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

SKRIPSI

PERANCANGAN DAN PEMBUATAN ALAT PENGATUR GELEMBUNG UNTUK MANDI SPA BERBASIS MIKROKONTROLER ATMEGA 8535

Disusun Oleh :
ANDRI BAYU Z.
99.17.250

MARET 2007

LEMBAR PERSETUJUAN

PERENCANAAN DAN PEMBUATAN

ALAT PENGATUR GELEMBUNG UDARA UNTUK MANDI SPA

BERBASIS MIKROKONTROLER ATMEGA 8535

SKRIPSI

Disusun Dan Diajukan Sebagai Salah Satu Syarat Untuk Memperoleh Gelar Sarjana Teknik Elektronika Strata Satu (S-1)

Disusun Oleh :

ANDRI BAYU Z.

99.17.250

Malang, Maret 2007

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Judul Skripsi	:	Perencanaan dan Pembuatan Alat Pengatur Gelembung Udara Untuk Mandi Spa Berbasis Mikrokontroler Atmega 8535

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ABSTRAKSI

PERENCANAAN DAN PEMBUATAN ALAT PENGATUR GELEMBUNG UDARA UNTUK MANDI SPA BERBASIS MIKROKONTROLLER ATMEGA 8535

(Andri Bayu Z., 9917250, Teknik Elektro / Elektronika S-1)
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Kata Kunci : Remote Control, IR Receiver, LM 35, IC ATmega 8535, Heater

Sebagai konsekuensi dari perkembangan ilmu pengetahuan dan teknologi dibidang elektronika menunjukkan kecenderungan untuk mengarah pada penciptaan alat agar mempermudah semua kegiatan manusia. Otomatisasi adalah salah satu gejala yang timbul dari alasan diatas. Untuk lainnya ialah pengontrolan dari jarak jauh merupakan hal yang sangat dibutuhkan mengingat efisiensi yang akan diperoleh dari pengontrolan tersebut.

Pembuatan alat pengatur gelembung udara untuk mandi spa dengan remote kontrol ini bertujuan untuk memberikan pelayanan yang bagus dan memberikan kemudahan dalam pelaksanaannya. Karena hanya menggunakan remote kontrol / pengontrol jarak jauh pemakai dapat menjalankannya tanpa harus keluar dari bak mandi.

Alat yang dibuat terdiri dari IC Atmega 8535 sebagai pengontrol dan pengolah data / masukan. Remote kontrol berfungsi sebagai pemberi perintah yang diterima IR Receiver yang diteruskan ke IC Atmega 8535, IC ini akan memberikan perintah ke kompresor dan heater sesuai perintah yang telah diolahnya. Selain itu IC ini memberi perintah pada LM 35 atau sensor suhu untuk mengecek apakah sesuai hasil yang telah dilakukan.

Dari semua proses yang telah dilakukan dari awal hingga selesai, IC Atmega 8535 juga memberikan keterangan yang ditampilkan pada sevent segment. Jadi dengan melihat tampilan seventh segment akan diketahui diposisi manakah alat ini bekerja.

KATA PENGANTAR

Dengan mengucapkan syukur kehadirat Tuhan Yang Maha Esa atas rahmat dan karunianya disertai segala cobaan dan rintangan serta keterbatasan waktu yang semua itu penulis menganggap sebagai tantangan dan rintangan yang harus terjawab akhirnya penulis dapat menyelesaikan skripsi ini yang berjudul :

" Perancangan Dan Pembuatan Alat Pengatur Gelembung Udara Untuk Mandi Spa Berbasis Mikrokontroller ATmega 8535 "

Tujuan penulisan skripsi ini antara lain untuk memenuhi persyaratan mencapai gelar sarjana teknik pada Jurusan Teknik Elektro S-1, Konsentrasi Teknik Elektronika, di Institut Teknologi Nasional Malang tercinta. Sehubungan dengan itu penulis menyampaikan ucapan terima kasih yang sebesar – besarnya kepada :

1. Bapak Prof. Dr. Ir. Abraham Lomi, MSME., selaku Rektor Institut Teknologi Nasional Malang.
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3. Bapak Ir. FX. Yudi Limpraptono, MT., selaku Ketua Jurusan Teknik Elektro Institut Teknologi Nasional Malang.
4. Bapak Ir. Eko Nurcahyo, selaku Dosen Pembimbing yang telah banyak meluangkan waktu, arahan, dan juga tuntutan yang progresif dalam penyusunan skripsi ini sampai selesai.

5. Bapak dan Ibu Dosen yang telah memberikan bekal ilmu selama penulis kulian di Institut Teknologi Nasional Malang.
6. Teman – teman Detasemen '99 ELKA 5-6 yang telah memberikan masukan serta saran – saran dan semangat belajar yang tidak dapat disebutkan satu per satu.

Akhir kata penulis memohon maaf sebesar – besarnya bila ada kata – kata atau kesalahan penulisan laporan ini tentunya tanpa ada unsur kesengajaan dari penulis. Penulis mengharapkan saran dan kritik yang membangun dari pembaca dan harapan saya laporan tugas akhir ini dapat bermanfaat bagi kita semua dan bangsa. AMIEEN.

Malang, Maret 2007

Penulis

DAFTAR ISI

BAB III PERENCANAAN DAN PEMBUATAN ALAT

DAFTAR GAMBAR

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BAB I

PENDAHULUAN

1.1. Latar Belakang

Stres, kelelahan melingkupi kita hampir setiap hari. Ditengah bising dan macetnya lalu lintas kota para karyawan dan pekerja lainnya harus memutar otak, mengerahkan tenaga yang banyak akhirnya menimbulkan keletihan, kejenuhan, jaga stress. Itu wajar saja apalagi di jaman sekarang yang ternyata keadaan ekonomi Negara pun kurang menguntungkan, krisis multidimensi terjadi.

Kenyataan itu membuat orang yang sibuk memerlukan upaya untuk relaksasi, istirahat, refresing. Berbagai cara dilakukan orang, seperti meluangkan waktu untuk istirahat dan menenagkan pikiran disekitar rumah, berolah raga,yoga, pijat refleksi, dan tidur yang cukup.

Salah satu cara yang ditempuh mereka yang sibuk, terutama masyarakat di tingkat menengah ke atas adalah dengan mengunjungi spa yang kini marak dimana-mana, di salon, tempat khusus hingga hotel berbintang.selain tempat pemandian air panas di sebuah spa biasanya diberikan layanan pijat yang dilakukan secara manual oleh para karyawan atau pekerja salon tersebut.

Dengan perkembangan teknologi yang semakin canggih, maka timbul rencana untuk membuat alat pengatur gelembung udara dalam air untuk mandi spa menggunakan mikrokontroller ATMEGA 8535. Alat ini adalah penghasil gelembung udara panas oleh pemanas yang ditiup dengan motor, sebagai pijatan tubuh dalam bak mandi saat sipemakai berendam didalam bak mandi.Dimana gelembung udara ini dapat diletakan dibagian tubuh mana saja dan dapat diatur sesuai keinginan pemakai dengan menggunakan remote control yang telah disediakan.

1.2. Rumusan Masalah

Dalam perencanaan dan Pembuatan Alat Pengatur Gelembung Air untuk mandi Spa berbasis Mikrokontroller ATMEGA 8535 dapat dirumuskan beberapa permasalahan seperti dibawah ini:

1. Dalam pengaturan gelembung udara dalam air ini diharapkan dapat sesuai dengan apa yang dikehendaki si pemakai.
2. Bagaimana cara mendesain perangkat lunak (software) dan perangkat keras (hardware) alat pengatur gelembung udara dalam air mandi spa berbasis mikrokontroller ATMEGA 8535.
3. Bagaimana proses kerja sistem keseluruhan dapat bekerja.

1.3. Tujuan

Adapun tujuan dari perencanaan dan pembuatan alat ini adalah :

1. Memberikan kenyamanan pemakai dengan pijatan udara panas saat mandi spa.
2. Perencanaan dan pembuatan alat penghasil gekembung udara panas dengan rangkaian elektronika dan mekanikal yang sederhana

1.4. Batasan Masalah

Agar permasalahan yang dibahas dalam tugas akhir ini tidak terlalu meluas maka akan dibatasi pada hal-hal berikut:

1. Pada perancangan ini membahas tentang perancangan alat gelembung udara dalam air secara keseluruhan.
2. Tidak membahas catu daya / power supply.
3. Tidak membahas pengaruh medium air panas yang digunakan mandi spa.
4. Tidak membahas kompresor.

1.5. Metode Penulisan

Untuk merealisasikan sistem yang dirancang maka dilakukan langkah langkah :

1. Studi literatur, yaitu mempelajari teori serta aplikasi sistem kontrol menggunakan mikrokontroler ATMEGA 8535 dengan mencari informasi dan data data dari referensi yang berhubungan dengan alat.

   Studi literatur disini akan mempelajari hal hal sebagai berikut :

   a. Arsitektur mikrokontroler ATMEGA 8535
   b. Karakteristik umum.
   c. Interface dengan input/output mikrokontoler.

2. Perancangan hardware dan software, yaitu melakukan kegiatan pembuatan program, rangkaian perblok hingga pembuatan perangkat keras secara keseluruhan.
3. Pengujian dan analisa, pada bagian ini melakukan uji coba hardware dan software kemudian melakukan analisa berdasarkan hasil pengujian yang dilakukan.

1.6. Sistematika Pembahasan

Agar sistematis dan dapat mencapai pemahaman yang tepat maka skripsi ini disusun dalam beberapa bab yaitu :

BAB I **PENDAHULUAN**

Berisi latar belakang, rumusan masalah, tujuan, batasan masalah, metodologi penulisan dan sistematika pembahasan.

BAB II **LANDASAN TEORI**

Berisi teori dasar atau penunjang yang membantu dalam pembuatan alat.

BAB III **PERRANCANGAN DAN PEMBUATAN ALAT**

Berisi tentang perancanga perangkat keras (hardware) Dan perangkat lunak (software).

BAB IV PENGUJIAN ALAT

Berisi tentang hasil pengujian alat yang telah dibuat secara keseluruhan.

BAB V PENUTUP

Berisi kesimpulan dan saran dari perancangan pembuatan sampai pengujian.

BAB II

TEORI PENUNJANG

2.1 Pendahuluan

Dalam Bab II akan dibahas mengenai dasar dasar teori yang menunjang dalam perencanaan sistem kontrol yang diaplikasikan pada pengaturan suhu. Pertama akan dijelaskan secara umum tentang teori dasar mikrokontroler AT mega 8535L yang sangat penting dalam sistem kontrol ini. Selanjutnya akan dibahas komponen komponen penunjang dalam pembuatan sistem kontrol ini.

2.2. Teori Dasar Mikrokontroller ATmega8535L

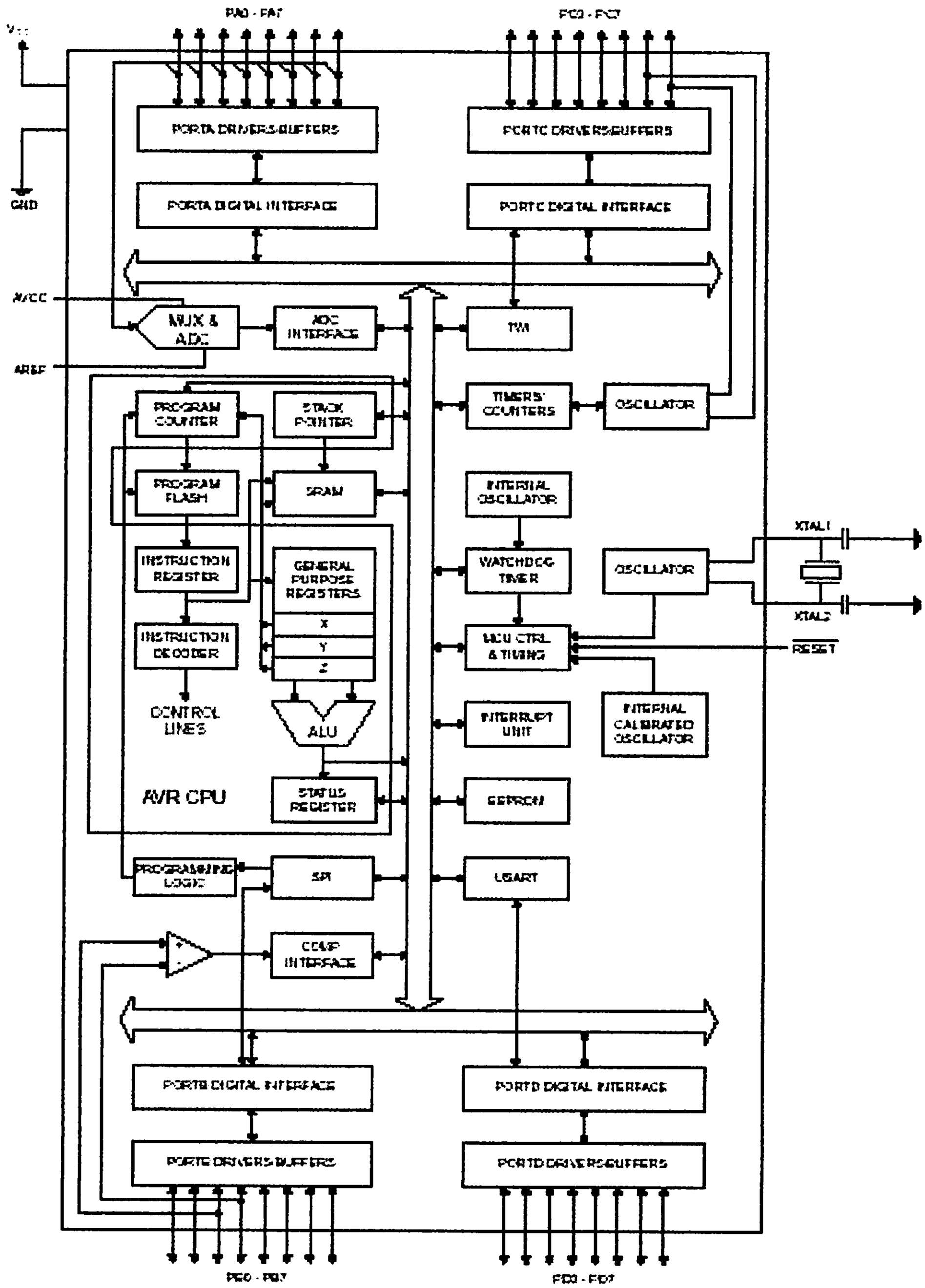
Secara sederhana mikrokontroler merupakan suatu IC yang didalamnya berisi CPU, ROM, RAM dan port I/O yang merupakan kelengkapan sebagai sistem minimum mikrokomputer sehingga sebuah mikrokontroler dapat dikatakan sebagai mikrokomputer dalam kepingan tunggal (*single chip microcomputer*) yang dapat berdiri sendiri.

Mikrokontroller ATmega8535L merupakan mikrokontrol buatan AMEL *Inc* yang merupakan mikrokontrol tipe terbaru buatan ATMEL dan memiliki beberapa kelebihan dari pada yang lainnya. Fitur-fitur yang ada pada ATmega8535L antara lain :

- 8 bit CPU (Cental Proccessing Unit).
- 8 Kbyte self-programming flash program memory.
- *SRAM* berukuran 512 *bytes.*

- *EEPROM* berkapasitas 512 *bytes.*
- Memiliki 32 pin *I/O.*
- Memiliki 8 channel ADC 10 bit.
- Eksternal dan Internal sumber interrupt.
- Programming lock for software security.
- Tegangan operasi 2.7 – 5.5 Volt.
- Programmable serial USART.

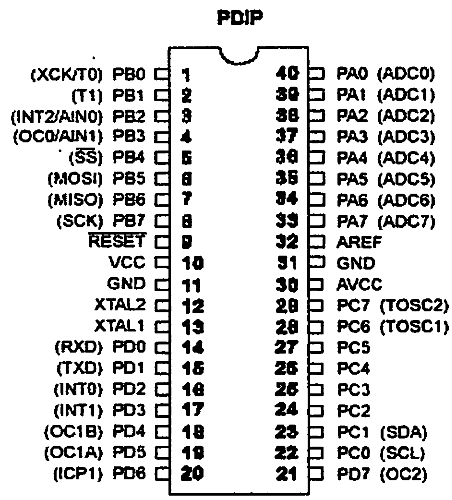
Arsitektur dasar dari mikrokontrller ATmega8535L dapat dilihat pada gambar dibawah ini :



Gambar 2.1.
Block Diagram ATmega8535L
Sumber: Data sheet 8-bit AVR Microcontroller With 8K Bytes In-System Programmable Flash ATmega8535,ATmega8535L

2.3. Susunan Kaki – kaki ATmega8535

Berikut ini adalah bentuk fisik dan susunan pin – pin dari ATmega8535L yang dapat dilihat pada gambar dibawah ini :



Gambar 2.2.
Konfigurasi pin ATmega8535L
Sumber: Data sheet 8-bit AVR Microcontroller With 8K Bytes In-System Programmable Flash ATmega8535,ATmega8535L

Adapun fungsi dari tiap – tiap pin pada ATmega8535L berdasarkan gambar diatas adalah sebagai berikut :

1. VCC

   Pin – pin ini merupakan pin catu daya dengan level tegangan + 2.7 – 5.5 Volt DC untuk VCC.

2. GND

   Merupakan ground.

3. Port A (PA7 – PA0)

Port A merupakan input analog untuk ADC, jika ADC tidak digunakan maka port A dapat berfungsi sebagai port I/O dua jalur. Port A merupakan port I/O 8 bit yang dapat menyediakan *internal pull up resistors* dan *buffer* pada outputnya mempunyai *symmetrical drive characteristics.*

Jika PA_0 - PA_7 digunakan sebagai input dan *internal pull up resistors* dalam keadaan aktif maka *external pull low* port ini akan mengalirkan arus.

Selain fungsi diatas, port B juga mempunyai fungsi khusus yang lain seperti berikut :

Tabel 2-1.
Fungsi Alternatif dari Pin Port A

Pin	Fungsi Alternatif
PA7	ADC7 (ADC Input Channel 7)
PA6	ADC6 (ADC Input Channel 6)
PA5	ADC5 (ADC Input Channel 5)
PA4	ADC4 (ADC Input Channel 4)
PA3	ADC3 (ADC Input Channel 3)
PA2	ADC2 (ADC Input Channel 2)
PA1	ADC1 (ADC Input Channel 1)
PA0	ADC0 (ADC Input Channel 0)

Sumber: Data sheet 8-bit AVR Microcontroller With 8K Bytes In-System Programmable Flash ATmega8535,ATmega8535L

4. Port B (PB7 – PB0)

Port B merupakan *bi-directional* port I/O 8 bit dengan *internal pull up resistors, buffer* pada output port ini juga memiliki *symmetrical drive characteristics*. Jika digunakan sebagai input dan jika resistor *pull up* dalam keadaan aktif, maka *external pull low* akan mengalirkan arus.

Selain fungsi diatas, port B juga mempunyai fungsi khusus yang lain seperti berikut :

Tabel 2-2.
Fungsi Alternatif dari pin port B

Pin	Fungsi Alternatif
PB7	SCK (SPI Bus Serial Clock)
PB6	MISO (SPI Bus Master Input / Slave Output)
PB5	MOSI (SPI Bus Master Output / Slave Input)
PB4	SS (SPI Slave Select Input)
PB3	AIN1 (Analog Comparator Negative Input)
	OC0 (Time/Counter 0 Output Compare Match Output)
PB2	AIN0 (Analog Comparator Positive Input)
	INT1 (External Interrupt 2 Input)
PB1	T1 (Timer / Counter 1 External Counter Input)
	T0 (Timer / Counter 0 External Counter Input)
PB0	XCK (USART External Clock Input / Output)

***Sumber:** Data sheet 8-bit AVR Microcontroller With 8K Bytes In-System Programmable Flash ATmega8535,ATmega8535L*

5. Port C (PC7 – PC0)

Port C merupakan port I/O 8 bit dengan *internal pull up resistor. buffer* pada output port ini juga memiliki *symmetrical drive characteristics.* Jika digunakan sebagai input, maka *external pull low* akan mengalirkan arus jika resistor *pull up* dalam keadaan aktif.

6. Port D (PD7 – PD0)

Port D merupakan port I/O 8 bit dengan *internal pull up resistor. buffer* pada output port ini juga memiliki *symmetrical drive characteristics.* Jika digunakan sebagai input, maka *external pull low* akan mengalirkan arus jika resistor *pull up* dalam keadaan aktif.

Selain fungsi diatas, port B juga mempunyai fungsi khusus yang lain seperti berikut :

Tabel 2-3. Fungsi Khusus Dari Port D

Pin	Alternative Function
PD7	OC2 (Timer/Counter2 Output Compare Match Output)
PD6	ICP1 (Timer/Counter1 Input Capture pin)
PD5	OC1A (Timer/Counter1 Output Compare A Match Output)
PD4	OC1B (Timer/Counter1 Output Compare B Match Output)
PD3	INT1 (External Interrupt 1 Input)
PD2	INT0 (External Interrupt 0 Input)
PD1	TXD (USART Output Pin)
PD0	RXD (USART Input Pin)

Sumber: *Data sheet 8-bit AVR Microcontroller With 8K Bytes In-System Programmable Flash ATmega8535,ATmega8535L*

7. RESET

   Pin ini adalah untuk input RESET,

8. XTAL1

   Merupakan input untuk oscillator *inverting amplifier* dan input untuk *clock* internal pada operasi rangkaian.

9. XTAL2

   Output dari oscillator *inverting amplifier.*

10. AVCC

    Merupakan pin tegangan untuk port A dan ADC. Tegangan ini harus berbeda dengan tegangan VCC, jika ADC tidak digunakan. Dan jika ADC digunakan maka tegangan ini harus disambunga dengan tegangan VCC melalui sebuah *low-pass filter.*

11. AREF

    Merupakan pin referensi untuk ADC

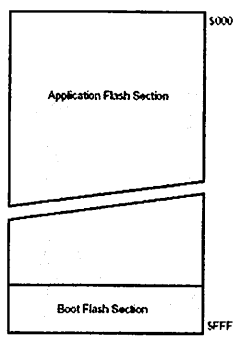
2.4. Organisasi Memori

Organisasi memori pada mikrokontroller ATmega8535L dibagi menjadi dua bagian utama yaitu memori program (Flash Memori) dan memori data. Pembagian tersebut didasarkan atas fungsi dari penyimpangan data maupun program. Mikrokontroller ATmega8535L telah dilengkapi dengan EEPROM yang digunakan sebagai media penyimpanan data.

Berikut ini adalah penjelasan memori pada Mikrokontroller ATmega8535L :

❖ Flash Memory

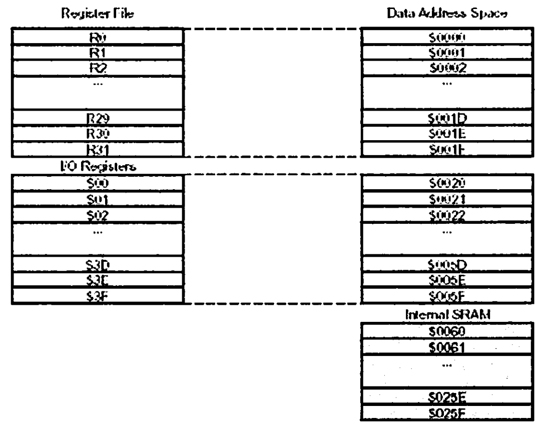
Mikrokontroller ATmega8535L memiliki 8Kb *System Reprogrammable Flash Memory* untuk penyimpanan data, selama semua instruksi pada MCU ini menggunakan data 16 atau 32 bit maka *Flash Memory* terorganisasi atas 4K x 16. Untuk pengamanan program, *Flash Memory* ini terbagi menjadi 2 bagian yaitu Boot Program dan Application Program.



Gambar 2.3.
Map Memori Program Flash Memori
Sumber: Data sheet 8-bit AVR Microcontroller With 8K Bytes In-System Programmable Flash ATmega8535,ATmega8535L

❖ Data Memory

Terdapat 608 l;okasi data memori yang dialamatkan pada *register file, I/O memory dan internal data SRAM*, 96 lokasi memori tersebut terletak pada *register file dan I/O memory* sedangkan sisanya terdapat pada *internal data SRAM.*



Gambar 2.4.
Memori Map Program Data Memori
Sumber: Data sheet 8-bit AVR Microcontroller With 8K Bytes In-System Programmable Flash ATmega8535,ATmega8535L

2.5. Sistem Reset

Mikrokontroller Atmega8535 mempunyai empat (4)sumber reset baik internal maupun eksternal, berikut ini adalah sumber reset dari Atmega8535 :

1.Eksternal Reset

MCU dalam kondisi reset apabila pin *reset* pada pin 9 diberikan sebuah input berupa pulsa low dalam waktu lama.

2. Power-On Reset

MCU akan mereset jika tegangan power supply menurun atau berada dibawah tegangan power-on reset.

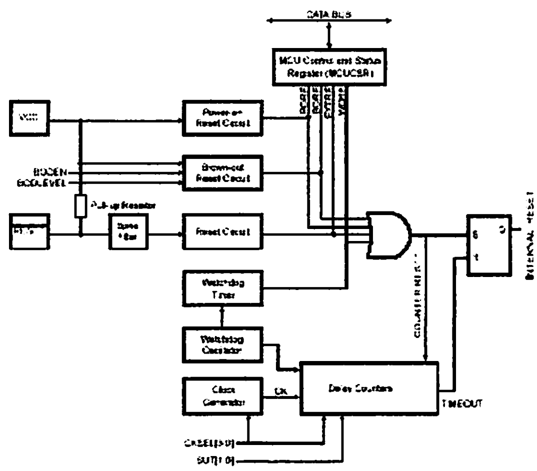
3. Watchdog Reset

MCU akan mereset apabila watchdog timer dalam kondisi enable dan periodenya telah habis.

4. Brown-Out Reset

MCU akan mereset apabila tegangan power supply Vcc berada dibawah atau mendekati tegangan brown-out reset dan ketika detector brown-out dalam keadaan enable.

Berikut ini akan menjelaskan sistem logika pe-reset-an mikrokontroller Atmega8535 :

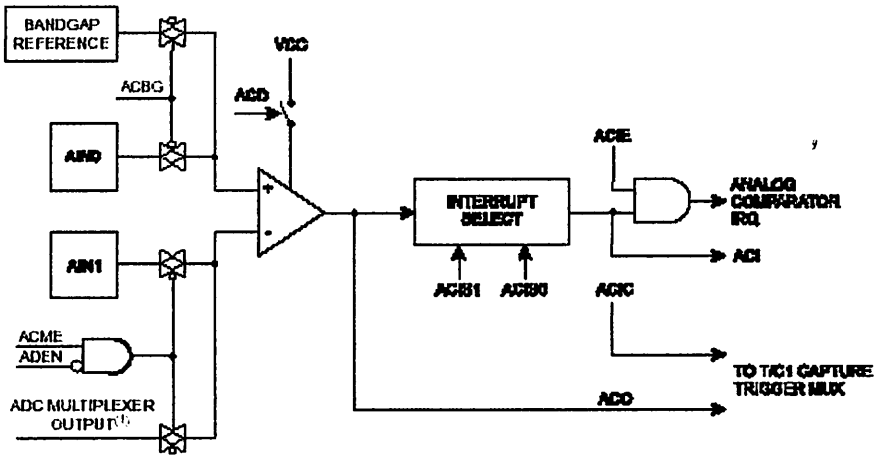


Gambar 2.5.
Logika Reset Mikrokontroller Atmega8535
Sumber: Data sheet 8-bit AVR Microcontroller With 8K Bytes In-System Programmable Flash ATmega8535,ATmega8535L

2.6. Analog Comparator

Analog Comparator ini akan membandingkan harga input pada pin positif AIN0 dan pin negatif AIN1.Output *analog comparator* (ACO) akan berada dalam Kondisi *set* jika tegangan positif pada pin AIN0 lebih tinggi dari pada tegangan negatif pada pin AIN1.

Output Comparator dapat digunakan men-*set* trigger untuk timer atau counter. Sebagai fungsi tambahan, comparator juga dapat digunakan untuk men-*set* trigger sebuah interrupt secara terpisah. Pada proses *intrrupt triggering, u*ser dapat memilih dua (2) pilihan yaitu *Fall* atau *Toggle* pada setiap kenaikan output dari comparator. Blok diagram analog comparator dapat dilihat pada gambar dibawah ini :



Gambar 2.6.
Blok Diagram Analog Comparator
Sumber: Data sheet 8-bit AVR Microcontroller With 8K Bytes In-System Programmable Flash ATmega8535,ATmega8535L

2.7. Analog To Digital Converter (ADC)

Agar dapat mengolah suatu variable fisik yang umumnya berupa besaran analog maka dibutuhkan suatu komponen yang dapat merubah besaran analog menjadi besaran digital supaya dapat diolah oleh mikrokontroller. Konversi ini dapat dilakukan oleh ADC yang merupakan konverter analog ke digital.

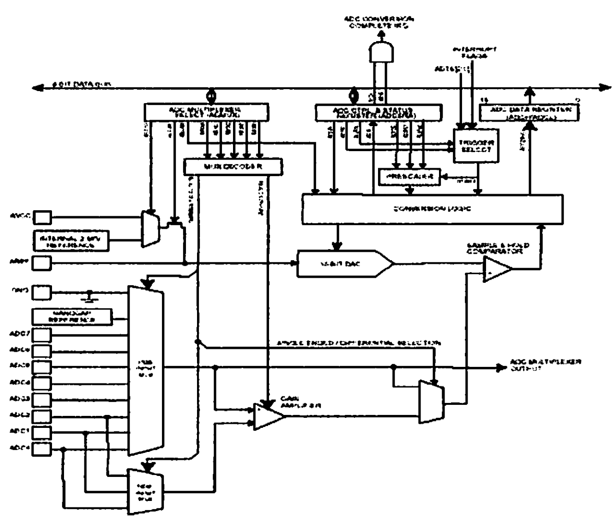
ADC internal pada MCU Atmega 8535 ini termasuk tipe SAC (Successive Approximation ADC).

Berikut ini adalah fitur – fitur yang dimiliki oleh ADC internal pada MCU ATmega 8535L :

- ❖ 10 bit resolusi
- ❖ Waktu konversi yang singkat yaitu 65 – 260 μs

- ❖ 0.5 LSB Integral Non-Liniarity
- ❖ ± 2 LSB Absolute Accuracy
- ❖ 0 – Vcc Range Tegangan Input ADC
- ❖ Single convertion mode
- ❖ Resolusi maksimum 15 kSPS

Berikut ini adalah blok skematik system pengkonversian dari ADC internal Mikrokontroller ATmega8535L :



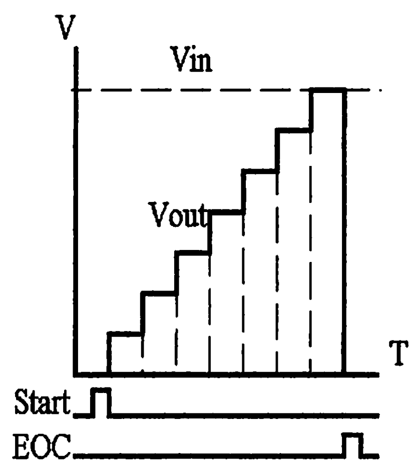
Gambar 2.7.
Blok Skematik ADC Internal
Sumber: Data sheet 8-bit AVR Microcontroller With 8K Bytes In-System Programmable Flash ATmega8535,ATmega8535L

Dalam proses konversi ADC, ada beberapa parameter yang perlu diperhatikan karena parameter ini yang akan menentukan mutu hasil dari pembacaan sebuah ADC, yaitu :

- Kesalahan kuantitatis
- Ketidaklinieran
- Kode tidak lengkap *(missing code)*

– Waktu konversi

Karakteristik yang linier didekati dengan karakteristik dalam bentuk anak tangga sehingga timbul kesalahan kuantitas sebesar setengah dari anak tangga. Karena tinggi anak tangga adalah sama dengan bit paling rendah *(least significant, LSB)* dalam bilangan biner, maka kesalahan tersebut sama dengan ½ LSB. Kadang-kadang kombinasi bit-bit tertentu tidak tersedia, dengan perkataan lain sebuah tangga dilompati. Kombinasi semacam itu disebut kode yang hilang *(missing code)*. Kode hilang tidak akan terjadi bila kesalahan linieritas kurang dari ± ½ LSB.



Gambar 2.8.
Fungsi Linieritas ADC Dalam Bentuk Anak Tangga
Sumber: Data sheet 8-bit AVR Microcontroller With 8K Bytes In-System Programmable Flash ATmega8535,ATmega8535L

Waktu konversi *(convertion time)* adalah waktu yang diperlukan oleh ADC untuk menghasilkan kode biner yang valid. Waktu konversi maksimum dari ADC dapat ditentukan dengan rumus sebagai berikut :

$$f = \frac{1}{1{,}1RC}\ \text{Hz} \qquad\qquad T = \frac{2^n}{f}\ \text{detik}$$

dengan:

T : waktu konversi maksimum

n : bit konverter

f : frekwensi clock ADC

R : nilai tahanan pada rangkaian clock ADC

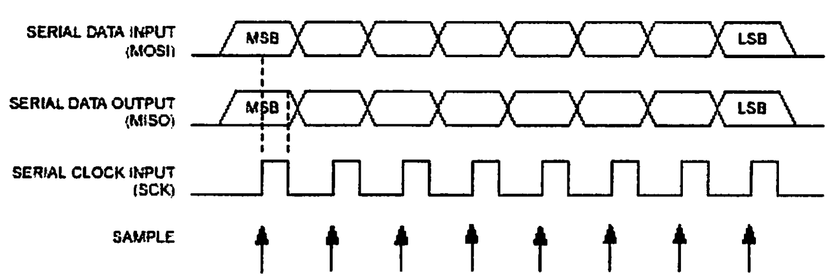
C : nilai kapasitansi pada rangkaian clock ADC

Tabel 2-4.
Pin – Pin Serial Programming

Symbol	Pins	I/O	Description
MOSI	PB5	I	Serial Data in
MISO	PB6	O	Serial Data out
SCK	PB7	I	Serial Clock

Sumber: Data sheet 8-bit AVR Microcontroller With 8K Bytes In-System Programmable Flash ATmega8535,ATmega8535L

Timing Diagram Serial Programming



Gambar 2. 9.
Timing Diagram Serial Programming
Sumber: Data sheet 8-bit AVR Microcontroller With 8K Bytes In-System Programmable Flash ATmega8535,ATmega8535L

Tabel 2-5.
Serial Programming Instruksi Set

a = address high bits, b = address low bits, H = 0 - Low byte, 1 - High Byte, o = data out, i = data in, x = don't care

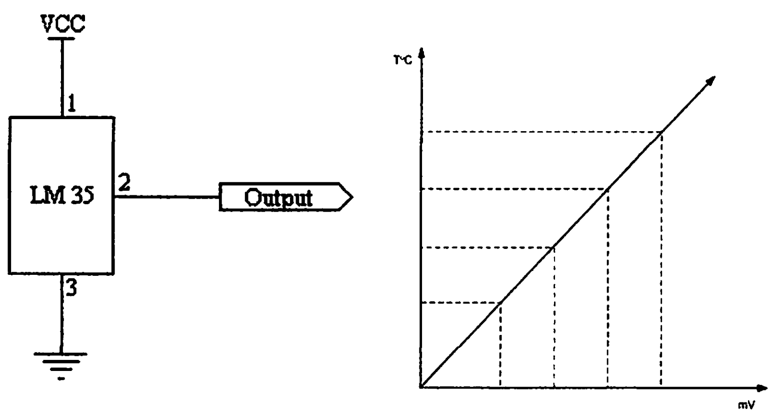
Instruction	Instruction Format				Operation
	Byte 1	Byte 2	Byte 3	Byte4	
Programming Enable	1010 1100	0101 0011	xxxx xxxx	xxxx xxxx	Enable Serial Programming after RESET goes low.
Chip Erase	1010 1100	100x xxxx	xxxx xxxx	xxxx xxxx	Chip Erase EEPROM and Flash.
Read Program Memory	0010 H000	0000 aaaa	bbbb bbbb	oooo oooo	Read H (high or low) data o from Program memory at word address a:b.
Load Program Memory Page	0100 H000	0000 xxxx	xxxb bbbb	iiii iiii	Write H (high or low) data i to Program Memory page at word address b. Data low byte must be loaded before Data high byte is applied within the same address.
Write Program Memory Page	0100 1100	0000 aaaa	bbbx xxxx	xxxx xxxx	Write Program Memory Page at address a:b.
Read EEPROM Memory	1010 0000	00xx xxxa	bbbb bbbb	oooo oooo	Read data o from EEPROM memory at address a:b.
Write EEPROM Memory	1100 0000	00xx xxxa	bbbb bbbb	iiii iiii	Write data i to EEPROM memory at address a:b.
Read Lock Bits	0101 1000	0000 0000	xxxx xxxx	xxoo oooo	Read Lock bits. "0" = programmed, "1" = unprogrammed. See Table 98 on page 233 for details.
Write Lock Bits	1010 1100	111x xxxx	xxxx xxxx	11ii iiii	Write Lock bits. Set bits = "0" to program Lock bits. See Table 98 on page 233 for details.
Read Signature Byte	0011 0000	00xx xxxx	xxxx xxbb	oooo oooo	Read Signature Byte o at address b.
Write Fuse Bits	1010 1100	1010 0000	xxxx xxxx	iiii iiii	Set bits = "0" to program, "1" to unprogram. See Table 99 on page 235 for details.
Write Fuse High Bits	1010 1100	1010 1000	xxxx xxxx	iiii iiii	Set bits = "0" to program, "1" to unprogram. See Table 98 on page 234 for details.
Read Fuse Bits	0101 0000	0000 0000	xxxx xxxx	oooo oooo	Read Fuse bits. "0" = programmed, "1" = unprogrammed. See Table 99 on page 235 for details.
Read Fuse High Bits	0101 1000	0000 1000	xxxx xxxx	oooo oooo	Read Fuse high bits. "0" = programmed, "1" = unprogrammed. See Table 98 on page 234 for details.
Read Calibration Byte	0011 1000	00xx xxxx	0000 00bb	oooo oooo	Read Calibration Byte

Sumber: Data sheet 8-bit AVR Microcontroller With 8K Bytes In-System Programmable Flash ATmega8535,ATmega8535L

2.8. Sensor Suhu

Sensor suhu yang digunakan pada tugas akhir ini adalah sensor suhu LM 35, dimana sensor suhu LM 35 dapat menghasilkan tegangan keluaran yang proporsional liniear dengan suhu yang dinyatakan dengan satuan *derajat celcius* (^{o}C), selain itu sensor suhu LM 35 juga mempunyai keunggulan dengan sensor suhu yang berkalibrasi dalam *derajat kelvin* (^{o}K), sehingga di dalam penggunaanya tidak diperlukan pengurangan tegangan konstan yang besar dari output yang mendapatkan skala tetap. Sensor suhu LM 35 tidak memerlukan kalibrasi eksternal atau trimming. Adapun karakteristik umum dari sensor suhu LM 35 adalah sebagai berikut :

- Dapat dikalibrasi secara langsung pada °C
- Faktor skala linier sebasar 10 mV/°C
- Range temperature dimulai pada -55 °C sampai +150 °C
- LM 35 adalah sensor suhu presisi yang mudah dikalibrasi dan keluaranya linier.

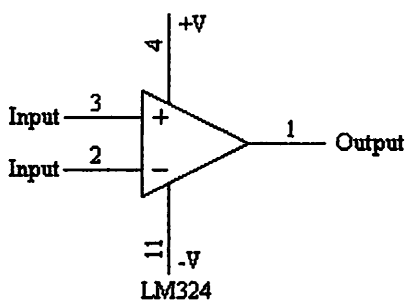


Gambar 2.10. Konfigurasi Pin LM 35 Dan Karakteristiknya
Sumber : National Semiconductor Data Sheet

2.9. Penguat (Op-Amp)

Amplifier atau lazimnya disebut sebagai penguat, dalam suatu rangkaian dapat difungsikan sebagai penguat sinyal input, rangkaian penjumlah tegangan input, rangkaian pembanding antara dua sinyal input, rangkaian filter dan masih banyak lagi yang lainya.

Rangkaian penguat ini sangat sederhana dalam pemakaianya baik cara merangkainya maupun dalam penggunaanya. Rangkaian ini terdiri dari kombinasi antara penguat operasional *(Op-Amp)* yang dirangkai bersama komponen pasif *(Resistor dan Capasitor).* Dengan kombinasi tersebut diatas maka Op-Amp dapat dikembangkan lagi menjadi rangkaian yang mempunyai spesifikasi khusus seperti rangkaian instrumentasi, rangkaian oscilator dan lain sebagainya. Gambar 2.4 menunjukkan simbol dadi Op-Amp dengan lima terminal dasar yaitu terdiri dari 2 buah terminal catu daya, 2 buah terminal input atau masukan yaitu (+) dan (-) dan 1 buah terminal output (keluaran)

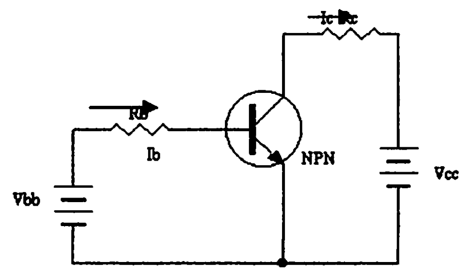


Gambar 2.11. Simbol Op-Amp
Sumber : Penguat Operasional Dan Rangkaian Terpadu Linier

2.10. Transistor

Transistor merupakan sebuah komponen semikonduktor yang banyak digunakan pada berbagai rangkaian elektronika baik sebagai rangkaian penguat maupun sebagai saklar.

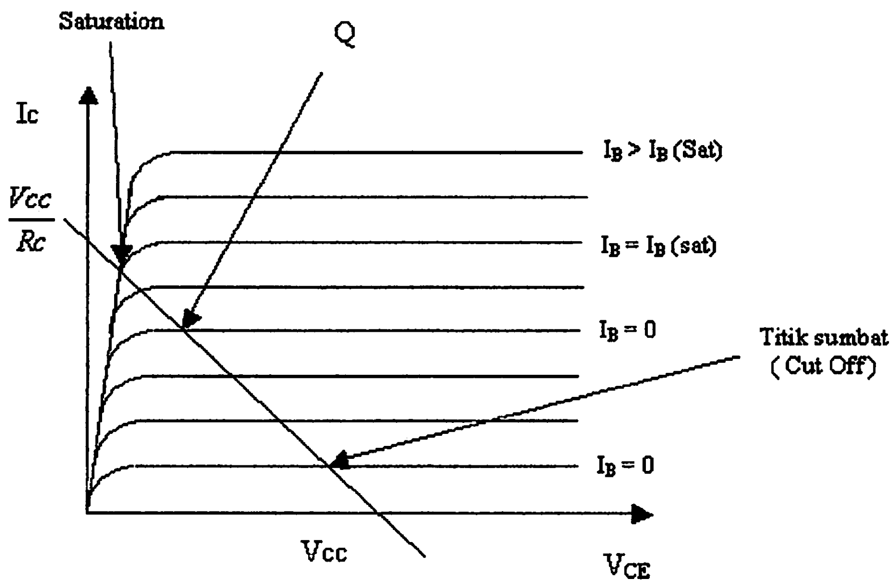
Azas kerja dari transistor adalah akan ada arus yang mengalir diantara terminal kolektor-emitor apabila ada arus yang mengalir diantara terminal basis-emitor. Jadi transistor harus dioperasikan didaerah linier agar diperoleh sinyal keluaran yang tidak cacat *(distorsi).* Untuk dapat mmengoperasikan secara tapat, maka pengertian tentang titik kerja transistor amatlah penting serta harus dipahami dan dimengerti dengan benar.



Gambar 2.12. Rangkaian Transistor sebagai Saklar
Sumber : Malvino, Prinsip-prinsip Elektronika

Garis beban akan memotong sekelompok kurva arus basis konstan I_B. Dengan I_B tertentu (yang diatur dengan bias), garis beban akan memotong kurva I_B tersebut. Di titik Q yang disebut dengan titik kerja transistor. Titik kerja ini menjadi kondisi awal dari pengoperasian transistor, dimana transistor tersebut mempnyai tiga daerah kerja, yaitu : aktif *(active),* jenuh *(saturation)* dan tersumbat *(cut-off).*

Pada gambar 2.10 dapat dilihat, titik dimana garis beban memotong kurva $I_B = 0$ disebut sebagai titik sumbat *(cut-off).* Pada titik ini arus kolektor (I_C) sangat kecil (hanya arus bocor) sehingga diabaikan, disini transistor kehilangan kerja normalnya dan dapat dikatakan bahwa tegangan kolektor-emitor sama dengan ujung garis bebab tersebut.



Gambar 2.13. Karakteristik I_C – V_{CE} Sebuah Transistor Bipolar
Sumber : Malvino, Prinsip-prinsip Elektronika

Perpotongan garis beban kurva $I_B = I_{B(sat)}$ disebut titik jenuh *(saturation)*. Pada titik ini arus kolektor maksimum atau dapat dikatakan bahwa arus kolektor sama dengan ujung dari garis beban.

$$I_{C(sat)} \cong \frac{V_{CC}}{R_C}$$

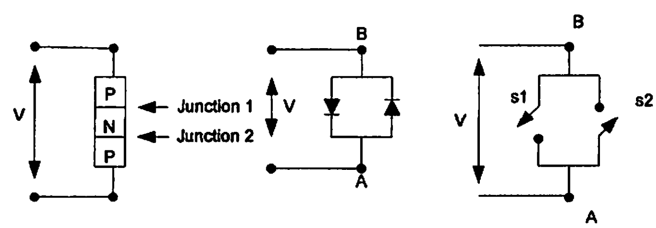
Jika arus basis I_B lebih kecil dari $I_{B(sat)}$ maka transistor akan beroperasi pada daerah aktif, yaitu titik kerjanya terletak disepanjang garis beban.

Jadi dapat disimpulkan bahwa transistor bipolar bekerja sebagai sumber arus (penguat) dimana saja sepanjang garis beban, kecuali titik jenuh *(saturation)* atau titik sumbat *(cut-off)* dimana transistor sudah tidak lagi bekerja sebagai sumber arus *(penguat)* melainkan sebagai saklar *(switch)*.

Pada alat ini transistor difungsikan sebagai saklar, dengan demikian maka transistor harus dioperasikan dalam keadaan saturasi. Pada keadaan ini tegangan antara kaki kolektor dan kaki emitor dianggap 0 Volt (ideal) atau $V_{CE} \approx 0$ Volt.

2.11. Diac (Diode Alternating Current)

Diac adalah dua dioda yang disusun secara berlawanan yang mengalirkan arus bolak balik, yang artinya bergantian, bias maju (forward).dan bias mundur (reverse) bila diberi tegangan pada elektrodanya, sebenarnya susunan diac ini hamper sama dengan susunana transistor namun elektrodanya ada dua dan mempunyai dua sambungan (junction) seperti pada gambar 2.14.



(A) (B) (C)

Gambar 2.14. Diac

(A) Susunan Diac

(B) Rangkaian Diac

(C) Rangkaian Pengganti Diac

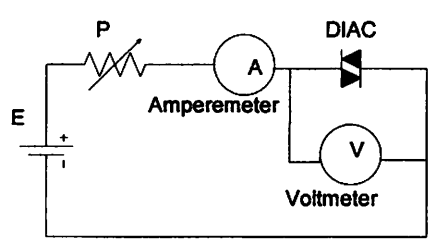
Sumber : Malvino,Prinsip-prinsip Elektronika,1994

Apabila titik A adalah titik muatan positif maka junction ke satu pada bias maju sedangkan junction kedua pada keadaan bias mundur pada saat titik A. Tegangan positif terhadap titik B. Maka setelah tegangan tertentu dapat menembus tegangan *break down* sehingga arus mengalir pada diac, demikian juga apabila titik B tegangannya lebih positif terhadap titik A. Sampai menembus junction kesatu maka arus mengalir melalui diac untuk lebih jelasnya dapat dilihat pada gambar 2.12.c yaitu apabila titik A pada keadaan bias maju maka saklar S1 pada keadaan ON sedangkan pada saklar S2 pada keadaan OFF.

Sebaliknya jika titik B pada keadaan bias maju maka saklar S2 pada keadaan ON sedangkan pada saklar S1 pada keadaan OFF. Dengan demikian jelaslah bahwa prinsip kerja dari diac hamper sama dengan arus bolak balik yaitu bergantian forward bias dan reverse biasnya apabila diberi teganan bolak balik (AC).

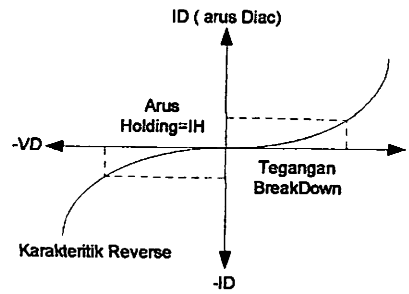
2.11.1. Karakteristik Diac

Rangkain percobaan untuk karakteristik diac ini dapat dilihat seperti gambar 2.15



Gambar 2.15.
Rangkaian Percobaan Karakteristik Diac
Sumber : Malvino,Prinsip-prinsip Elektronika,1994

Pada waktu diberikan forward bias pada diac penunjukan Voltmeter dan Amperemeter diamati dan hasilnya digambarkan pada sebuah koordinat sumbu kemudian potensiometer diatur dan diamati lagi. Dan dilakukan pengaturan potensiometer berulang ulang sehingga didapat titik yang tepat

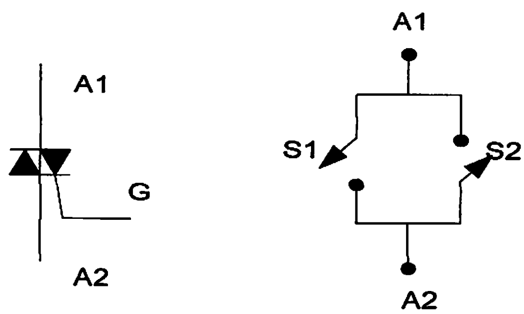


Gambar 2.16.
Kurva Karakteristik Diac
Sumber : Malvino,Prinsip-prinsip Elektronika,1994

Kemudian sewaktu pemberian reverse bias pelaksanaan penggambarannya pun seperti forward bias tadi sehingga dari pengukuran kedua meter yang berulang ulang diamati dengan pemutaran potensiometer dapat dibuat gambarnya seperti pada gambar 2.16. demikian juga untuk menentukan tegangan holding maupun arus holding dan tegangan breakdown dari diac secara tepat harus dicobakan berulang ulang. Diac ini digunakan untuk Triger SCR dan untuk mengatur daya sebagai trigger pada SCR,fungsinya seolah olah seperti saklar elektronik demikian juga untuk mengatur daya.

2.12. Triac (Triode Alternating Current)

Triac adalah saklar triode untuk arus bolak balik, berdasarkan gambar 2.17. Triac tersusun atas dua buah SCR secar pararel. Simbol triac dan rangkaian pengganti sebagai saklar seperti pada gambar 2.17.



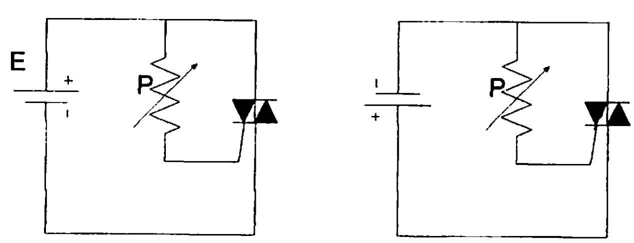
(A) (B)

Gambar 2.17. Triac

(A) Simbol Triac (B) Rangkaian Penggantinya sebagai Saklar

Sumber : Malvino,Prinsip-prinsip Elektronika,1994

Pada gambar 2.17 triac terdiri dari tiga kaki yaitu Gate MT1 MT2 prinsip kerjanya adalah apabila MT1 diberi forward bias maka saklar S1 menutup (ON) dan sebaliknya jika MT1 diberi reverse bias maka saklar S2 menutup dengan kata lain triac bekerja secara bergantian skema pemberian reverse bias dan forward bias adalah seperti pada gambar 2.18.

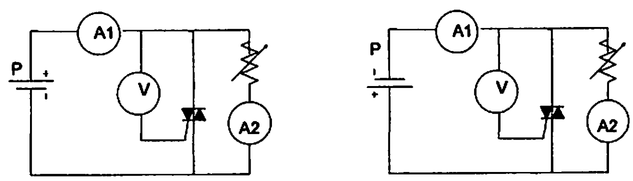


(A) (B)
Gambar 2.18. Rangkaian Triac
(A) Forward Bias (B) Reverse Bias
Sumber : Malvino,Prinsip-prinsip Elektronika,1994

Triac dapat dipakai untuk alat kontrol rangkaian arus bolak balik (AC) pada beban atau juga untuk pengatur daya pada beban

2.12.1. Karakteristik Triac

Rangkaian percobaan untuk karakteristik Triac adalah seperti pada gambar 2.19.



(A) (B)

Gambar 2.19.
Rangkaian Percobaan Karakteristik Triac
(A) Rangkaian Untuk Karakteristik Forward
(B) Rangkaian Untuk Karakteristik Reverse

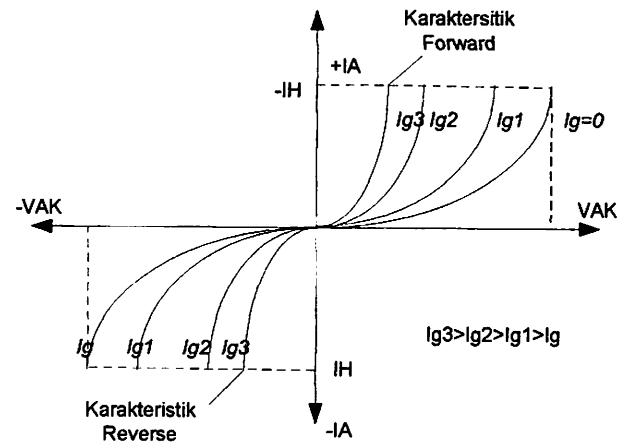
A1 = Amperemeter untuk mengukur arus melalui Triac

A2 = Amperemeter untuk mengukur arus melalui Gate

V = Voltmeter untuk mengukur V breakdown antara MT1 dan MT2

E = Sumber Arus

Sumber : Malvino, Prinsip-prinsip Elektronika, 1994

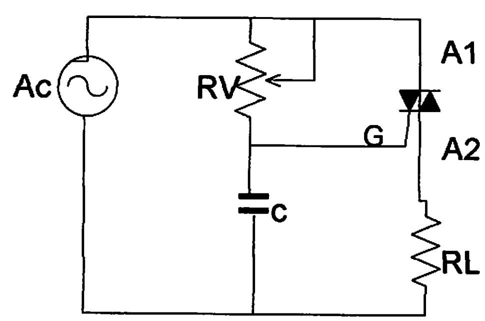


Keterangan : VBD = Tegangan Breakdown *Ig = Arus Gate*

IH = Arus Holding *VAK = Tegangan MT1 Triac*

Gambar 2.20.
Kurva Karakteristik Triac
Tidak ada perbedaan antara karakteristik forward dan reversenya
Sumber : Malvino,Prinsip-prinsip Elektronika,1994

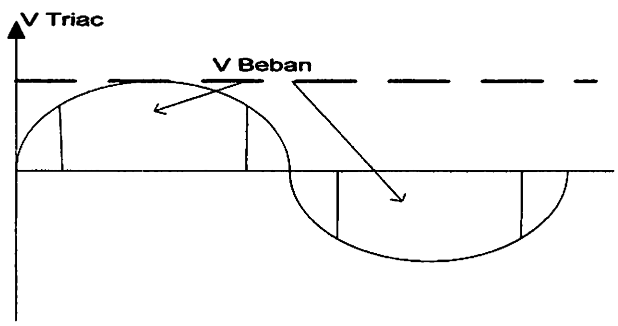
Rangkaian dasarnya dapat dijelaskan pada gambar 2.21.



Gambar 2.21.
Rangkaian Dasar Kontrol
Sumber : Malvino,Prinsip-prinsip Elektronika,1994

Jika Resistor variable (RV) diatur pada posisi minimum maka kerugian tegangan pada RV lebih besar dibandingkan dengan pada Gate, sekarang jika RV diatur pada posisi maximum maka tegangan pada Gate akan bertambah besar.

Apabila tegangan trigger diperbesar maka pada saat tegangan tertentu triac akan menghantar sehingga ada arus mengalir melalui beban, oleh karena itu pada beban terdapat daya. Bentuk gelombang yang terdapat pada beban adalah seperti pada gambar 2.22.



Gambar 2.22.
Bentuk Gelombang Pada Beban Rangkaian Dasar Kontrol
Sumber : Malvino,Prinsip-prinsip Elektronika,1994

Dari gambar 2.22. dapat dilihat bahwa tegangan yang terdapat pada beban tidak berbentuk gelombang penuh tetapi dikurangi tegangan pada triac itu sendiri

2.13. Display Seventh Segment

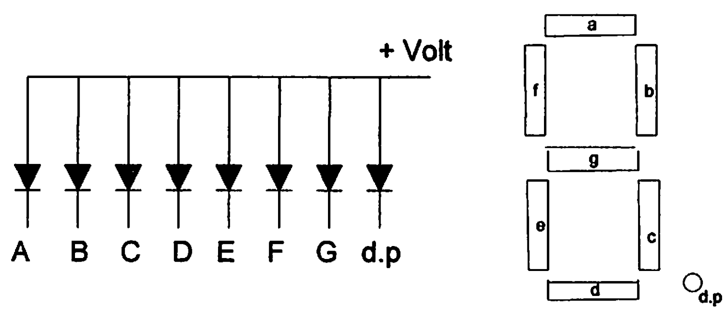
Display seventh merupakan gabungan dari beberapa LED yang dapat dicatu secara individu atau masing masing, warna yang ditampilkan pada display ini baisanya berwarna merah led led tersebut tersusun menyerupak angka delapan dan dicatu semuanya sehingga akan menampilkan angka delapan seperti namanya terdapat tujuh buah led yang dapat diatur kombinasinya untuk menampilkan angka dan huruf ada dua macam hubungan pada display seventh segment, yaitu:

1.Common Anoda

Pada hubungan ini semua anoda dihubungkan menjadi satu kebagian positif dari catu daya sedangkan katodanya difungsikan sebagai masukan.

2.Common Katoda

Pada hubungan ini semua katoda dihubungkan menjadi satu kebagian ground sedangkan anodanya difungsikan sebagai masukan. Dalam penggunaan display seventh segment ini harus dipasang resistor seri terhadap setiap LED yang berfungsi untuk membatasi arus yang mengalir adapun jenis seventh segment yang digunakan disini adalah tipe common anoda.



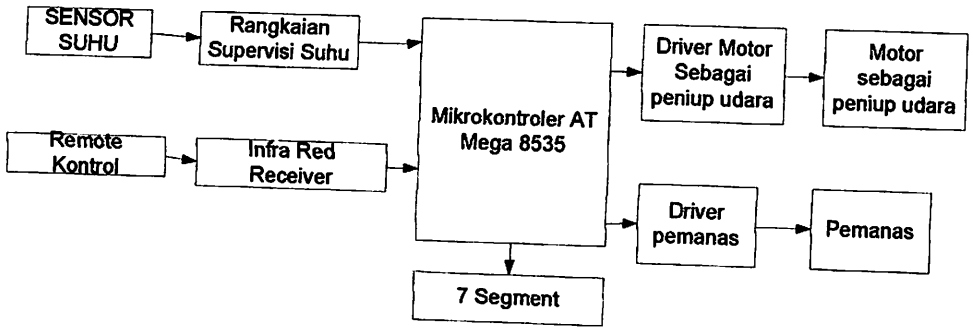
Gambar 2.23.
Seventh Segment Common Anoda

BAB III

PERENCANAAN DAN PEMBUATAN ALAT

Untuk mendapatkan keseluruhan system pada alat diperlukan tahapan tahapan perencanaan yang nantinya sedapat mungkin terwujud hasil yang diinginkan diagram blok alat terlihat pada gambar 3.1.

3.1. Diagram Blok Rangkaian



Gambar 3.1.
Diagram Blok Pengaturan Gelembung Udara Mandi Spa

Cara kerja blok diagram adalah sebagai berikut :

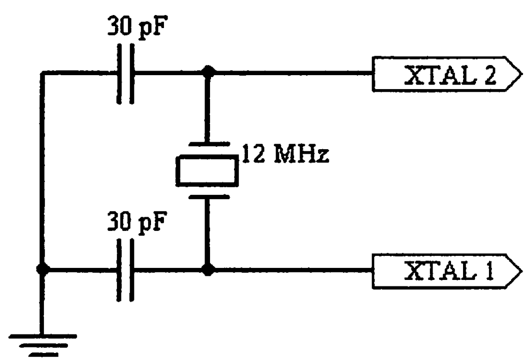
1. Sensor suhu, berfungsi untuk menditeksi temperature udara yang ditiup oleh kompresor yang dipanaskan oleh kawat nikelin, sehingga perubahan temperatur udara akan dideteksi oleh sensor ini
2. Rangkaian supervisi, pada rangkaian supervisi ini sinyal keluaran dari sensor yang masih terlalu lemah untuk diproses lebih lanjut,maka perlu suatu penguatan,yang diperlukan berupa OP-AMP.

3.2.2. Rangkaian Pewaktu (Clock)

Kecepatan proses pengolahan data pada mikrokontroler ditentukan oleh *Clock* (pewaktu) yang dikendalikan oleh Mikrokontroller tersebut. Pada Mikrokontroller ATMEGA 8535 terdapat *internal clock. Internal Clock* generator berfungsi sebagai sumber *Clock*, tapi masih memerlukan rangkaian tambahan untuk membangkitkan *Clock* yang diperlukan. Rangkaian *Clock* ini terdiri dari dua buah kapasitor dan sebuah kristal yang dirangkai sedemikian rupa dan kemudian dihubungkan dengan Pin 12 dan 13 pada ATMEGA 8535.

Dalam perancangan rangkaian ini menggunakan :

1. C = 30 pF, penentuan besarnya kapasitansi disesuaikan dengan spesifikasi pada data sheet ATMEGA 8535.
2. Kristal 12 MHZ (berdasarkan data sheet ATMEGA 8535) adapun gambar rangkaian clock tampak seperti pada gambar 3-3.



Gambar 3.3. Perancangan Rangkaian Clock

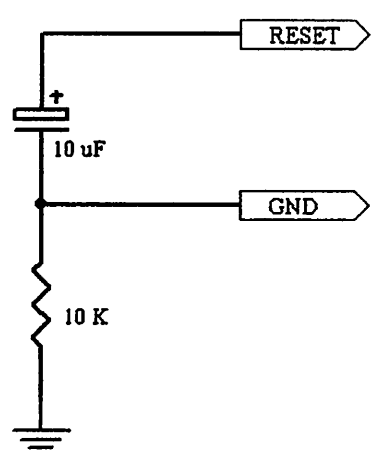
Dalam perancangan ini digunakan kristal sebagai sumber *clock*, kristal dihubungkan diantara kaki – kaki XTAL1 DAN XTAL2 pada mikrokontroler dan kapasitornya dihubungkan ke ground. Kristal yang digunakan sebesar 12 MHz. Waktu yang dibutuhkan untuk mikrokontroler mengolah data, adalah :

$$T = \frac{1}{12.10^6} \times 12 \text{ periode}$$

$$= 1\ \mu s$$

3.2.3. Perancangan Rangkaian Reset

Reset pada Mikrokontroler merupakan masukkan aktif High '1'. Pulsa transisi dari rendah '0' ke tinggi '1' akan mereset Mikrokontroler menuju alamat 0000H. Pin reset dihubungkan dengan rangkaian power on reset seperti pada gambar 3.4.



Gambar 3.4. Rangkaian Power On Reset

Rangkaian reset bertujuan agar mikrokontroler dapat menjalankan proses dari awal. Rangkaian reset untuk Mikrokontoler dirancang agar mempunyai kemampuan *Power On Reset*, yaitu reset yang terjadi pada saat sistem dinyalakan untuk pertama kalinya.

Rangkaian Reset terbentuk oleh komponen R dan C yang sudah baku (ditetapkan oleh perusahaan pembuat IC ATMEGA 8535). Nilai R yang dipakai adalah 10 KΩ dan nilai C adalah 10 μF.

Sedangkan untuk mencari frekuensi dari reset tersebut dengan menggunakan rumus sebagai berikut :

$$fo = \frac{1}{1{,}1R.C}$$

Sehingga dengan komponen resistor dengan nilai 10 KΩ serta kapasitor dengan nilai 10 uF akan dihasilkan frekuensi.

$$fo = \frac{1}{1{,}1.RC}$$
$$= \frac{1}{1{,}1 \times 10.10^{3} \times 10.10^{-6}}$$

$$fo = 9{,}09\ Hz$$

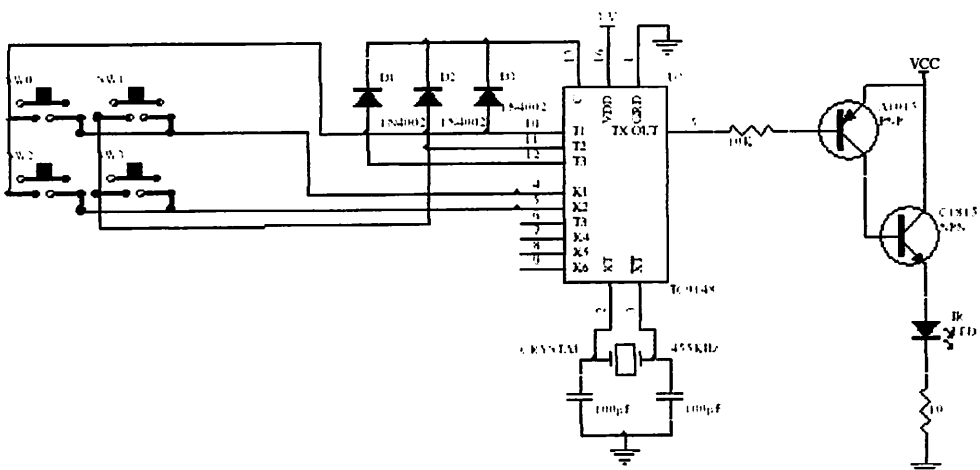
Maka periode clock :

$$T = \frac{1}{fo}$$
$$T = \frac{1}{9{,}09}$$

$$T = 0{,}11 \text{ detik}$$

3.2.4. Rangkaian Infra merah (IRD)

Sebagai media pengiriman data atau kode pulsa. Rangkaian dapat bekerja secara normal pada jangkauan tegangan dari 2,2 Volt – 5 Volt. Jadi apabila tegangan diluar jangkauan maka rangkaian tidak dapat bekerja secara baik. Apabila terjadi penekanan tombol maka proses pada IC TC9148 akan memberikan data logic High pada pengiriman data transmisi secara serial. Sehingga apabila tombol 1 ditekan maka data tombol 1 berlogic High (1) dan yang lainnya berlogic Low (0). Kombinasi inilah yang akan dikirim secara serial melalui cahaya infra merah.



Gambar 3.5. Rangkaian inframerah

3.2.5. Photodioda (*receiver*)

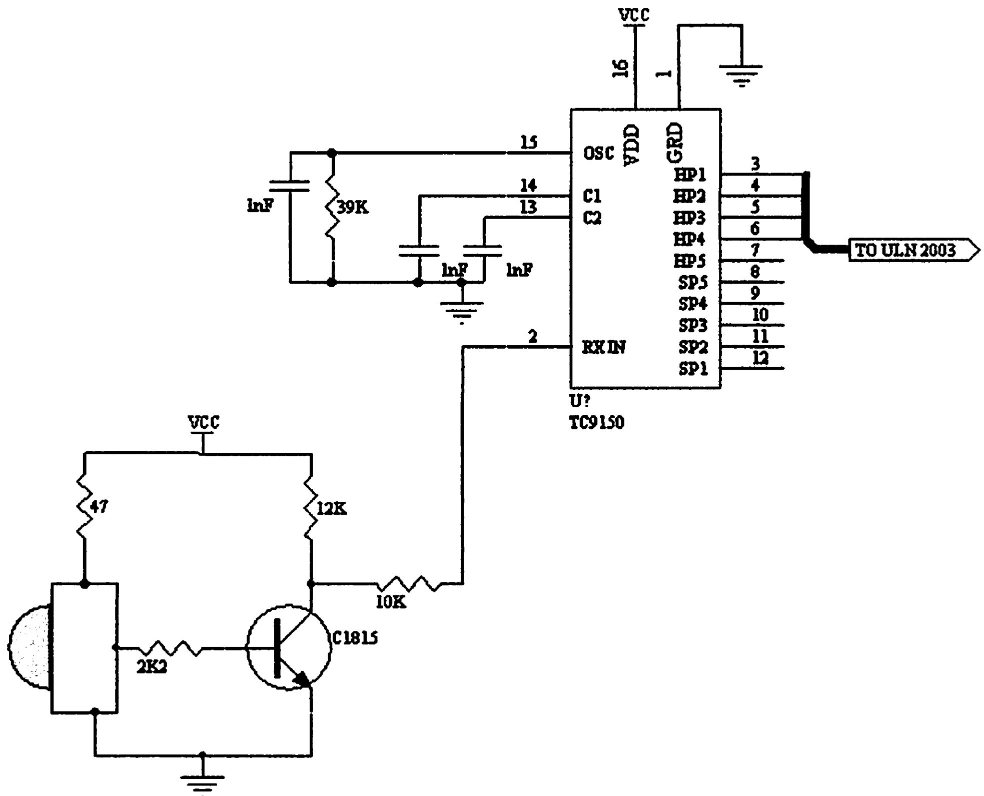
IR Modul adalah sebuah komponen penerima cahaya infra merah yang akan mengeluarkan output berupa pulsa atau frekuensi sesuai yang diterima dari remote. Output dari IR Modul dikuatkan dengan menggunakan transistor C1815 kemudian diinputkan ke IC TC9149 untuk diterjemahkan frekuensinya yang akan menghasilkan output berupa logic untuk memicu mikrokontroler yang nantinya diproses oleh program yang ada didalamnya.

Apabila tombol 1 pada remote ditekan maka akan memberikan inputan berupa logic 1 (High), dimana hal ini berarti mikrokontroler akan menjalankan perintah untuk mengaktifkan heater pada 30 °C dan kompresor bertekanan rendah.

Apabila tombol 2 pada remote ditekan maka akan memberikan inputan berupa logic 1 (High), dimana hal ini berarti mikrokontroler akan menjalankan perintah untuk mengaktifkan heater pada 40 °C dan kompresor bertekanan sedang.

Apabila tombol 3 pada remote ditekan maka akan memberikan inputan berupa logic 1 (High), dimana hal ini berarti mikrokontroler akan menjalankan perintah untuk mengaktifkan heater pada 50 °C dan kompresor bertekanan tinggi.

Apabila tombol 4 pada remote ditekan maka akan memberikan inputan berupa logic 1 (High), dimana hal ini berarti mikrokontroler akan mematikan heater namun kompresor akan bertekanan rendah.



Gambar 3.6. Rangkaian Receiver

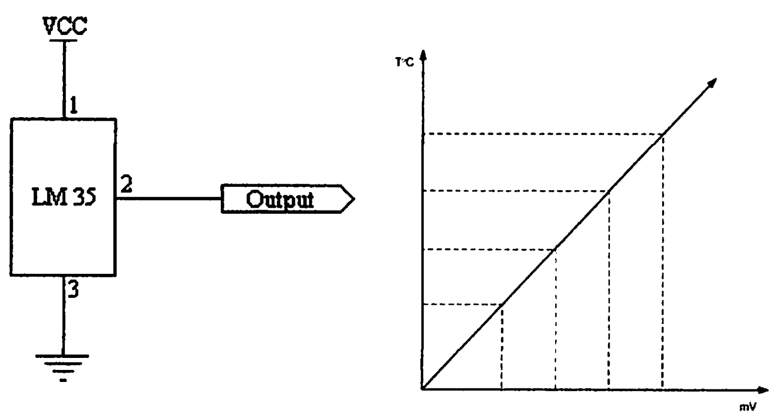
3.2.6. Sensor Suhu

Untuk sensor suhu yang digunakan adalah LM 35. sensor ini memiliki output yang linier yaitu menghasilkan kenaikan tegangan output sebesar 10mv untuk setiap kenaikan suhu 1°C sehingga memudahkan dalam pengolahan datanya. Output dari LM 35 ini adalah linier, ini dibuktikan dengan semakin naiknya suhu maka semakin besar pula tegangan yang dihasilkan.

Disini sensor disupply dengan tegangan (Vs) 5 Volt DC. Tegangan yang dikeluarkan oleh sensor ini dimaksimalkan pada suhu 150°C dengan nilai tegangan sekitar 1 Volt DC pada Vout sensor. Gambar sensor suhu LM 35 seperti gambar 3.2 Sensor suhu yang digunakan pada tugas akhir ini adalah sensor suhu

LM 35, dimana sensor suhu LM 35 dapat menghasilkan tegangan keluaran yang proporsional liniear dengan suhu yang dinyatakan dengan satuan *derajat celcius* (°C), selain itu sensor suhu LM 35 juga mempunyai keunggulan dengan sensor suhu yang berkalibrasi dalam *derajat kelvin* (°K),sehingga di dalam penggunaanya tidak diperlukan pengurangan tegangan konstan yang besar dari output yang mendapatkan skala tetap. Sensor suhu LM 35 tidak memerlukan kalibrasi eksternal atau trimming. Adapun karakteristik umum dari sensor suhu LM 35 adalah sebagai berikut :

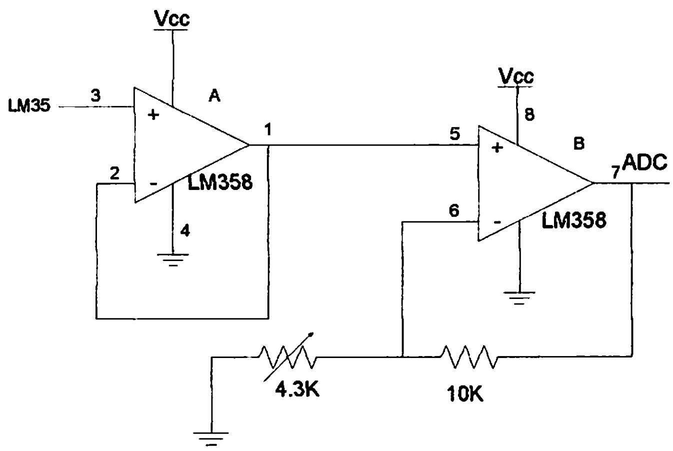
- Dapat dikalibrasi secara langsung pada °C
- Faktor skala linier sebasar 10 mV/°C
- Range temperature dimulai pada -55 °C sampai +150 °C
- LM 35 adalah sensor suhu presisi yang mudah dikalibrasi dan keluaranya linier.



Gambar 3.7. Sensor suhu
Sumber : National Semiconductor Data Sheet

3.2.7. Rangkaian Supervisi Suhu

Pada rangkaian ini terdapat dua buah operational amplifier yang menggunakan satu IC LM 358 dimana terdapat dua buah Op-Amp didalamnya. Op-Amp yang pertama dikondisikan sebagai buffer (pengikut tegangan) dan yang dieua difungsikan sebagai penguat diferensial dengan penguatan yang dibutuhkan sebesar 3 kali penguatan. Rangkaian supervisi suhu seperti pada gambar 3.8.



Gambar 3.8. Rangkaian Supervisi Suhu

Nilai R1 pada gambar 3.8. ditentukan 4,3 KΩ sedangkan nilai Rf didapat dari persamaan sebagai berikut :

$$\frac{Rf}{R1} = Av - 1$$

$$\frac{Rf}{R1} = 3 - 1$$

$$= 2$$

Maka :

$$Rf = 2\,R1$$

$$= 2\ (4{,}3\ k\Omega)$$

$$Rf = 8{,}6\ k\Omega$$

Pada aplikasinya nilai resistansi diatas tidak terdapat dipasaran oleh karena itu untuk mendapatkan nilai resistansi yang mendekati nilai Rf diatas maka resistor (Rf) dipasang 10 kΩ.

Untuk menguji apakah penguatan sebesar 3 kali, setelah didapat nilai Rf sebesar 8,6 kΩ dan R1 sebesar 4,3 kΩ maka untuk mencari penguatan apakah sesuai dengan yang diinginkan, adalah sebagai berikut :

$$Av = \frac{Rf}{R1} + 1$$

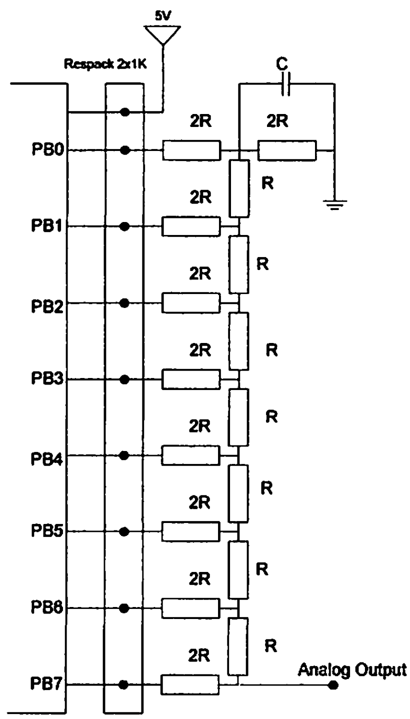
Dimana :

$$Av = \frac{8{,}6}{4{,}3} + 1$$

$$Av = 3 \text{ kali}$$

3.2.8. Perancangan Digital to Analog Converter

Suatu cara untuk menyelesaikan masalah yang timbul pada converter dengan hambatan yang diberi bobot biner adalah menggunakan suatu rangkaian tangga seperti pada gambar 3.9. dibawah ini :



Gambar 3.9. Rangkaian Tangga R-2R DAC

Rangkaian DAC pada gambar 3.9. mendapatkan input digital sehingga perbandingan tegangan keluaran yang dihasilkan adalah :

$$Vout = \frac{decimal\_input}{decimal\_maksimum} . Vref$$

Rumus diatas berlaku untuk rangkaian tanpa beban, jika pada keluaran diberikan beban, maka beban harus diperhitungkan jika ingin mendapat hasil yang sesuai. Untuk mengatasi permasalahan tersebut maka ditambah penyangga atau rangkaian Op-Amp.

Untuk mendapatkan hasil konversi yang tepat biasanya ditemui juga permalahan mengenai resolusi, dimana besarnya resolusi DAC ditentukan oleh jumlah bit masukan digital. Sebagai contoh kita membandingkan resolusi DAC antara DAC 4 bit – DAC 8 bit.

DAC 4 bit ; Vref= 5 volt

Nilai skala penuh = $2^4 = 16$

Resolusi = $(\frac{1}{16}).5 = 0.315$ Volt

Sedangkan pada 8 bit :

DAC 8 Bit ; Vref = 5 Volt

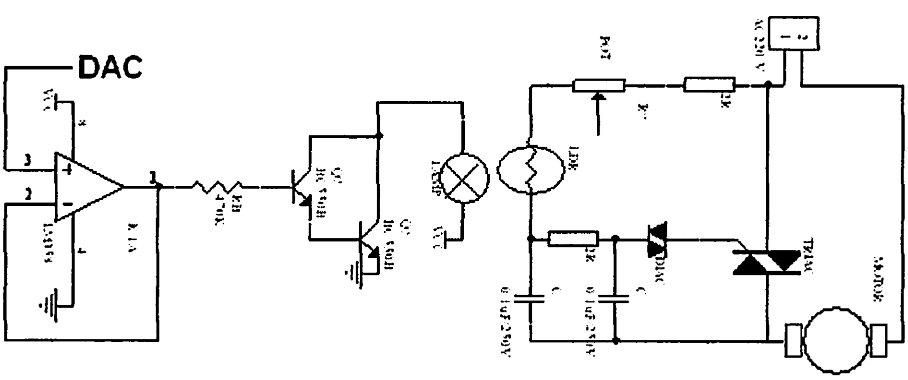
Nilai Skala penuh = $2^8 = 256$

Resolusi= $(\frac{1}{256}).5 = 0.0039$ Volt

JIka diamati DAC 8 Bit memiliki resolusi lebih kecil daripada DAC 4 BIT Hal ini berarti jika tegangan reverensi diberikan 5 volt akan memiliki kenaikan sebesar 0.0039 volt per bit sedangkan 4 bit jauh jauh lebih besar kenaikan perbitnya.

3.2.9. Driver Kompresor

Berikut ini adalah gambar dari driver kompresor lihat pada gambar 3.10 :



Gambar 3.10. Driver Kompresor

Output dari DAC mempunyai tegangan maksimal 5 Volt dimana tegangan ini merupakan tegangan input driver lampu. Tegangan ini dilewatkan lebih dahulu ke rangkaian buffer LM358 yang diaplikasikan sebagai rangkaian pengikut tegangan (Voltage Folower). Dimana tegangan outputnya :

Vin=Vout

Didalam internal satu IC LM 358 ini memiliki dua buah rangkaian op-amp yang mana pada aplikasinya hanya dipakai satu buah op-amp yang kemudian keluaran dari IC ini diinputkan ke basis transistor untuk mengaktifkan transistor. Diketahui dari gambar rangkaian diatas keluaran dari DAC masuk ke basis transistor penguat darlington BC550 dan BC547 dengan penguatan *Hfe* ß=ß1.ß2 dimana terlebih dahulu melewati Rb yang digunakan untuk mengontrol cahaya pada lampu DC. Untuk menghitung analisa rangkaian driver kompresor adalah sebagai berikut :

Dari data sheet transistor BC550 dan BC 547 diperoleh :

- Hfe : 110 (BC550) ;110 (BC547)
- Vcc :12 V
- IC :100mA (BC550 dan BC547)
- VBE :0.7 V

Untuk arus yang mengalir pada basis (Ib) :

$$Ib = \frac{Ic}{Hfe}$$

$$= \frac{100mA}{110*110} = 8.26 \text{ uA}$$

Maka nilai Rb dapat dicari :

$$Rb = \frac{VB - 2.Vbe}{Ib}$$

$$Rb = \frac{5v - 2*0.7V}{8.26uA}$$

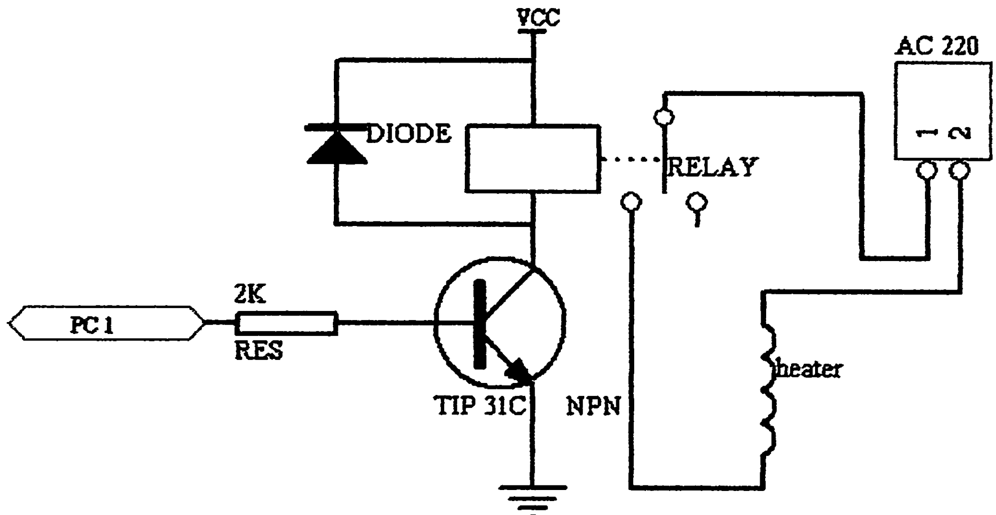
$$= 435.835\ K\Omega$$

Pada aplikasinya nilai resistansi diatas tidak terdapat dipasaran oleh karena itu untuk mendapatkan nilai resistansi yang mendekati nilai Rb diatas Rb dipasang 440 KΩ

Pada rangkaian gambar 3.10. terdapat rangkaian peredup lampu Dimmer Lamp yang menggunakan diac triac Q40006LT prinsip kerjanya jika cahaya lampu dc jatuh pada sensor cahaya LDR berada pada harga terendahnya (cahaya yang jatuh pada lDR besar kapasitor C1 mengisi muatan dengan cepat pada permulaan masing masing setengah siklus tegangan AC. Jika tegangan antara C1 mencapai tegangan lebih triac (over) dari diac maka C1 mengosongkan muatan pada gerbang triac jadi triac hidup lebih awal pada setengah siklus dan mempertahankan kondisi sampai setengah siklus berikutnya oleh karena itu arus akan mengalir pada kompresor untuk sebagian besar dari setengah siklus diac dan menghasilkan kecerahan yang penuh saat tahanan sensor cahaya LDR naik (cahaya yang jatuh pada LDR rendah) waktu yang diperlukan untuk mengisi C1 sampai tegangan breakover dari diac bertambah, hal ini menyebabkan triac menyala kemudian pada setiap setengah siklus. Sehingga panjang waktu arus mengalir pada lampu menjadi berkurang dan cahaya yang dipancarkan menjadi berkurang

3.2.10. Driver Heater

Rangkaian driver untuk pemanas ditunjukan pada gambar berikut :



Gambar 3.11. Rangkaian Driver Heater

Heater akan bekerja jika mendapat perintah dari sistem utama mikrokontroller yang mendapat masukan/input dari remote kontrol yang diterimaIR receiver. Sebagai driver untuk heater digunakan transistor dengan tipe TIP 31 dimana besar tahanan Rb yang diperlukan jika tegangan keluaran dari mikro (VH) =5 Volt adalah

Dari data sheet transistor

- TIP31 dengan hfe 50
- Rrelay = 400 Ω
- Vcc = 12 V

$$I\ relay = \frac{Vcc}{Rrelay}$$

$$= \frac{12}{400}$$

$= 30\ mA$

Maka pada saat jenuh (saturation) besar arus Ib total adalah :

$$Ib\ total = \frac{IC}{hfe}$$

$$= \frac{30.10^{-3}}{50} = 0{,}6\ mA$$

Dengan demikian besar tahanan RB yang diperlukan jika VH = 5 V,VBE =0,7 V(hasil pengukuran) adalah :

$$RB = \frac{Vcc - Vbe}{IB}$$

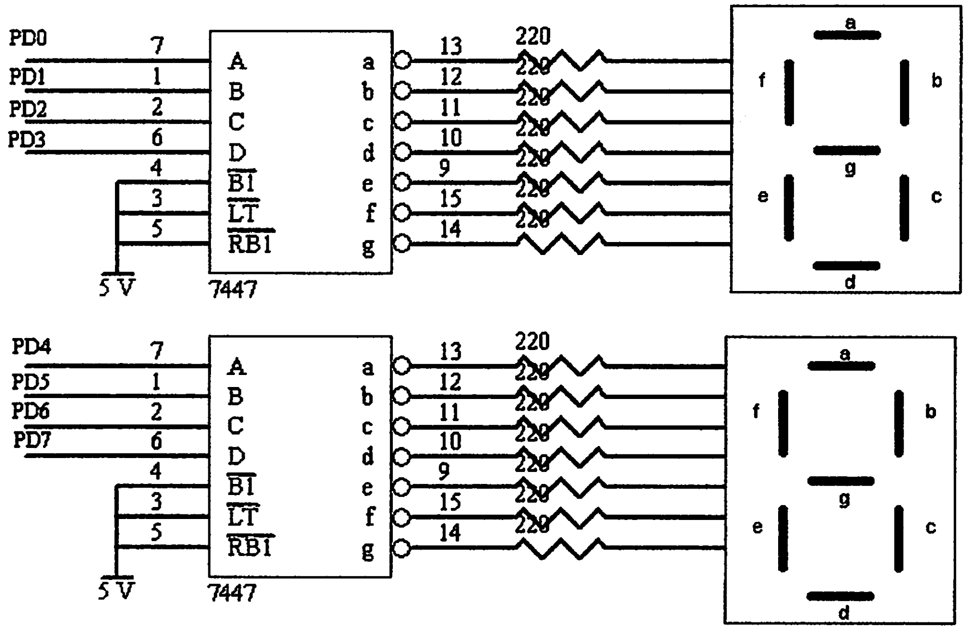
$$= \frac{12V - 0{,}7V}{0{,}6.10^{-3}}$$

$$= 18{,}83\ K\Omega$$

Pada aplikasinya nilai resistansi diatas tidak terdapat dipasaran sehingga dipasang resistor yang mendekati yaitu 20 KΩ.

3.2.11. Display Seven Segment

Display atau penampil adalah alat peraga yang dapat menampilkan informasi bilangan desimal atau diterjemahkan. Pada seven-segment digunakan tujuh buah ruas yang berasal dari LED yang disusun sedemikian rupa membentuk angka delapan berupa garis-garis lurus. Dengan demikian ruas-ruas tersebut akan menyala secara simultan dengan menunjukkan angka-angka tertentu dari angka 0 sampai angka 9.



Gambar 3.12. Display Seven Segment

Ada dua jenis penyambungan kaki-kaki dioda yang membentuk seven segment, yaitu common anoda dan common katoda. Dalam Tugas Akhir ini dipergunakan Seven segment jenis common anoda.

Sebelum menuju ke segment-segment biasanya diberi tahanan dengan nilai tertentu yang bertujuan agar segment-segment pada seven segment tidak mudah rusak. Tahanan tersebut ditentukan denagn menggunakan rumus sebagai berikut :

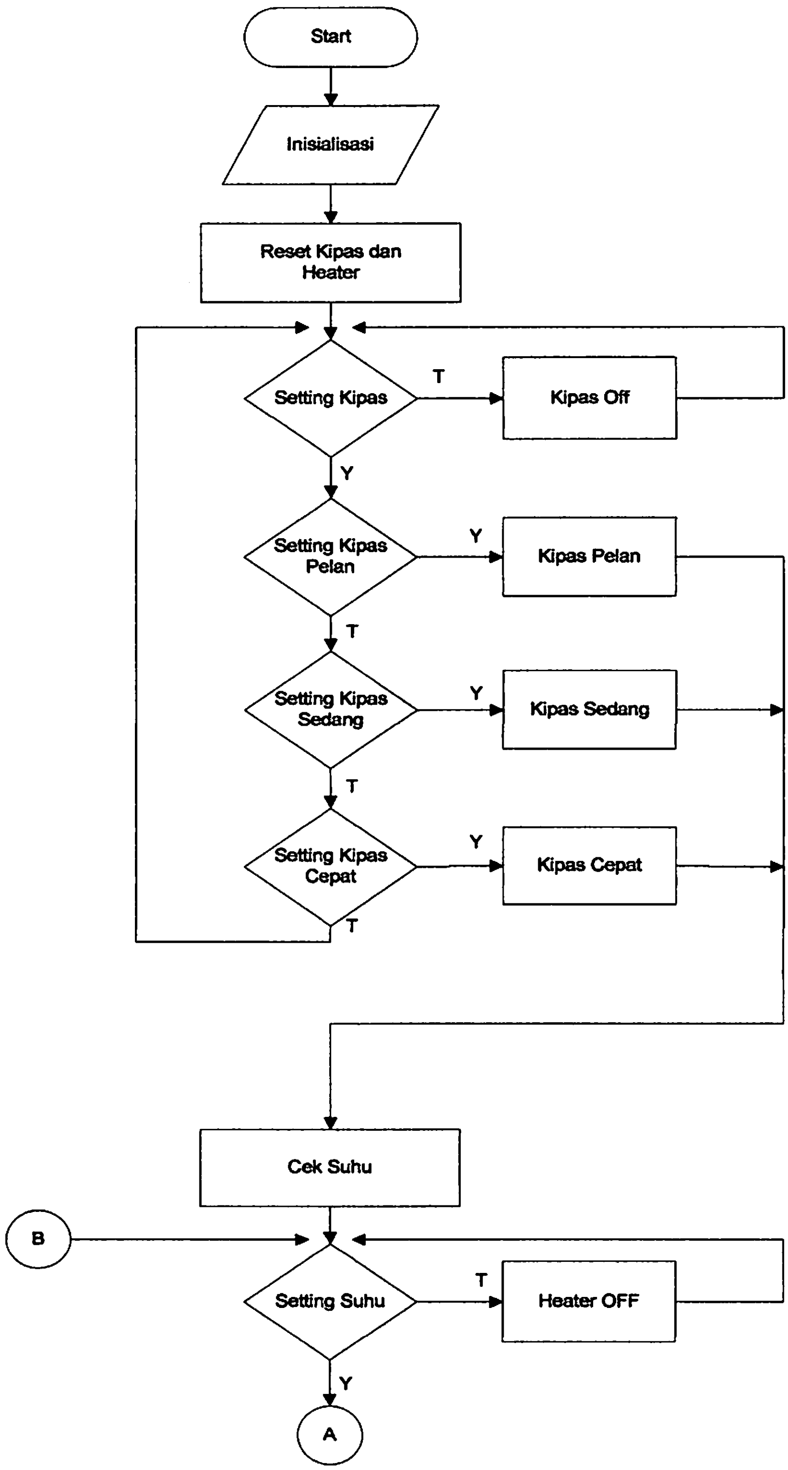
$$R = \frac{V - Vdioda}{I}$$

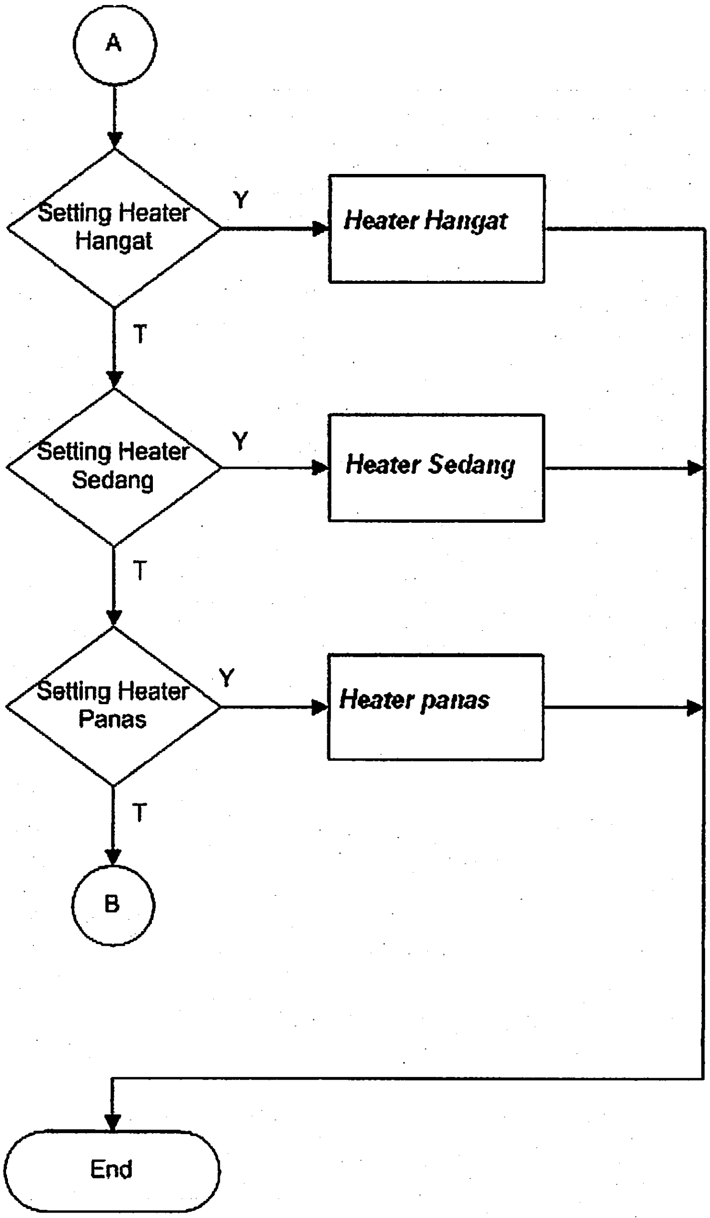
Arus yang mengalir melalui LED direncanakan sebesar 15μA sehingga LED menyala pada status aman, Tegangan LED (Vdioda) adalah 1,5V dan tegangan sumber VCC adalah 5V.

$$R = \frac{5V - 1{,}5V}{15uA} = 233{,}33\ \Omega$$

Sehingga resistor pengamannya adalah 220 Ω.

FLOW CHART ALAT PENGATUR GELEMBUNG UDARA PADA MANDI




A
Setting Heater Hangat
Y
Heater Hangat
T
Setting Heater Sedang
Y
Heater Sedang
T
Setting Heater Panas
Y
Heater panas
T
B
End

BAB IV

PENGUJIAN ALAT

4.1. Tujuan

Pada bab ini akan dibahas tentang pengujian alat yang telah dirancang dengan tujuan agar antar perancangan dan pembuatan sesuai dengan hasil keperluan yang ada. Dipandang dari segi perancangan perangkat keras maupun perangkat lunak dapat sesuai dengan kondisi yang diinginkan. Dengan diadakan pengujian alat, maka pada tugas akhir ini dapat membuktikan bahwa alat yang dirancang dapat berjalan sesuai dengan kondisi masukan yang ada, sehingga memberikan keluaran yang sesuai pula. Untuk mengetahui kemampuan dan sistem kerja alat sesuai dengan perancangan maka dilakukan pengujian pada alat dan sistem kerja alat, dimana prosedur pengujian meliputi pengujian perangkat keras.

4.2. Pengujian Hardware

Pengujian perangkat keras ini mencakup pengujian rangkaian elektronika pada masing – masing blok maupun blok secara keseluruhan yang telah dirancang dengan menggunakan multimeter digital.

4.2.1. Pengujian Sensor

Untuk pengujian sensor suhu dilakukan beberapa kali untuk memperkecil kesalahan mengingat adanya kemungkinan penyimpangan data dengan teori, karena suhu diamati cenderung berubah – ubah.

4.2.1.1. Pengujian Sensor Suhu

Peralatan yang digunakan dalam pengujian adalah sebagai berikut :

a. Multimeter Digital

b. Termometer

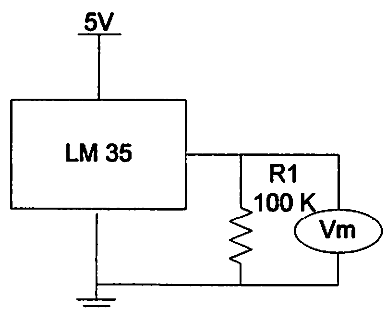
c. Sumber Catu Daya 5 VDC dan 12 VDC

4.2.1.2. Prosedur Pengujian

a. Menyusun rangkaian sesuai gambar 4.1

b. Mengamati dan mencatat nilai tegangan keluaran yang dihasilkan

Sensor suhu yang digunakan adalah LM35 yang diberi tegangan suplay 5 V Dc. Penggunaan resistor dengan nilai 100KΩ sebagai kalibrasi antara tegangan supalay dengan tegangan output sensor, dikana hal ini mengindikasikan bahwa sensor digunakan pada range antara -55°C-150°C seperti pada gambar 4.1.



Gambar 4.1. Rangkaian Pengujian Sensor Suhu

Pada pengujian yang dilakukan batas range awal pada suhu 28°C-50°C didapatkan tegangan yang bervariasi mulai 0,284 V sampai dengan 0,49 V. Dimana besarnya kenaikan tegangan pada IC LM35 tanpa penguatan adalah ±10mV/°C.

Sehingga :

V_{out} = Suhu (°C)x10mV

Dari rumus diatas maka didapatkan perbandingan hasil pengukuran dengan hasil perhitungan tegangan keluaran sensor suhu tanpa penguatan seperti terliha pada tabel 4.1.

TABEL 4-1.
HASIL PENGUKURAN DAN PERHITUNGAN TEGANGAN SENSOR SUHU

NO	*SUHU °C*	*HASIL PENGUKURAN Volt*	*HASIL PERHITUNGAN Volt*
1	28	0.280	0.28
2	30	0.289	0.30
3	31	0.295	0.31
4	32	0.301	0.32
5	33	0.309	0.33
6	34	0.319	0.34
7	35	0.331	0.35
8	36	0.345	0.36
9	37	0.361	0.37
10	38	0.367	0.38
11	39	0.377	0.39
12	40	0.386	0.40
13	42	0.405	0.42
14	44	0.428	0.44
15	46	0.443	0.46
16	48	0.467	0.48
17	50	0.489	0.50

Sedangkan pada tabel 4.2 merupakan tabel hasil pengukuran dan hasil perhitungan sensor suhu beserta hasil penguatan dari rangkaian supervisi, dimana penguatan sebesar 3.3 kali

TABEL 4.2
Hasil Pengukuran Dan Perhitungan Tegangan Sensor Suhu Beserta Penguatan

NO	*SUHU* (*° C*)	*HASIL PENGUKURAN* (*Volt*)	*HASIL PERHITUNGAN* (*Volt*)	*HASIL PENGUKURAN PENGUATAN* (*Kali*)
1	28	0.280	0.28	0.84
2	30	0.289	0.30	0.90
3	31	0.295	0.31	0.93
4	32	0.301	0.32	0.96
5	33	0.309	0.33	0.99
6	34	0.319	0.34	1.02
7	35	0.331	0.35	1.05
8	36	0.345	0.36	1.08
9	37	0.361	0.37	1.11
10	38	0.367	0.38	1.14
11	39	0.377	0.39	1.17
12	40	0.386	0.40	1.20
13	42	0.405	0.42	1.26
14	44	0.428	0.44	1.32
15	46	0.443	0.46	1.38
16	48	0.467	0.48	1.44
17	50	0.489	0.50	1.50

Gambar 4.2. Hasil Pengujian Penguatan

4.2.2. Pengujian DAC (Digital to Analog Converter)

Dalam pengujian rangkaian DAC model tangga R-2R, menggunakan input berupa data biner untuk mendapatkan output berupa tegangan analog.

4.2.2.1. Peralatan Yang Digunakan

a. Multimeter Digital

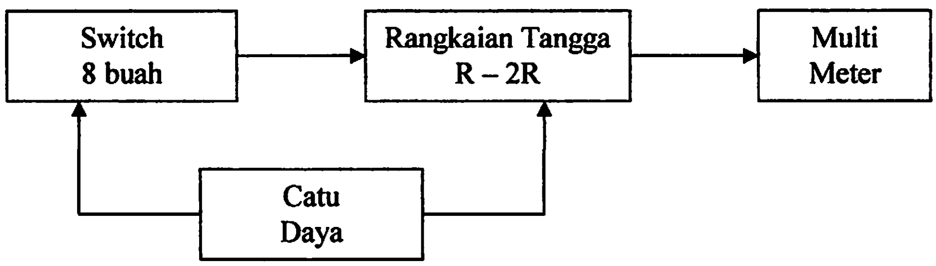
b. Sumber Catu Daya 5 VDC dan 12 VDC

c. Switch 8 buah

d. Rangkaian Tangga R – 2R

4.2.2.2. Prosedur Pengujian

a. Menyusun urutan peralatan seperti pada diagram blok rangkaian sesuai gambar 4.3.



Gambar 4.3. Diagram Blok Pengujian DAC

b. Switch 8 buah tersebut digunakan untuk memberikan inputan 8 bit.

c. Mengamati dan mencatat nilai tegangan keluaran yang dihasilkan

4.2.2.3. Hasil Pengujian DAC

Hasil dari bermacam-macam input biner seperti terlihat pada tabel 4.4.

TABEL 4.4.
HASIL PENGUKURAN DARI RANGKAIAN DAC R-2R

INPUT DIGITAL								*Pengukuran Tegangan (Volt)*	*Nilai Hexa*
D7	*D6*	*D5*	*D4*	*D3*	*D2*	*D1*	*D0*		
0	0	0	0	0	0	0	0	0.34	00
0	0	0	0	0	0	1	1	0.36	03
0	0	0	0	0	1	0	1	0.41	05
0	1	0	0	1	0	1	0	1.5	4A
1	0	0	0	0	0	0	0	2.4	80
1	0	1	0	0	0	1	1	3.01	A3
1	1	0	1	0	1	1	1	4.01	D7
1	1	1	1	1	1	1	1	4.92	FF

4.2.3. Pegujian Rangkaian Driver Heater

Dalam pengujian rangkaian driver heater, untuk mengetahui apakah heater bekerja dengan baik.

4.2.3.1. Peralatan Yang Digunakan

a. Multimeter

b. Rangkaian Driver Heater

c. Catu Daya

4.2.3.2. Prosedur Pengujian

a. Menyusun urutan peralatan seperti pada diagram blok rangkaian sesuai gambar 4.3.

Gambar 4.4.
Blok Diagram Pengujian Rangkaian Heater
Sumber : Perancangan

b. Pada basis transistor rangkaian diberikan tegangan, kemudian keluaran kolektor transistor diukur dengan voltmeter.

4.2.3.3. Hasil Pengujian Driver Heater

Tabel 4.5.
Hasil Pengukuran Rangkaian Heater

Level	V in (V)	V out (V)	Keterangan Lampu DC	Keterangan Heater
I	0.85	1.65	Redup	Hangat
II	1.51	1.76	Sedang	Agak Panas
III	3.72	1.85	Terang	Panas

Dengan melihat hasil tabel diatas bisa didapat bahwa semakim bertambah tahanan maka maka nyala lampu DC akan semakin terang, keadaan lampu DC yang terang membuat LDR pada dimmer lamp mencapai tahanan rendahnya, sehingga tegangan yang menuju kawat nikelin/heater menjadi besar.

BAB V

PENUTUP

5.1. Kesimpulan

Setelah melakukan perencanaan dan pembuatan alat pengatur gelembung udara untuk mandi spa dengan menggunakan mikrokontroller AT Mega 8535. Maka pada bab ini diberikan kesimpulan :

a. Pada pengujian sensor suhu dimana pada pemgujian diambil data suhu antara 28°C sampai 50°C diperoleh range tegangan keluaran sebesar 0.280 Volt sampai 0.489 Volt dengan kesalahan relative yang terjadi rata rata 3.77 %.

b. Dari hasil pengujian DAC dimana percobaan dengan nilai data 00H-FFH diperoleh range nilai/data analog atau tegangan keluaran sebesar 0.34 Volt - 4.92 Volt dapat disimpulkan bahwa kenaikan nilai digit keluaran dari mikro diikuti pula naiknya nilai data analog setelah dikonversi oleh DAC sebagai masukan untuk rangkaian driver.

c. Pada pengujian driver heater disimpulkan bahwa nilai tegangan output (1.65 V, 1.76 V, 1.85 V) yang mengalir pada lampu DC menyala dari redup, sedang, terang. Dimana keadaan lampu DC akan diterima LDR pada dimmer lamp yang menyebabkan tegangan mengalir pada kawat nikelin sehingga menimbulkan kondisi hangat, agak panas dan panas.

5.2. Saran-saran

Untuk pengembangan lebih lanjut yang memungkinkan penyempurnaan alat ini untuk dapat dilakukan sesuai kebutuhan baik penerapan maupun perluasan sistemnya.

Akan lebih bermanfaat lagi jika alat ini dilengkapi dengan sensor suhu yang lebih bagus lagi.

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LAMPIRAN

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FAKULTAS TEKNOLOGI INDUSTRI
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JL.Raya Karanglo Km. 2
Malang

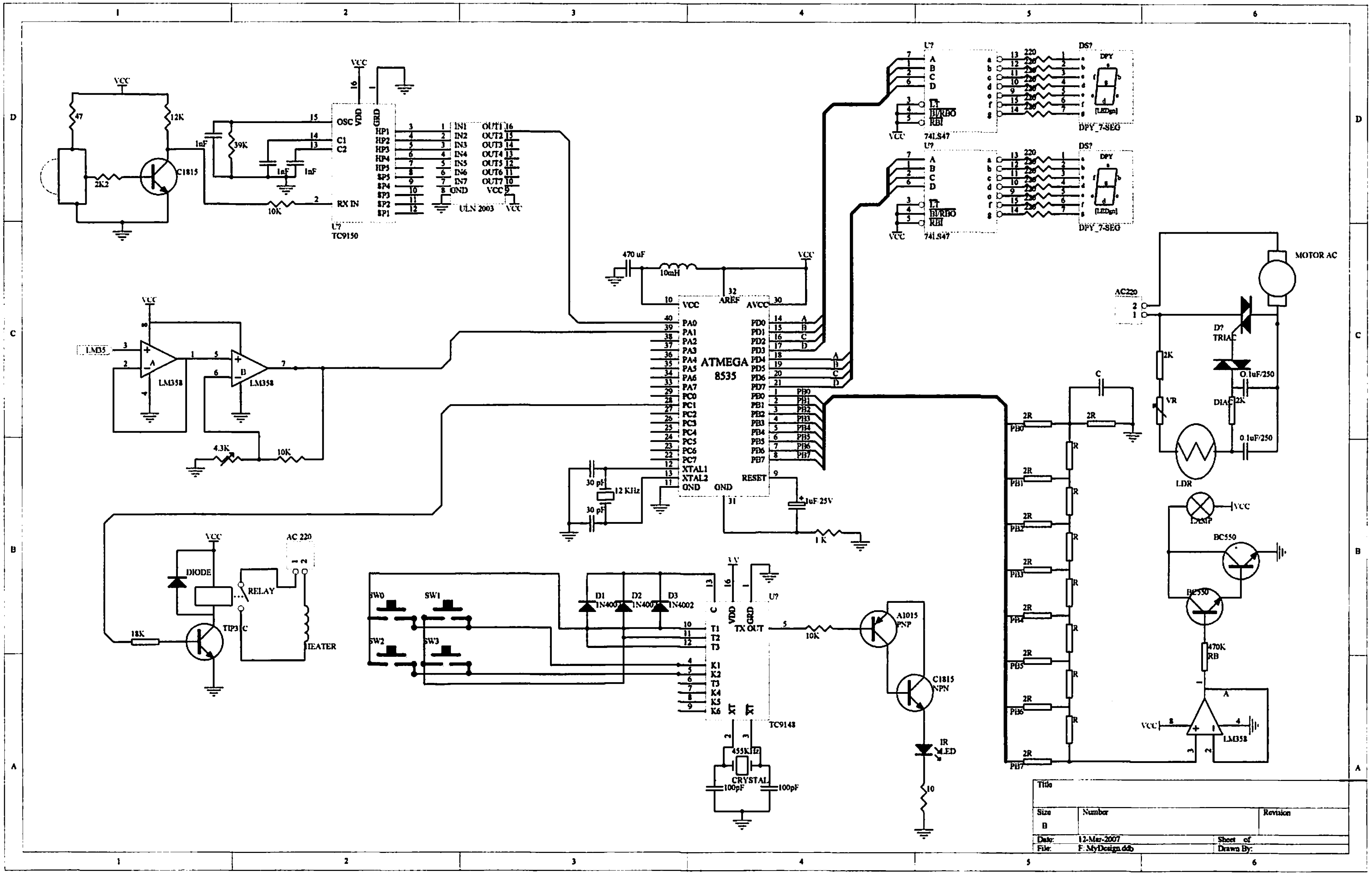
FORMULIR BIMBINGAN SKRIPSI

Nama : Andri Bayu Zusanto
Nim : 99.17.250
Masa Bimbingan : 15 Agustus 2006 s/d 15 Februari 2007
Judul Skripsi : Perencanaan dan Pembuatan Alat Pengatur Gelembung Udara Untuk Mandi Spa Berbasis Mikrokontroler Atmega 8535

No.	Tanggal	Uraian	Paraf Pembimbing
1	23-09-2006	Bab I, II, III	
2	02-10-2006	Revisi Blok Diagram	
3	07-12-2006	Acc. Bab I, II, III,	
4	14-12-2006	Bab IV, V	
5	10-01-2007	Revisi Pengujian	
6	15-01-2007	Revisi Perhitungan Analisa	
7	02-02-2007	Acc. Makalah Seminar	
8	08-03-2007	Maju Acc. Seminar Hasil	
9	09-03-2007	Revisi Seminar Hasil	
10	13-03-2007	Acc. Maju Ujian Skripsi	

Malang, Maret 2007
Dosen Pembimbing I

Ir. Eko Nurcahyo
NIP.Y. 102 870 0172


ATMEGA
8535
VCC
AREF
AVCC
RESET
GND
XTAL1
XTAL2
470 uF
10mH
1uF 25V
1 K
30 pF
12 KHz
TC9150
ULN 2003
TC9148
74LS47
DPY_7-SEG
LM35
LM358
4.3K
10K
C1815
2K2
12K
47
39K
1nF
MOTOR AC
AC220
D? TRIAC
DIAC
0.1uF/250
VR
LDR
LAMP
BC550
470K RB
A1015 PNP
C1815 NPN
IR LED
455KHz
CRYSTAL
100pF
D1
D2
D3
1N4002
SW0
SW1
SW2
SW3
AC 220
RELAY
HEATER
DIODE
TIP31C
18K
Title
Size
B
Number
Revision
Date: 12-Mar-2007
File: F: MyDesign.ddb
Sheet of
Drawn By:

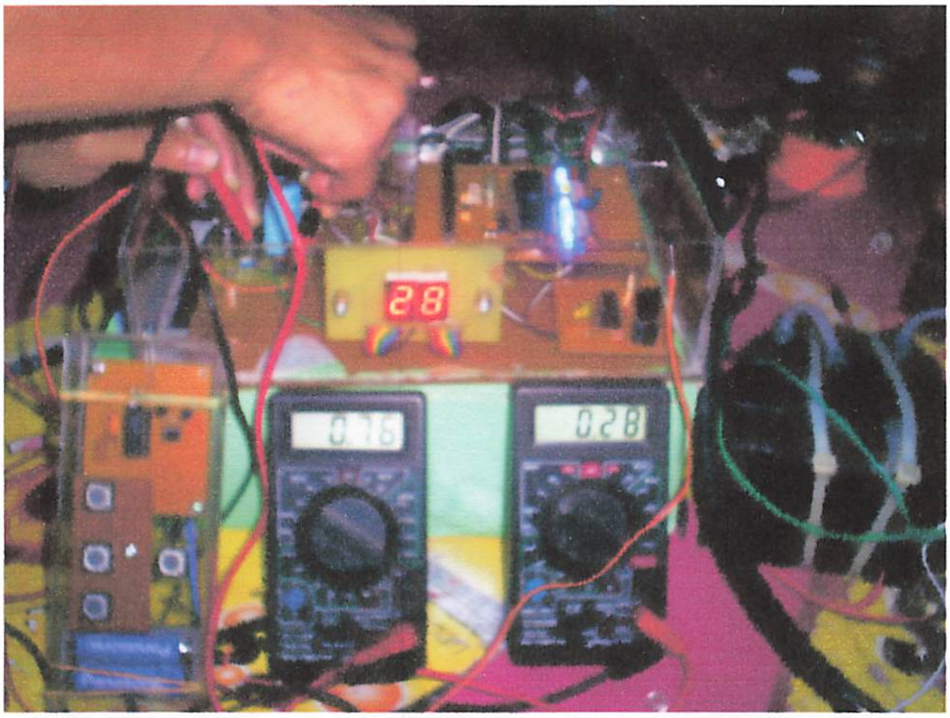


FOTO PENGUJIAN PENGUATAN

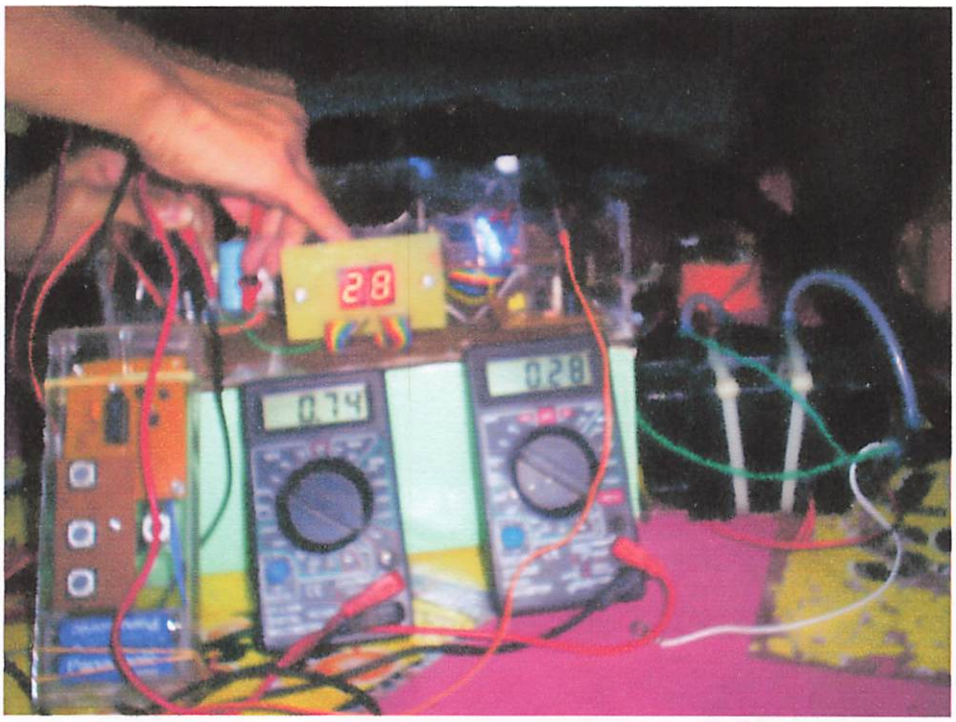


FOTO ALAT KESELURUHAN

```
/*****************************************************
This program was produced by the
CodeWizardAVR V1.24.7d Evaluation
Automatic Program Generator
© Copyright 1998-2005 Pavel Haiduc, HP InfoTech s.r.l.
http://www.hpinfotech.com
e-mail:office@hpinfotech.com

Project :
Version :
Date    : 2/27/2007
Author  : Freeware, for evaluation and non-commercial use only
Company :
Comments:


Chip type           : ATmega8535
Program type        : Application
Clock frequency     : 4.000000 MHz
Memory model        : Small
External SRAM size  : 0
Data Stack size     : 128
*****************************************************/

#include <mega8535.h>

#define ADC_VREF_TYPE 0x20
#define D_PIN1  PINC.0
#define D_PIN2  PINC.1
#define D_PIN3  PINC.2
#define D_PIN4  PINC.3
#define RELAY   PORTA.4
#define PILIHAN1    PORTA.5
#define PILIHAN2    PORTA.6
#define PILIHAN3    PORTA.7
#include <delay.h>
unsigned char adc_data;
unsigned int temp;
unsigned int temp1;
unsigned int temp2;
unsigned int tam;
// ADC interrupt service routine
interrupt [ADC_INT] void adc_isr(void)
{
//unsigned char adc_data;
adc_data=ADCH;
```

```
ADCSRA|=0x40;

//if (adc_data < 0x0f)
// {PORTD.6 = 1;}
 //else
// PORTD.6 =0;
//PORTB = adc_data;

}
void waktuu(void)
{

         if((adc_data==ADCH)&(adc_data>0x00))

         {

        tam = adc_data;/*
        temp=((tam/100)&0x0f)|0x00;
        if (temp> 0x09)temp=temp+7;

        temp1=(((tam%100)/10)&0x0f)|0x00;
        if (temp1> 0x09)temp1=temp1+7;

        temp2=(((tam%100)%10)&0x0f)|0x00;
        if (temp2> 0x09)temp2=temp2+7;*/
              if (tam<0x01)
                {
                 PORTB = 0x00;
                }else
                if (tam<0x02)
                {
                 PORTB = 0x01;
                }else
                if (tam<0x04)
                {
                 PORTB = 0x02;
                }else
                if (tam<0x06)
                {
                 PORTB = 0x03;
                }else
                if (tam<0x08)
                {
                 PORTB = 0x04;
                }else
                if (tam<0x0A)
```

```
{
 PORTB = 0x05;
}else
if (tam<0x0C)
{
 PORTB = 0x06;
}else
if (tam<0x0D)
{
 PORTB = 0x07;
}else
if (tam<0x0F)
{
 PORTB = 0x08;
}else
if (tam<0x10)
{
 PORTB = 0x09;
}else
if (tam<0x12)
{
 PORTB = 0x10;
}else
if (tam<0x13)
{
 PORTB = 0x11;
}else
if (tam<0x14)
{
 PORTB = 0x12;
}else
if (tam<0x15)
{
 PORTB = 0x13;
}else
if (tam<0x16)
{
 PORTB = 0x14;
}else
if (tam<0x17)
{
 PORTB = 0x15;
}else
if (tam<0x18)
{
 PORTB = 0x16;
```

```
}else
if (tam<0x19)
{
 PORTB = 0x17;
}else
if (tam<0x1A)
{
 PORTB = 0x18;
}else
if (tam<0x1B)
{
 PORTB = 0x19;
}else
if (tam<0x1C)
{
 PORTB = 0x20;
}else
if (tam<0x1D)
{
 PORTB = 0x21;
}else
if (tam<0x1F)
{
 PORTB = 0x22;
}else
if (tam<0x20)
{
 PORTB = 0x23;
}else
if (tam<0x21)
{
 PORTB = 0x24;
}else
if (tam<0x22)
{
 PORTB = 0x25;
}else
if (tam<0x23)
{
 PORTB = 0x26;
}else
if (tam<0x24)
{
 PORTB = 0x27;
}else
if (tam<0x25)
```

```
{
 PORTB = 0x28;
}else
if (tam<0x26)
{
 PORTB = 0x29;
}else
if (tam<0x27)
{
 PORTB = 0x30;
}else
if (tam<0x28)
{
 PORTB = 0x31;
}else
if (tam<0x29)
{
 PORTB = 0x32;
}else
if (tam<0x2A)
{
 PORTB = 0x33;
}else
if (tam<0x2B)
{
 PORTB = 0x34;
}else
if (tam<0x2C)
{
 PORTB = 0x35;
}else
if (tam<0x2D)
{
 PORTB = 0x36;
}else
if (tam<0x2F)
{
 PORTB = 0x37;
}else
if (tam<0x30)
{
 PORTB = 0x38;
}else
if (tam<0x31)
{
 PORTB = 0x39;
```

```
}else
if (tam<0x32)
{
 PORTB = 0x40;
}else
if (tam<0x33)
{
 PORTB = 0x41;
}else
if (tam<0x34)
{
 PORTB = 0x42;
}else
if (tam<0x35)
{
 PORTB = 0x43;
}else
if (tam<0x36)
{
 PORTB = 0x44;
}else
if (tam<0x37)
{
 PORTB = 0x45;
}else
if (tam<0x38)
{
 PORTB = 0x46;
}else
if (tam<0x39)
{
 PORTB = 0x47;
}else
if (tam<0x3A)
{
 PORTB = 0x48;
}else
if (tam<0x3B)
{
 PORTB = 0x49;
}else
if (tam<0x3C)
{
 PORTB = 0x50;
}else
if (tam<0x3D)
```

```
{
 PORTB = 0x51;
}else
if (tam<0x3F)
{
 PORTB = 0x52;
}else
if (tam<0x40)
{
 PORTB = 0x53;
}else
if (tam<0x41)
{
 PORTB = 0x54;
}else
if (tam<0x42)
{
 PORTB = 0x55;
}else
if (tam<0x43)
{
 PORTB = 0x56;
}else
if (tam<0x44)
{
 PORTB = 0x57;
}else
if (tam<0x45)
{
 PORTB = 0x58;
}else
if (tam<0x46)
{
 PORTB = 0x59;
}else
if (tam<0x47)
{
 PORTB = 0x60;
} else
if (tam<0x48)
{
 PORTB = 0x61;
}else
if (tam<0x49)
{
 PORTB = 0x62;
```

```
}else
if (tam<0x4A)
{
 PORTB = 0x63;
}else
if (tam<0x4B)
{
 PORTB = 0x64;
}else
if (tam<0x4C)
{
 PORTB = 0x65;
}else
if (tam<0x4D)
{
 PORTB = 0x66;
}else
if (tam<0x4F)
{
 PORTB = 0x67;
}else
if (tam<0x50)
{
 PORTB = 0x68;
}else
if (tam<0x51)
{
 PORTB = 0x69;
}else
if (tam<0x52)
{
 PORTB = 0x70;
}else
if (tam<0x53)
{
 PORTB = 0x71;
}else
if (tam<0x54)
{
 PORTB = 0x72;
}else
if (tam<0x55)
{
 PORTB = 0x73;
}else
if (tam<0x56)
```

```
{
 PORTB = 0x74;
}else
if (tam<0x57)
{
 PORTB = 0x75;
}else
if (tam<0x58)
{
 PORTB = 0x76;
}else
if (tam<0x59)
{
 PORTB = 0x77;
}else
if (tam<0x5A)
{
 PORTB = 0x78;
}else
if (tam<0x5B)
{
 PORTB = 0x79;
}else
if (tam<0x5C)
{
 PORTB = 0x80;
}else
if (tam<0x5D)
{
 PORTB = 0x81;
}else
if (tam<0x5F)
{
 PORTB = 0x;
}else
if (tam<0x60)
{
 PORTB = 0x82;
}else
if (tam<0x61)
{
 PORTB = 0x83;
}else
if (tam<0x62)
{
 PORTB = 0x84;
```

```
}else
if (tam<0x63)
{
 PORTB = 0x85;
}else
if (tam<0x64)
{
 PORTB = 0x86;
}else
if (tam<0x65)
{
 PORTB = 0x87;
}else
if (tam<0x66)
{
 PORTB = 0x89;
}else
if (tam<0x67)
{
 PORTB = 0x90;
}else
if (tam<0x68)
{
 PORTB = 0x91;
}else
if (tam<0x69)
{
 PORTB = 0x92;
}else
if (tam<0x6A)
{
 PORTB = 0x93;
}else
if (tam<0x6B)
{
 PORTB = 0x94;
}else
if (tam<0x6C)
{
 PORTB = 0x95;
}else
if (tam<0x6D)
{
 PORTB = 0x96;
}else
if (tam<0x6F)
```

```
                {
                 PORTB = 0x97;
                }else
                if (tam<0x70)
                {
                 PORTB = 0x98;
                }else
                if (tam<0x71)
                {
                 PORTB = 0x99;
                }


 }
 }
 void waktuu1(void)
{

        if((adc_data==ADCH)&(adc_data>0x00))

        {
       temp2 = adc_data;

       if (temp2 <= temp1)
       {
       RELAY = 1;
     RELAY = 1;
        } else
       if (temp2 >= temp1)
       {
       RELAY = 0;
     RELAY = 0;
        }
        }
}


void main(void)
{

PORTA=0x00;
DDRA=0xf0;
PORTB=0xFF;
DDRB=0xff;
//PORTC=0x00;
//DDRC=0x00;
```

```
PORTD=0x00;
DDRD=0xFF;
TCCR0=0x00;
TCNT0=0x00;
OCR0=0x00;
TCCR1A=0x00;
TCCR1B=0x00;
TCNT1H=0x00;
TCNT1L=0x00;
ICR1H=0x00;
ICR1L=0x00;
OCR1AH=0x00;
OCR1AL=0x00;
OCR1BH=0x00;
OCR1BL=0x00;
ASSR=0x00;
TCCR2=0x00;
TCNT2=0x00;
OCR2=0x00;
MCUCR=0x00;
MCUCSR=0x00;

TIMSK=0x00;

ACSR=0x80;
SFIOR=0x00;

ADMUX=0x60;
ADCSRA=0x8E;

#asm("sei")
ADCSRA|=0x40;

while (1)
    {
 if ( D_PIN1==1)
  {
  temp = 0x03;
  }
  else
if ( D_PIN2==1)
  {
  temp = 0x02;
  }
  else
if ( D_PIN3==1)
```

```
  {
  temp = 0x04;
  }
  else
if ( D_PIN4==1)
  {
  temp = 0x05;
  }
  else
if ( temp == 0x03)
  {
   PORTD = 0x0A;
   temp1 = 0x27;
   PILIHAN1 = 1 ;
    PILIHAN2 = 0 ;
    PILIHAN3 = 0 ;
   waktuu();
   waktuu1();
  }
   else
if ( temp == 0x02)
  {
  PORTD = 0x5F;
  temp1 = 0x32;
   PILIHAN2 = 1 ;
    PILIHAN1 = 0 ;
    PILIHAN3 = 0 ;
   waktuu();
   waktuu1();
   }
   else
if ( temp == 0x04)
  {
   PORTD = 0xFF;
   temp1 = 0x3C;
   PILIHAN1 = 0 ;
    PILIHAN2 = 0 ;
    PILIHAN3 = 1 ;
   waktuu();
   waktuu1();
  }
  else
if ( temp == 0x05)
  {
   PORTD = 0x00;
   temp1 = 0x00;
```

```
    PILIHAN1 = 0 ;
    PILIHAN2 = 0 ;
    PILIHAN3 = 0 ;
    RELAY = 0;
     Waktuu();
   }
     }
}
```

eatures

- High-performance, Low-power AVR® 8-bit Microcontroller
- Advanced RISC Architecture
  - 130 Powerful Instructions – Most Single Clock Cycle Execution
  - 32 x 8 General Purpose Working Registers
  - Fully Static Operation
  - Up to 16 MIPS Throughput at 16 MHz
  - On-chip 2-cycle Multiplier
- Nonvolatile Program and Data Memories
  - 8K Bytes of In-System Self-Programmable Flash
    Endurance: 10,000 Write/Erase Cycles
  - Optional Boot Code Section with Independent Lock Bits
    In-System Programming by On-chip Boot Program
    True Read-While-Write Operation
  - 512 Bytes EEPROM
    Endurance: 100,000 Write/Erase Cycles
  - 512 Bytes Internal SRAM
  - Programming Lock for Software Security
- Peripheral Features
  - Two 8-bit Timer/Counters with Separate Prescalers and Compare Modes
  - One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
  - Real Time Counter with Separate Oscillator
  - Four PWM Channels
  - 8-channel, 10-bit ADC
    8 Single-ended Channels
    7 Differential Channels for TQFP Package Only
    2 Differential Channels with Programmable Gain at 1x, 10x, or 200x for TQFP Package Only
  - Byte-oriented Two-wire Serial Interface
  - Programmable Serial USART
  - Master/Slave SPI Serial Interface
  - Programmable Watchdog Timer with Separate On-chip Oscillator
  - On-chip Analog Comparator
- Special Microcontroller Features
  - Power-on Reset and Programmable Brown-out Detection
  - Internal Calibrated RC Oscillator
  - External and Internal Interrupt Sources
  - Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby and Extended Standby
- I/O and Packages
  - 32 Programmable I/O Lines
  - 40-pin PDIP, 44-lead TQFP, 44-lead PLCC, and 44-pad QFN/MLF
- Operating Voltages
  - 2.7 - 5.5V for ATmega8535L
  - 4.5 - 5.5V for ATmega8535
- Speed Grades
  - 0 - 8 MHz for ATmega8535L
  - 0 - 16 MHz for ATmega8535

8-bit AVR® Microcontroller with 8K Bytes In-System Programmable Flash

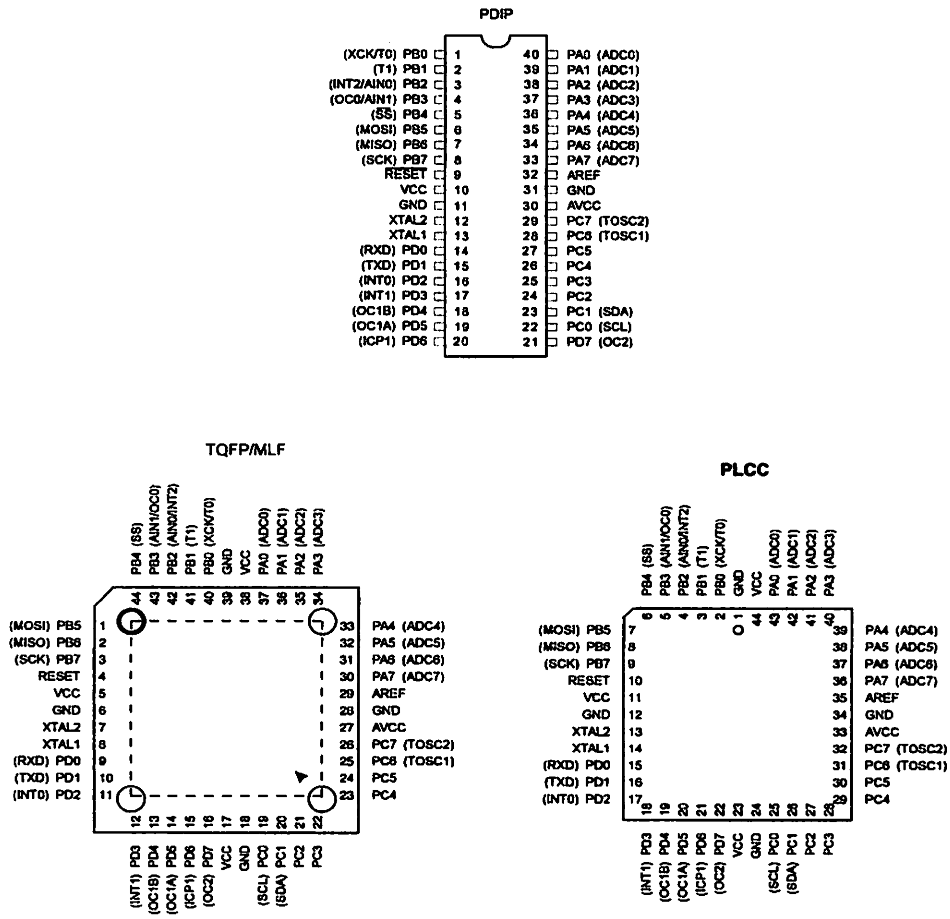
ATmega8535
ATmega8535L

Preliminary Summary

Rev. 2502JS–AVR–08/06

Pin Configurations

Figure 1. Pinout ATmega8535



NOTE: MLF Bottom pad should be soldered to ground.

Disclaimer

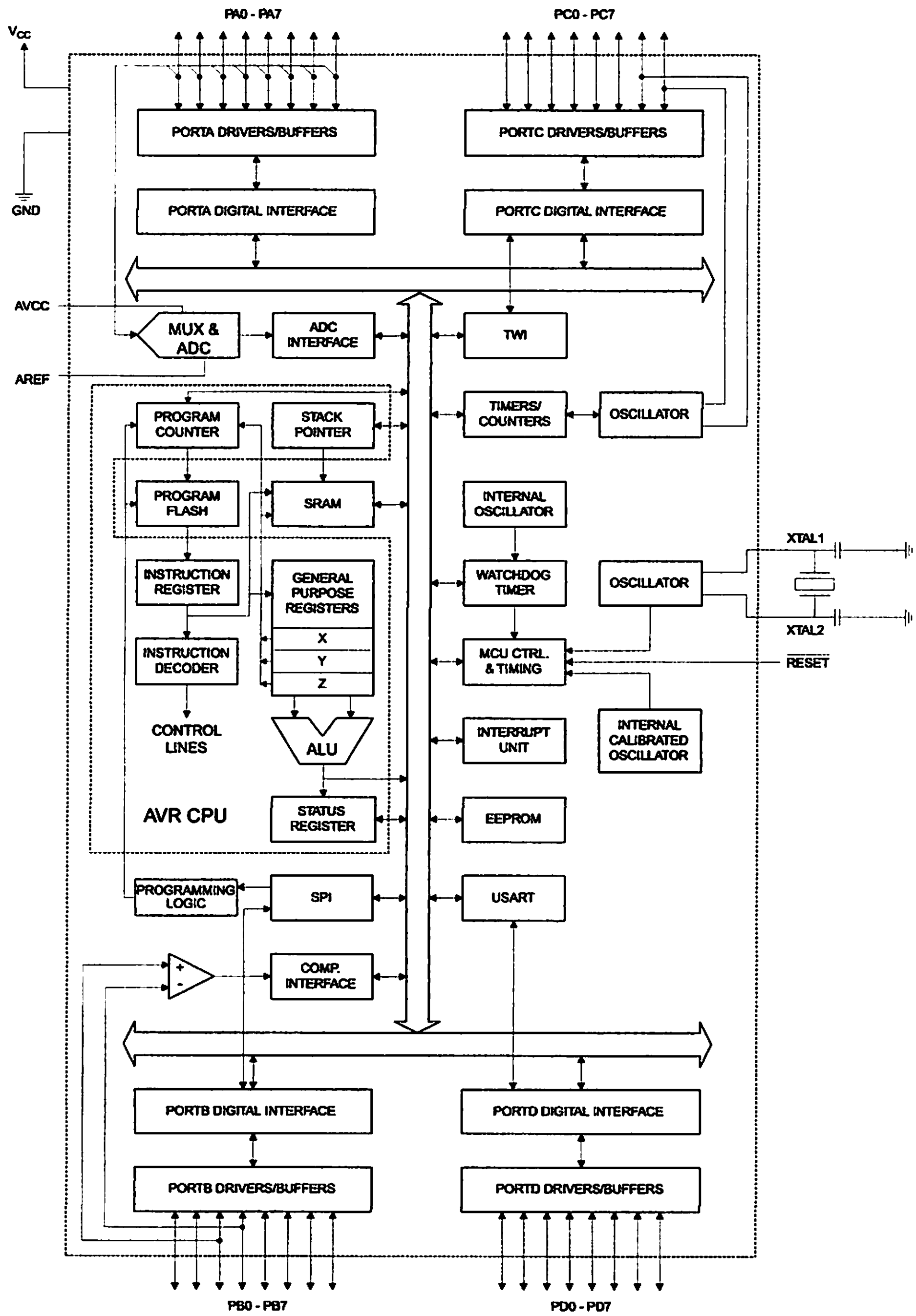
Typical values contained in this data sheet are based on simulations and characterization of other AVR microcontrollers manufactured on the same process technology. Min and Max values will be available after the device is characterized.

Overview

The ATmega8535 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing instructions in a single clock cycle, the ATmega8535 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

Block Diagram

Figure 2. Block Diagram



The AVR core combines a rich instruction set with 32 general purpose working registers. All 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers.

The ATmega8535 provides the following features: 8K bytes of In-System Programmable Flash with Read-While-Write capabilities, 512 bytes EEPROM, 512 bytes SRAM, 32 general purpose I/O lines, 32 general purpose working registers, three flexible Timer/Counters with compare modes, internal and external interrupts, a serial programmable USART, a byte oriented Two-wire Serial Interface, an 8-channel, 10-bit ADC with optional differential input stage with programmable gain in TQFP package, a programmable Watchdog Timer with Internal Oscillator, an SPI serial port, and six software selectable power saving modes. The Idle mode stops the CPU while allowing the SRAM, Timer/Counters, SPI port, and interrupt system to continue functioning. The Power-down mode saves the register contents but freezes the Oscillator, disabling all other chip functions until the next interrupt or Hardware Reset. In Power-save mode, the asynchronous timer continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping. The ADC Noise Reduction mode stops the CPU and all I/O modules except asynchronous timer and ADC, to minimize switching noise during ADC conversions. In Standby mode, the crystal/resonator Oscillator is running while the rest of the device is sleeping. This allows very fast start-up combined with low-power consumption. In Extended Standby mode, both the main Oscillator and the asynchronous timer continue to run.

The device is manufactured using Atmel's high density nonvolatile memory technology. The On-chip ISP Flash allows the program memory to be reprogrammed In-System through an SPI serial interface, by a conventional nonvolatile memory programmer, or by an On-chip Boot program running on the AVR core. The boot program can use any interface to download the application program in the Application Flash memory. Software in the Boot Flash section will continue to run while the Application Flash section is updated, providing true Read-While-Write operation. By combining an 8-bit RISC CPU with In-System Self-Programmable Flash on a monolithic chip, the Atmel ATmega8535 is a powerful microcontroller that provides a highly flexible and cost effective solution to many embedded control applications.

The ATmega8535 AVR is supported with a full suite of program and system development tools including: C compilers, macro assemblers, program debugger/simulators, In-Circuit Emulators, and evaluation kits.

T90S8535 Compatibility

The ATmega8535 provides all the features of the AT90S8535. In addition, several new features are added. The ATmega8535 is backward compatible with AT90S8535 in most cases. However, some incompatibilities between the two microcontrollers exist. To solve this problem, an AT90S8535 compatibility mode can be selected by programming the S8535C fuse. ATmega8535 is pin compatible with AT90S8535, and can replace the AT90S8535 on current Printed Circuit Boards. However, the location of fuse bits and the electrical characteristics differs between the two devices.

T90S8535 Compatibility ode

Programming the S8535C fuse will change the following functionality:

- The timed sequence for changing the Watchdog Time-out period is disabled. See "Timed Sequences for Changing the Configuration of the Watchdog Timer" on page 45 for details.
- The double buffering of the USART Receive Register is disabled. See "AVR USART vs. AVR UART – Compatibility" on page 146 for details.

'in Descriptions

'cc — Digital supply voltage.

;ND — Ground.

'ort A (PA7..PA0) — Port A serves as the analog inputs to the A/D Converter.

Port A also serves as an 8-bit bi-directional I/O port, if the A/D Converter is not used. Port pins can provide internal pull-up resistors (selected for each bit). The Port A output buffers have symmetrical drive characteristics with both high sink and source capability. When pins PA0 to PA7 are used as inputs and are externally pulled low, they will source current if the internal pull-up resistors are activated. The Port A pins are tri-stated when a reset condition becomes active, even if the clock is not running.

ort B (PB7..PB0) — Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port B output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port B pins that are externally pulled low will source current if the pull-up resistors are activated. The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Port B also serves the functions of various special features of the ATmega8535 as listed on page 60.

ort C (PC7..PC0) — Port C is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port C output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port C pins that are externally pulled low will source current if the pull-up resistors are activated. The Port C pins are tri-stated when a reset condition becomes active, even if the clock is not running.

ort D (PD7..PD0) — Port D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port D output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port D pins that are externally pulled low will source current if the pull-up resistors are activated. The Port D pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Port D also serves the functions of various special features of the ATmega8535 as listed on page 64.

$\overline{\text{ESET}}$ — Reset input. A low level on this pin for longer than the minimum pulse length will generate a reset, even if the clock is not running. The minimum pulse length is given in Table 15 on page 37. Shorter pulses are not guaranteed to generate a reset.

TAL1 — Input to the inverting Oscillator amplifier and input to the internal clock operating circuit.

TAL2 — Output from the inverting Oscillator amplifier.

VCC — AVCC is the supply voltage pin for Port A and the A/D Converter. It should be externally connected to V_{CC}, even if the ADC is not used. If the ADC is used, it should be connected to V_{CC} through a low-pass filter.

REF — AREF is the analog reference pin for the A/D Converter.

Resources

A comprehensive set of development tools, application notes and datasheets are available for download on http://www.atmel.com/avr.

Register Summary

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
0x3F (0x5F)	SREG	I	T	H	S	V	N	Z	C	10
0x3E (0x5E)	SPH	–	–	–	–	–	–	SP9	SP8	12
0x3D (0x5D)	SPL	SP7	SP6	SP5	SP4	SP3	SP2	SP1	SP0	12
0x3C (0x5C)	OCR0	Timer/Counter0 Output Compare Register								85
0x3B (0x5B)	GICR	INT1	INT0	INT2	–	–	–	IVSEL	IVCE	49, 69
0x3A (0x5A)	GIFR	INTF1	INTF0	INTF2	–	–	–	–	–	70
0x39 (0x59)	TIMSK	OCIE2	TOIE2	TICIE1	OCIE1A	OCIE1B	TOIE1	OCIE0	TOIE0	85, 115, 133
0x38 (0x58)	TIFR	OCF2	TOV2	ICF1	OCF1A	OCF1B	TOV1	OCF0	TOV0	86, 116, 134
0x37 (0x57)	SPMCR	SPMIE	RWWSB	–	RWWSRE	BLBSET	PGWRT	PGERS	SPMEN	228
0x36 (0x56)	TWCR	TWINT	TWEA	TWSTA	TWSTO	TWWC	TWEN	–	TWIE	181
0x35 (0x55)	MCUCR	SM2	SE	SM1	SM0	ISC11	ISC10	ISC01	ISC00	32, 68
0x34 (0x54)	MCUCSR	–	ISC2	–	–	WDRF	BORF	EXTRF	PORF	40, 69
0x33 (0x53)	TCCR0	FOC0	WGM00	COM01	COM00	WGM01	CS02	CS01	CS00	83
0x32 (0x52)	TCNT0	Timer/Counter0 (8 Bits)								85
0x31 (0x51)	OSCCAL	Oscillator Calibration Register								30
0x30 (0x50)	SFIOR	ADTS2	ADTS1	ADTS0	–	ACME	PUD	PSR2	PSR10	59,88,135,203,223
0x2F (0x4F)	TCCR1A	COM1A1	COM1A0	COM1B1	COM1B0	FOC1A	FOC1B	WGM11	WGM10	110
0x2E (0x4E)	TCCR1B	ICNC1	ICES1	–	WGM13	WGM12	CS12	CS11	CS10	113
0x2D (0x4D)	TCNT1H	Timer/Counter1 – Counter Register High Byte								114
0x2C (0x4C)	TCNT1L	Timer/Counter1 – Counter Register Low Byte								114
0x2B (0x4B)	OCR1AH	Timer/Counter1 – Output Compare Register A High Byte								114
0x2A (0x4A)	OCR1AL	Timer/Counter1 – Output Compare Register A Low Byte								114
0x29 (0x49)	OCR1BH	Timer/Counter1 – Output Compare Register B High Byte								114
0x28 (0x48)	OCR1BL	Timer/Counter1 – Output Compare Register B Low Byte								114
0x27 (0x47)	ICR1H	Timer/Counter1 – Input Capture Register High Byte								114
0x26 (0x46)	ICR1L	Timer/Counter1 – Input Capture Register Low Byte								114
0x25 (0x45)	TCCR2	FOC2	WGM20	COM21	COM20	WGM21	CS22	CS21	CS20	128
0x24 (0x44)	TCNT2	Timer/Counter2 (8 Bits)								130
0x23 (0x43)	OCR2	Timer/Counter2 Output Compare Register								131
0x22 (0x42)	ASSR	–	–	–	–	AS2	TCN2UB	OCR2UB	TCR2UB	131
0x21 (0x41)	WDTCR	–	–	–	WDCE	WDE	WDP2	WDP1	WDP0	42
0x20[1] (0x40)[1]	UBRRH	URSEL	–	–	–	UBRR[11:8]				169
	UCSRC	URSEL	UMSEL	UPM1	UPM0	USBS	UCSZ1	UCSZ0	UCPOL	167
0x1F (0x3F)	EEARH	–	–	–	–	–	–	–	EEAR8	19
0x1E (0x3E)	EEARL	EEPROM Address Register Low Byte								19
0x1D (0x3D)	EEDR	EEPROM Data Register								19
0x1C (0x3C)	EECR	–	–	–	–	EERIE	EEMWE	EEWE	EERE	19
0x1B (0x3B)	PORTA	PORTA7	PORTA6	PORTA5	PORTA4	PORTA3	PORTA2	PORTA1	PORTA0	66
0x1A (0x3A)	DDRA	DDA7	DDA6	DDA5	DDA4	DDA3	DDA2	DDA1	DDA0	66
0x19 (0x39)	PINA	PINA7	PINA6	PINA5	PINA4	PINA3	PINA2	PINA1	PINA0	66
0x18 (0x38)	PORTB	PORTB7	PORTB6	PORTB5	PORTB4	PORTB3	PORTB2	PORTB1	PORTB0	66
0x17 (0x37)	DDRB	DDB7	DDB6	DDB5	DDB4	DDB3	DDB2	DDB1	DDB0	66
0x16 (0x36)	PINB	PINB7	PINB6	PINB5	PINB4	PINB3	PINB2	PINB1	PINB0	67
0x15 (0x35)	PORTC	PORTC7	PORTC6	PORTC5	PORTC4	PORTC3	PORTC2	PORTC1	PORTC0	67
0x14 (0x34)	DDRC	DDC7	DDC6	DDC5	DDC4	DDC3	DDC2	DDC1	DDC0	67
0x13 (0x33)	PINC	PINC7	PINC6	PINC5	PINC4	PINC3	PINC2	PINC1	PINC0	67
0x12 (0x32)	PORTD	PORTD7	PORTD6	PORTD5	PORTD4	PORTD3	PORTD2	PORTD1	PORTD0	67
0x11 (0x31)	DDRD	DDD7	DDD6	DDD5	DDD4	DDD3	DDD2	DDD1	DDD0	67
0x10 (0x30)	PIND	PIND7	PIND6	PIND5	PIND4	PIND3	PIND2	PIND1	PIND0	67
0x0F (0x2F)	SPDR	SPI Data Register								143
0x0E (0x2E)	SPSR	SPIF	WCOL	–	–	–	–	–	SPI2X	143
0x0D (0x2D)	SPCR	SPIE	SPE	DORD	MSTR	CPOL	CPHA	SPR1	SPR0	141
0x0C (0x2C)	UDR	USART I/O Data Register								164
0x0B (0x2B)	UCSRA	RXC	TXC	UDRE	FE	DOR	PE	U2X	MPCM	165
0x0A (0x2A)	UCSRB	RXCIE	TXCIE	UDRIE	RXEN	TXEN	UCSZ2	RXB8	TXB8	166
0x09 (0x29)	UBRRL	USART Baud Rate Register Low Byte								169
0x08 (0x28)	ACSR	ACD	ACBG	ACO	ACI	ACIE	ACIC	ACIS1	ACIS0	203
0x07 (0x27)	ADMUX	REFS1	REFS0	ADLAR	MUX4	MUX3	MUX2	MUX1	MUX0	219
0x06 (0x26)	ADCSRA	ADEN	ADSC	ADATE	ADIF	ADIE	ADPS2	ADPS1	ADPS0	221
0x05 (0x25)	ADCH	ADC Data Register High Byte								222
0x04 (0x24)	ADCL	ADC Data Register Low Byte								222
0x03 (0x23)	TWDR	Two-wire Serial Interface Data Register								183
0x02 (0x22)	TWAR	TWA6	TWA5	TWA4	TWA3	TWA2	TWA1	TWA0	TWGCE	183
0x01 (0x21)	TWSR	TWS7	TWS6	TWS5	TWS4	TWS3	–	TWPS1	TWPS0	183

Register Summary (Continued)

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
0x00 (0x20)	TWBR	Two-wire Serial Interface Bit Rate Register								181

Notes: 1. Refer to the USART description for details on how to access UBRRH and UCSRC.

2. For compatibility with future devices, reserved bits should be written to zero if accessed. Reserved I/O memory addresses should never be written.

3. Some of the status flags are cleared by writing a logical one to them. Note that the CBI and SBI instructions will operate on all bits in the I/O Register, writing a one back into any flag read as set, thus clearing the flag. The CBI and SBI instructions work with registers 0x00 to 0x1F only.

nstruction Set Summary

Mnemonics	Operands	Description	Operation	Flags	#Clocks
ARITHMETIC AND LOGIC INSTRUCTIONS					
ADD	Rd, Rr	Add two Registers	Rd ← Rd + Rr	Z,C,N,V,H	1
ADC	Rd, Rr	Add with Carry two Registers	Rd ← Rd + Rr + C	Z,C,N,V,H	1
ADIW	Rdl,K	Add Immediate to Word	Rdh:Rdl ← Rdh:Rdl + K	Z,C,N,V,S	2
SUB	Rd, Rr	Subtract two Registers	Rd ← Rd - Rr	Z,C,N,V,H	1
SUBI	Rd, K	Subtract Constant from Register	Rd ← Rd - K	Z,C,N,V,H	1
SBC	Rd, Rr	Subtract with Carry two Registers	Rd ← Rd - Rr - C	Z,C,N,V,H	1
SBCI	Rd, K	Subtract with Carry Constant from Reg.	Rd ← Rd - K - C	Z,C,N,V,H	1
SBIW	Rdl,K	Subtract Immediate from Word	Rdh:Rdl ← Rdh:Rdl - K	Z,C,N,V,S	2
AND	Rd, Rr	Logical AND Registers	Rd ← Rd • Rr	Z,N,V	1
ANDI	Rd, K	Logical AND Register and Constant	Rd ← Rd • K	Z,N,V	1
OR	Rd, Rr	Logical OR Registers	Rd ← Rd v Rr	Z,N,V	1
ORI	Rd, K	Logical OR Register and Constant	Rd ← Rd v K	Z,N,V	1
EOR	Rd, Rr	Exclusive OR Registers	Rd ← Rd ⊕ Rr	Z,N,V	1
COM	Rd	One's Complement	Rd ← 0xFF – Rd	Z,C,N,V	1
NEG	Rd	Two's Complement	Rd ← 0x00 – Rd	Z,C,N,V,H	1
SBR	Rd,K	Set Bit(s) in Register	Rd ← Rd v K	Z,N,V	1
CBR	Rd,K	Clear Bit(s) in Register	Rd ← Rd • (0xFF - K)	Z,N,V	1
INC	Rd	Increment	Rd ← Rd + 1	Z,N,V	1
DEC	Rd	Decrement	Rd ← Rd – 1	Z,N,V	1
TST	Rd	Test for Zero or Minus	Rd ← Rd • Rd	Z,N,V	1
CLR	Rd	Clear Register	Rd ← Rd ⊕ Rd	Z,N,V	1
SER	Rd	Set Register	Rd ← 0xFF	None	1
MUL	Rd, Rr	Multiply Unsigned	R1:R0 ← Rd x Rr	Z,C	2
MULS	Rd, Rr	Multiply Signed	R1:R0 ← Rd x Rr	Z,C	2
MULSU	Rd, Rr	Multiply Signed with Unsigned	R1:R0 ← Rd x Rr	Z,C	2
FMUL	Rd, Rr	Fractional Multiply Unsigned	R1:R0 ← (Rd x Rr) << 1	Z,C	2
FMULS	Rd, Rr	Fractional Multiply Signed	R1:R0 ← (Rd x Rr) << 1	Z,C	2
FMULSU	Rd, Rr	Fractional Multiply Signed with Unsigned	R1:R0 ← (Rd x Rr) << 1	Z,C	2
BRANCH INSTRUCTIONS					
RJMP	k	Relative Jump	PC ← PC + k + 1	None	2
IJMP		Indirect Jump to (Z)	PC ← Z	None	2
RCALL	k	Relative Subroutine Call	PC ← PC + k + 1	None	3
ICALL		Indirect Call to (Z)	PC ← Z	None	3
RET		Subroutine Return	PC ← STACK	None	4
RETI		Interrupt Return	PC ← STACK	I	4
CPSE	Rd,Rr	Compare, Skip if Equal	if (Rd = Rr) PC ← PC + 2 or 3	None	1 / 2 / 3
CP	Rd,Rr	Compare	Rd – Rr	Z, N,V,C,H	1
CPC	Rd,Rr	Compare with Carry	Rd – Rr – C	Z, N,V,C,H	1
CPI	Rd,K	Compare Register with Immediate	Rd – K	Z, N,V,C,H	1
SBRC	Rr, b	Skip if Bit in Register Cleared	if (Rr(b)=0) PC ← PC + 2 or 3	None	1 / 2 / 3
SBRS	Rr, b	Skip if Bit in Register is Set	if (Rr(b)=1) PC ← PC + 2 or 3	None	1 / 2 / 3
SBIC	P, b	Skip if Bit in I/O Register Cleared	if (P(b)=0) PC ← PC + 2 or 3	None	1 / 2 / 3
SBIS	P, b	Skip if Bit in I/O Register is Set	if (P(b)=1) PC ← PC + 2 or 3	None	1 / 2 / 3
BRBS	s, k	Branch if Status Flag Set	if (SREG(s) = 1) then PC←PC+k + 1	None	1 / 2
BRBC	s, k	Branch if Status Flag Cleared	if (SREG(s) = 0) then PC←PC+k + 1	None	1 / 2
BREQ	k	Branch if Equal	if (Z = 1) then PC ← PC + k + 1	None	1 / 2
BRNE	k	Branch if Not Equal	if (Z = 0) then PC ← PC + k + 1	None	1 / 2
BRCS	k	Branch if Carry Set	if (C = 1) then PC ← PC + k + 1	None	1 / 2
BRCC	k	Branch if Carry Cleared	if (C = 0) then PC ← PC + k + 1	None	1 / 2
BRSH	k	Branch if Same or Higher	if (C = 0) then PC ← PC + k + 1	None	1 / 2
BRLO	k	Branch if Lower	if (C = 1) then PC ← PC + k + 1	None	1 / 2
BRMI	k	Branch if Minus	if (N = 1) then PC ← PC + k + 1	None	1 / 2
BRPL	k	Branch if Plus	if (N = 0) then PC ← PC + k + 1	None	1 / 2
BRGE	k	Branch if Greater or Equal, Signed	if (N ⊕ V= 0) then PC ← PC + k + 1	None	1 / 2
BRLT	k	Branch if Less Than Zero, Signed	if (N ⊕ V= 1) then PC ← PC + k + 1	None	1 / 2
BRHS	k	Branch if Half Carry Flag Set	if (H = 1) then PC ← PC + k + 1	None	1 / 2
BRHC	k	Branch if Half Carry Flag Cleared	if (H = 0) then PC ← PC + k + 1	None	1 / 2
BRTS	k	Branch if T Flag Set	if (T = 1) then PC ← PC + k + 1	None	1 / 2
BRTC	k	Branch if T Flag Cleared	if (T = 0) then PC ← PC + k + 1	None	1 / 2
BRVS	k	Branch if Overflow Flag is Set	if (V = 1) then PC ← PC + k + 1	None	1 / 2
BRVC	k	Branch if Overflow Flag is Cleared	if (V = 0) then PC ← PC + k + 1	None	1 / 2
BRIE	k	Branch if Interrupt Enabled	if (I = 1) then PC ← PC + k + 1	None	1 / 2
BRID	k	Branch if Interrupt Disabled	if (I = 0) then PC ← PC + k + 1	None	1 / 2
DATA TRANSFER INSTRUCTIONS					

Mnemonics	Operands	Description	Operation	Flags	#Clocks
MOV	Rd, Rr	Move Between Registers	Rd ← Rr	None	1
MOVW	Rd, Rr	Copy Register Word	Rd+1:Rd ← Rr+1:Rr	None	1
LDI	Rd, K	Load Immediate	Rd ← K	None	1
LD	Rd, X	Load Indirect	Rd ← (X)	None	2
LD	Rd, X+	Load Indirect and Post-Inc.	Rd ← (X), X ← X + 1	None	2
LD	Rd, - X	Load Indirect and Pre-Dec.	X ← X - 1, Rd ← (X)	None	2
LD	Rd, Y	Load Indirect	Rd ← (Y)	None	2
LD	Rd, Y+	Load Indirect and Post-Inc.	Rd ← (Y), Y ← Y + 1	None	2
LD	Rd, - Y	Load Indirect and Pre-Dec.	Y ← Y - 1, Rd ← (Y)	None	2
LDD	Rd,Y+q	Load Indirect with Displacement	Rd ← (Y + q)	None	2
LD	Rd, Z	Load Indirect	Rd ← (Z)	None	2
LD	Rd, Z+	Load Indirect and Post-Inc.	Rd ← (Z), Z ← Z+1	None	2
LD	Rd, -Z	Load Indirect and Pre-Dec.	Z ← Z - 1, Rd ← (Z)	None	2
LDD	Rd, Z+q	Load Indirect with Displacement	Rd ← (Z + q)	None	2
LDS	Rd, k	Load Direct from SRAM	Rd ← (k)	None	2
ST	X, Rr	Store Indirect	(X) ← Rr	None	2
ST	X+, Rr	Store Indirect and Post-Inc.	(X) ← Rr, X ← X + 1	None	2
ST	- X, Rr	Store Indirect and Pre-Dec.	X ← X - 1, (X) ← Rr	None	2
ST	Y, Rr	Store Indirect	(Y) ← Rr	None	2
ST	Y+, Rr	Store Indirect and Post-Inc.	(Y) ← Rr, Y ← Y + 1	None	2
ST	- Y, Rr	Store Indirect and Pre-Dec.	Y ← Y - 1, (Y) ← Rr	None	2
STD	Y+q,Rr	Store Indirect with Displacement	(Y + q) ← Rr	None	2
ST	Z, Rr	Store Indirect	(Z) ← Rr	None	2
ST	Z+, Rr	Store Indirect and Post-Inc.	(Z) ← Rr, Z ← Z + 1	None	2
ST	-Z, Rr	Store Indirect and Pre-Dec.	Z ← Z - 1, (Z) ← Rr	None	2
STD	Z+q,Rr	Store Indirect with Displacement	(Z + q) ← Rr	None	2
STS	k, Rr	Store Direct to SRAM	(k) ← Rr	None	2
LPM		Load Program Memory	R0 ← (Z)	None	3
LPM	Rd, Z	Load Program Memory	Rd ← (Z)	None	3
LPM	Rd, Z+	Load Program Memory and Post-Inc	Rd ← (Z), Z ← Z+1	None	3
SPM		Store Program Memory	(Z) ← R1:R0	None	-
N	Rd, P	In Port	Rd ← P	None	1
OUT	P, Rr	Out Port	P ← Rr	None	1
PUSH	Rr	Push Register on Stack	STACK ← Rr	None	2
POP	Rd	Pop Register from Stack	Rd ← STACK	None	2
BIT AND BIT-TEST INSTRUCTIONS					
SBI	P,b	Set Bit in I/O Register	I/O(P,b) ← 1	None	2
CBI	P,b	Clear Bit in I/O Register	I/O(P,b) ← 0	None	2
LSL	Rd	Logical Shift Left	Rd(n+1) ← Rd(n), Rd(0) ← 0	Z,C,N,V	1
LSR	Rd	Logical Shift Right	Rd(n) ← Rd(n+1), Rd(7) ← 0	Z,C,N,V	1
ROL	Rd	Rotate Left Through Carry	Rd(0)←C,Rd(n+1)← Rd(n),C←Rd(7)	Z,C,N,V	1
ROR	Rd	Rotate Right Through Carry	Rd(7)←C,Rd(n)← Rd(n+1),C←Rd(0)	Z,C,N,V	1
ASR	Rd	Arithmetic Shift Right	Rd(n) ← Rd(n+1), n=0..6	Z,C,N,V	1
SWAP	Rd	Swap Nibbles	Rd(3..0)←Rd(7..4),Rd(7..4)←Rd(3..0)	None	1
BSET	s	Flag Set	SREG(s) ← 1	SREG(s)	1
BCLR	s	Flag Clear	SREG(s) ← 0	SREG(s)	1
BST	Rr, b	Bit Store from Register to T	T ← Rr(b)	T	1
BLD	Rd, b	Bit load from T to Register	Rd(b) ← T	None	1
SEC		Set Carry	C ← 1	C	1
CLC		Clear Carry	C ← 0	C	1
SEN		Set Negative Flag	N ← 1	N	1
CLN		Clear Negative Flag	N ← 0	N	1
SEZ		Set Zero Flag	Z ← 1	Z	1
CLZ		Clear Zero Flag	Z ← 0	Z	1
SEI		Global Interrupt Enable	I ← 1	I	1
CLI		Global Interrupt Disable	I ← 0	I	1
SES		Set Signed Test Flag	S ← 1	S	1
CLS		Clear Signed Test Flag	S ← 0	S	1
SEV		Set Twos Complement Overflow.	V ← 1	V	1
CLV		Clear Twos Complement Overflow	V ← 0	V	1
SET		Set T in SREG	T ← 1	T	1
CLT		Clear T in SREG	T ← 0	T	1
SEH		Set Half Carry Flag in SREG	H ← 1	H	1
CLH		Clear Half Carry Flag in SREG	H ← 0	H	1
MCU CONTROL INSTRUCTIONS					
NOP		No Operation		None	1

Mnemonics	Operands	Description	Operation	Flags	#Clocks
SLEEP		Sleep	(see specific descr. for Sleep function)	None	1
WDR		Watchdog Reset	(see specific descr. for WDR/Timer)	None	1
BREAK		Break	For On-chip Debug Only	None	N/A

Ordering Information

Speed (MHz)	Power Supply	Ordering Code	Package[1]	Operation Range
8	2.7 - 5.5V	ATmega8535L-8AC	44A	Commercial (0°C to 70°C)
		ATmega8535L-8PC	40P6	
		ATmega8535L-8JC	44J	
		ATmega8535L-8MC	44M1	
		ATmega8535L-8AI	44A	Industrial (-40°C to 85°C)
		ATmega8535L-8PI	40P6	
		ATmega8535L-8JI	44J	
		ATmega8535L-8MI	44M1	
		ATmega8535L-8AU[2]	44A	
		ATmega8535L-8PU[2]	40P6	
		ATmega8535L-8JU	44J	
		ATmega8535L-8MU[2]	44M1	
16	4.5 - 5.5V	ATmega8535-16AC	44A	Commercial (0°C to 70°C)
		ATmega8535-16PC	40P6	
		ATmega8535-16JC	44J	
		ATmega8535-16MC	44M1	
		ATmega8535-16AI	44A	Industrial (-40°C to 85°C)
		ATmega8535-16PI	40P6	
		ATmega8535-16JI	44J	
		ATmega8535-16MI	44M1	
		ATmega8535-16AU[2]	44A	
		ATmega8535-16PU[2]	40P6	
		ATmega8535-16JU[2]	44J	
		ATmega8535-16MU[2]	44M1	

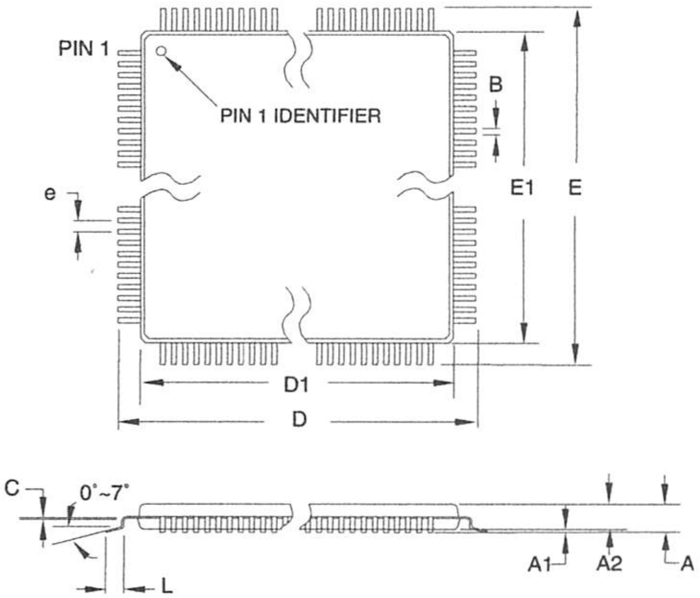
Note: 1. This device can also be supplied in wafer form. Please contact your local Atmel sales office for detailed ordering information and minimum quantities..

2. Pb-free packaging alternative, complies to the European Directive for Restriction of Hazardous Substances (RoHS directive).Also Halide free and fully Green.

	Package Type
14A	44-lead, Thin (1.0 mm) Plastic Gull Wing Quad Flat Package (TQFP)
10P6	40-pin, 0.600" Wide, Plastic Dual Inline Package (PDIP)
14J	44-lead, Plastic J-leaded Chip Carrier (PLCC)
14M1-A	44-pad, 7 x 7 x 1.0 mm body, lead pitch 0.50 mm, Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF)

Packaging Information

44A



COMMON DIMENSIONS
(Unit of Measure = mm)

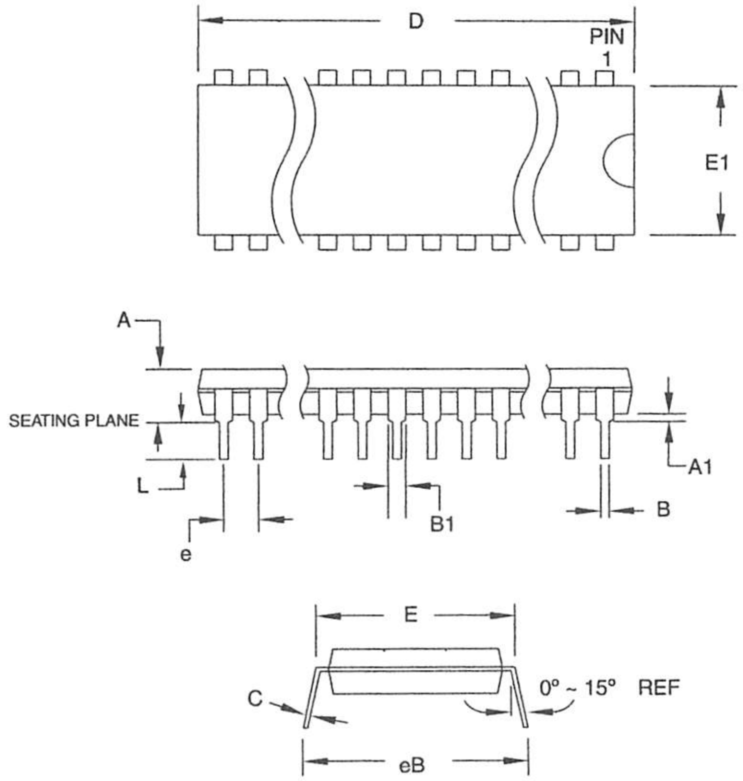
SYMBOL	MIN	NOM	MAX	NOTE
A	–	–	1.20	
A1	0.05	–	0.15	
A2	0.95	1.00	1.05	
D	11.75	12.00	12.25	
D1	9.90	10.00	10.10	Note 2
E	11.75	12.00	12.25	
E1	9.90	10.00	10.10	Note 2
B	0.30	–	0.45	
C	0.09	–	0.20	
L	0.45	–	0.75	
e	0.80 TYP			

Notes:
1. This package conforms to JEDEC reference MS-026, Variation ACB.
2. Dimensions D1 and E1 do not include mold protrusion. Allowable protrusion is 0.25 mm per side. Dimensions D1 and E1 are maximum plastic body size dimensions including mold mismatch.
3. Lead coplanarity is 0.10 mm maximum.

10/5/2001

	TITLE	DRAWING NO.	REV.
ATMEL 2325 Orchard Parkway San Jose, CA 95131	**44A,** 44-lead, 10 x 10 mm Body Size, 1.0 mm Body Thickness, 0.8 mm Lead Pitch, Thin Profile Plastic Quad Flat Package (TQFP)	44A	B

40P6



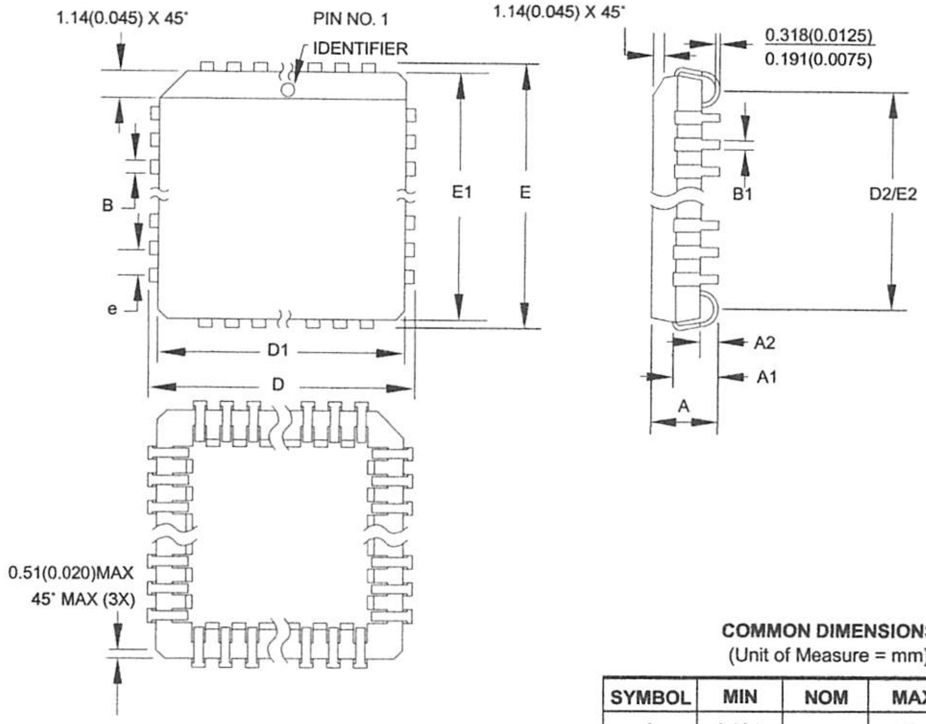
COMMON DIMENSIONS
(Unit of Measure = mm)

SYMBOL	MIN	NOM	MAX	NOTE
A	–	–	4.826	
A1	0.381	–	–	
D	52.070	–	52.578	Note 2
E	15.240	–	15.875	
E1	13.462	–	13.970	Note 2
B	0.356	–	0.559	
B1	1.041	–	1.651	
L	3.048	–	3.556	
C	0.203	–	0.381	
eB	15.494	–	17.526	
e	2.540 TYP			

Notes:
1. This package conforms to JEDEC reference MS-011, Variation AC.
2. Dimensions D and E1 do not include mold Flash or Protrusion. Mold Flash or Protrusion shall not exceed 0.25 mm (0.010").

09/28/01

	TITLE	DRAWING NO.	REV.
2325 Orchard Parkway San Jose, CA 95131	**40P6**, 40-lead (0.600"/15.24 mm Wide) Plastic Dual Inline Package (PDIP)	40P6	B



COMMON DIMENSIONS
(Unit of Measure = mm)

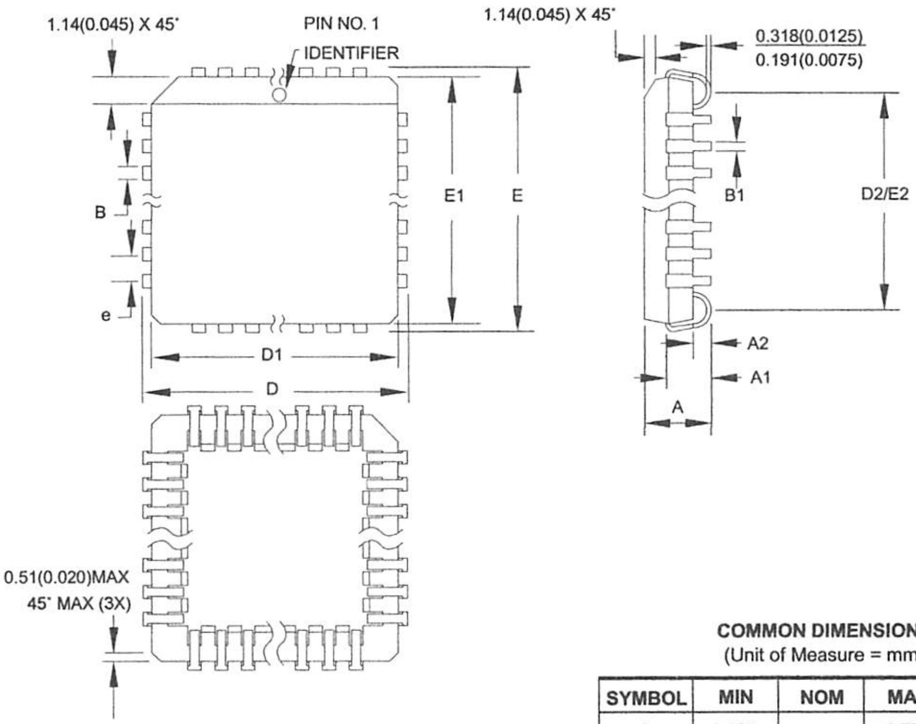
SYMBOL	MIN	NOM	MAX	NOTE
A	4.191	–	4.572	
A1	2.286	–	3.048	
A2	0.508	–	–	
D	17.399	–	17.653	
D1	16.510	–	16.662	Note 2
E	17.399	–	17.653	
E1	16.510	–	16.662	Note 2
D2/E2	14.986	–	16.002	
B	0.660	–	0.813	
B1	0.330	–	0.533	
e	1.270 TYP			

Notes:
1. This package conforms to JEDEC reference MS-018, Variation AC.
2. Dimensions D1 and E1 do not include mold protrusion. Allowable protrusion is .010"(0.254 mm) per side. Dimension D1 and E1 include mold mismatch and are measured at the extreme material condition at the upper or lower parting line.
3. Lead coplanarity is 0.004" (0.102 mm) maximum.

10/04/01

	TITLE	DRAWING NO.	REV.
2325 Orchard Parkway San Jose, CA 95131	**44J**, 44-lead, Plastic J-leaded Chip Carrier (PLCC)	44J	B

44J



COMMON DIMENSIONS
(Unit of Measure = mm)

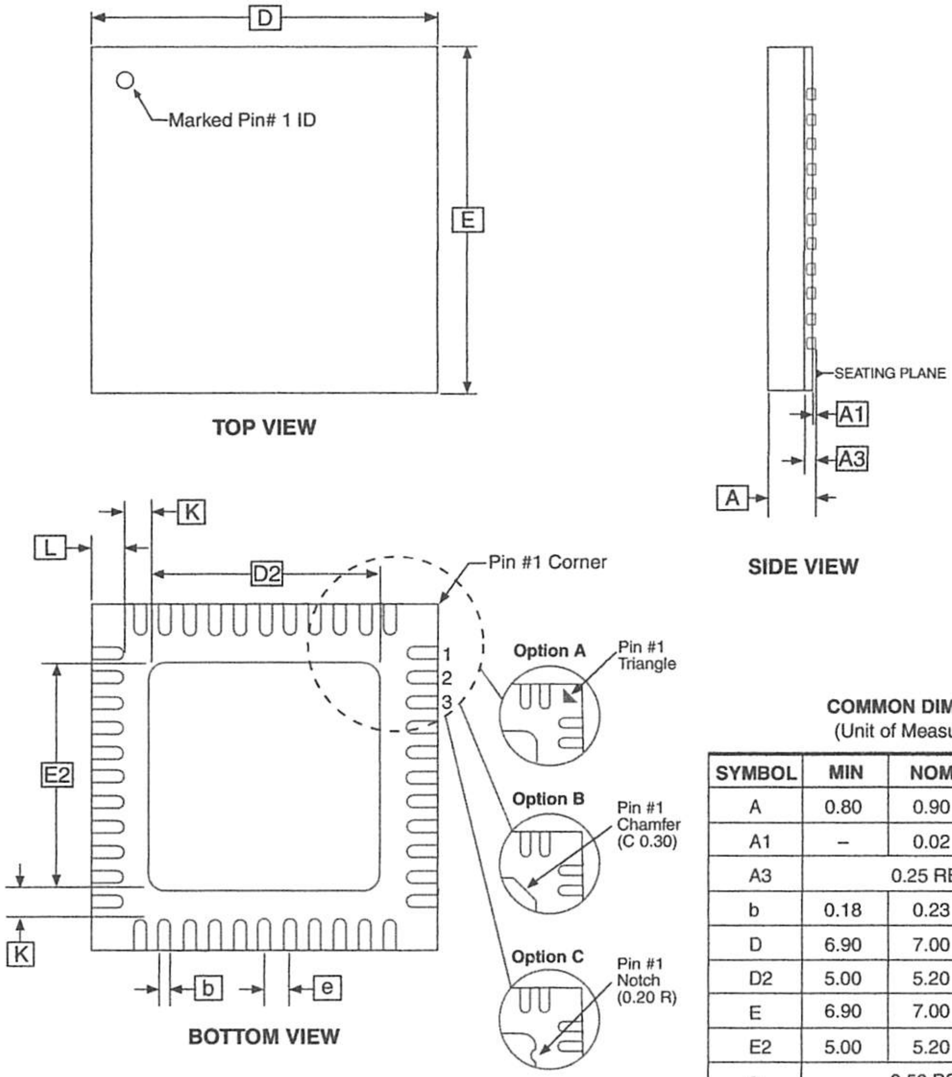
SYMBOL	MIN	NOM	MAX	NOTE
A	4.191	–	4.572	
A1	2.286	–	3.048	
A2	0.508	–	–	
D	17.399	–	17.653	
D1	16.510	–	16.662	Note 2
E	17.399	–	17.653	
E1	16.510	–	16.662	Note 2
D2/E2	14.986	–	16.002	
B	0.660	–	0.813	
B1	0.330	–	0.533	
e	1.270 TYP			

Notes:
1. This package conforms to JEDEC reference MS-018, Variation AC.
2. Dimensions D1 and E1 do not include mold protrusion. Allowable protrusion is .010"(0.254 mm) per side. Dimension D1 and E1 include mold mismatch and are measured at the extreme material condition at the upper or lower parting line.
3. Lead coplanarity is 0.004" (0.102 mm) maximum.

10/04/01

	TITLE	DRAWING NO.	REV.
ATMEL 2325 Orchard Parkway San Jose, CA 95131	**44J**, 44-lead, Plastic J-leaded Chip Carrier (PLCC)	44J	B

44M1-A



Note: JEDEC Standard MO-220, Fig. 1 (SAW Singulation) VKKD-3.

COMMON DIMENSIONS
(Unit of Measure = mm)

SYMBOL	MIN	NOM	MAX	NOTE
A	0.80	0.90	1.00	
A1	–	0.02	0.05	
A3		0.25 REF		
b	0.18	0.23	0.30	
D	6.90	7.00	7.10	
D2	5.00	5.20	5.40	
E	6.90	7.00	7.10	
E2	5.00	5.20	5.40	
e		0.50 BSC		
L	0.59	0.64	0.69	
K	0.20	0.26	0.41	

5/27/06

	TITLE	DRAWING NO.	REV.
2325 Orchard Parkway San Jose, CA 95131	**44M1**, 44-pad, 7 x 7 x 1.0 mm Body, Lead Pitch 0.50 mm, 5.20 mm Exposed Pad, Micro Lead Frame Package (MLF)	44M1	G

:rrata

\Tmega8535 all rev. No known errata.

)atasheet Revision listory

Please note that the referring page numbers in this section are referring to this document. The referring revision in this section are referring to the document revision.

;hanges from Rev. :502I- 06/06 to Rev. :502J- 08/06

1. **Updated code example "Ordering Information" on page 304.**

;hanges from Rev. :502H- 04/06 to Rev. :502I- 06/06

1. **Updated code example "USART Initialization" on page 150.**

;hanges from Rev. :502G- 04/05 to Rev. :502H- 04/06

1. **Added "Resources" on page 6.**
2. **Updated Table 7 on page 29, Table 17 on page 42 and Table 111 on page 258.**
3. **Updated "Serial Peripheral Interface – SPI" on page 136.**
4. **Updated note in "Bit Rate Generator Unit" on page 180.**

;hanges from Rev. 502F- 06/04 to Rev. 502G- 04/05

1. **Removed "Preliminary" and TBD's.**
2. **Updated Table 37 on page 69 and Table 113 on page 261.**
3. **Updated "Electrical Characteristics" on page 255.**
4. **Updated "Ordering Information" on page 304.**

;hanges from Rev. 502-12/03 to Rev. 502-06/04

1. **MLF-package alternative changed to "Quad Flat No-Lead/Micro Lead Frame Package QFN/MLF".**

;hanges from Rev. 502E-12/03 to Rev. 502F-06/04

1. **Updated "Reset Characteristics" on page 37.**
2. **Updated SPH in "Stack Pointer" on page 12.**
3. **Updated C code in "USART Initialization" on page 150.**
4. **Updated "Errata" on page 309.**

;hanges from Rev. 502D-09/03 to Rev. 502E-12/03

1. **Updated "Calibrated Internal RC Oscillator" on page 29.**
2. **Added section "Errata" on page 309.**

;hanges from Rev. 502C-04/03 to Rev. 502D-09/03

1. **Removed "Advance Information" and some TBD's from the datasheet.**
2. **Added note to "Pinout ATmega8535" on page 2.**
3. **Updated "Reset Characteristics" on page 37.**

4. Updated "Absolute Maximum Ratings" and "DC Characteristics" in "Electrical Characteristics" on page 255.

5. Updated Table 111 on page 258.

6. Updated "ADC Characteristics – Preliminary Data" on page 263.

7. Updated "ATmega8535 Typical Characteristics – Preliminary Data" on page 266.

8. Removed CALL and JMP instructions from code examples and "Instruction Set Summary" on page 301.

Changes from Rev. 2502B-09/02 to Rev. 2502C-04/03

1. Updated "Packaging Information" on page 305.

2. Updated Figure 1 on page 2, Figure 84 on page 179, Figure 85 on page 185, Figure 87 on page 191, Figure 98 on page 207.

3. Added the section "EEPROM Write During Power-down Sleep Mode" on page 22.

4. Removed the references to the application notes "Multi-purpose Oscillator" and "32 kHz Crystal Oscillator", which do not exist.

5. Updated code examples on page 44.

6. Removed ADHSM bit.

7. Renamed Port D pin ICP to ICP1. See "Alternate Functions of Port D" on page 64.

8. Added information about PWM symmetry for Timer 0 on page 79 and Timer 2 on page 126.

9. Updated Table 68 on page 169, Table 75 on page 190, Table 76 on page 193, Table 77 on page 196, Table 108 on page 253, Table 113 on page 261.

10. Updated description on "Bit 5 – TWSTA: TWI START Condition Bit" on page 182.

11. Updated the description in "Filling the Temporary Buffer (Page Loading)" and "Performing a Page Write" on page 231.

12. Removed the section description in "SPI Serial Programming Characteristics" on page 254.

13. Updated "Electrical Characteristics" on page 255.

14. Updated "ADC Characteristics – Preliminary Data" on page 263.

14. Updated "Register Summary" on page 299.

15. Various Timer 1 corrections.

16. Added WD_FUSE period in Table 108 on page 253.

;hanges from Rev. :502A-06/02 to Rev. :502B-09/02

1. Canged the Endurance on the Flash to 10,000 Write/Erase Cycles.

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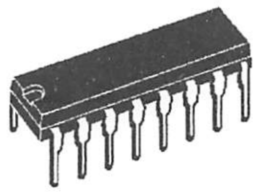
Literature Requests
www.atmel.com/literature

ULN2001A-ULN2002A
ULN2003A-ULN2004A

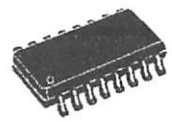
SEVEN DARLINGTON ARRAYS

- SEVEN DARLINGTONS PER PACKAGE
- OUTPUT CURRENT 500mA PER DRIVER (600mA PEAK)
- OUTPUT VOLTAGE 50V
- INTEGRATED SUPPRESSION DIODES FOR INDUCTIVE LOADS
- OUTPUTS CAN BE PARALLELED FOR HIGHER CURRENT
- TTL/CMOS/PMOS/DTL COMPATIBLE INPUTS
- INPUTS PINNED OPPOSITE OUTPUTS TO SIMPLIFY LAYOUT



DIP16

ORDERING NUMBERS: ULN2001A/2A/3A/4A



SO16

ORDERING NUMBERS: ULN2001D/2D/3D/4D

DESCRIPTION

The ULN2001A, ULN2002A, ULN2003 and ULN2004A are high voltage, high current darlington arrays each containing seven open collector darlington pairs with common emitters. Each channel rated at 500mA and can withstand peak currents of 600mA. Suppression diodes are included for inductive load driving and the inputs are pinned opposite the outputs to simplify board layout.

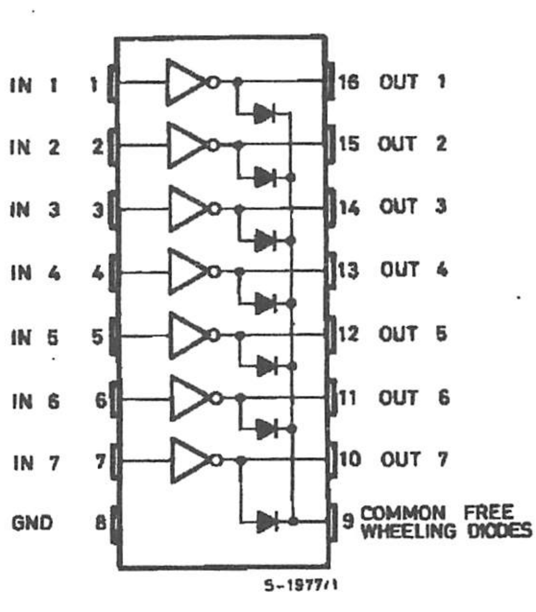
The four versions interface to all common logic families :

ULN2001A	General Purpose, DTL, TTL, PMOS, CMOS
ULN2002A	14-25V PMOS
ULN2003A	5V TTL, CMOS
ULN2004A	6–15V CMOS, PMOS

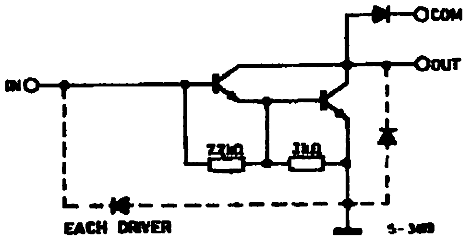
These versatile devices are useful for driving a wide range of loads including solenoids, relays DC motors, LED displays filament lamps, thermal printheads and high power buffers.

The ULN2001A/2002A/2003A and 2004A are supplied in 16 pin plastic DIP packages with a copper leadframe to reduce thermal resistance. They are available also in small outline package (SO-16) as ULN2001D/2002D/2003D/2004D.

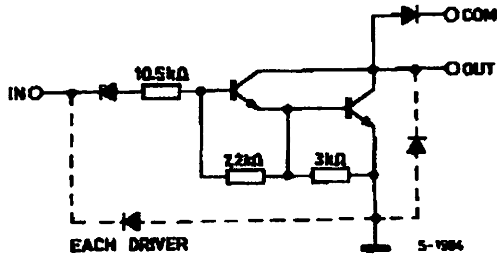
PIN CONNECTION



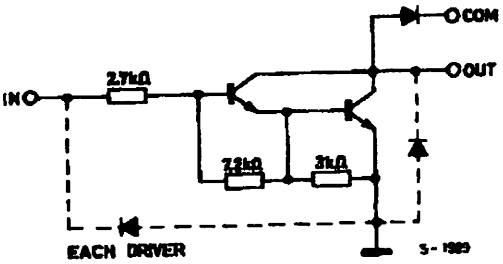
SCHEMATIC DIAGRAM



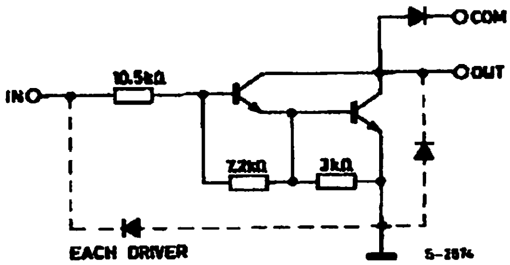
Series ULN-2001A
(each driver)



Series ULN-2002A
(each driver)



Series ULN-2003A
(each driver)



Series ULN-2004A
(each driver)

ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
V_o	Output Voltage	50	V
V_{in}	Input Voltage (for ULN2002A/D - 2003A/D - 2004A/D)	30	V
I_c	Continuous Collector Current	500	mA
I_b	Continuous Base Current	25	mA
T_{amb}	Operating Ambient Temperature Range	– 20 to 85	°C
T_{stg}	Storage Temperature Range	– 55 to 150	°C
T_j	Junction Temperature	150	°C

THERMAL DATA

Symbol	Parameter		DIP16	SO16	Unit
$R_{th\ j\text{-}amb}$	Thermal Resistance Junction-ambient	Max.	70	100	°C/W

ELECTRICAL CHARACTERISTICS (T_{amb} = 25°C unless otherwise specified)

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit	Fig.
I_{CEX}	Output Leakage Current	V_{CE} = 50V T_{amb} = 70°C, V_{CE} = 50V T_{amb} = 70°C for ULN2002A V_{CE} = 50V, V_i = 6V for ULN2004A V_{CE} = 50V, V_i = 1V			50 100 500 500	µA µA µA µA	1a 1a 1b 1b
$V_{CE(sat)}$	Collector-emitter Saturation Voltage	I_C = 100mA, I_B = 250µA I_C = 200 mA, I_B = 350µA I_C = 350mA, I_B = 500µA		0.9 1.1 1.3	1.1 1.3 1.6	V V V	2 2 2
$I_{i(on)}$	Input Current	for ULN2002A, V_i = 17V for ULN2003A, V_i = 3.85V for ULN2004A, V_i = 5V V_i = 12V		0.82 0.93 0.35 1	1.25 1.35 0.5 1.45	mA mA mA mA	3 3 3 3
$I_{i(off)}$	Input Current	T_{amb} = 70°C, I_C = 500µA	50	65		µA	4
$V_{i(on)}$	Input Voltage	V_{CE} = 2V for ULN2002A I_C = 300mA for ULN2003A I_C = 200mA I_C = 250mA I_C = 300mA for ULN2004A I_C = 125mA I_C = 200mA I_C = 275mA I_C = 350mA			 13 2.4 2.7 3 5 6 7 8	V	5
h_{FE}	DC Forward Current Gain	for ULN2001A V_{CE} = 2V, I_C = 350mA	1000				2
C_i	Input Capacitance			15	25	pF	
t_{PLH}	Turn-on Delay Time	0.5 V_i to 0.5 V_o		0.25	1	µs	
t_{PHL}	Turn-off Delay Time	0.5 V_i to 0.5 V_o		0.25	1	µs	
I_R	Clamp Diode Leakage Current	V_R = 50V T_{amb} = 70°C, V_R = 50V			50 100	µA µA	6 6
V_F	Clamp Diode Forward Voltage	I_F = 350mA		1.7	2	V	7

TEST CIRCUITS

Figure 1a.

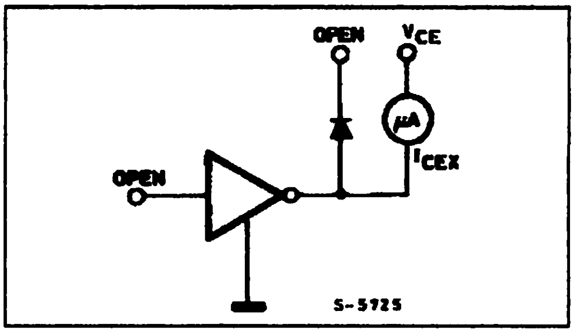


Figure 1b.

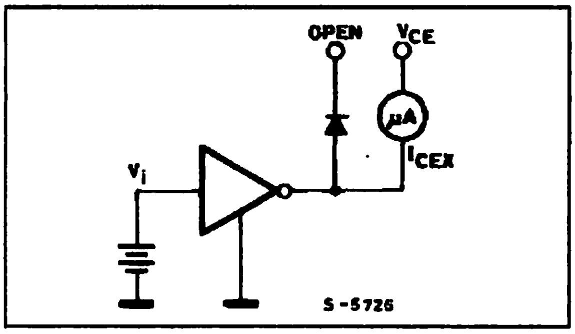


Figure 2.

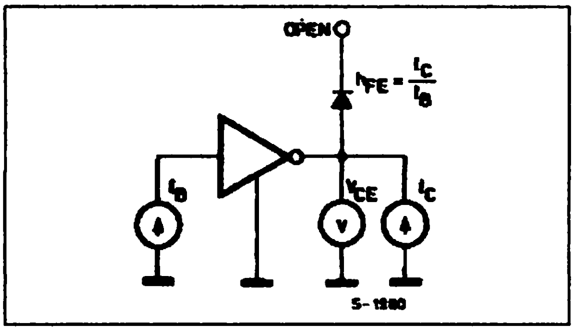


Figure 3.

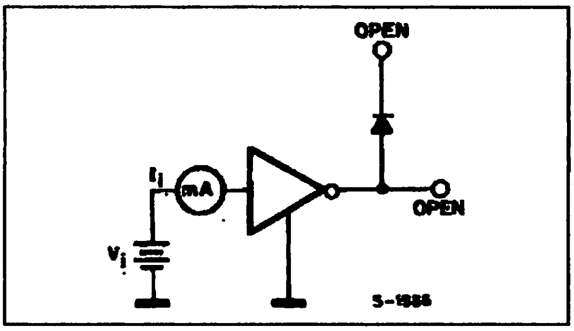


Figure 4.

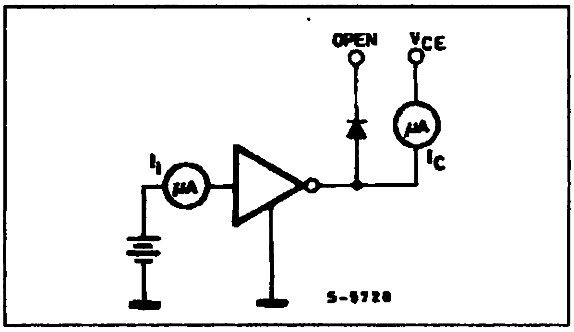


Figure 5.

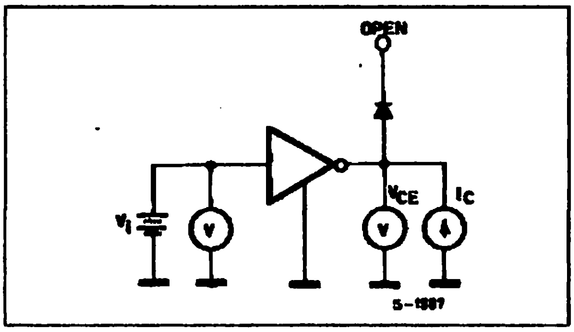


Figure 6.

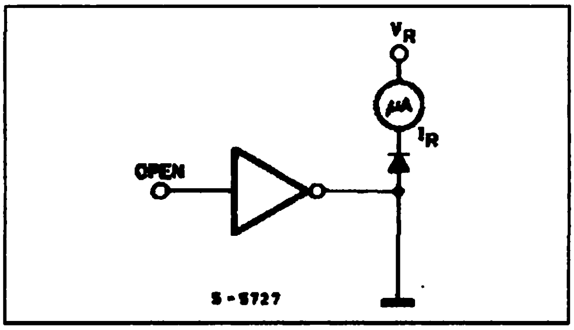


Figure 7.

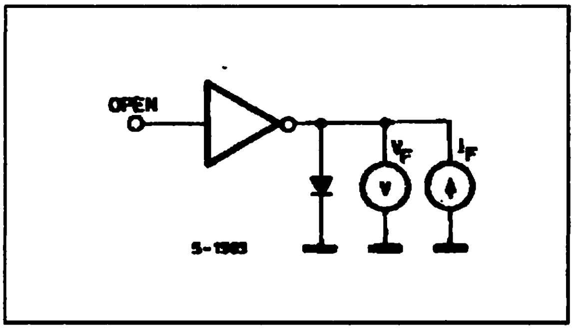


Figure 8: Collector Current versus Input Current

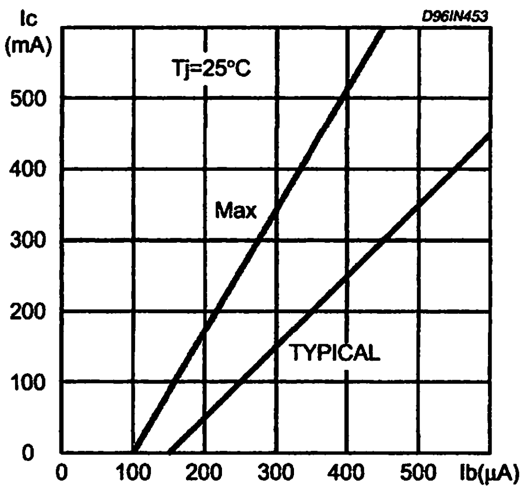


Figure 9: Collector Current versus Saturation Voltage

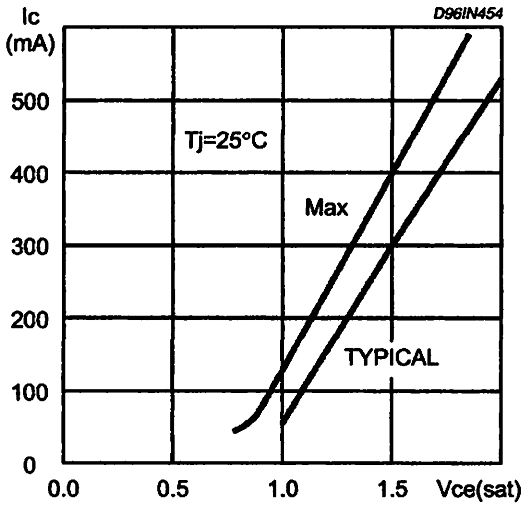


Figure 10: Peak Collector Current versus Duty Cycle

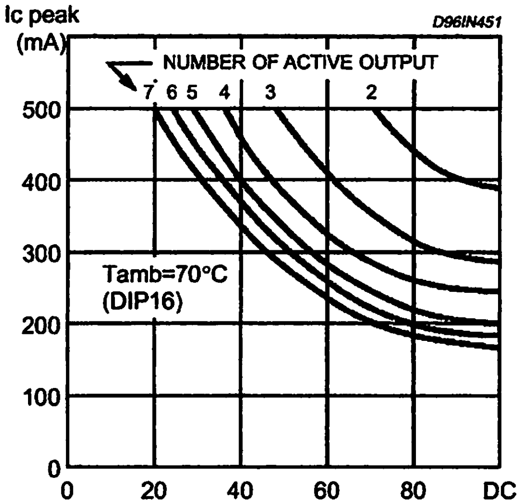
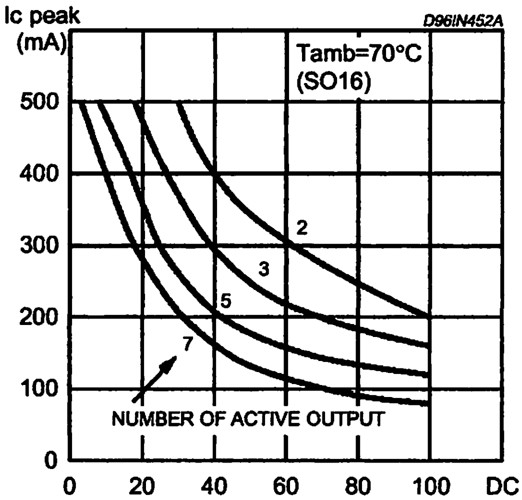
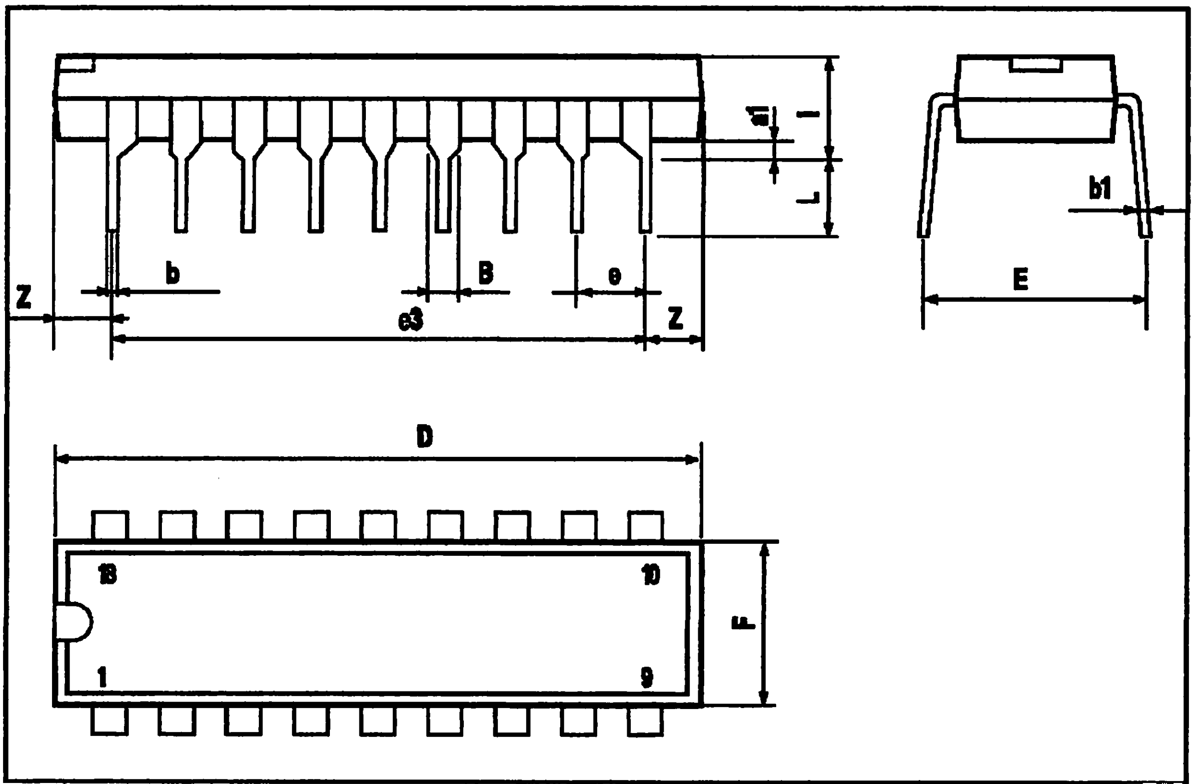


Figure 11: Peak Collector Current versus Duty Cycle



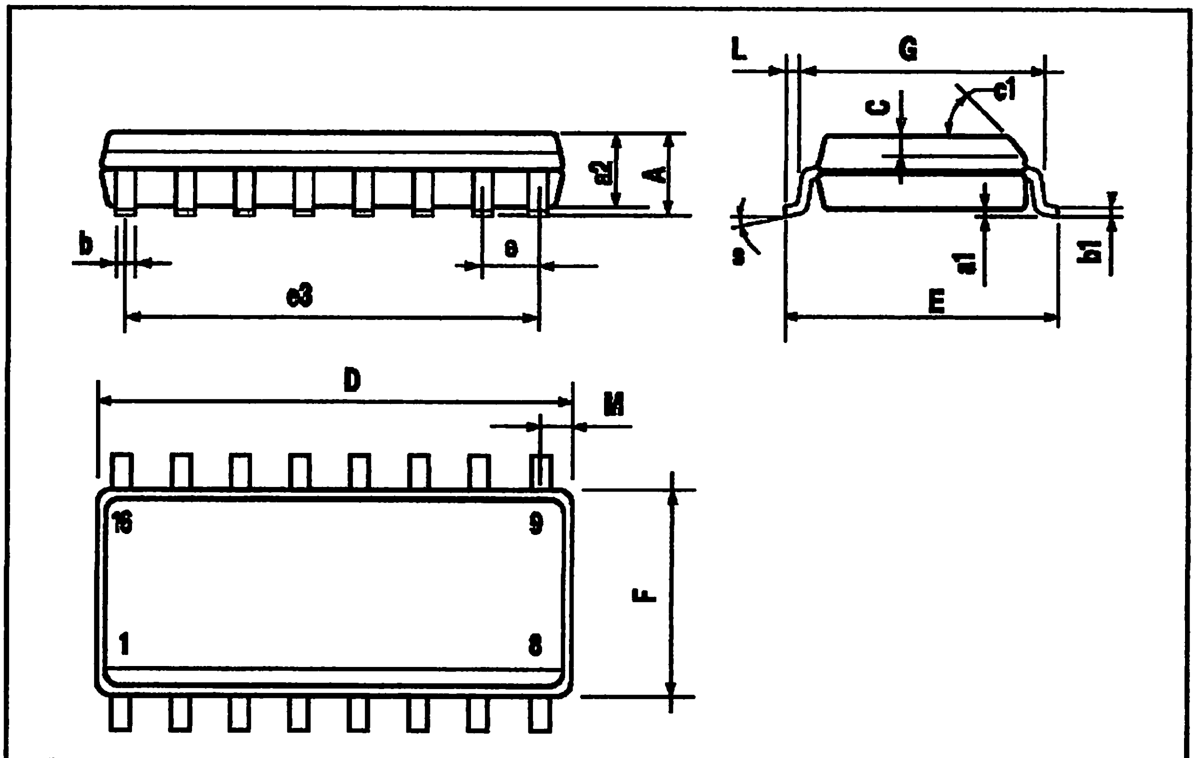
DIP16 PACKAGE MECHANICAL DATA

DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
a1	0.51			0.020		
B	0.77		1.65	0.030		0.065
b		0.5			0.020	
b1		0.25			0.010	
D			20			0.787
E		8.5			0.335	
e		2.54			0.100	
e3		17.78			0.700	
F			7.1			0.280
I			5.1			0.201
L		3.3			0.130	
Z			1.27			0.050



SO16 PACKAGE MECHANICAL DATA

DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A			1.75			0.069
a1	0.1		0.25	0.004		0.009
a2			1.6			0.063
b	0.35		0.46	0.014		0.018
b1	0.19		0.25	0.007		0.010
C		0.5			0.020	
c1	45 (typ.)					
D	9.8		10	0.386		0.394
E	5.8		6.2	0.228		0.244
e		1.27			0.050	
e3		8.89			0.350	
F	3.8		4.0	0.150		0.157
L	0.4		1.27	0.016		0.050
M			0.62			0.024
S	8 (max.)					

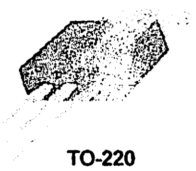


FAIRCHILD
SEMICONDUCTOR ™

TIP31 Series(TIP31/31A/31B/31C)

Medium Power Linear Switching Applications

- Complementary to TIP32/32A/32B/32C



1 TO-220

1.Base 2.Collector 3.Emitter

NPN Epitaxial Silicon Transistor

Absolute Maximum Ratings T_C=25°C unless otherwise noted

Symbol	Parameter	Value	Units
V_{CBO}	Collector-Base Voltage : TIP31	40	V
	: TIP31A	60	V
	: TIP31B	80	V
	: TIP31C	100	V
V_{CEO}	Collector-Emitter Voltage : TIP31	40	V
	: TIP31A	60	V
	: TIP31B	80	V
	: TIP31C	100	V
V_{EBO}	Emitter-Base Voltage	5	V
I_C	Collector Current (DC)	3	A
I_{CP}	Collector Current (Pulse)	5	A
I_B	Base Current	1	A
P_C	Collector Dissipation (T_C=25°C)	40	W
P_C	Collector Dissipation (T_a=25°C)	2	W
T_J	Junction Temperature	150	°C
T_{STG}	Storage Temperature	- 65 ~ 150	°C

Electrical Characteristics T_C=25°C unless otherwise noted

Symbol	Parameter	Test Condition	Min.	Max.	Units
V_{CEO}(sus)	* Collector-Emitter Sustaining Voltage				
	: TIP31	I_C = 30mA, I_B = 0	40		V
	: TIP31A		60		V
	: TIP31B		80		V
	: TIP31C		100		V
I_{CEO}	Collector Cut-off Current				
	: TIP31/31A	V_{CE} = 30V, I_B = 0		0.3	mA
	: TIP31B/31C	V_{CE} = 60V, I_B = 0		0.3	mA
I_{CES}	Collector Cut-off Current				
	: TIP31	V_{CE} = 40V, V_{EB} = 0		200	μA
	: TIP31A	V_{CE} = 60V, V_{EB} = 0		200	μA
	: TIP31B	V_{CE} = 80V, V_{EB} = 0		200	μA
	: TIP31C	V_{CE} = 100V, V_{EB} = 0		200	μA
I_{EBO}	Emitter Cut-off Current	V_{EB} = 5V, I_C = 0		1	mA
h_{FE}	* DC Current Gain	V_{CE} = 4V, I_C = 1A	25		
		V_{CE} = 4V, I_C = 3A	10	50	
V_{CE}(sat)	* Collector-Emitter Saturation Voltage	I_C = 3A, I_B = 375mA		1.2	V
V_{BE}(sat)	* Base-Emitter Saturation Voltage	V_{CE} = 4V, I_C = 3A		1.8	V
f_T	Current Gain Bandwidth Product	V_{CE} = 10V, I_C = 500mA	3.0		MHz

* Pulse Test: PW≤300μs, Duty Cycle≤2%

Typical Characteristics

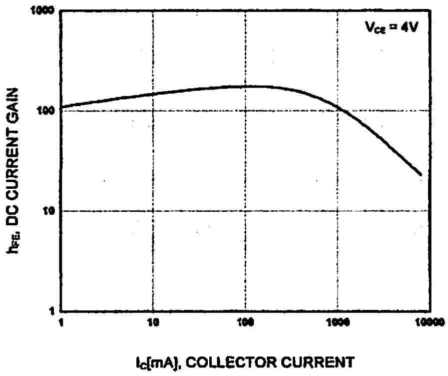


Figure 1. DC current Gain

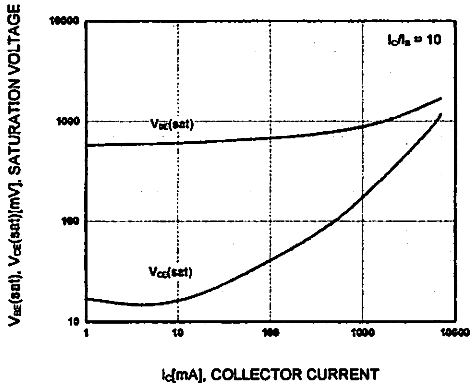


Figure 2. Base-Emitter Saturation Voltage Collector-Emitter Saturation Voltage

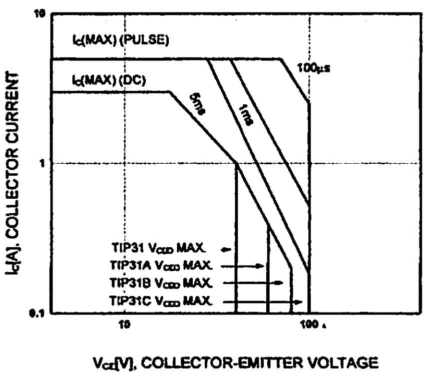


Figure 3. Safe Operating Area

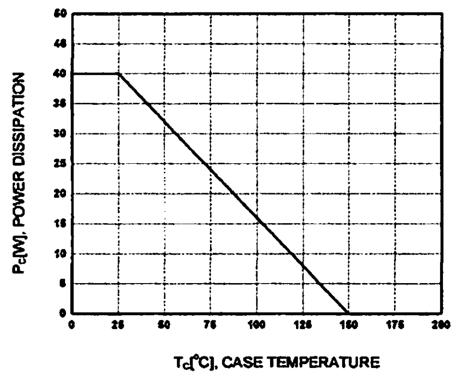
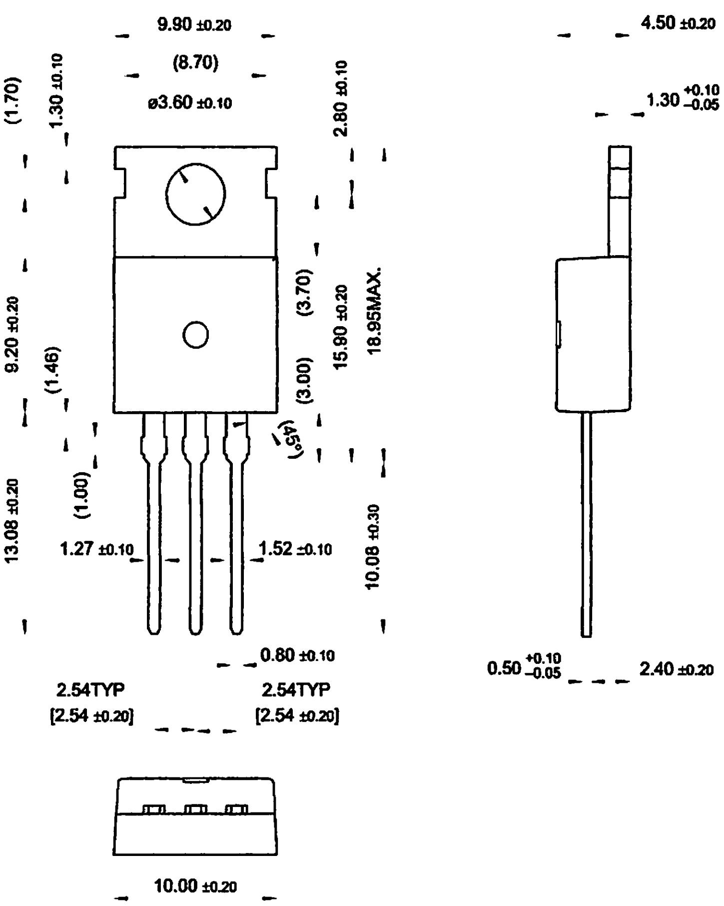


Figure 4. Power Derating

Package Demensions

TO-220



Dimensions in Millimeters

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FAST®
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GTO™
HiSeC™
ISOPLANAR™
MICROWIRE™
POP™
PowerTrench®
QFET™
QS™
Quiet Series™
SuperSOT™-3
SuperSOT™-6
SuperSOT™-8
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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

PRODUCT STATUS DEFINITIONS

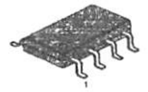
Definition of Terms

Datasheet Identification	Product Status	Definition
Advance Information	Formative or In Design	This datasheet contains the design specifications for product development. Specifications may change in any manner without notice.
Preliminary	First Production	This datasheet contains preliminary data, and supplementary data will be published at a later date. Fairchild Semiconductor reserves the right to make changes at any time without notice in order to improve design.
No Identification Needed	Full Production	This datasheet contains final specifications. Fairchild Semiconductor reserves the right to make changes at any time without notice in order to improve design.
Obsolete	Not In Production	This datasheet contains specifications on a product that has been discontinued by Fairchild semiconductor. The datasheet is printed for reference information only.

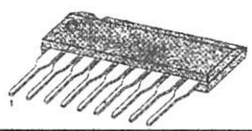
DUAL OPERATIONAL AMPLIFIERS

The LM258 series consists of four independent, high gain, internally Frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltage.
Operation from split power supplies is also possible and the low power Supply current drain is independent of the magnitude of the power Supply voltage. Application areas include transducer amplifier, DC gain blocks and all the conventional OP amp circuits which now can be easily implemented in single 8 SOP power supply system.

8 DIP



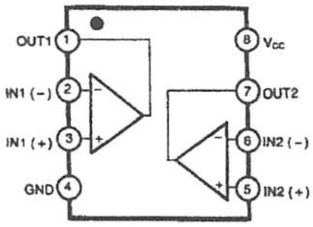
9 SIP

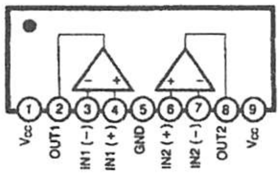


FEATURES

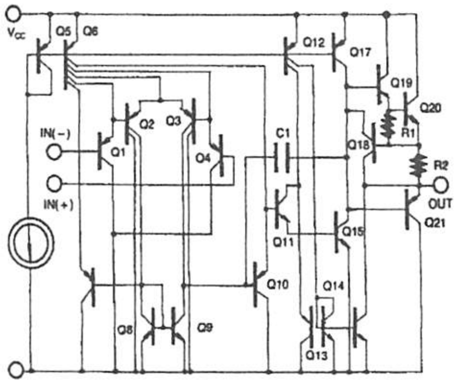
- Internally frequency compensated for unity gain
- Large DC voltage gain: 100dB
- Wide power supply range: LM258/A, LM358/A: 3V~32V (or ±1.5V~16V)
  LM2904: 3V~26V (or ±1.5V~13V)
- Input common-mode voltage range Includes ground
- Large output voltage swing: 0V DC to Vcc - 1.5V DC
- Power drain suitable for battery operation.

BLOCK DIAGRAM





SCHEMATIC DIAGRAM (One section only)



ORDERING INFORMATION

Device	Package	Operating Temperature
LM358N LM358AN	8 DIP	0 ~ + 70°C
LM358S LM358AS	9 SIP	
LM358M LM358AM	8 SOP	
LM258N LM258AN	8 DIP	-25 ~ + 85°C
LM258S LM258AS	9 SIP	
LM258M LM258AM	8 SOP	
LM2904N	8 DIP	-40 ~ + 85°C
LM2904S	9 SIP	
LM2904M	8 SOP	

FAIRCHILD SEMICONDUCTOR TM

Rev. B

ABSOLUTE MAXIMUM RATINGS

Characteristic	Symbol	LM258/LM258A	LM358/LM358A	LM2904	Unit
Supply Voltage	V_{CC}	±16 or 32	±16 or 32	±13 or 26	V
Differential Input Voltage	$V_{I(DIFF)}$	32	32	26	V
Input Voltage	V_I	-0.3 to +32	-0.3 to +32	-0.3 to +26	V
Output Short Circuit to GND $V_{CC} \leq V$, T_A = 25°C(One Amp)		Continuous	Continuous	Continuous	
Operating Temperature Range	T_{OPR}	-25 ~ + 85	0 ~ + 70	-40 ~ + 85	°C
Storage Temperature Range	T_{STG}	-65 ~ + 150	-65 ~ + 150	-65 ~ + 150	°C

ELECTRICAL CHARACTERISTICS

(V_{CC} = 5.0V, V_{EE} = GND, T = 25°C, unless otherwise specified)

Characteristic	Symbol	Test Conditions	LM258			LM358			LM2904			Unit
			Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	V_{IO}	V_{CM} = 0V to V_{CC} -1.5V $V_{O(P)}$ = 1.4V, R_S = 0Ω		2.9	5.0		2.9	7.0		2.9	7.0	mV
Input Offset Current	I_{IO}			3	30		5	50		5	50	nA
Input Bias Current	I_{BIAS}			45	150		45	250		45	250	nA
Input Common-Mode Voltage Range	$V_{I(R)}$	V_{CC} = 30V (KA2904, V_{CC} = 26V)	0		V_{CC} -1.5	0		V_{CC} -1.5	0		V_{CC} -1.5	V
Supply Current	I_{CC}	R_L = ∞, V_{CC} = 30V (KA2902, V_{CC} = 26V)		0.8	2.0		0.8	2.0		0.8	2.0	mA
		R_L = ∞,over full temperature range		0.5	1.2		0.5	1.2		0.5	1.2	mA
Large Signal Voltage Gain	G_V	V_{CC} = 15V, $R_L \geq 2K\Omega$ $V_{O(P)}$ = 1V to 11V	50	100		25	100		25	100		V/mV
Output Voltage Swing	$V_{O(H)}$	V_{CC} = 30V, R_L = 2KΩ	26			26			22			V
		V_{CC} = 26V for 2904, R_L = 10KΩ	27	28		27	28		23	24		V
	$V_{O(L)}$	V_{CC} = 5V, $R_L \geq 10K\Omega$		5	20		5	20		5	100	mV
Common-Mode Rejection Ratio	CMRR		70	85		65	80		50	80		dB
Power Supply Rejection Ratio	PSRR		65	100		65	100		50	100		dB
Channel Separation	CS	f = 1KHz to 20KHz		120			120			120		dB
Short Circuit to GND	I_{SC}			40	60		40	60		40	60	mA
Output Current	I_{SOURCE}	$V_{I(+)}$ = 1V, $V_{I(-)}$ = 0V V_{CC} = 15V, $V_{O(P)}$ = 2V	10	30		10	30		10	30		mA
	I_{SINK}	$V_{I(+)}$ = 0V, $V_{I(-)}$ = 1V V_{CC} = 15V, $V_{O(P)}$ = 2V	10	15		10	15		10	15		mA
		$V_{I(+)}$ = 0V, $V_{I(-)}$ = 1V V_{CC} = 15V, $V_{O(P)}$ = 200mA	12	100		12	100					µA
Differential Input Voltage	$V_{I(DIFF)}$				V_{CC}			V_{CC}			V_{CC}	V

ELECTRICAL CHARACTERISTICS

(V_{CC}=5.0V, V_{EE}=GND, unless otherwise specified)
The following specification apply over the range of - 25°C ≤ T_A ≤ + 85°C for the KA258; and the 0°C ≤ T_A ≤ + 70°C for the LM358; and the -40°C ≤ T_A ≤ +85°C for the LM2904

Characteristic	Symbol	Test Conditions	LM258			LM358			LM2904			Unit
			Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	V_{IO}	V_{CM} = 0V to V_{CC} = 1.5V $V_{O(P)}$ = 1.4V, R_S = 0Ω			7.0			9.0			10.0	mV
Input Offset Voltage Drift	V_{IO}	R_S = 0Ω		7.0			7.0			7.0		μV/°C
Input Offset Current	I_{IO}				100			150		45	200	nA
Input Offset Current Drift	$\Delta I_{IO}/\Delta T$			10			10			10		pA/°C
Input Bias Current	I_{BIAS}			40	300		40	500		40	500	nA
Input Common-Mode Voltage Range	$V_{I(R)}$	V_{CC} = 30V (KA2904, V_{CC} = 26V)	0		V_{CC} =2.0	0		V_{CC} =2.0	0		V_{CC} =2.0	V
Large Signal Voltage Gain	G_V	V_{CC} = 15V, R_L≥2.0KΩ $V_{O(P)}$ = 1V to 11V	25			15			15			V/mV
Output Voltage Swing	$V_{O(H)}$	V_{CC} = 30V, R_L = 2KΩ	26			26			26			V
		V_{CC} = 26V for 2904, R_L = 10KΩ	27	28		27	28		27	28		V
	$V_{O(L)}$	V_{CC} = 5V, R_L≥10KΩ		5	20		5	20		5	20	mV
Output Current	I_{SOURCE}	$V_{I(+)}$ = 1V, $V_{I(-)}$ = 0V V_{CC} = 15V, $V_{O(P)}$ = 2V	10	30		10	30		10	30		mA
	I_{SINK}	$V_{I(+)}$ = 0V, $V_{I(-)}$ = 1V V_{CC} = 15V, $V_{O(P)}$ = 2V	5	8		5	9		5	9		mA
Differential Input Voltage	$V_{I(DIFF)}$				V_{CC}			V_{CC}			V_{CC}	V

ELECTRICAL CHARACTERISTICS

(V_{CC} = 5.0V, V_{EE}=GND, T_A=25°C, unless otherwise specified)

Characteristic	Symbol	Test Conditions		LM258A			LM358A			Unit
				Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	V_{IO}	V_{CM} = 0V to V_{CC} = 1.5V $V_{O(P)}$ = 1.4V, R_S = 0Ω			1.0	3.0		2.0	3.0	mV
Input Offset Current	I_{IO}				2	15		5	30	nA
Input Bias Current	I_{BIAS}				40	80		45	100	nA
Input Common-Mode Voltage Range	$V_{I(R)}$	V_{CC} = 30V		0		V_{CC} =1.5	0		V_{CC} =1.5	V
Supply Current	I_{CC}	R_L = ∞, V_{CC} = 30V			0.8	2.0		0.8	2.0	mA
		RL = ∞, over full temperature range			0.5	1.2		0.5	1.2	mA
Large Signal Voltage Gain	G_V	V_{CC} = 15V, R_L≥2KΩ V_O = 1V to 11V		50	100		25	100		V/mV
Output Voltage Swing	V_{OH}	V_{CC} = 30V	R_L = 2KΩ	26			26			V
		V_{CC} = 26V for 2904	R_L = 10KΩ	27	28		27	28		V
	$V_{O(L)}$	V_{CC} = 5V, R_L≥10KΩ			5	20		5	20	mV
Common-Mode Rejection Ratio	CMRR			70	85		65	85		dB
Power Supply Rejection Ratio	PSRR			65	100		65	100		dB
Channel Separation	CS	f = 1KHz to 20KHz			120			120		dB
Short Circuit to GND	I_{SC}				40	60		40	60	mA
Output Current	I_{SOURCE}	$V_{I(+)}$ = 1V, $V_{I(-)}$ = 0V V_{CC} = 15V, $V_{O(P)}$ = 2V		20	30		20	30		mA
	I_{SINK}	$V_{I(+)}$ = 1V, $V_{I(-)}$ = 0V V_{CC} = 15V, $V_{O(P)}$ = 2V		10	15		10	15		mA
		V_{in+} = 0V, V_{in-} = 1V $V_{O(P)}$ = 200mV		12	100		12	100		μA
Differential Input Voltage	$V_{I(DIFF)}$					V_{CC}			V_{CC}	V

ELECTRICAL CHARACTERISTICS (V_{CC} = 5.0V, V_{EE} = GND. unless otherwise specified)

The following specification apply over the range of -25°C ≤ T_A ≤ +85°C for the LM258A; and the 0°C ≤ T_A ≤ +70°C for the LM358A

Characteristic	Symbol	Test Conditions	LM258A			LM358A			Unit
			Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	V_{IO}	V_{CM} = 0V to V_{CC} = 1.5V $V_{O(P)}$ = 1.4V, R_S = 0Ω			4.0			5.0	mV
Input Offset Voltage Drift	$\Delta V_{IO}/\Delta T$			7.0	15		7.0	20	µV/°C
Input Offset Current	I_{IO}				30			75	nA
Input Offset Current Drift	$\Delta I_{IO}/\Delta T$			10	200		10	300	pA/°C
Input Bias Current	I_{BIAS}			40	100		40	200	nA
Input Common-Mode Voltage Range	$V_{I(R)}$	V_{CC} = 30V	0		Vcc =2.0	0		Vcc =2.0	V
Output Voltage Swing	$V_{O(H)}$	V_{CC} = 30V, R_L = 2KΩ	26			26			V
		V_{CC} = 30V, R_L = 10KΩ	27	28		27	28		V
	$V_{O(L)}$	V_{CC} = 5V, R_L≥10KΩ		5	20		5	20	mV
Large Signal Voltage Gain	G_V	V_{CC} = 15V, R_L≥2.0KΩ $V_{O(P)}$ = 1V to 11V	25			15			V/mV
Output Current	I_{SOURCE}	$V_{I(+)}$ = 1V, $V_{I(-)}$ = 0V V_{CC} = 15V, $V_{O(P)}$ = 2V	10	30		10	30		mA
	I_{SINK}	$V_{I(+)}$ = 1V, $V_{I(-)}$ = 0V V_{CC} = 15V, $V_{O(P)}$ = 2V	5	9		5	9		mA
Differential Input Voltage	$V_{I(DIFF)}$				V_{CC}			V_{CC}	V

TYPICAL PERFORMANCE CHARACTERISTICS

Fig. 1 SUPPLY CURRENT

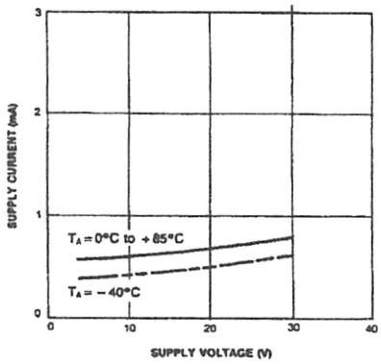


Fig. 2 VOLTAGE GAIN

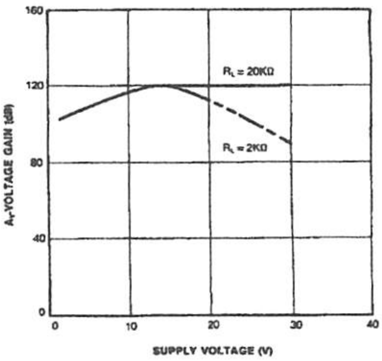


Fig. 3 OPEN LOOP FREQUENCY RESPONSE

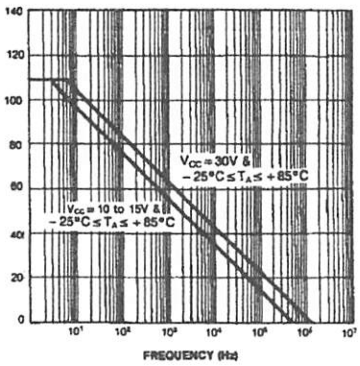


Fig. 4 LARGE SIGNAL FREQUENCY

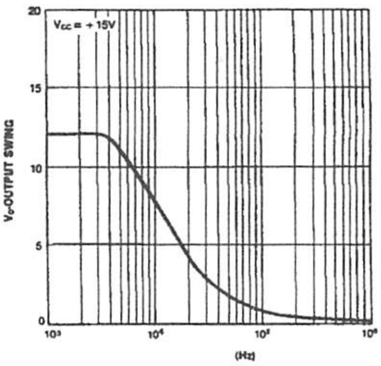


Fig. 5 OUTPUT CHARACTERISTICS CURRENT SOURCING

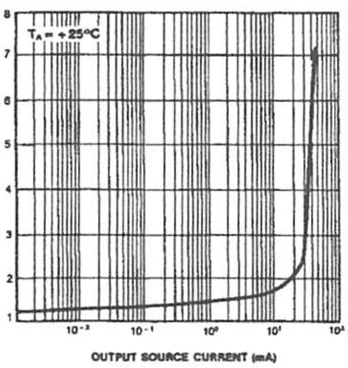


Fig. 6 OUTPUT CHARACTERISTICS CURRENT SINKING

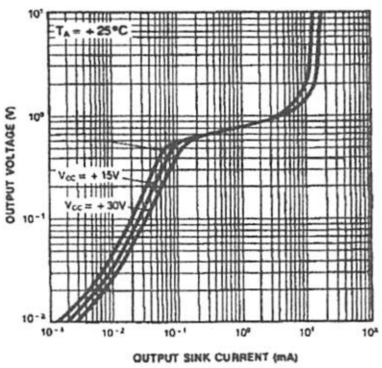


Fig. 7 INPUT VOLTAGE RANGE

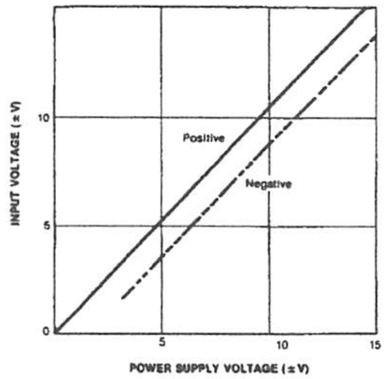


Fig. 8 COMMON-MODE REJECTION RATIO

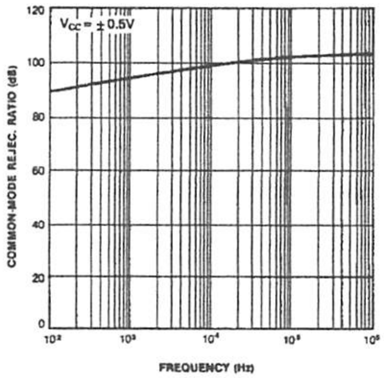


Fig. 9 CURRENT LIMITING

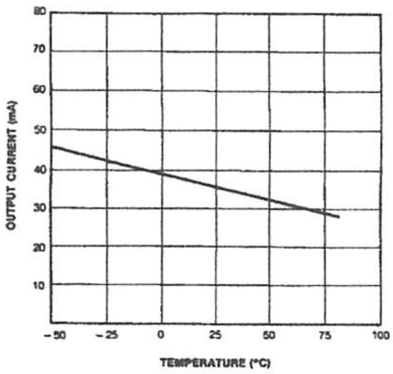


Fig. 10 INPUT CURRENT

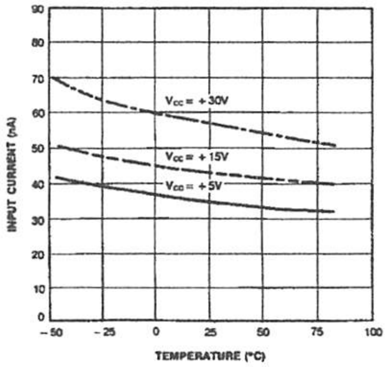


Fig. 11 VOLTAGE FOLLOWER PULSE RESPONSE

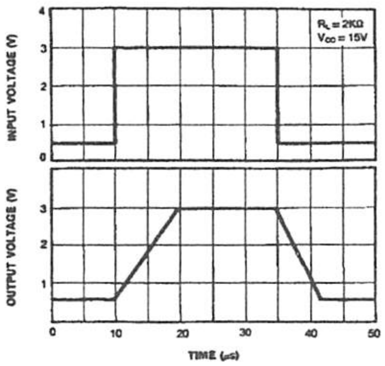
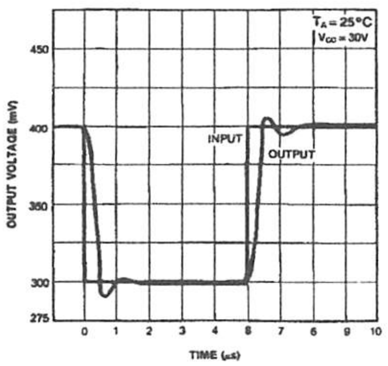


Fig. 12 VOLTAGE FOLLOWER PULSE RESPONSE (SMALL SIGNAL)



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PRODUCT STATUS DEFINITIONS

Definition of Terms

Datasheet Identification	Product Status	Definition
Advance Information	Formative or In Design	This datasheet contains the design specifications for product development. Specifications may change in any manner without notice.
Preliminary	First Production	This datasheet contains preliminary data, and supplementary data will be published at a later date. Fairchild Semiconductor reserves the right to make changes at any time without notice in order to improve design.
No Identification Needed	Full Production	This datasheet contains final specifications. Fairchild Semiconductor reserves the right to make changes at any time without notice in order to improve design.
Obsolete	Not In Production	This datasheet contains specifications on a product that has been discontinued by Fairchild semiconductor. The datasheet is printed for reference information only.

National Semiconductor

September 1997

LM35/LM35A/LM35C/LM35CA/LM35D Precision Centigrade Temperature Sensors

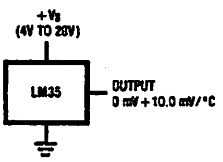
General Description

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55 to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 µA from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35 is rated to operate over a −55° to +150°C temperature range, while the LM35C is rated for a −40° to +110°C range (−10° with improved accuracy). The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-220 package.

Features

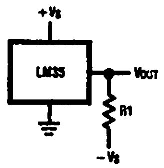
- Calibrated directly in ° Celsius (Centigrade)
- Linear + 10.0 mV/°C scale factor
- 0.5°C accuracy guaranteeable (at +25°C)
- Rated for full −55° to +150°C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60 µA current drain
- Low self-heating, 0.08°C in still air
- Nonlinearity only ±¼°C typical
- Low impedance output, 0.1 Ω for 1 mA load

Typical Applications



DS005516-3

FIGURE 1. Basic Centirade Temperature Sensor (+2°C to +150°C)



DS005516-4

Choose $R_1 = -V_S/50\ \mu A$
$V_{OUT} = +1{,}500$ mV at +150°C
$= +250$ mV at +25°C
$= -550$ mV at −55°C

FIGURE 2. Full-Range Centigrade Temperature Sensor

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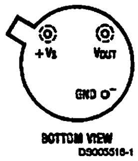
Connection Diagrams

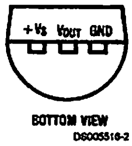
TO-46
Metal Can Package*



*Case is connected to negative pin (GND)

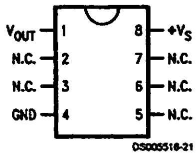
Order Number LM35H, LM35AH, LM35CH, LM35CAH or LM35DH
See NS Package Number H03H

TO-92
Plastic Package



Order Number LM35CZ, LM35CAZ or LM35DZ
See NS Package Number Z03A

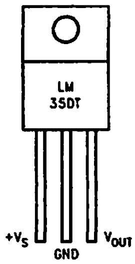
SO-8
Small Outline Molded Package



N.C. = No Connection

Top View
Order Number LM35DM
See NS Package Number M08A

TO-220
Plastic Package*



DS005516-24

*Tab is connected to the negative pin (GND).
Note: The LM35DT pinout is different than the discontinued LM35DP.

Order Number LM35DT
See NS Package Number TA03F

Absolute Maximum Ratings (Note 10)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Supply Voltage	+35V to −0.2V
Output Voltage	+6V to −1.0V
Output Current	10 mA
Storage Temp.;	
TO-46 Package,	−60°C to +180°C
TO-92 Package,	−60°C to +150°C
SO-8 Package,	−65°C to +150°C
TO-220 Package,	−65°C to +150°C
Lead Temp.:	
TO-46 Package, (Soldering, 10 seconds)	300°C
TO-92 and TO-220 Package, (Soldering, 10 seconds)	260°C
SO Package (Note 12)	
Vapor Phase (60 seconds)	215°C
Infrared (15 seconds)	220°C
ESD Susceptibility (Note 11)	2500V

Specified Operating Temperature Range: T_{MIN} to T_{MAX} (Note 2)

LM35, LM35A	−55°C to +150°C
LM35C, LM35CA	−40°C to +110°C
LM35D	0°C to +100°C

Electrical Characteristics

(Notes 1, 6)

Parameter	Conditions	LM35A			LM35CA			Units
		Typical	Tested Limit (Note 4)	Design Limit (Note 5)	Typical	Tested Limit (Note 4)	Design Limit (Note 5)	(Max.)
Accuracy (Note 7)	T_A=+25°C	±0.2	±0.5		±0.2	±0.5		°C
	T_A=−10°C	±0.3			±0.3		±1.0	°C
	$T_A=T_{MAX}$	±0.4	±1.0		±0.4	±1.0		°C
	$T_A=T_{MIN}$	±0.4	±1.0		±0.4		±1.5	°C
Nonlinearity (Note 8)	$T_{MIN}\leq T_A\leq T_{MAX}$	±0.18		±0.35	±0.15		±0.3	°C
Sensor Gain (Average Slope)	$T_{MIN}\leq T_A\leq T_{MAX}$	+10.0	+9.9, +10.1		+10.0		+9.9, +10.1	mV/°C
Load Regulation (Note 3) $0\leq I_L\leq 1$ mA	T_A=+25°C	±0.4	±1.0		±0.4	±1.0		mV/mA
	$T_{MIN}\leq T_A\leq T_{MAX}$	±0.5		±3.0	±0.5		±3.0	mV/mA
Line Regulation (Note 3)	T_A=+25°C	±0.01	±0.05		±0.01	±0.05		mV/V
	$4V\leq V_S\leq 30V$	±0.02		±0.1	±0.02		±0.1	mV/V
Quiescent Current (Note 9)	V_S=+5V, +25°C	56	67		56	67		μA
	V_S=+5V	105		131	91		114	μA
	V_S=+30V, +25°C	56.2	68		56.2	68		μA
	V_S=+30V	105.5		133	91.5		116	μA
Change of Quiescent Current (Note 3)	$4V\leq V_S\leq 30V$, +25°C	0.2	1.0		0.2	1.0		μA
	$4V\leq V_S\leq 30V$	0.5		2.0	0.5		2.0	μA
Temperature Coefficient of Quiescent Current		+0.39		+0.5	+0.39		+0.5	μA/°C
Minimum Temperature for Rated Accuracy	In circuit of *Figure 1*, I_L=0	+1.5		+2.0	+1.5		+2.0	°C
Long Term Stability	$T_J=T_{MAX}$, for 1000 hours	±0.08			±0.08			°C

Electrical Characteristics

(Notes 1, 6)

Parameter	Conditions	LM35			LM35C, LM35D			Units (Max.)
		Typical	Tested Limit (Note 4)	Design Limit (Note 5)	Typical	Tested Limit (Note 4)	Design Limit (Note 5)	
Accuracy,	T_A=+25°C	±0.4	±1.0		±0.4	±1.0		°C
LM35, LM35C	T_A=−10°C	±0.5			±0.5		±1.5	°C
(Note 7)	T_A=T_{MAX}	±0.8	±1.5		±0.8		±1.5	°C
	T_A=T_{MIN}	±0.8		±1.5	±0.8		±2.0	°C
Accuracy, LM35D	T_A=+25°C				±0.6	±1.5		°C
(Note 7)	T_A=T_{MAX}				±0.9		±2.0	°C
	T_A=T_{MIN}				±0.9		±2.0	°C
Nonlinearity (Note 8)	T_{MIN}≤T_A≤T_{MAX}	**±0.3**		**±0.5**	**±0.2**		**±0.5**	°C
Sensor Gain (Average Slope)	T_{MIN}≤T_A≤T_{MAX}	**+10.0**	**+9.8, +10.2**		**+10.0**		**+9.8, +10.2**	mV/°C
Load Regulation	T_A=+25°C	±0.4	±2.0		±0.4	±2.0		mV/mA
(Note 3) 0≤I_L≤1 mA	T_{MIN}≤T_A≤T_{MAX}	**±0.5**		**±5.0**	**±0.5**		**±5.0**	mV/mA
Line Regulation	T_A=+25°C	±0.01	±0.1		±0.01	±0.1		mV/V
(Note 3)	4V≤V_S≤30V	**±0.02**		**±0.2**	**±0.02**		**±0.2**	mV/V
Quiescent Current	V_S=+5V, +25°C	56	80		56	80		µA
(Note 9)	V_S=+5V	**105**		**158**	**91**		**138**	µA
	V_S=+30V, +25°C	56.2	82		56.2	82		µA
	V_S=+30V	**105.5**		**161**	**91.5**		**141**	µA
Change of	4V≤V_S≤30V, +25°C	0.2	2.0		0.2	2.0		µA
Quiescent Current (Note 3)	4V≤V_S≤30V	**0.5**		**3.0**	**0.5**		**3.0**	µA
Temperature Coefficient of Quiescent Current		**+0.39**		**+0.7**	**+0.39**		**+0.7**	µA/°C
Minimum Temperature for Rated Accuracy	In circuit of *Figure 1*, I_L=0	+1.5		+2.0	+1.5		+2.0	°C
Long Term Stability	T_J=T_{MAX}, for 1000 hours	±0.08			±0.08			°C

Note 1: Unless otherwise noted, these specifications apply: −55°C≤T_J≤+150°C for the LM35 and LM35A; −40°≤T_J≤+110°C for the LM35C and LM35CA; and 0°≤T_J≤+100°C for the LM35D. V_S=+5Vdc and I_{LOAD}=50 µA, in the circuit of *Figure 2*. These specifications also apply from +2°C to T_{MAX} in the circuit of *Figure 1*. Specifications in **boldface** apply over the full rated temperature range.

Note 2: Thermal resistance of the TO-46 package is 400°C/W, junction to ambient, and 24°C/W junction to case. Thermal resistance of the TO-92 package is 180°C/W junction to ambient. Thermal resistance of the small outline molded package is 220°C/W junction to ambient. Thermal resistance of the TO-220 package is 90°C/W junction to ambient. For additional thermal resistance information see table in the Applications section.

Note 3: Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the internal dissipation by the thermal resistance.

Note 4: Tested Limits are guaranteed and 100% tested in production.

Note 5: Design Limits are guaranteed (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.

Note 6: Specifications in **boldface** apply over the full rated temperature range.

Note 7: Accuracy is defined as the error between the output voltage and 10mv/°C times the device's case temperature, at specified conditions of voltage, current, and temperature (expressed in °C).

Note 8: Nonlinearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the device's rated temperature range.

Note 9: Quiescent current is defined in the circuit of *Figure 1*.

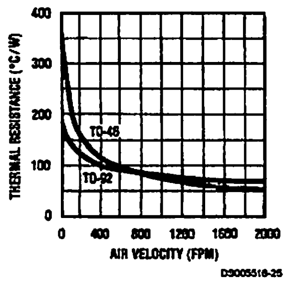
Note 10: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions. See Note 1.

Note 11: Human body model, 100 pF discharged through a 1.5 kΩ resistor.

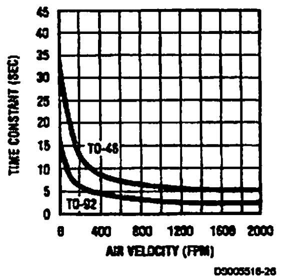
Note 12: See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" or the section titled "Surface Mount" found in a current National Semiconductor Linear Data Book for other methods of soldering surface mount devices.

Typical Performance Characteristics

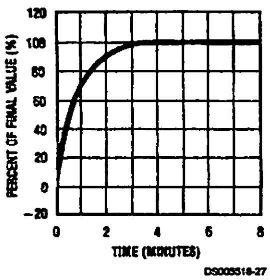
Thermal Resistance Junction to Air



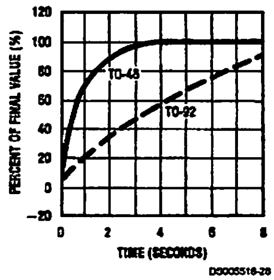
Thermal Time Constant



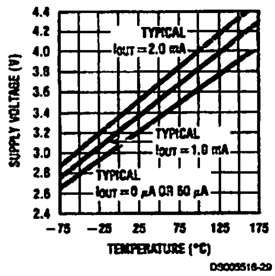
Thermal Response in Still Air



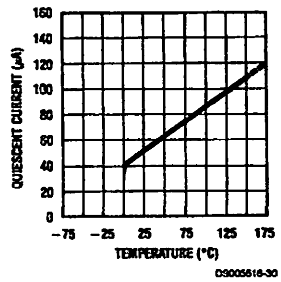
Thermal Response in Stirred Oil Bath



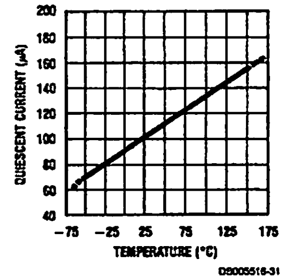
Minimum Supply Voltage vs. Temperature



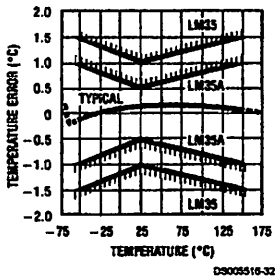
Quiescent Current vs. Temperature (In Circuit of *Figure 1.*)



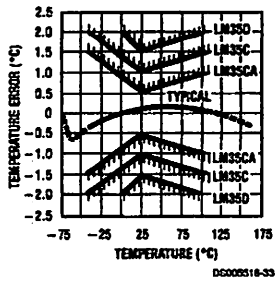
Quiescent Current vs. Temperature (In Circuit of *Figure 2.*)



Accuracy vs. Temperature (Guaranteed)

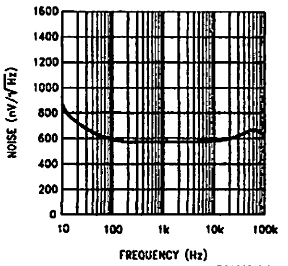


Accuracy vs. Temperature (Guaranteed)



Typical Performance Characteristics (Continued)

Noise Voltage



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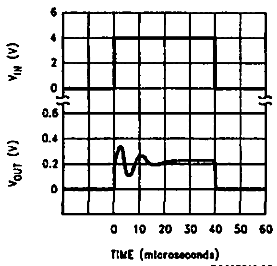
Start-Up Response



DS005516-35

Applications

The LM35 can be applied easily in the same way as other integrated-circuit temperature sensors. It can be glued or cemented to a surface and its temperature will be within about 0.01°C of the surface temperature.

This presumes that the ambient air temperature is almost the same as the surface temperature; if the air temperature were much higher or lower than the surface temperature, the actual temperature of the LM35 die would be at an intermediate temperature between the surface temperature and the air temperature. This is expecially true for the TO-92 plastic package, where the copper leads are the principal thermal path to carry heat into the device, so its temperature might be closer to the air temperature than to the surface temperature.

To minimize this problem, be sure that the wiring to the LM35, as it leaves the device, is held at the same temperature as the surface of interest. The easiest way to do this is to cover up these wires with a bead of epoxy which will insure that the leads and wires are all at the same temperature as the surface, and that the LM35 die's temperature will not be affected by the air temperature.

The TO-46 metal package can also be soldered to a metal surface or pipe without damage. Of course, in that case the V− terminal of the circuit will be grounded to that metal. Alternatively, the LM35 can be mounted inside a sealed-end metal tube, and can then be dipped into a bath or screwed into a threaded hole in a tank. As with any IC, the LM35 and accompanying wiring and circuits must be kept insulated and dry, to avoid leakage and corrosion. This is especially true if the circuit may operate at cold temperatures where condensation can occur. Printed-circuit coatings and varnishes such as Humiseal and epoxy paints or dips are often used to insure that moisture cannot corrode the LM35 or its connections.

These devices are sometimes soldered to a small light-weight heat fin, to decrease the thermal time constant and speed up the response in slowly-moving air. On the other hand, a small thermal mass may be added to the sensor, to give the steadiest reading despite small deviations in the air temperature.

Temperature Rise of LM35 Due To Self-heating (Thermal Resistance,Θ_{JA})

	TO-46, no heat sink	TO-46*, small heat fin	TO-92, no heat sink	TO-92**, small heat fin	SO-8 no heat sink	SO-8** small heat fin	TO-220 no heat sink
Still air	400°C/W	100°C/W	180°C/W	140°C/W	220°C/W	110°C/W	90°C/W
Moving air	100°C/W	40°C/W	90°C/W	70°C/W	105°C/W	90°C/W	26°C/W
Still oil	100°C/W	40°C/W	90°C/W	70°C/W			
Stirred oil	50°C/W	30°C/W	45°C/W	40°C/W			
(Clamped to metal, Infinite heat sink)	(24°C/W)				(55°C/W)		

*Wakefield type 201, or 1" disc of 0.020" sheet brass, soldered to case, or similar.
**TO-92 and SO-8 packages glued and leads soldered to 1" square of 1/16" printed circuit board with 2 oz. foil or similar.

Typical Applications

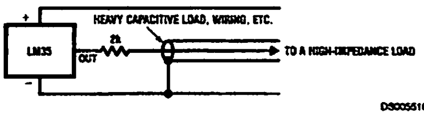


FIGURE 3. LM35 with Decoupling from Capacitive Load

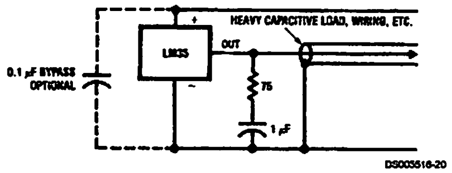


FIGURE 4. LM35 with R-C Damper

CAPACITIVE LOADS

Like most micropower circuits, the LM35 has a limited ability to drive heavy capacitive loads. The LM35 by itself is able to drive 50 pf without special precautions. If heavier loads are anticipated, it is easy to isolate or decouple the load with a resistor; see *Figure 3*. Or you can improve the tolerance of capacitance with a series R-C damper from output to ground; see *Figure 4*.

When the LM35 is applied with a 200Ω load resistor as shown in *Figure 5*, *Figure 6* or *Figure 8* it is relatively immune to wiring capacitance because the capacitance forms a bypass from ground to input, not on the output. However, as with any linear circuit connected to wires in a hostile environment, its performance can be affected adversely by intense electromagnetic sources such as relays, radio transmitters, motors with arcing brushes, SCR transients, etc, as its wiring can act as a receiving antenna and its internal junctions can act as rectifiers. For best results in such cases, a bypass capacitor from V_{IN} to ground and a series R-C damper such as 75Ω in series with 0.2 or 1 μF from output to ground are often useful. These are shown in *Figure 13*, *Figure 14*, and *Figure 16*.

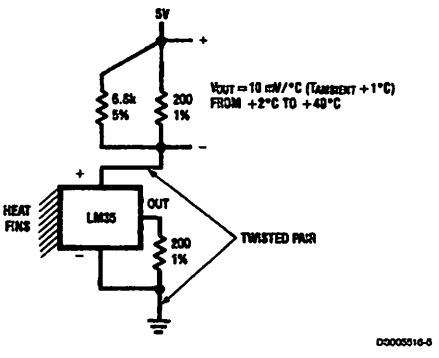


FIGURE 5. Two-Wire Remote Temperature Sensor (Grounded Sensor)

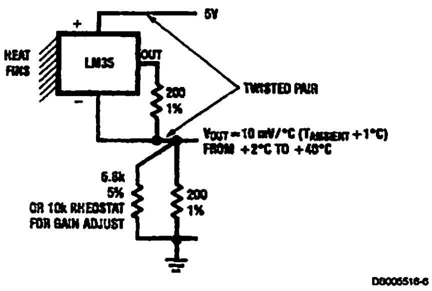


FIGURE 6. Two-Wire Remote Temperature Sensor (Output Referred to Ground)

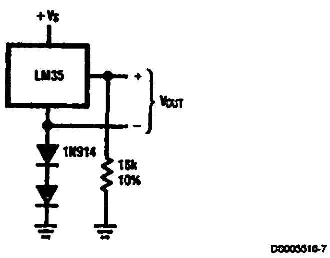


FIGURE 7. Temperature Sensor, Single Supply, −55° to +150°C

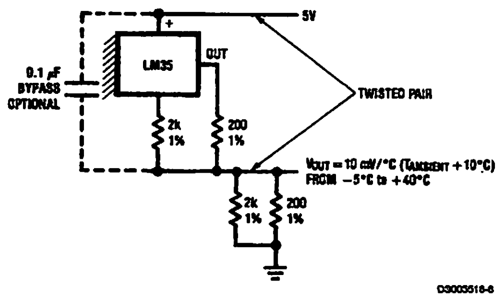


FIGURE 8. Two-Wire Remote Temperature Sensor (Output Referred to Ground)

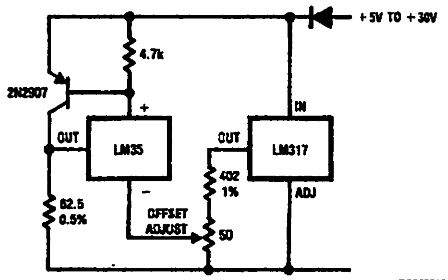


FIGURE 9. 4-To-20 mA Current Source (0°C to +100°C)

Typical Applications (Continued)

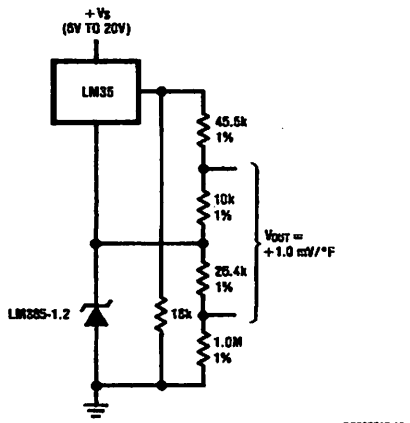


FIGURE 10. Fahrenheit Thermometer

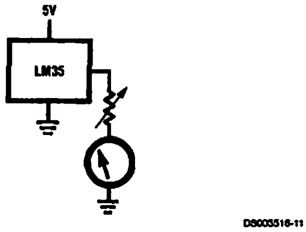


FIGURE 11. Centigrade Thermometer (Analog Meter)

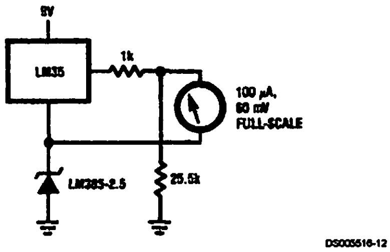


FIGURE 12. Fahrenheit ThermometerExpanded Scale Thermometer
(50° to 80° Fahrenheit, for Example Shown)

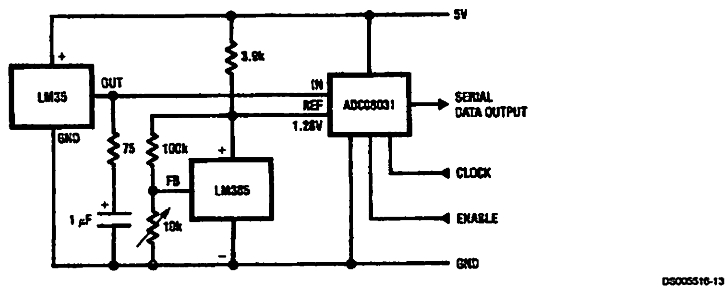


FIGURE 13. Temperature To Digital Converter (Serial Output) (+128°C Full Scale)

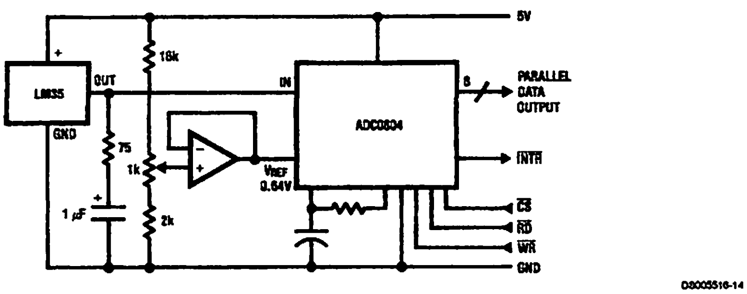
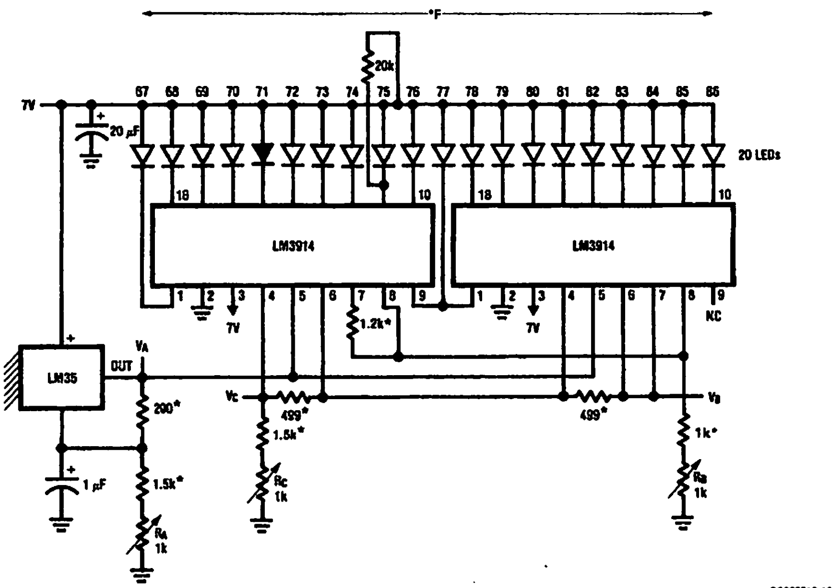


FIGURE 14. Temperature To Digital Converter (Parallel TRI-STATE® Outputs for Standard Data Bus to µP Interface) (128°C Full Scale)

Typical Applications (Continued)



*=1% or 2% film resistor
Trim R_B for V_B=3.075V
Trim R_C for V_C=1.955V
Trim R_A for V_A=0.075V + 100mV/°C x $T_{ambient}$
Example, V_A=2.275V at 22°C

FIGURE 15. Bar-Graph Temperature Display (Dot Mode)

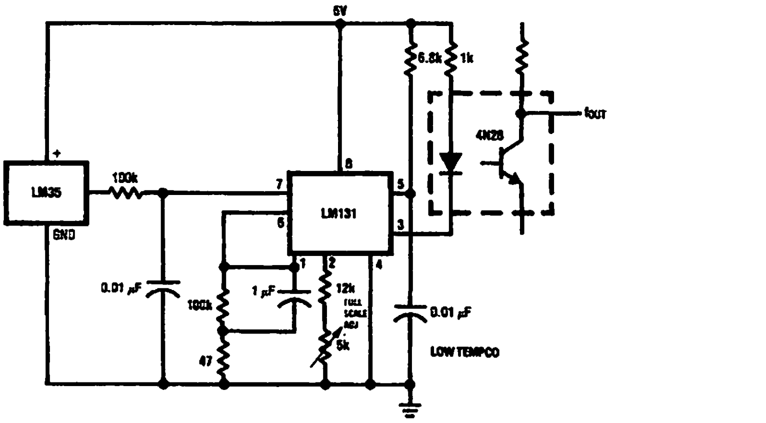
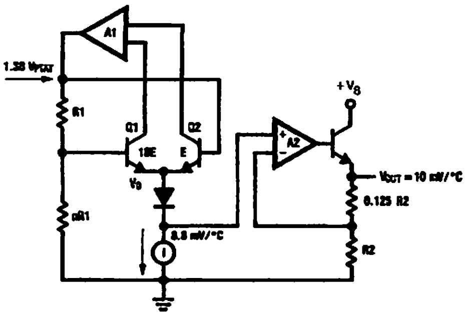


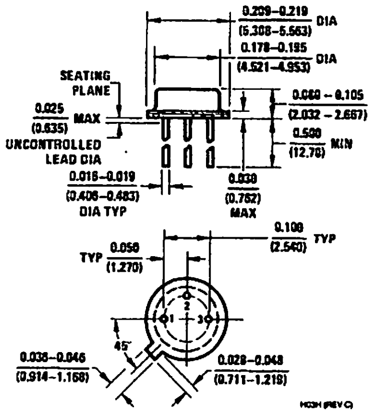
FIGURE 16. LM35 With Voltage-To-Frequency Converter And Isolated Output (2°C to +150°C; 20 Hz to 1500 Hz)

Block Diagram

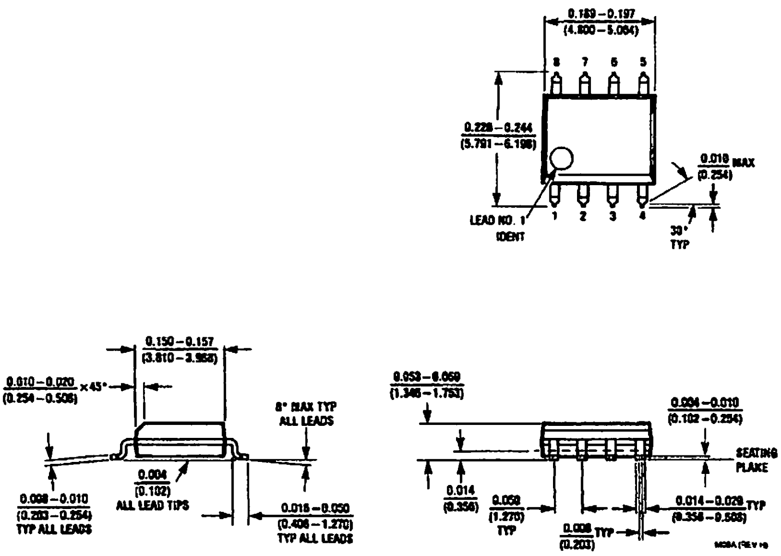


DS005516-23

Physical Dimensions inches (millimeters) unless otherwise noted

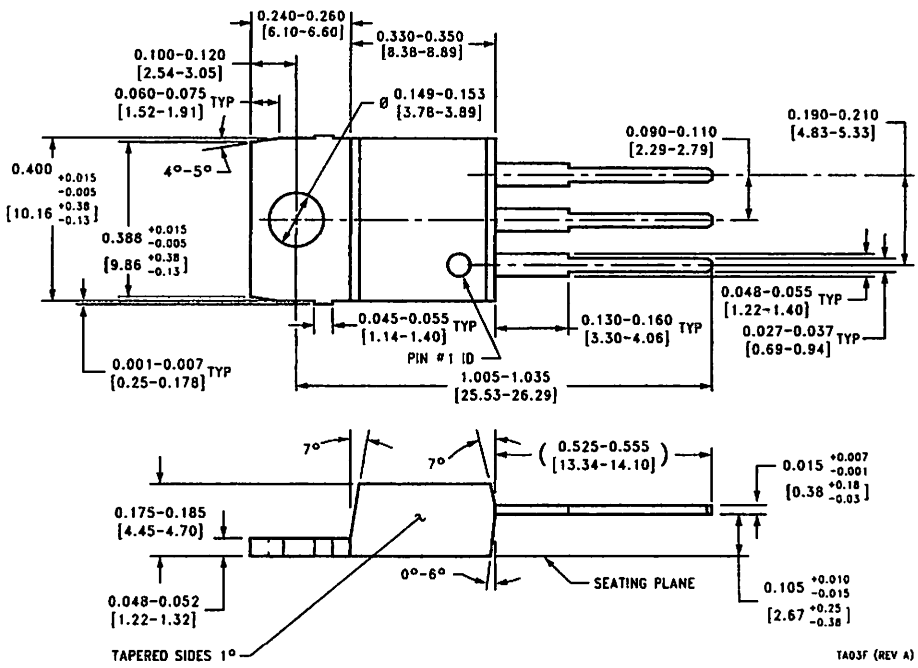


TO-46 Metal Can Package (H)
Order Number LM35H, LM35AH, LM35CH, LM35CAH, or LM35DH
NS Package Number H03H

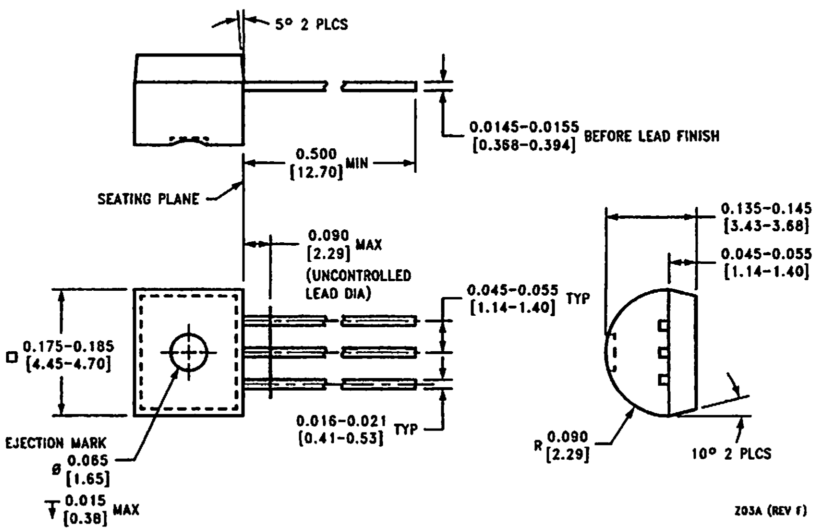


SO-8 Molded Small Outline Package (M)
Order Number LM35DM
NS Package Number M08A

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



Power Package TO-220 (T)
Order Number LM35DT
NS Package Number TA03F



TO-92 Plastic Package (Z)
Order Number LM35CZ, LM35CAZ or LM35DZ
NS Package Number Z03A

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)

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MOTOROLA

BCD TO 7-SEGMENT DECODER/DRIVER

SN54/74LS47

BCD TO 7-SEGMENT DECODER/DRIVER

LOW POWER SCHOTTKY

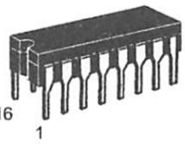
The SN54/74LS47 are Low Power Schottky BCD to 7-Segment Decoder/Drivers consisting of NAND gates, input buffers and seven AND-OR-INVERT gates. They offer active LOW, high sink current outputs for driving indicators directly. Seven NAND gates and one driver are connected in pairs to make BCD data and its complement available to the seven decoding AND-OR-INVERT gates. The remaining NAND gate and three input buffers provide lamp test, blanking input/ripple-blanking output and ripple-blanking input.

The circuits accept 4-bit binary-coded-decimal (BCD) and, depending on the state of the auxiliary inputs, decodes this data to drive a 7-segment display indicator. The relative positive-logic output levels, as well as conditions required at the auxiliary inputs, are shown in the truth tables. Output configurations of the SN54/74LS47 are designed to withstand the relatively high voltages required for 7-segment indicators.

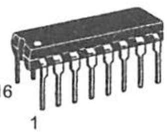
These outputs will withstand 15 V with a maximum reverse current of 250 µA. Indicator segments requiring up to 24 mA of current may be driven directly from the SN74LS47 high performance output transistors. Display patterns for BCD input counts above nine are unique symbols to authenticate input conditions.

The SN54/74LS47 incorporates automatic leading and/or trailing-edge zero-blanking control (RBI and RBO). Lamp test (LT) may be performed at any time which the BI/RBO node is a HIGH level. This device also contains an overriding blanking input (BI) which can be used to control the lamp intensity by varying the frequency and duty cycle of the BI input signal or to inhibit the outputs.

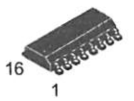
- Lamp Intensity Modulation Capability (BI/RBO)
- Open Collector Outputs
- Lamp Test Provision
- Leading/Trailing Zero Suppression
- Input Clamp Diodes Limit High-Speed Termination Effects



J SUFFIX
CERAMIC
CASE 620-09



N SUFFIX
PLASTIC
CASE 648-08

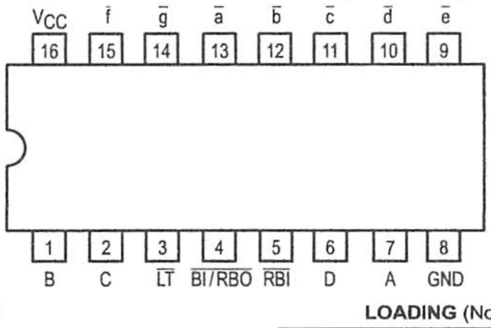


D SUFFIX
SOIC
CASE 751B-03

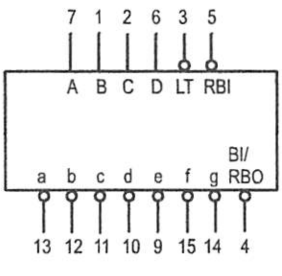
ORDERING INFORMATION

SN54LSXXJ	Ceramic
SN74LSXXN	Plastic
SN74LSXXD	SOIC

CONNECTION DIAGRAM DIP (TOP VIEW)



LOGIC SYMBOL

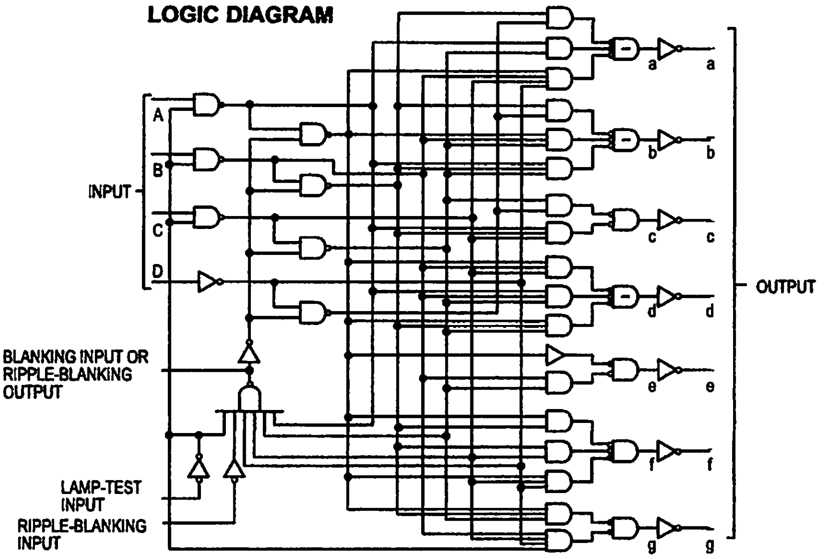


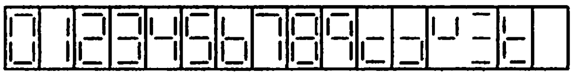
PIN NAMES		LOADING (Note a) HIGH	LOW
A, B, C, D	BCD Inputs	0.5 U.L.	0.25 U.L.
$\overline{\text{RBI}}$	Ripple-Blanking Input	0.5 U.L.	0.25 U.L.
$\overline{\text{LT}}$	Lamp-Test Input	0.5 U.L.	0.25 U.L.
$\overline{\text{BI}/\text{RBO}}$	Blanking Input or	0.5 U.L.	0.75 U.L.
	Ripple-Blanking Output	1.2 U.L.	2.0 U.L.
$\overline{a}$, to $\overline{g}$	Outputs	Open-Collector	15 (7.5) U.L.

NOTES:
a) 1 Unit Load (U.L.) = 40 µA HIGH, 1.6 mA LOW.
b) Output current measured at V_{OUT} = 0.5 V
The Output LOW drive factor is 7.5 U.L. for Military (54) and 15 U.L. for Commercial (74) Temperature Ranges.

SN54/74LS47

LOGIC DIAGRAM





NUMERICAL DESIGNATIONS — RESULTANT DISPLAYS

TRUTH TABLE

DECIMAL OR FUNCTION	INPUTS $\overline{LT}$	$\overline{RBI}$	D	C	B	A	$\overline{BI}/\overline{RBO}$	OUTPUTS $\overline{a}$	$\overline{b}$	$\overline{c}$	$\overline{d}$	$\overline{e}$	$\overline{f}$	$\overline{g}$	NOTE
0	H	H	L	L	L	L	H	L	L	L	L	L	L	H	A
1	H	X	L	L	L	H	H	H	L	L	H	H	H	H	A
2	H	X	L	L	H	L	H	L	L	H	L	L	H	L	
3	H	X	L	L	H	H	H	L	L	L	L	H	H	L	
4	H	X	L	H	L	L	H	H	L	L	H	H	L	L	
5	H	X	L	H	L	H	H	L	H	L	L	H	L	L	
6	H	X	L	H	H	L	H	H	H	L	L	L	L	L	
7	H	X	L	H	H	H	H	L	L	L	H	H	H	H	
8	H	X	H	L	L	L	H	L	L	L	L	L	L	L	
9	H	X	H	L	L	H	H	L	L	L	H	H	L	L	
10	H	X	H	L	H	L	H	H	H	H	L	L	H	L	
11	H	X	H	L	H	H	H	H	H	L	L	H	H	L	
12	H	X	H	H	L	L	H	H	L	H	H	H	L	L	
13	H	X	H	H	L	H	H	L	H	H	L	H	L	L	
14	H	X	H	H	H	L	H	H	H	H	L	L	L	L	
15	H	X	H	H	H	H	H	H	H	H	H	H	H	H	
$\overline{BI}$	X	X	X	X	X	X	L	H	H	H	H	H	H	H	B
$\overline{RBI}$	H	L	L	L	L	L	L	H	H	H	H	H	H	H	C
$\overline{LT}$	L	X	X	X	X	X	H	L	L	L	L	L	L	L	D

H = HIGH Voltage Level
L = LOW Voltage Level
X = Immaterial

NOTES:

(A) BI/RBO is wire-AND logic serving as blanking Input (BI) and/or ripple-blanking output ($\overline{RBO}$). The blanking out (BI) must be open or held at a HIGH level when output functions 0 through 15 are desired, and ripple-blanking input (RBI) must be open or at a HIGH level if blanking of a decimal 0 is not desired. X = input may be HIGH or LOW.

(B) When a LOW level is applied to the blanking input (forced condition) all segment outputs go to a LOW level regardless of the state of any other input condition.

(C) When ripple-blanking input (RBI) and inputs A, B, C, and D are at LOW level, with the lamp test input at HIGH level, all segment outputs go to a HIGH level and the ripple-blanking output ($\overline{RBO}$) goes to a LOW level (response condition).

(D) When the blanking input/ripple-blanking output (BI/RBO) is open or held at a HIGH level, and a LOW level is applied to lamp test input, all segment outputs go to a LOW level.

GUARANTEED OPERATING RANGES

Symbol	Parameter		Min	Typ	Max	Unit
V_{CC}	Supply Voltage	54 74	4.5 4.75	5.0 5.0	5.5 5.25	V
T_A	Operating Ambient Temperature Range	54 74	−55 0	25 25	125 70	°C
I_{OH}	Output Current — High $\overline{BI}/\overline{RBO}$	54, 74			−50	µA
I_{OL}	Output Current — Low $\overline{BI}/\overline{RBO}$ $\overline{BI}/\overline{RBO}$	54 74			1.6 3.2	mA
$V_{O\ (off)}$	Off-State Output Voltage $\bar{a}$ to $\bar{g}$	54, 74			15	V
$I_{O\ (on)}$	On-State Output Current $\bar{a}$ to $\bar{g}$ $\bar{a}$ to $\bar{g}$	54 74			12 24	mA

DC CHARACTERISTICS OVER OPERATING TEMPERATURE RANGE (unless otherwise specified)

Symbol	Parameter		Limits			Unit	Test Conditions	
			Min	Typ	Max			
V_{IH}	Input HIGH Voltage		2.0			V	Guaranteed Input HIGH Theshold Voltage for All Inputs	
V_{IL}	Input LOW Voltage	54			0.7	V	Guaranteed Input LOW Threshold Voltage for All Inputs	
		74			0.8			
V_{IK}	Input Clamp Diode Voltage			−0.65	−1.5	V	V_{CC} = MIN, I_{IN} = −18 mA	
V_{OH}	Output HIGH Voltage, $\overline{BI}/\overline{RBO}$		2.4	4.2		V	V_{CC} = MIN, I_{OH} = −50 µA, V_{IN} = V_{IN} or V_{IL} per Truth Table	
V_{OL}	Output LOW Voltage $\overline{BI}/\overline{RBO}$	54, 74		0.25	0.4	V	I_{OL} = 1.6 mA	V_{CC} = MIN, V_{IN} = V_{IN} or V_{IL} per Truth Table
		74		0.35	0.5	V	I_{OL} = 3.2 mA	
$I_{O\ (off)}$	Off-State Output Current a thru g				250	µA	V_{CC} = MAX, V_{IN} = V_{IN} or V_{IL} per Truth Table, $V_{O\ (off)}$ = 15 V	
$V_{O\ (on)}$	On-State Output Voltage a thru g	54, 74		0.25	0.4	V	$I_{O\ (on)}$ = 12 mA	V_{CC} = MAX, V_{IN} = V_{IH} or V_{IL} per Truth Table
		74		0.35	0.5	V	$I_{O\ (on)}$ = 24 mA	
I_{IH}	Input HIGH Current				20	µA	V_{CC} = MAX, V_{IN} = 2.7 V	
					0.1	mA	V_{CC} = MAX, V_{IN} = 7.0 V	
I_{IL}	Input LOW Current $\overline{BI}/\overline{RBO}$ Any Input except $\overline{BI}/\overline{RBO}$				−1.2 −0.4	mA	V_{CC} = MAX, V_{IN} = 0.4 V	
I_{OS} $\overline{BI}/\overline{RBO}$	Output Short Circuit Current (Note 1)		−0.3		−2.0	mA	V_{CC} = MAX, V_{OUT} = 0 V	
I_{CC}	Power Supply Current			7.0	13	mA	V_{CC} = MAX	

Note 1: Not more than one output should be shorted at a time, nor for more than 1 second.

AC CHARACTERISTICS (T_A = 25°C)

Symbol	Parameter	Limits			Unit	Test Conditions
		Min	Typ	Max		
t_{PHL} t_{PLH}	Propagation Delay, Address Input to Segment Output			100 100	ns ns	V_{CC} = 5.0 V C_L = 15 pF
t_{PHL} t_{PLH}	Propagation Delay, $\overline{RBI}$ Input To Segment Output			100 100	ns ns	

AC WAVEFORMS

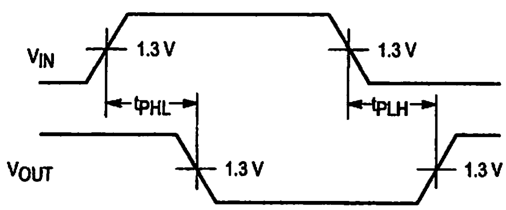


Figure 1

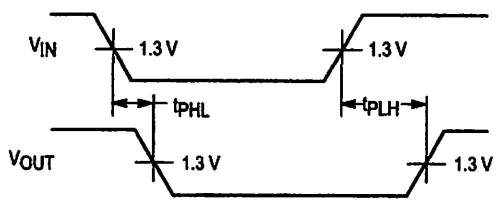


Figure 2

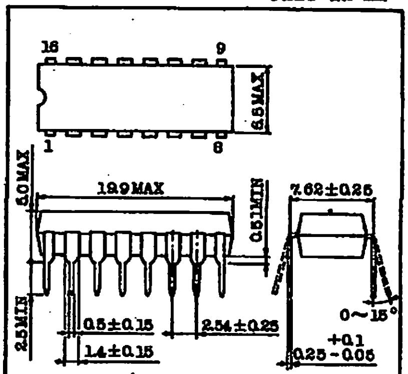
TC9148P

FOR INFRARED REMOTE CONTROL TRANSMITTER.

The TC9148P is C-MOS LSI developed for use on the infrared remote control transmitter.
This LSI has 18 functions, and total 75 commands can be transmitted : 63 commands by the continuous keys of multiple keying is possible and 12 commands by the single shot keys.

- Wide Range of Operating Supply Voltage Allows Low Voltage Operation (V_{DD}=2.2~5.0V)
- C-MOS Structure Assures Extremely Low Power Dissipation.
- Multiple Keying is Possible (Max. Sextet).
- Less External Parts
- Adaptable to other Models as Code Bits are Available
- An Oscillator can be Constructed only by Connecting an LC or Ceramic Resonater as the Oscillation Circuit is Housed.

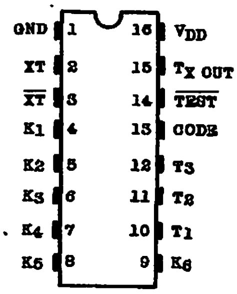
Unit in mm



Lead pitch is 2.54 and tolerance is ±0.25 against theoretical center of each lead that is obtained on the basis of No.1 and No.16 leads.

JEDEC	—
TOSHIBA	SD16A-P

PIN CONNECTION



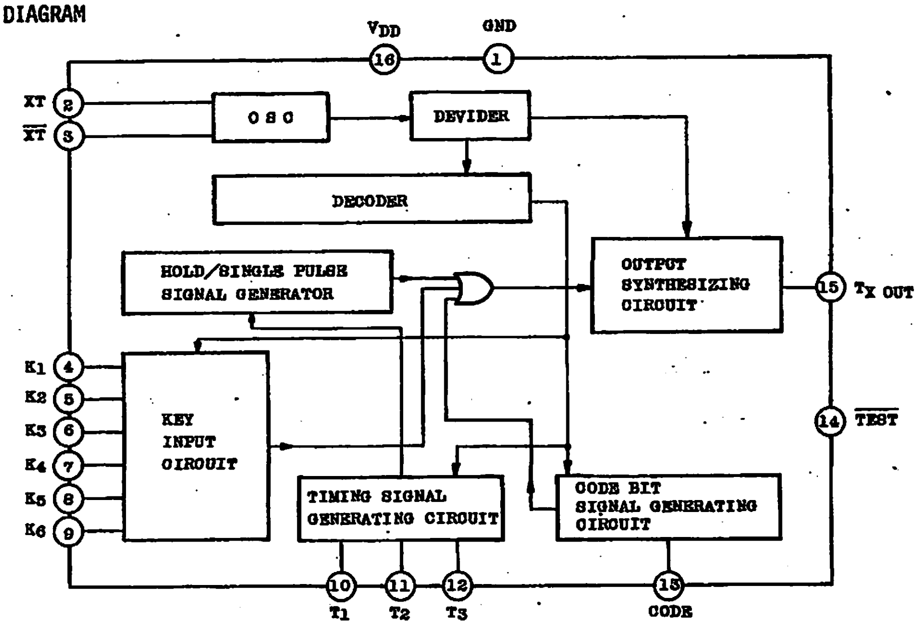
MAXIMUM RATINGS (Ta=25°C)

CHARACTERISTIC	SYMBOL	RATING	UNIT
Supply Voltage	V_{DD}	6.0	V
Input/Output Voltage	V_{IN}	V_{SS}-0.3 ~ V_{DD}+0.3	V
Power Dissipation	P_D	200	mW
Operating Temperature	T_{opr}	-20~75	°C
Storage Temperature	T_{stg}	-55~125	°C
TXOUT Output Current	I_{OUT}	-5	mA

TC9148P

T-77-11

BLOCK DIAGRAM



DESCRIPTION OF TERMINALS

PIN No.	SYMBOL	TERMINAL	FUNCTION / OPERATION
1, 16	GND, V_{DD}	GND/Power	Supply Voltage Terminal
2, 3	XT, $\overline{XT}$	Terminal for OSC	Terminal for OSC, and used for connecting a 455kHz ceramic resonater etc. (with a built-in feedback resistor)
4~9	K_1~K_6	Key Input Terminal	Key input terminal for Key matrix. 18 keys can be connected at T_1~T_3×K_1~K_6 (with a built-in pull-down resistor)
10~12	T_1~T_3	Timing Signal Output Terminal	Digit timing output terminal for Key matrix.
13	CODE	Code bit Input Terminal	Terminal for matching code between transmitting and receiving.
14	$\overline{TEST}$	Test Terminal	Keep this terminal open.
15	TXOUT	Transmitting Output Terminal	Transmitting signal output. Modulation is made by 12 bits 1 cycle and 38kHz carrier wave.

TC9148P

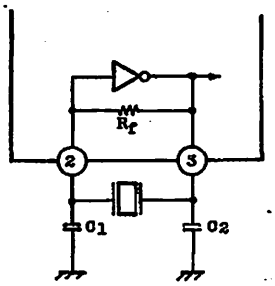
ELECTRICAL CHARACTERISTICS (Unless otherwise specified, V_{DD}=3.0V, Ta=25°C)

Characteristic				Symbol	Test Circuit	Test Condition	Min.	Typ.	Max.	Unit
Operating Supply Voltage				V_{DD}	-	All Function Operation	2.2	-	5.0	V
Operating Supply Current				I_{DD}	-	Key ON, Without Load	-	-	1.0	mA
Quiescent Current Consumption				I_{DS}	-	All Key OFF, Stop of OSC	-	-	10	μA
Input Terminal	$K_1 \sim K_6$ CODE	Input Voltage	"H" Level	V_{IH}	-	-	2.0	-	3.0	V
Input Terminal	$K_1 \sim K_6$ CODE	Input Voltage	"L" Level	V_{IL}	-	-	0	-	0.5	V
Input Terminal	$K_1 \sim K_6$	Input Current	"H" Level	I_{IH}	-	V_{IH}=3.0V	20	30	60	μA
Input Terminal	$K_1 \sim K_6$	Input Current	"L" Level	I_{IL}	-	V_{IL}=0V	-1.0	-	1.0	μA
Input Terminal	CODE	Input Current	"H" Level	I_{IH}	-	V_{IH}=3.0V	-1.0	-	1.0	μA
Input Terminal	TEST	Input Current	"L" Level	I_{IL}	-	V_{IL}=0V	20	30	60	μA
Output Terminal	$T_1 \sim T_3$	Output Current	"H" Level	I_{OH}	-	V_{OH}=2.0V	-500	-	-	μA
Output Terminal	$T_1 \sim T_3$	Output Current	"L" Level	I_{OL}	-	V_{OL}=3.0V	50	-	-	μA
Output Terminal	T_X	Output Current	"H" Level	I_{OH}	-	V_{OH}=2.0V	-0.1	-	-	mA
Output Terminal	T_X	Output Current	"L" Level	I_{OL}	-	V_{OL}=2.0V	1.0	-	-	mA
OSC Feedback Resistor				R_f	-	-	-	500	-	kΩ
Oscillation Frequency				f_{OSC}	-	-	400	455	600	kHz

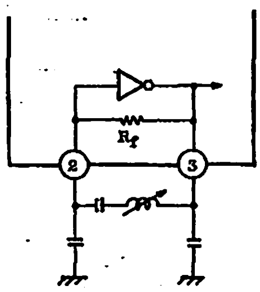
FUNCTIONAL DESCRIPTION

1. OSCILLATION CIRCUIT

As the self-bias type amplifier by means of C-MOS inverter has been housed, the oscillation circuit can be constructed when an LC or ceramic resonater is connected.



CERAMIC RESONATOR
KBR-455B
KYOCERA Co. Ltd
OR EQUIVALENT
C_1, C_2=50~150pF

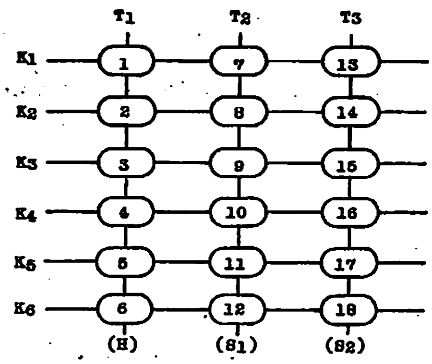


When oscillation frequency is set at 455kHz, carrier wave of transmitting signal is set at 38kHz, oscillation of the oscillation circuit is kept stopped unless the keys are operated, thus reducing power consumption.

2. KEY INPUT

18 keys can be connected by Key input K_1~K_6 and 6×3 matrix by means of timing signal T_1~T_3.
Multiple keying is possible for the keys connected to T1 line up to sextet, and all key inputs are output. (Output becomes continuous pulses.)
Between the timing signal lines, priority has been decided in order of T1, T2 and T_3. The keys connected to T_2 and T_3 lines have priority and input is made through more than 2 keys, single signal is preferentially output in order of K_1~K_6.
Further, the keys connected to T_2 and T_3 lines are for single signals and no second signal is transmitted unless input is made again after the key is released once.

TC9148P



KEY MATRIX

- Key No.1 ~ 6

  Continuous key output with it pressed, and multiple keying is possible.

- Key No.7 ~ 18

  These keys are the single-shot keys and when input is made, signal is output only one time.

3. TRANSMISSION COMMAND

Transmission command is in one word 12-bits configuration.

C_1 ~ C_3 are code bits adaptable to many models, H, S_1 and S_2 are continuous signal and single-shot signal codes, and D_1 ~ D_6 are Key Input data codes in 6-bits.

C_1	C_2	C_3	H	S_1	S_2	D_1	D_2	D_3	D_4	D_5	D_6
CODE BIT			CONTINUOUS/ SINGLE-SHOT CODE			KEY INPUT CODE					

4. DATA CODE

KEY No.	DATA									OUTPUT FORM	KEY No.	DATA									OUTPUT FORM
	H	S1	S2	D1	D2	D3	D4	D5	D6			H	S1	S2	D1	D2	D3	D4	D5	D6	
1	1	0	0	1	0	0	0	0	0	CONTINUOUS	10	0	1	0	0	0	0	1	0	0	SINGLE-SHOT
2	1	0	0	0	1	0	0	0	0	"	11	0	1	0	0	0	0	0	1	0	"
3	1	0	0	0	0	1	0	0	0	"	12	0	1	0	0	0	0	0	0	1	"
4	1	0	0	0	0	0	1	0	0	"	13	0	0	1	1	0	0	0	0	0	"
5	1	0	0	0	0	0	0	1	0	"	14	0	0	1	0	1	0	0	0	0	"
6	1	0	0	0	0	0	0	0	1	"	15	0	0	1	0	0	1	0	0	0	"
7	0	1	0	1	0	0	0	0	0	SINGLE-SHOT	16	0	0	1	0	0	0	1	0	0	"
8	0	1	0	0	1	0	0	0	0	"	17	0	0	1	0	0	0	0	1	0	"
9	0	1	0	0	0	1	0	0	0	"	18	0	0	1	0	0	0	0	0	1	"

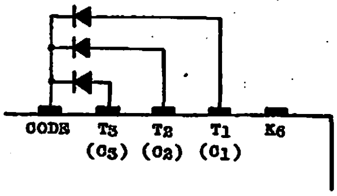
As the multiple keying is possible, Key No. 1~6 are capable of output 63 commands through a combination of D_1~D_6 data.

Key No. 7~18 are the single-shot keys for output 12 commands, and 75 commands can be output through a combination of continuous key (multiple keying is possible) and Single-Shot key.

TC9148P

5. CODE BITS (C_1, C_2, C_3)

Code bit can be made at one terminal with diodes connected through $T_1 \sim T_3$ timing terminals.



Data of C_1, C_2 and C_3 code bit become "1" when diodes are connected to CODE Terminal through Timing Signal. Terminals $T_1 \sim T_3$, and "0" when not connected.
(In the above diagram, C_1, C_2 and C_3 are 1, 1 and 1 data.)
The TC9148P has 3 code bits. However, the TC9149P that is a receiving IC (DIP 16 PIN) and the TC9150P (DIP 24 PIN) are able to use only C_2 and C_3, and C_1 and C_2 2 code bits, respectively.
Therefore, diodes must be connected so that code bit data of the TC9148P agreement with the receiving IC.

CODE BIT	
C_1	C_2
C_3	C_2
1	0
0	1
1	1

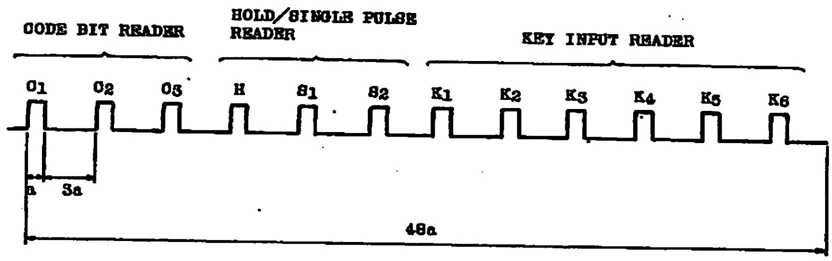
C_1, C_2 .... TC9150P
C_2, C_3 .... TC9149P

* CODE BIT, "0", "0" CANNOT BE USED.

Note. For C_3 and C_1 code bit data not used on the TC9150P and TC9149P, it is necessary to transmit "1" and diodes must be so connected.

6. TRANSMITTING WAVEFORM

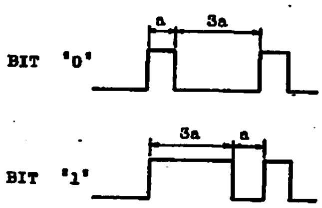
6.1 BASIC TRANSMITTING WAVEFORM (at f_{OSC}=455kHz)

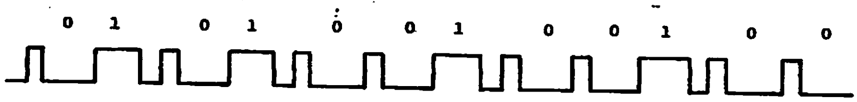


Basic transmitting waveform is 12-bits serial data in configuration as shown above.
The time of each bit "a" is decided as shown below by oscillation frequency f_{osc} by means of X_T and $\overline{X_T}$.

$$a = (1/f_{osc}) \times 192 \text{ (sec)}$$

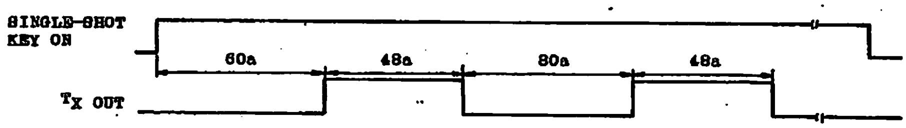
6.2 DISTINCTION OF BIT "0" AND "1"





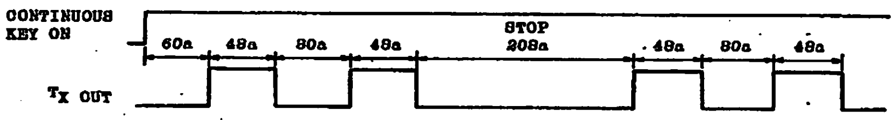
One word of the above transmission command is in the configuration of (010100100100).

6.3 SINGLE-SHOT SIGNAL



When any one of the single-shot keys is depressed, the above single-shot signal is transmitted in 2 cycles, and the transmitting output ends.

6.4 CONTINUOUS SIGNAL



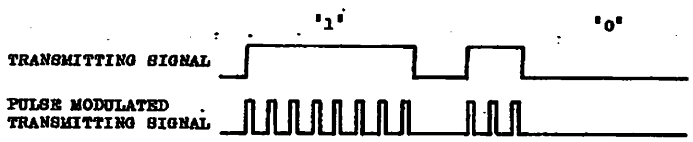
When any one of the continuous keys is depressed, the above continuous signal is 2 cycles output, repeatedly output 208a pause and 2 cycles output is 2 pause of 208a.

6.5 CARRIER WAVE

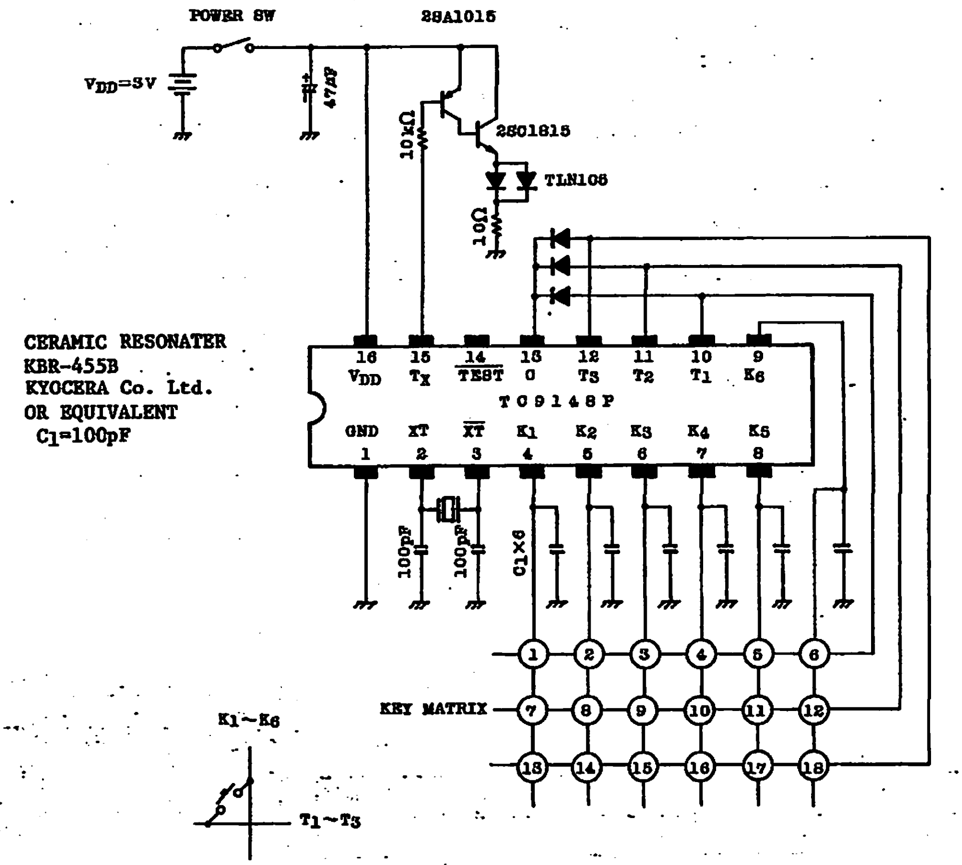
About 50~100mA current is normally applied through an infrared LED in order to extend an infrared ray reaching distance. Therefore, if a time when LED is ON is shortened as could as possible, it leads to reduction in power consumption. On this IC, when single-shot or continuous signal is transmitting, each bit is switching by a carrier of duty 1/3, output after the pulse modulated.

Carrier (f_c) is decided by oscillation frequency f_{osc} by means of X_T and $\overline{X_T}$.

$f_c = \frac{f_{osc}}{12}$ (Hz) $f_c \fallingdotseq 38$kHz at $f_{osc} = 455$kHz



APPLICATION CIRCUIT



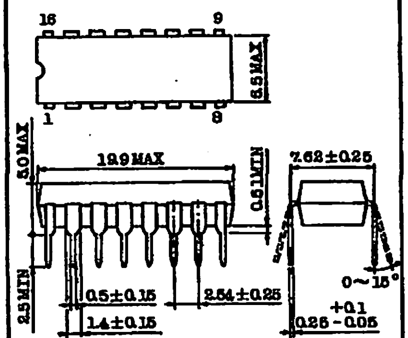
TC9149P, TC9150P

FOR INFRARED RAY REMOTE CONTROL RECEIVER

The TC9149P/TC9150P is LSI designed for use on the infrared ray remote control receiver, and when this LSI is used in combination with LSI TC9148P for transmitter, the remote control system can be constructed. The TC9149P is DIP 16 PIN type and is capable of controlling 10 functions, while the TC9150P is DIP 24 PIN type and is capable of controlling 18 functions.

- Able to output parallely multiple keying signals sent from the transmitter.
  (The TC9149P is able to output parallely up to 5 functions, while the TC9150P is able to output parallely up to 6 functions.)
- Output for single pulse, hold pulse and cyclic pulse are provided.
  (Cyclic pulse is available only for TC9150P.)
- A single terminal type oscillator by means of CR is provided.
- Code detection circuit provided for code check with the transmitter prevents interferences from various types of machines and apparatus.

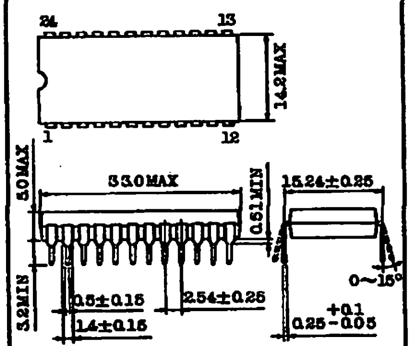
Unit in mm



Lead pitch is 2.54 and tolerance is ±0.25 against theoretical center of each lead that is obtained on the basis of No.1 and No.16 leads.

JEDEC	—
TOSHIBA	SD16A-P

Unit in mm



Lead pitch is 2.54 and tolerance is ±0.25 against theoretical center of each lead that is obtained on the basis of No.24 leads.

JEDEC	—
TOSHIBA	SD24A-P

MAXIMUM RATINGS (Ta=25°C)

CHARACTERISTIC	SYMBOL	RATING	UNIT
Supply Voltage	V_{DD}	0～6	V
Input/Output Voltage	V_{IN}, V_{OUT}	V_{SS}-0.3～V_{DD}+0.3	V
Power Dissipation	P_D	200	mW
Operating Temperature	T_{opr}	-20～75	°C
Storage Temperature	T_{stg}	-55～125	°C

TC9149P, TC9150P

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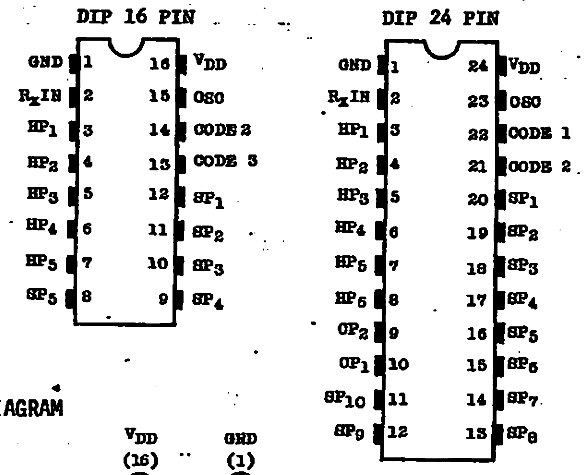
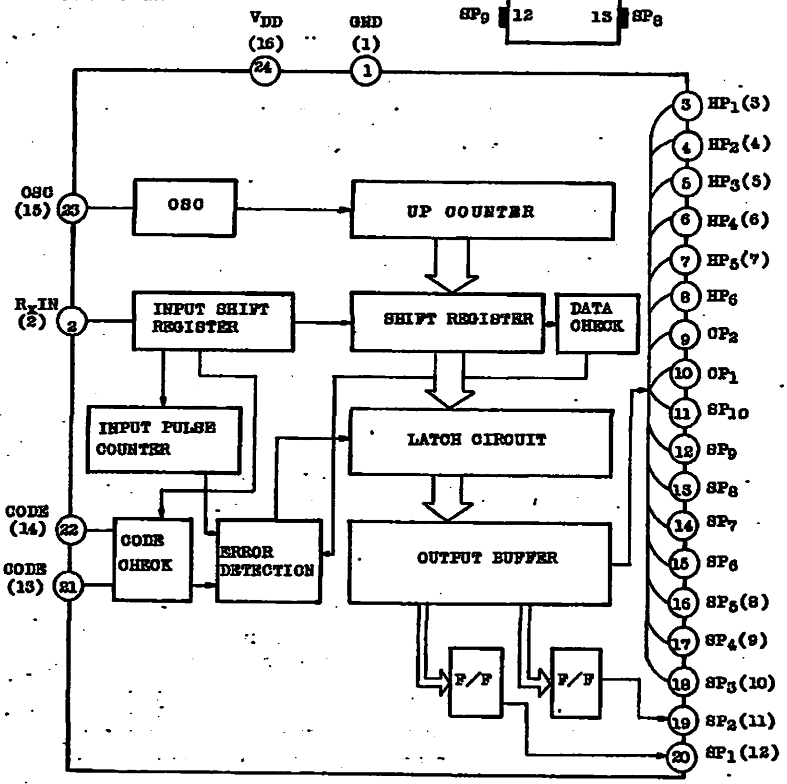
PIN CONNECTIONS



BLOCK DIAGRAM



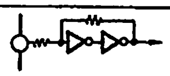
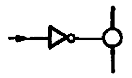
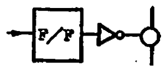
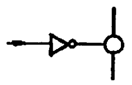
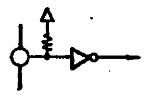
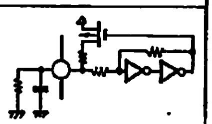
PIN NO. OF TC9149P IS GIVEN IN PARENTHESIS.

TC9149P, TC9150P

ELECTRICAL CHARACTERISTICS (Unless otherwise specified, Ta=25°C, V_{DD}=5V)

CHARACTERISTIC		SYMBOL	TEST CIRCUIT	TEST CONDITION	MIN.	TYP.	MAX.	UNIT
Operating Supply Voltage		V_{DD}	–	Ta=-20∿75°C	4.5	∿	5.5	V
Operating Supply Current		I_{DD}	–	Output without Load	–	–	1.0	mA
Oscillation Frequency		f_{OSC}	–	Ta=-20∿75°C, V_{DD}=4.5∿5.5V	27	∿	57	kHz
Standard OSC Frequency		Sf_{OSC}	–		–	38	–	kHz
Variance of Oscillation Frequency by V_{DD}		ΔV_{fOSC}	–	Ta=25°C, V_{DD}=4.5∿5.5V	-5	–	5	%
Variance of Oscillation Frequency by Temperature		ΔT_{fOSC}	–	Ta=-30∿75°C	-5	–	5	%
Output Current	"H" Level	I_{OH}	–	all output, V_{OH}=4V	–	–	-1.0	mA
	"L" Level	I_{OL}	–	all output, V_{OL}=1V	1.0	–	–	mA
Input Current	"H" Level	I_{IH}	–	CODE Terminal, V_{IH}=5.0V	-1.0	–	1.0	μA
Pull-up Resistor		R_{up}	–	CODE Terminal	10	20	40	kΩ
Input Circuit Threshold Voltage		V_{IN}	–	R_x Terminal	2.0	2.5	3.0	V
Hysteresis Width		V_{HIS}	–	R_x Terminal	–	0.8	–	V

DESCRIPTION OF TERMINALS

PIN NO. 16 PIN	PIN NO. 24 PIN	SYMBOL	TERMINAL	FUNCTION/OPERATION	INPUT/OUTPUT CONFIGURATION
1	1	GND	GND		
2	2	R_xIN	Receiving signal Input	Instruction signal with carrier signal eliminated is input.	
3∿7	–	HP_1∿HP_5	Continuous signal Input	As long as receiving signal is input, this output is held at "H" level.	
–	3∿8	HP_1∿HP_6			
–	9·10	CP_1·CP_2	Cyclic signal output	When receiving signal is input, output is reversed.	
8∿12	–	SP_1∿SP_5	Single-shot signal output	When receiving signal is input, output is placed at "H" level only for a fixed time. (about 107 msec)	
–	11∿20	SP_1∿SP_{10}			
13·14	21·22	CODE	Code input	Transmitter code is compared with a code set at this terminal and if they agree each other, input is accepted.	 Built-in pull-up resistor
15	23	OSC	Timing oscillation	A resistor and a capacitor are parallely connected between this terminal and GND.	
16	24	V_{DD}	Power Supply		

TC9149P, TC9150P

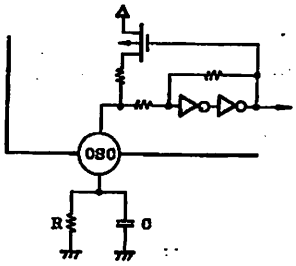
T-77-11

FUNCTIONAL DESCRIPTION

1. OSCILLATION CIRCUIT

Timing with transmitter signal and internal operating clock are all decided by this oscillator.

The oscillator has been so far constructed through a combination of a linear amplifier by means of C MOS inverter in IC and 455 kHz ceramic resonator; however, when TC9149P/TC9150P is used, a stable oscillator can be constructed by parallelly connecting C and R between the oscillator and GND by a single terminal oscillator.

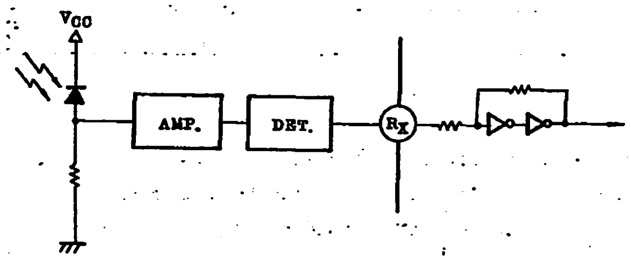


R : 39kΩ ±5%
C : 1000pF ±5%
(POLYPROPYLENE FILM CAPACITOR SHOULD BE USED.)

Oscillation frequency is about 38 kHz ± 5 kHz at R=39kΩ and C=1000pF.
(Refer to Graph 1 Oscillation Frequency Characteristic)

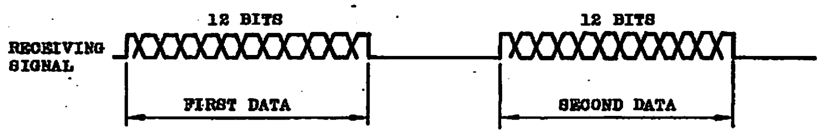
2. RECEIVING SIGNAL INPUT CIRCUIT

Signal received by the light receiving element is sent through the amplifier to the detector where 38 kHz carrier wave is eliminated and is input into the receiving signal input circuit. The reciving signal input circuit (Rx IN) has a built-in Schmitt circuit for shaping receiving signal waveform to eliminate rounding.



3. RECEIVING SIGNAL CHECK

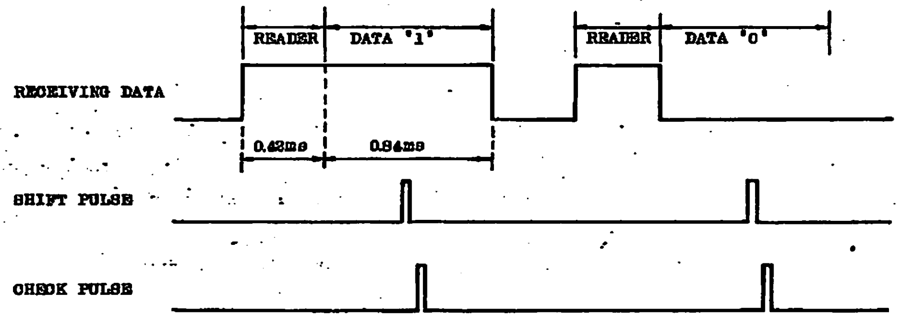
The receiving signal check is to check 2 cycle transmitting signal sent from the transmitter to determine if it is normal signal.



First, the first data is stored in the 12-bits shift register. Then, when the second data is put into the shift register, data is forced out of the shift register by one bit, where the first data has been stored.

Now, pushed out data and incoming data are checked to see if they are same.

If an error is caused in the receiving data 12-bits check, the system is reset at that point of time. Conversely, when all receiving data are OK, output is raised from "L" level to "H" level.



The status of receiving data, shift pulse and check pulse is shown above. Shift pulse is provided in the data center by taking frequency margins of the transmitter and the receiver into consideration.

Code Comparison

To prevent interference with other models, C1, C2 and C3 code bits are provided for checking whether the transmitter and receiver codes agree each other.

Only when both codes agreed, internal latch strobe pulse is generated to latch receiving data and output is raised from "L" level to "H" level. If both codes do not agree, no latch strobe pulse is generated and output remains at "L" level.

Code bits used differ depending upon receiver as shown below:

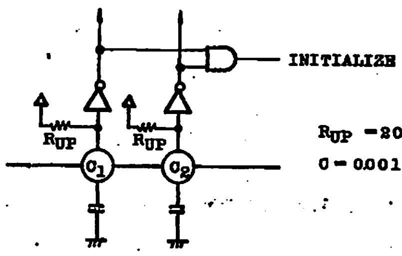
CODE BIT	
C_1	C_2
C_3	C_2
1	0
0	1
1	1

TC9149P .... C2,C3 CODE BIT
TC9150P .... C1,C2 CODE BIT
* CODE BIT '0'.'0' CANNOT BE USED.

4. INITIALIZATION AT TIME OF POWER ON

In order to initialize the internal status at time of power ON, it is necessary to perform the initialization.

The initialization is carried out when a capacitor is connected to the code bit terminal.



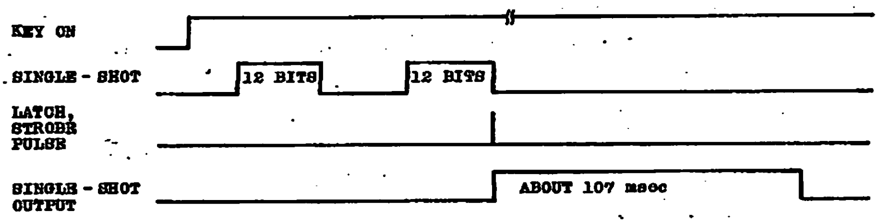
R_{UP} =20kΩ (TYP.)
C=0.001µF~0.022µF

* In case of TC9149P, connect a capacitor to C2 and C3.

* A capacitor for initialization is unnecessary for the terminal for which Code Bit "0" is selected. However, Code Bit "0". "0" cannot be used. Either one terminal must be set at "H".

5. EXPLANATION OF OUTPUT PULSE SP, HP, CP

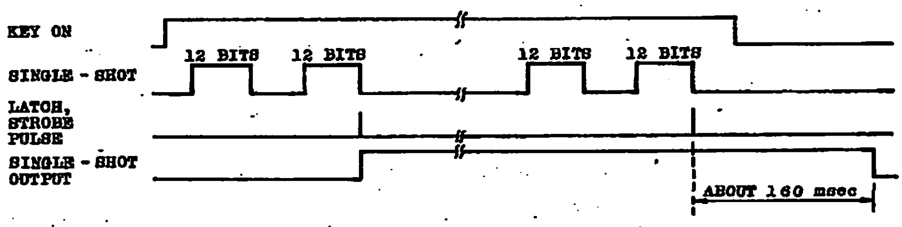
5-1. SP1 - SP10 (Single pulse)



After checking 12-bits receiving data, if data agree and OK, single pulse is output.

Output is raised from "L" level to "H" level and returned again to "L" level after about 107 msec.

5-2. HP1 - HP6 (Hold pulse)



Hold pulse is output by the first latch strobe pulse after key ON.

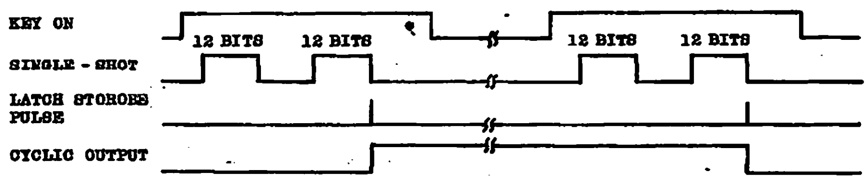
Output is kept at "H" level as long as Continuous Signal is input.

When the key is released and continuous signal is stopped, about 160 msec later, output is reversed to "L" level by the last latch strobe pulse.

Further, HP1 - HP6 are able to parallelly and simultaneously max sextet outputs at "H" level by continuous signal sent from the transmitter.

These outputs are optimum as outputs of REC-PALY, REC-PAUSE, and CUE/REVIEW of a tape deck.

5-3. CP1, CP2 (Cyclic pulse)



When single-shot signal is received, cyclic pulse output is reversed. This cyclic pulse is used for power ON/OFF, MUTE, etc.

6. CODE ALLOCATION (KEY No. is of TC9148P)

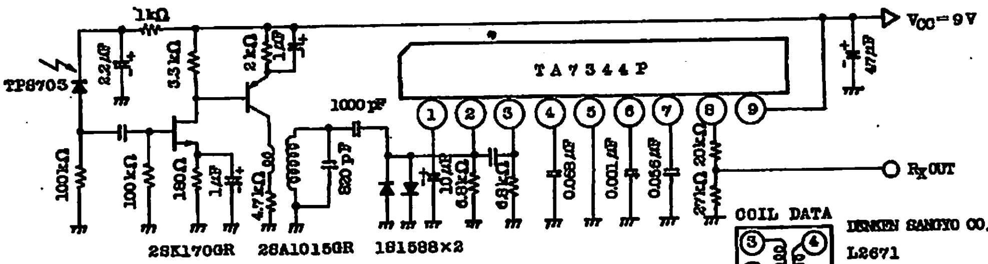
KEY №	DATA BIT									FUNCTION OF INSTRUCTION	
	H	S_1	S_2	K_1	K_2	K_3	K_4	K_5	K_6		
1	1	0	0	1	0	0	0	0	0	CONTINUOUS SIGNAL	HP_1
2	1	0	0	0	1	0	0	0	0	〃	HP_2
3	1	0	0	0	0	1	0	0	0	〃	HP_3
4	1	0	0	0	0	0	1	0	0	〃	HP_4
5	1	0	0	0	0	0	0	1	0	〃	HP_5
6	1	0	0	0	0	0	0	0	1	〃	HP_6
7	0	1	0	1	0	0	0	0	0	SINGLESHOT SIGNAL	SP_1
8	0	1	0	0	1	0	0	0	0	〃	SP_2
9	0	1	0	0	0	1	0	0	0	〃	SP_3
10	0	1	0	0	0	0	1	0	0	〃	SP_4
11	0	1	0	0	0	0	0	1	0	〃	SP_5
12	0	1	0	0	0	0	0	0	1	〃	SP_6
13	0	0	1	1	0	0	0	0	0	〃	SP_7
14	0	0	1	0	1	0	0	0	0	〃	SP_8
15	0	0	1	0	0	1	0	0	0	〃	SP_9
16	0	0	1	0	0	0	1	0	0	〃	SP_{10}
17	0	0	1	0	0	0	0	1	0	CYCLIC SIGNAL	CP_1
18	0	0	1	0	0	0	0	0	1	〃	CP_2

C1 - C3 code bits are available in addition to the above data bits for optional code selection.
TC9150P can use all keys, but TC9149P is able to use $KEY_1 \sim 5$ and $KEY_7 \sim 11$ only for 10 commands.

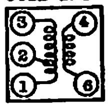
TC9149P, TC9150P

7. APPLICATION CIRCUITS

1. RECEIVING SECTION

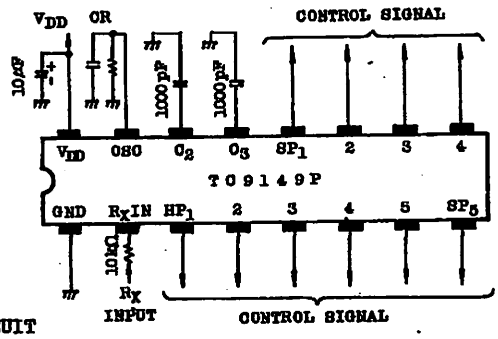


COIL DATA

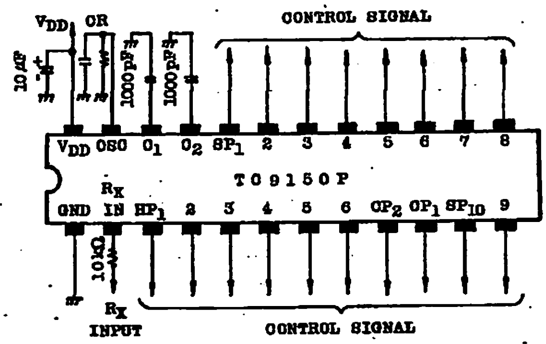


DENKEN SANGYO CO.,Ltd
L2671
f_0=38kHz
Q=40
L1(4-6)=134μH
L2(1-3)=17.5mH
L3(1-2)=16.6mH
4-6=43t
3-1=600t
3-2=103t
2UEW-0.08φ

2. TC9149P CIRCUIT



3. TC9150P CIRCUIT



* R should be 38kΩ ± 5%.

* C should be polypropylene film capacitor having good temperature characteristics 1000 pF ± 5%.

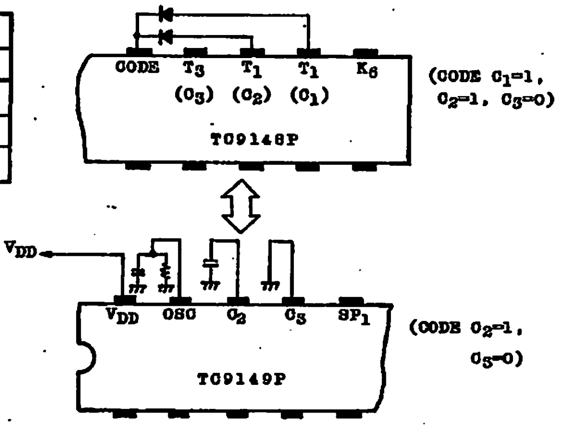
NOTE FOR APPLICATION CIRCUIT

1. COMBINATION OF TC9148P/TC9149P CODE BITS.

(TABLE 1)

TC9148P			TC9149P	
C_1	C_2	C_3	C_2	C_3
1	1	0	1	0
1	0	1	0	1
1	1	1	1	1

(EXAMPLE 1) IN CASE CODE C_2=1 AND C_3=0



The combination of code bits of TC9148P and TC9149P is shown in Table 1

To make Code Bit to "1" on TC9148P, connect diodes to CODE terminal from $T_1 \sim T_3$ Terminals. To set Code Bit at "0", open the circuit.

TC9149P has C2 and C3 code terminals. Code bit of C1 has been pulled up in IC and C1 is always kept at "1" status.

Therefore, on Transmitter TC9148P it is necessary to keep C1 code bit at "1".

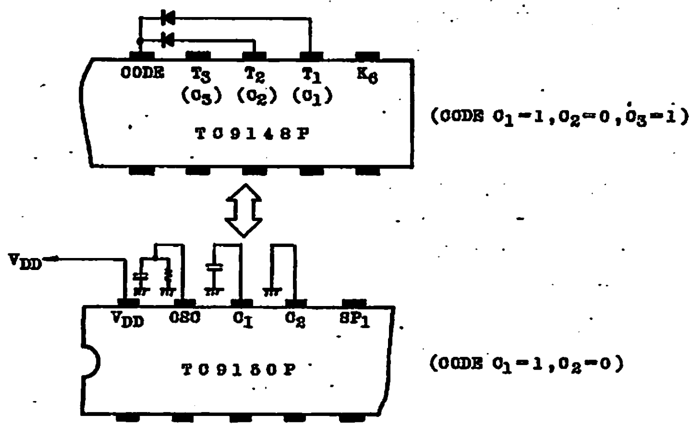
Example 1 is the external circuit diagram when Code Bit C2=1, and C3=0.

2. COMBINATION OF TC9148P/50P CODE BITS

(TABLE 2)

TC9148P			TC9150P	
C_1	C_2	C_3	C_1	C_2
1	0	1	1	0
0	1	1	0	1
1	1	1	1	1

(EXAMPLE 2) IN CASE CODE $C_1=1$ and $C_2=0$

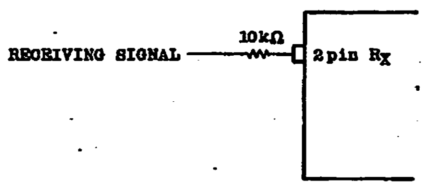


The combination of Code Bits of TC9148P and TC9150P is shown in Table 2

On TC9150P, C3 code has been pulled up in IC and always kept at "1" status. Therefore, it is necessary to keep Code Bit C3 of Transmitter TC9148P at "1". To keep Code Bit C3 at "1", connect a diode to CODE Terminal from T3 Terminal.

Example 2 is an example of the circuit when Code Bit C1=1 and C2=0.

3. *If input voltage above V_{DD} + 0.3V may possibly be applied to Rx Input Terminal (2 PIN), connect resistors of about 10kΩ in series to Rx Input Terminal. (This is to prevent latch-up.)*

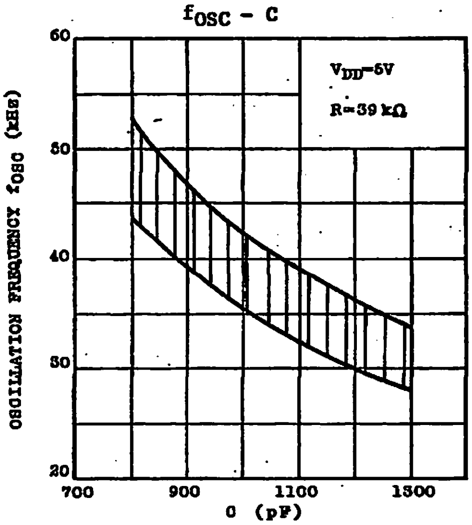


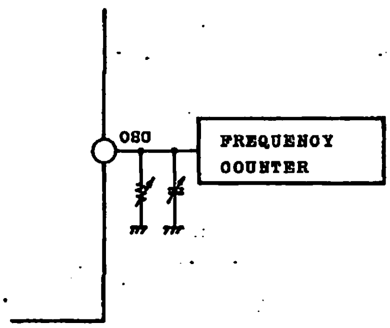
TC9149P, TC9150P

T-77-11

OSCILLATION FREQUENCY CHARACTERISTICS

f_{OSC} - C





f_{OSC} - R