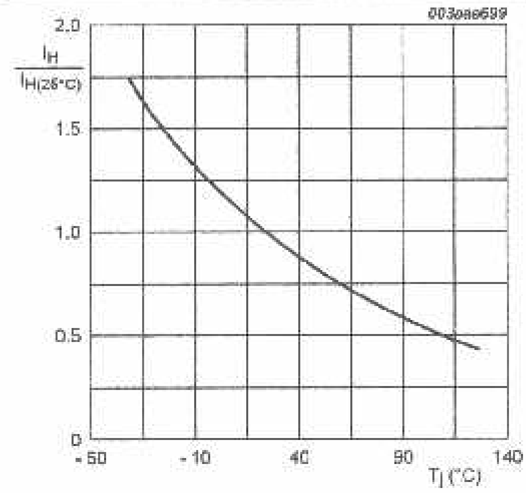
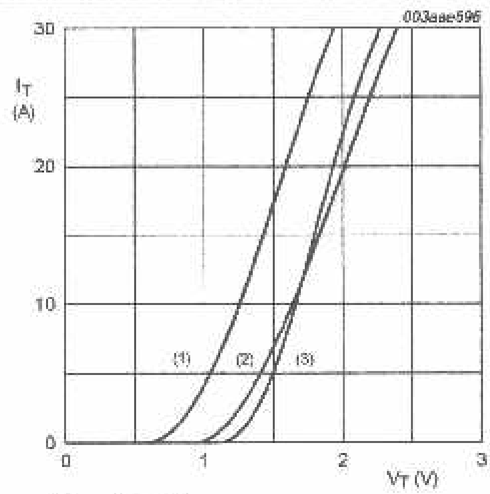


Fig. 8. Normalized latching current as a function of junction temperature



g. 9. Normalized holding current as a function of junction temperature



V_o = 1.264 V

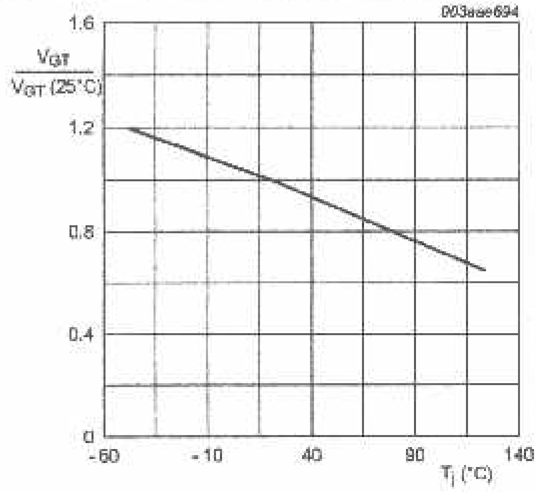
R_s = 0.038 Ω

(1) T_j = 125 °C; typical values

(2) T_j = 125 °C; maximum values

(3) T_j = 25 °C; maximum values

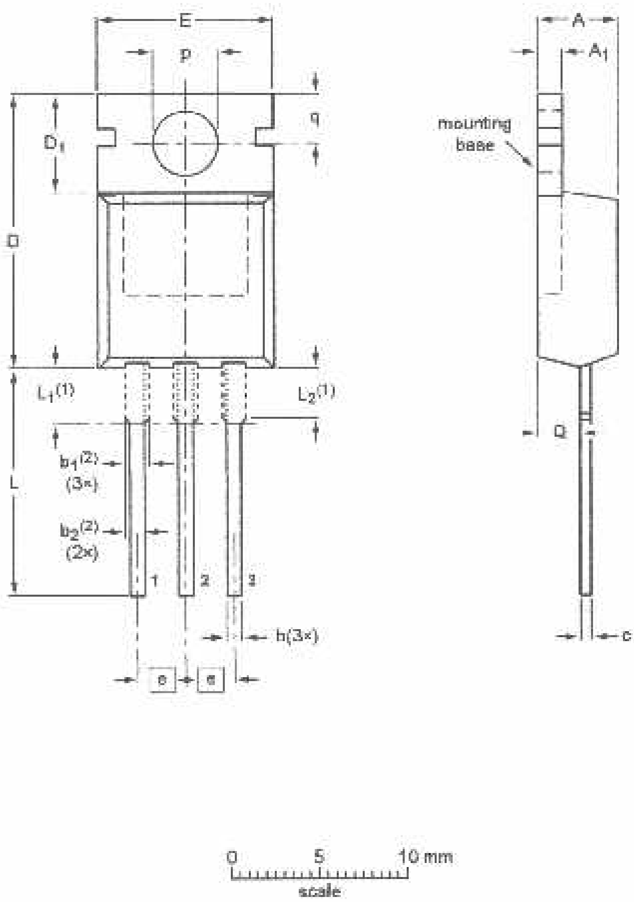
Fig. 10. On-state current as a function of on-state voltage



g. 11. Normalized gate trigger voltage as a function of junction temperature

. Package outline

lastic single-ended package; heatsink mounted; 1 mounting hole; 3-lead TO-220AB SOT78



DIMENSIONS (mm are the original dimensions)

UNIT	A	A_1	b	$b_1^{(2)}$	$b_2^{(2)}$	c	D	D_1	E	e	L	$L_1^{(1)}$	$L_2^{(1)}$ max.	p	q	Q
mm	4.7 4.1	1.40 1.25	0.9 0.6	1.6 1.0	1.3 1.0	0.7 0.4	16.0 15.2	6.6 5.9	10.3 9.7	2.54	15.0 12.8	3.30 2.79	3.0	3.8 3.5	3.0 2.7	2.6 2.2

Notes

1. Lead shoulder designs may vary.
2. Dimension includes excess dambar.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOT78		3-lead TO-220AB	SC-46			08-04-23 08-06-13

ig. 12. Package outline TO-220AB (SOT78)

2. Legal information

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cument itus [1][2]	Product status [3]	Definition
›jective ›ort] data eet	Development	This document contains data from the objective specification for product development.
eliminary ›ort] data eet	Qualification	This document contains data from the preliminary specification.
oduct ›ort] data eet	Production	This document contains the product specification.

Please consult the most recently issued document before initiating or completing a design.
The term 'short data sheet' is explained in section "Definitions".
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3. Contents

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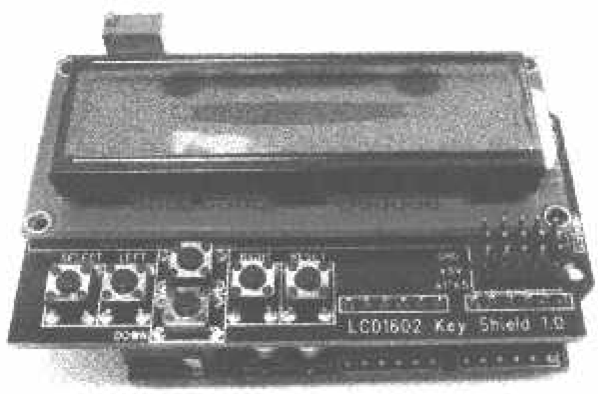
e of release: 12 June 2014

LCD Keypad shield

- 1602 LCD and 6 AD buttons for Arduino

Overview



This Arduino 1602 LCD Keypad shield is developed for Arduino compatible boards, to provide a user-friendly interface that allows users to go through the menu, make selections etc. It consists of a LCD1602 white character blue backlight LCD. The keypad consists of 5 keys — select, up, right, down and left. To save the digital IO pins, the keypad interface uses only one ADC channel. The key value is read through a 5 stage voltage divider.

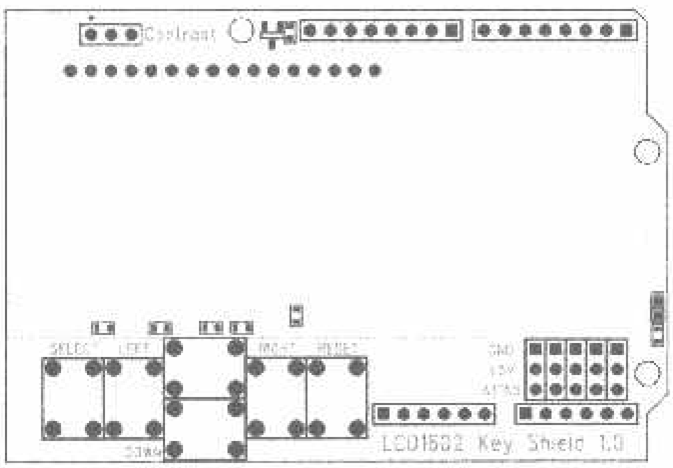
Specifications

PCB size	82.8mm X 56.6mm X 1.6mm
Power supply	5V DC
RoSH	Yes

Electrical Characteristics

Specification		Min	Type	Max	Unit
Power Voltage		4.5	5	5.5	VDC
Input Voltage VH	Target Voltage = 3.3V	3	3.3	3.6	V
	Target Voltage = 5V	4.5	5	5.5	
Input Voltage VL:		-0.3	0	0.5	V
Current Consumption		-	20	40	mA

Pins description



Pin	Function
A0	Button (select, up, right, down and left)
D4	DB4
D5	DB5
D6	DB6
D7	DB7
D8	RS (Data or signal display selection)
D9	LCD1602 Enable
D10	Backlight control

Revision History

Rev.	Description	Release date
v1.0	Initial version	6/23/2010