

**PERENCANAAN DAN PEMBUATAN
ALAT PENGATUR GELEMBUNG UDARA UNTUK
MANDI SPA BERBASIS MICROCONTROLLER AT 89C51**

TUGAS AKHIR



**Disusun Oleh :
YUDI AGUNG PRASETYO
NIM : 99.17.249**



**JURUSAN TEKNIK ELEKTRO S-1
KONSENTRASI TEKNIK ELEKTRONIKA
FAKULTAS TEKNOLOGI INDUSTRI
INSTITUT TEKNOLOGI NASIONAL MALANG
2005**

LEMBAR PERSETUJUAN

PERENCANAAN DAN PEMBUATAN ALAT PENGATUR GELEMBUNG UDARA UNTUK MANDI SPA BERBASIS MICROCONTROLLER AT89C51

SKRIPSI

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

Disusun Oleh :

YUDI AGUNG PRASETYO
NIM : 99.17.249

Malang, September 2005



Mengetahui
Ketua Jurusan Teknik Elektro S-1

(Ir. F. Yudi Limpraptono, MT)

Disetujui
Dosen Pembimbing

(Joseph Dedy Irawan, ST, MT)

**KONSENTRASI TEKNIK ELEKTRONIKA
JURUSAN TEKNIK ELEKTRO S-1
FAKULTAS TEKNOLOGI INDUSTRI
INSTITUT TEKNOLOGI NASIONAL MALANG
2005**



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

BERITA ACARA UJIAN SKRIPSI FAKULTAS TEKNOLOGI INDUSTRI

Nama Mahasiswa : Yudi Agung Prasetyo
Nim : 99.17.249
Jurusan : Teknik Elektro (S-1)
Konsentrasi : Teknik Elektronika
Judul Skripsi : Perencanaan Dan Pembuatan Alat Pengatur
Gelembung Udara Untuk Mandi Spa Berbasis
Mikrokontroller AT89C51.

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

Hari : Selasa

Tanggal : 04 Oktober 2005

Dengan Nilai : 79,65 (B⁺)



Ir. Mochtar Asroni, MSME
Ketua

Panitia Ujian Skripsi



Ir. F. Yudi Limptaptono, MT
Sekretaris

Anggota Penguji

Ir. Sidik Noertjahjono, MT
Penguji Pertama

Ir. Cahyo Crysdian, MSc
Penguji Kedua

ABSTRAKSI

PERENCANAAN DAN PEMBUATAN ALAT PENGATUR GELEMBUNG UDARA UNTUK MANDI SPA BERBASIS MIKROKONTROLLER AT89C51

(Yudi Agung P, 9917249, Teknik Elektro / Elektronika S-1, 66 halaman)
(Dosen Pembimbing : Joseph Dedy Irawan, ST. MT.)

Kata Kunci : Remote Control, IR Receiver, LM 35, IC AT89C51, Fan, 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. Bentuk 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 control ini bertujuan untuk memberikan pelayanan yang bagus dan memberikan kemudahan dalam pelaksanaannya. Karena hanya menggunakan remote control / pengontrol jarak jauh pemakai dapat menjalankannya tanpa harus keluar dari bak mandi.

Alat yang dibuat terdiri dari IC AT89C51 sebagai pengontrol dan pengolah data / masukan. Remote control berfungsi sebagai pemberi perintah yang diterima IR Receiver yang diteruskan ke IC AT89C51, IC ini akan memberikan perintah ke Fan dan Heater sesuai perintah yang telah diolahnya. Selain itu IC ini memberikan perintah pada LM35 / sensor suhu untuk mengecek apakah sesuai hasil yang telah dilakukan.

Dari semua proses yang telah dilakukan mulai dari awal dan selesai, IC AT89C51 juga memberikan keterangan yang ditampilkan pada seven segment. Jadi dengan melihat tampilan seven segment akan diketahui diposisi manakah alat ini bekerja.

KATA PENGANTAR

Dengan mengucapkan syukur kehadiran Tuhan Yang Maha Esa atas rahmat dan karunia-Nya kepada penulis, sehingga dapat terselesaikan skripsi ini dengan judul :

“ Perencanaan Dan Pembuatan Alat Pengatur Gelembung Udara Untuk Mandi SPA Berbasis Mikrokontroller AT89C51 “

Adapun maksud dari penulisan skripsi ini diajukan untuk memenuhi salah satu syarat guna memperoleh gelar Sarjana Elektro pada Jurusan Elektronika Fakultas Teknologi Industri Institut Teknologi Malang.

Penulis menyadari sepenuhnya bahwa dalam penyusunan skripsi ini tentu saja tidak terlepas dari bantuan dan bimbingan berbagai pihak, maka dalam kesempatan ini penulis ingin menghaturkan rasa terima kasih yang setulusnya kepada :

1. Bapak Joseph Dedy Irawan, ST, MT, selaku Dosen Pembimbing Skripsi yang telah memberikan bimbingan, arahan dan dorongan kepada penulis selama penyusunan skripsi ini.
2. Bapak Ir. F. Yudi Limpraptono, M.T selaku Ketua Jurusan Teknik Elektro / Elektronika.

3. Ibu Ir. Mimien Mustikawati, selaku Sekretaris Jurusan Teknik Elektro / Elektronika.
4. Bapak dan Ibu yang telah memberikan dukungan moril dan materiil dengan segenap rasa cinta, juga adikku tersayang terimakasih atas dukungannya, ya.
5. Dik Juwita, yang dengan penuh pengertian dan kasih yang tulus yang selalu memberikan semangat, dorongan dan motivasi kepada penulis untuk segera menyelesaikan skripsi ini, jangan marah ya...percaya deh aku sayang adik.
6. Bapak dan Ibu Kost yang telah memberikan tempat untuk tidur, belajar, mandi, bercanda dan masih banyak lagi selama saya menuntut ilmu. Terimakasih ya Pak, Buk semoga Allah SWT membalas semua kebaikan yang telah diberikan kepada saya "Amin".
7. Sahabat-sahabatku : Big Bayu, Heru, Antok ke2nya terimakasih atas bantuannya, Choliq, Angga, Dhani, Onyeng, Telo, Zainul, Andrei than'ks atas dukungannya. Doger, Tongki, Punk, Adi yang ada dikost than'ks ya, anak-anak Meyari sukses ya, serta teman-teman lain yang tidak dapat penulis sebutkan satu persatu, terima kasih atas segala bantuan dan doanya.
8. Oh... iya, buat adik-adikku. Yang gendut, cakep, centil, dan manis: dik Uut, dik ika, dik ila', dik erna dan dik dinda. Makasih ya atas doanya, motivasinya dukungannya dan kopinya. Dan buat dik dinda, maaf aku gak bisa datang di pernikahan adik, ya aku ucapin selamat, semoga bahagia dan direstui oleh Allah swt. Amin...

Dengan segala keterbatasannya, penulis juga menyadari bahwa skripsi ini jauh dari sempurna karena ' Kesempurnaan ' adalah milik Allah semata. Kritik

dan saran sangat diharapkan demi perbaikan skripsi ini. Akhirnya penulis berharap semoga skripsi ini dapat memberikan sumbangan pemikiran dan manfaat bagi pembaca.

Malang, 26 September 2005

Penulis,

(Yudi Agung Prasetyo)

DAFTAR ISI

HALAMAN JUDUL	i
LEMBAR PERSETUJUAN.....	ii
BERITA ACARA.....	iii
KATA PENGANTAR	iv
ABSTRAKSI	vii
DAFTAR ISI	viii
DAFTAR GAMBAR	xi
DAFTAR TABEL	xiii
BAB I : PENDAHULUAN	
1.1. Latar Belakang.....	1
1.2. Rumusan Masalah	2
1.3. Tujuan	2
1.4. Batasan Masalah.....	3
1.5. Metode Penelitian	3
1.6. Sistematika Pembahasan.....	4
BAB II : DASAR TEORI	
2.1. Pendahuluan.....	5
2.2. Sistem Mikrokontroller AT89C51.....	5
2.2.1. Perangkat Keras Mikrokontroller AT89C51	6
2.2.2. Definisi Pin Mikrokontroller AT89C51	8
2.2.3. Organisasi Memori.....	11

2.2.4. Register Fungsi Khusus (Special Function Register)	12
2.2.5. Reset.....	14
2.2.6. RAM / ROM.....	15
2.2.6.1. Memori Yang Diakses Secara Acak (RAM).....	15
2.2.6.2. Memori Yang Hanya Dapat Dibaca (ROM)	15
2.2.6.3. Metode Pengalamatan	16
2.2.7. Bahasa Assembler	17
2.3. Sensor Temperatur.....	18
2.4. Penguat Tidak Membalik (Non Inverting Amplifier).....	20
2.5. Pengikut Tegangan (Voltage Follower).....	21
2.6. Analog To Digital Converter (ADC).....	23
2.7. Diac (Diode Alternating Current).....	26
2.7.1. Karakteristik Diac	28
2.8. Triac (Triode Alternating Current)	29
2.8.1. Karakteristik Triac.....	30
2.9. Display Seven Segment.....	32

BAB III : PERENCANAAN DAN PEMBUATAN ALAT

3.1. Diagram Blok Rangkaian.....	34
3.2. Perencanaan Hardware	35
3.2.1. Sensor Suhu.....	36
3.2.2. Rangkaian Supervisi Suhu	37
3.2.3. Perancangan ADC 0809 (Analog To Digital Converter).....	38
3.2.4. Digital Analog Converter (DAC)	40

3.2.5. Driver Pemanas	42
3.2.6. Driver Kipas	46
3.2.7. Minimum Sistem AT89C51	48
3.2.7.1. Konfigurasi Pin Mikrokontroler AT89C51	48
3.2.7.2. Rangkaian Clock Minimum Sistem	51
3.2.7.3. Rangkaian Reset	51

BAB IV : PENGUJIAN ALAT

4.1. Tujuan	56
4.2. Pengujian Hardware	56
4.2.1. Pengujian Sensor	57
4.2.1.1. Pengujian Sensor Suhu	57
4.2.2. Pengujian ADC (Analog To Digital Converter)	60
4.2.3. Pengujian DAC (Digital To Analog Converter)	62
4.2.4. Pengujian Rangkaian Heater	63
4.2.5. Pengujian Rangkaian Penggerak Fan	64

BAB V : PENUTUP

5.1. Kesimpulan	65
5.2. Saran – Saran	66

DAFTAR PUSTAKA

LAMPIRAN

DAFTAR GAMBAR

GAMBAR 2.1	Diagram Blok Mikrokontroller AT89C51	7
GAMBAR 2.2	Susunan Pin AT89C51	8
GAMBAR 2.3	Organisasi Program Memory	11
GAMBAR 2.4	Sensor Temperatur	19
GAMBAR 2.5	Rangkaian Penguat Tidak Membalik	20
GAMBAR 2.6	Rangkaian Pengikut Tegangan	22
GAMBAR 2.7	Pin Konfigurasi ADC 0809	23
GAMBAR 2.8	Karakteristik Kerja ADC 0809	26
GAMBAR 2.9	(A) Susunan Diac (B) Rangkaian Diac (C) Rangkaian Pengganti Diac	27
GAMBAR 2.10	Rangkaian Percobaan Karakteristik Diac	28
GAMBAR 2.11	Kurva Karakteristik	28
GAMBAR 2.12	(A) Simbol Triac (B) Rangkaian Penggantinya Sebagai Saklar	29
GAMBAR 2.13	(A) Forward Bias (B) Reserves Bias	30
GAMBAR 2.14	Rangkaian Percobaan Karakteristik Triac	30
GAMBAR 2.15	Kurva Karakteristik Triac. Tidak Ada Perbedaan Antara Karakteristik Forward Dan Reserves-nya	31
GAMBAR 2.16	Rangkaian Dasar Kontrol	31
GAMBAR 2.17	Bentuk Gelombang Pada Beban Rangkaian Dasar Kontrol	32
GAMBAR 2.18	Sevent Segment Common Anoda	33
GAMBAR 3.1	Diagram pengaturan Gelombang Udara Mandi Spa	34

DAFTAR TABEL

TABEL 2.1 Fungsi Pada Port 1.....	9
TABEL 2.2 Fungsi Khusus Pada Port 3.....	9
TABEL 2.3 Spesial Function Register	12
TABEL 4.1 Hasil Pengukuran Dan perhitungan Tegangan Sensor Suhu	58
TABEL 4.2 Hasil Pengukuran Dan Perhitungan Tegangan Sensor Suhu Beserta Penguatan.....	59
TABEL 4.3 Kesalahan / Error Antara Hasil Pengukuran Dengan Hasil Pengujian Sensor Suhu.....	60
TABEL 4.4 Hasil Pengukuran ADC Dengan Menggunakan Led Berdasarkan Suhu	61
TABEL 4.5 Hasil Pengukuran Dari Rangkaian DAC R-2R.....	62
TABEL 4.6 Hasil Pengukuran Rangkaian Heater.....	63
TABEL 4.7 Hasil Pengukuran Rangkaian Penggerak Fan.....	64

BAB I

PENDAHULUAN

1.1. Latar Belakang

Stres, kelelahan melingkupi kita hampir setiap hari. Di tengah bising dan macetnya lalu lintas kota para karyawan dan pekerja lainnya harus memutar otak, mengerahkan tenaga yang banyak akhirnya menimbulkan keletihan, kejenuhan, juga stres. Itu wajar saja apalagi di zaman 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 beristirahat dan menenangkan 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 suatu Alat Pengatur Gelembung Udara dalam Air untuk Mandi Spa menggunakan Mikrokontroller AT89C51. 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 sebuah remote control yang telah disediakan.

1.2. Rumusan Masalah

Dalam Perencanaan dan Pembuatan Alat Pengatur Gelembung Air untuk mandi Spa berbasis Mikrokontroller AT89C51 dapat dirumuskan beberapa permasalahan seperti dibawah ini :

1. Dalam pengaturan gelembung udara dalam air ini diharapkan dapat sesuai dengan apa yang akan dikehendaki si pemakai.
2. Bagaimana cara mendesain perangkat lunak (software) dan perangkat keras (hardware) alat pengatur gelembung udara dalam air mandi spa berbasis mikrokontroller AT89C51.
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 gelembung udara panas dengan rangkaian elektronika dan mekanikal yang sederhana.
-

1.4. Batasan Masalah

Agar permasalahan yang dibahas dalam tugas akhir ini tidak terlalu luas maka penulis membatasi hanya pada hal-hal berikut :

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

1.5. Metode Penulisan

Untuk merealisasikan system yang dirancang maka dilakukan langkah-langkah :

1. Study literature, yaitu mempelajari teori serta aplikasi system kontrol menggunakan mikrokontroler AT89C51 dengan mencari informasi dan data-data dari referensi yang berhubungan dengan alat.
Study literature disini akan mempelajari hal-hal sebagai berikut :
 - a. Arsitektur mikrokontroler AT89C51.
 - b. Karakteristik umum.
 - c. Interface dengan input/output mikrokontroler.
 2. Perancangan hardware dan software, yaitu melakukan kegiatan pembuatan program, rangkaian per blok hingga pembuatan perangkat keras (hardware) 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 / penunjang yang membantu dalam pembuatan alat.

BAB III PERANCANGAN DAN PEMBUATAN ALAT

Berisi tentang perancangan perangkat keras (hardware) dan perangkat lunak (software).

BAB IV PENGUJIAN ALAT

Berisi tentang hasil pengujian peralatan yang telah dibuat secara keseluruhan.

BAB V PENUTUP

Berisi kesimpulan dan saran dari perancangan, pembuatan sampai pengujian.

BAB II

DASAR TEORI

2.1. Pendahuluan

Dalam bab II akan dibahas mengenai dasar - dasar teori yang menunjang dalam perencanaan sistem kontrol yang diaplikasikan pada pengaturan suhu susu. Pertama akan dijelaskan secara umum tentang teori dasar Mikrokontroller AT89C51 yang sangat penting dalam sistem kontrol ini. Selanjutnya akan di bahas mengenai komponen-komponen penunjang dalam pembuatan sistem kontrol ini

2.2 Sistem Mikrokontroller AT89C51

Sistem mikroprosesor minimum terdiri dari mikroprosesor, ROM, RAM, dan I/O. Penggabungan keseluruhan komponen – komponen tersebut dalam satu chip menyebabkan dimensi serta daya yang dibutuhkan oleh sistem menjadi lebih kecil. Komponen baru ini kemudian disebut dengan one chip microcomputer.

Aplikasi one chip microcomputer dibatasi oleh kapasitas program yang mampu dilaksanakan, sehingga setiap aplikasinya selalu bercirikan :

- Perhitungan matematis yang sederhana.
- Program aplikasi yang relatif kecil.
- Aplikasi biasanya berorientasi pada sistem kontrol.

Berdasarkan ciri-ciri tersebut, one chip microcomputer juga sering disebut

microcontroller atau embedded (reprogrammable) controller.

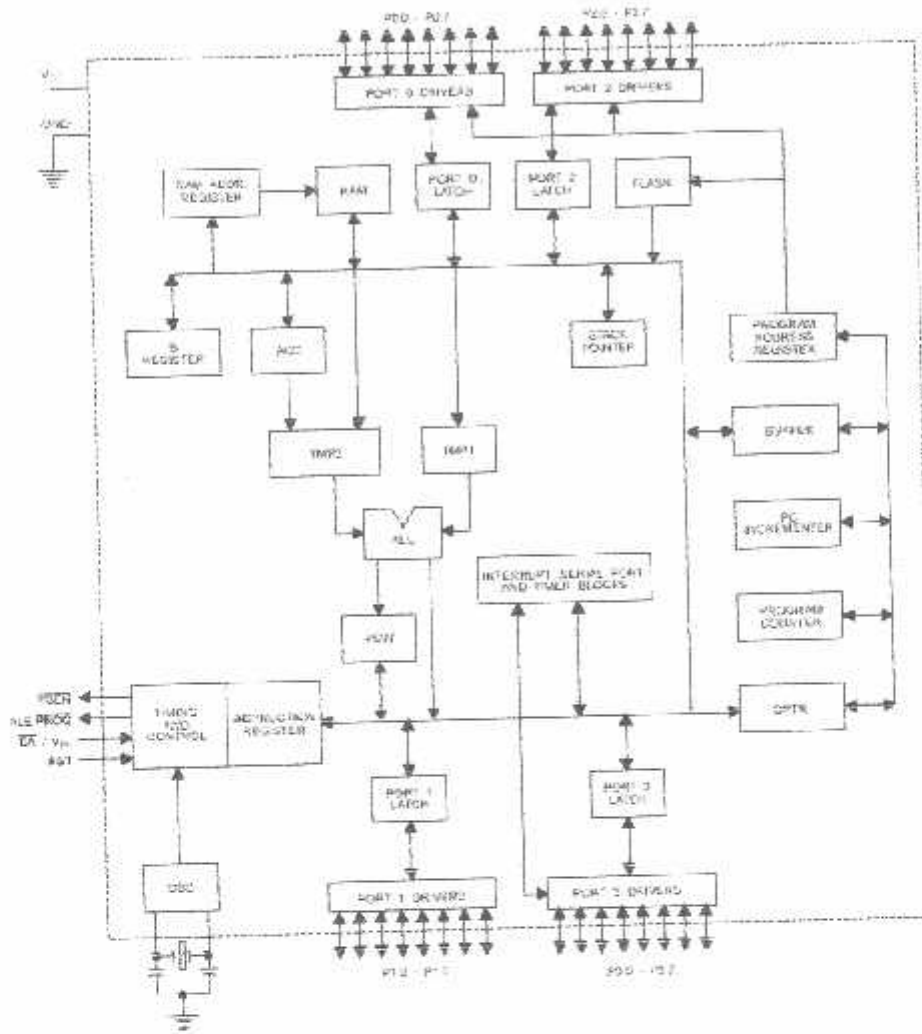
Mikrokontroller AT89C51 adalah mikrokontroller ATMEL yang termasuk mikrokontroler keluarga MCS – 51, membutuhkan daya rendah, memiliki performance yang tinggi dan merupakan mikrokomputer 8 bit yang dilengkapi 4Kbyte EEPROM (*Electrical Erasable and Programmable Read Only Memory*) dan 128 Byte RAM internal. Program memori dapat diprogram ulang dalam sistem atau menggunakan programmer *nonvolatile* memory konvensional. Dalam sistem mikrokontroller terdapat dua hal yang mendasar, yaitu: perangkat lunak dan perangkat keras yang keduanya saling terkait dan mendukung.

2.2.1. Perangkat keras mikrokontroler AT89C51

Secara umum Mikrokontroller AT89C51 memiliki :

- Sebuah CPU 8 bit yang dioptimasi untuk aplikasi kontrol
 - 16 bit PC (Program Counter) dan DPTR (Data Pointer)
 - 8 bit PSW (Program Status Word)
 - 8 bit SP (Stack Pointer)
 - Internal EEPROM selebar 4 Kbyte
 - RAM sebesar 128 byte
 - 32 pin I/O (Input/Output) yang tersusun dalam 4 port, masing-masing terdiri atas 8 jalur I/O
 - Dua buah timer/counter 16 byte
 - Data serial Receiver/Transmitter full duplex : SBUF
 - Control Register, yaitu TCON, TMOD, SCON, PCON, IP dan IE
 - Lima buah jalur interupsi (2 buah interupsi eksternal dan 3 buah
-

interupsi internal)



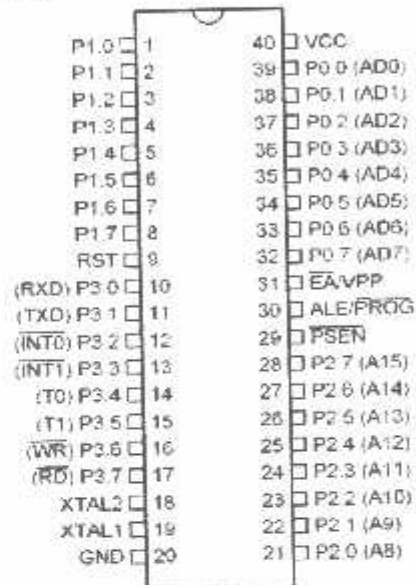
Gambar 2.1 Diagram Blok MCS AT89C51
Sumber : Data Sheet AT89C51 ATMEL

Gambar 2.1 memperlihatkan blok diagram mikrokontroller AT89C51. Mikrokontroller ini merupakan kombinasi dari unit pemroses pusat (Central Processing Unit), memori data berupa RAM, port masukan/keluaran, mode status, dan register data. Unit pemroses pusat terdiri dari 8 bit Arithmetic Logic Unit, register B, Program Status Word-PSW, stack pointer – SP, Program Counter-PC, dan data pointer – DP. Masing-masing elemen ini berkomunikasi melalui 8 bit bus

data internal. Jalur masukan/keluaran menyangga bus data ini bila hendak berhubungan dengan rangkaian diluar mikrokontroller.

2.2.2. Definisi Pin Mikrokontroler AT89C51

Pada mikrokontroller AT89C51 terdiri dari 40 pin yang dapat didefinisikan sebagai berikut :



Gambar 2.2 Susunan Pin AT89C51
Sumber : Data Sheet AT89C51 ATMBL

Adapun penjelasan tiap pin sebagai berikut:

1. VCC : Suply tegangan
2. GND : Ground
3. PORT 0 : Port I/O bidirectional, port ini dapat juga dimultipleks untuk address, data bus (LSB) selama mengakses program dan data memori eksternal.
4. PORT 1 : Port I/O bidirectional, dengan internal pull-up. Apabila digunakan sebagai input dan eksternal di pull-down maka akan mengalirkan arus (I_{IL}). Port 1 juga menerima alamat

bagian rendah selama pemrograman dan verifikasi flash.

Tabel 2.1 Fungsi pada Port 1

Port Pin	Alternate Functions
P1.5	MOSI (used for In-System Programming)
P1.6	MISO (used for In-System Programming)
P1.7	SPK (used for In-System Programming)

Sumber : Data Sheet AT89C51 Atmel

Dalam AT89C51 Port 1 merupakan Port yang digunakan sebagai ISP header.

5. PORT 2 : Port I/O bidirectional, dengan internal pull-up. Port ini dapat juga dimultipleks untuk address atau data bus (MSB), selama mengakses program dan data memory eksternal.
6. PORT 3 : Port I/O bidirectional, dengan pull-up. Disamping itu port ini bisa digunakan sebagai fungsi khusus, antara lain :
RXD(P3.0), TXD(P3.2), INT0(P3.2), INT1(P3.3),
T0(P3.4), T1(P3.5), WR(P3.6), RD(P3.7).

Tabel 2.2 Fungsi Khusus Pada Port 3

Nama Penyemat	Fungsi Khusus
Port 3.0	RxD (port masukan serial)
Port 3.1	TxD (port keluaran serial)
Port 3.2	/INT0 (masukan interupsi eksternal 0)
Port 3.3	/INT1 (masukan interupsi eksternal 1)
Port 3.4	T0 (masukan pewaktu eksternal 0)

<i>Port 3.5</i>	T1 (masukan pewaktu eksternal 1)
<i>Port 3.6</i>	/WR (sinyal tulis memori data eksternal)
<i>Port 3.7</i>	/RD (sinyal baca memori data eksternal)

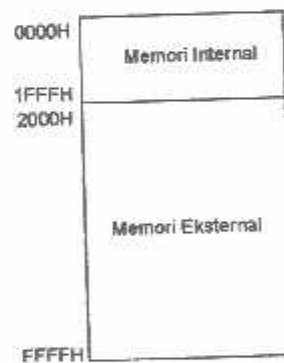
Sumber : Data Sheet AT89C51 ATME1

7. RESET : Merupakan pin yang aktif tinggi (high), pin ini aktif tinggi selama dua siklus mesin ketika osilator bekerja akan mereset peralatan.
8. ALE/PROG : Address Latch Enable, untuk melatch address LSB selama mengakses eksternal memori dan juga digunakan sebagai program pulsa input. ALE dapat disable dengan setting bit 0 dari SFR pada alamat 8EH. Selama instruksi MOVX atau MOVC ALE akan diset.
9. PSEN : Program Store Enable, pada waktu AT89C51 mengakses kode dari eksternal program memori PSEN diaktifkan dua kali setiap machine cycle.
10. EA/VPP : Eksternal Acces Enable, EA harus digroundkan jika digunakan untuk mengakses memori eksternal. Untuk mengakses internal memori maka EA dihubungkan ke VCC.
11. X1 dan X2 : Pin ini dihubungkan dengan kristal bila menggunakan osilator internal. X-TAL 1 merupakan masukan ke rangkaian osilator internal sedangkan X-TAL 2 keluaran dari rangkaian osilator internal. Untuk keperluan ini

diperlukan kapasitor penstabil sebesar 30pF. Dan nilai dari X-TAL tersebut antara 4–24 Mhz. Untuk lebih jelasnya dapat dilihat gambar 2.2 pemasangan X-TAL serta kapasitor yang digunakannya.

2.2.3. Organisasi Memory

Organisasi memori pada mikrokontroller AT89C51 dapat dibagi menjadi dua bagian besar yaitu memori program dan memori data. Pembagian tersebut didasarkan atas fungsi dari penyimpanan data maupun program. Memori program digunakan untuk menyimpan instruksi-instruksi yang akan dijalankan oleh mikrokontroller, sedangkan memori data digunakan sebagai tempat yang sedang diolah mikrokontroller. Organisasi memori AT89C51 dapat dilihat pada gambar 2.3.



Gambar 2.3 Organisasi Program memori
Sumber : Data Sheet AT89C51 ATMEL

Mikrokontroller AT89C51 dilengkapi dengan ROM *internal*, sehingga untuk menyimpan program tidak digunakan ROM *eksternal* yang terpisah dari mikrokontroller. Agar tidak menggunakan memori program *eksternal*, penyemat/E_A dihubungkan dengan V_{cc} (logika 1).

Memori program mikrokontroller menggunakan alamat 16 bit mulai 0000_H - 0FFF_H, sehingga kapasitas penyimpanan program maksimal adalah 4Kb. Sinyal */PSEN* (*Program Store Enable*) tidak digunakan jika digunakan memori program *internal*.

Selain program mikrokontroller AT89C51 juga memiliki data *internal* 128 byte dan mampu mengakses memori data *eksternal* sebesar 64 Kb. Semua memori data *internal* dapat dialamati dengan data langsung atau tidak langsung. Ciri dari pengalamatan langsung adalah *operand* adalah alamat *register* yang berisi alamat data yang akan diolah. Sebagian memori tersebut dapat dialamati dengan pengalamatan *register*, dan sebagian lagi dapat dialamati dengan memori satu *bit*. Untuk membaca data digunakan sinyal */RD* sedangkan untuk menulis digunakan sinyal */WR*.

2.2.4 Register Fungsi Khusus (Special Function Register)

Register dengan fungsi khusus (Special Function Register, SFR) terletak pada 128 Byte bagian atas memori data internal. Wilayah SFR ini terletak pada alamat 80H sampai FFH. Pengalamatannya harus diakses secara langsung baik per bit atau per byte. Secara perangkat keras, SFR ini dibedakan dengan memori data internal. Beberapa SFR yang digunakan dalam perancangan sistem penghitung waktu adalah:

Tabel 2.3 Special Function Register

Simbol	Nama Register	Alamat
ACC	Accumulator	E0 _H
B	Register B	F0 _H

PSW	Program Statut Word	D0 _H
SP	Stack Pointer	81 _H
DPTR	Data Pointer 2 Byte	
DPL	Bit rendah	82 _H
DPH	Bit Tinggi	83 _H
P0	Port 0	80 _H
P1	Port 1	90 _H
P2	Port 2	A0 _H
P3	Port 3	B0 _H
IP	Interupt Periority Control	D8 _H
IE	Interupt Enable Control	A8 _H
TMOD	Timer/Counter Mode Control	89 _H
TCON	Timer/Counter Control	88 _H
TH0	Timer/Counter 0 High Control	8C _H
TL0	Timer/Counter 0 Low Control	8A _H
TH1	Timer/Counter 1 High Control	8D _H
TL1	Timer/Counter 1 Low Control	8B _H
SCON	Serial Control	98 _H
SBUF	Serial Data Buffer	99 _H
PCON	Power Control	87 _H

Sumber : Agfianto Eko Putra, Belajar Mikrokontroller AT89C51/52/55, 2004

- ♦ *Accumulator* (ACC) merupakan register untuk penambahan dan pengurangan. Perintah *mnemonic* untuk mengakses akumulatur disederhanakan sebagai A.

- ♦ *Register B* merupakan register khusus yang berfungsi melayani operasi perkalian dan pembagian.
- ♦ *Stack Pointer (SP)* merupakan *register 8 bit* yang dapat diletakkan di alamat manapun pada *RAM internal*.
- ♦ *2 Data Pointer (DPTR)* terdiri dari dua *register*, yaitu untuk *byte tinggi (Data Pointer High, DPH)* dan *byte rendah (Data Pointer Low, DPL)* yang berfungsi untuk mengunci alamat *16 bit*.
- ♦ *Port 0* sampai *Port 3* merupakan register yang berfungsi untuk membaca dan mengeluarkan data pada port 0, 1, 2, 3. Masing - masing *register* ini dapat dialamati *per-byte* maupun *per-bit*.
- ♦ *Control Register* terdiri dari *register* yang mempunyai fungsi kontrol. Untuk mengontrol sistem *interupsi*, terdapat dua *register* khusus, yaitu *register IP (Interrupt Priority)* dan *register IE (Interrupt Enable)*. Untuk mengontrol pelayanan *timer/counter* terdapat *register* khusus, yaitu *register TCON (timer/counter control)* serta pelayanan *port serial* menggunakan *register SCON (Serial Port Control)*.

2.2.5 Reset

Untuk mereset rangkaian mikrokontroller, dipilih rangkaian power – on reset. Rangkaian ini akan mereset mikrokontroller secara otomatis setiap kali catu daya diaktifkan, rangkaian reset akan menahan logika tinggi pada penyemat. Reset untuk jangka waktu tertentu. Jangka waktu tertentu tersebut ditentukan oleh pengosongan muatan pada kondensator, untuk memastikan keabsahan reset, logika yang lebih lama dari dua siklus mesin ditambah waktu mulai hidup

(start – on) osilator.

2.2.6 RAM/ROM

Memori digunakan untuk menyimpan informasi dalam bentuk biner dan menyediakan informasi ini ke mikroprosesor setiap kali dibutuhkan. Informasi ini dapat berupa instruksi maupun data. Tipe utama memori yang dipakai dalam sistem mikroprosesor adalah RAM dan ROM .

2.2.6.1 Memori yang diakses secara acak (RAM)

RAM (Random Access Memory) adalah memori baca/tulis. Memori ini termasuk jenis memori yang mudah dihapus (volatile), yaitu apabila dayanya dimatikan, isi yang terdapat di dalam RAM menjadi hilang . ada dua teknologi yang dipakai oleh RAM yaitu statik dan dinamik. Informasi yang disimpan dalam memori dinamik akan hilang apabila tidak dilakukan penyegaran (refresh). Hal ini disebabkan informasi disimpan sebagai muatan dalam kapasitansi gerbang – substrat sebuah transistor MOS. Dalam beberapa mili detik sebagian besar muatan akan hilang. Untuk memelihara informasi tersebut, muatan harus disegarkan kembali. RAM statik menyimpan satu bit informasi dalam sebuah flip-flop. Beberapa transistor diimplementasikan dalam chip untuk menghasilkan sebuah flip-flop.

2.2.6.2 Memori yang hanya dapat dibaca (ROM)

ROM (Read Only Memory) adalah memori yang isinya sekali ditulis dan hanya dapat dibaca. Memori ini termasuk jenis memori yang tidak mudah terhapus (non-volatile) ; yaitu apabila dayanya dimatikan, isi yang terdapat didalam ROM tidak akan dapat hilang. Penulisan data kedalam ROM disebut

pemrograman ROM, karena biasanya programlah yang ditulis didalam ROM.

2.2.6.3 Metode Pengalamatan

Metode pengalamatan yang digunakan pada keluarga MCS 51 adalah sebagai berikut :

A. Pengalamatan Tak Langsung

Operasi pengalamatan tak langsung menuju ke sebuah register yang berisi lokasi alamat memory yang akan digunakan dalam operasi. Lokasi yang nyata tergantung dari isi register saat instruksi dijalankan. Untuk melaksanakan pengalamatan tak langsung digunakan simbol @.

Contoh :

ADD A,@R0 ; Tambahan isi RAM pada register 0 ke akumulator.

DEC@R1 ; Kurangi 1 isi RAM pada alamat R1.

B. Pengalamatan Langsung

Pengalamatan langsung dilakukan dengan memberi nilai ke suatu register secara langsung. Untuk melaksanakan hal tersebut digunakan tanda #.

Contoh :

MOVA,#01H ; Isi akumulator dengan bilangan 01H.

MOV DPTR,#19AB ; Isi DPTR dengan bilangan 19ABH.

Pengalamatan data langsung dari 0 sampai 127 akan mengakses register perangkat keras.

Contoh :

MOV P3,A ; Pindahkan isi akumulator ke alamat data BOH(alamat port 3)

INC 50 ; Naikan lokasi 50 (desimal) dalam memory.

2.2.7 Bahasa Assembler

Bahasa Assembler merupakan tata cara untuk mewakili operasi CPU dalam format bahasa simbol yang disusun berurutan dalam pernyataan – pernyataan. Masing – masing pernyataan akan menterjemahkan ke dalam intruksi bahasa mesin atau operasi biner yang disebut operasi code/OPCODE. Dalam penulisan bahasa mesin untuk program assembler umumnya, terdapat berbagai macam kelompok instruksi, diantaranya:

Perpindahan Data.

Instruksi ini memindahkan data antara register – register, memory – memory register – memory, antara muka register dan antara muka memory.

Contoh :

MOV A,R0 ; Menyalin isi register R0 ke akumulator.

MOV A,@R0 ; Menyalin data dialamat yang ditunjukan isi register R0 ke akumulator.

Operasi Aritmatik

Instruksi ini melaksanakan operasi aritmatik yang meliputi penjumlahan, pengurangan, perkalian maupun pembagian.

Contoh :

ADD A,#DATA ; Menambah akumulator dengan data.

ADC A #DATA ; Menambah akumulator dan cary.

INC R4 ; Menambah isi R4 dengan 1.

DEC R4 ; Mengurangi isi R4 dengan 1.

MUL A,B ; Mengalikan isi akumulator dengan isi register B.

DIV A,B ; Membagi isi akumulator dengan isi register B.

Operasi Percabangan

Instruksi ini mengubah urutan normal pelaksanaan suatu program untuk melaksanakan program di lain tempat yang kita perlukan pada saat itu

Contoh :

CJNE (Compare Memory to Accumulator)

Instruksi ini membandingkan isi lokasi memory tertentu dengan isi akumulator, jika sama instruksi selanjutnya akan dieksekusi. Jika tidak sama, eksekusi akan ke alamat kode.

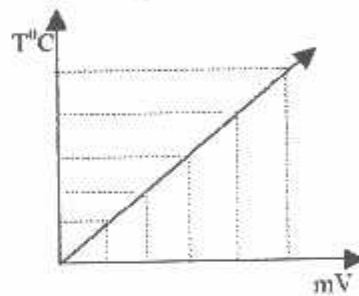
JB (Jump if Bit Set)

Instruksi ini menguji suatu alamat bit. Jika berisi satu, eksekusi akan menuju alamat kode, jika tidak instruksi selanjutnya akan dieksekusi. JBN (Jump if Bit Not Set) Instruksi ini menguji alamat bit. Jika berisi 0, eksekusi akan menuju ke alamat kode. Jika berisi 1, instruksi selanjutnya yang akan dieksekusi.

2.3.SENSOR TEMPERATUR

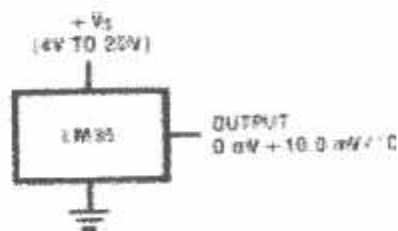
Dibutuhkan tranduser untuk mengukur temperatur. Suatu definisi mengatakan bahwa transducer adalah sebuah alat yang bila digerakkan oleh energi didalam sebuah sistem transmisi, menyalurkan energi dalam bentuk yang sama atau dalam bentuk yang berlawanan dari sistem transmisi kedua. Transmisi ini bisa listrik, mekanik, kimia, *optic* (radiasi) atau *termal* (panas). Ada bermacam-macam tranduser temperatur, dari dioda sederhana sampai IC khusus. Sensor temperatur yang digunakan disini adalah LM35. LM35 merupakan rangkaian

macam transduser temperatur, dari dioda sederhana sampai IC khusus. Sensor temperatur yang digunakan disini adalah LM35. LM35 merupakan rangkaian integrasi untuk sensor temperatur, yang mana tegangan keluaran dari sensor ini berbanding lurus dengan perubahan temperatur dalam $^{\circ}\text{C}$. IC LM35 menghasilkan kenaikan tegangan 10mV pada *output* setiap kenaikan temperatur 1°C dengan *range* suhu antara -55°C sampai $+150^{\circ}\text{C}$. Tegangan catudaya yang digunakan menggunakan catu daya tunggal.



Sumber : National Semiconductor LM35 Precision Centigrated Temperature Sensors, Data Sheet.

IC LM35 mempunyai keuntungan lebih linier dari sensor suhu yang disesuaikan pada $^{\circ}\text{kelvin}$, sehingga pengguna tidak harus mengurangi besar tegangan konstan dari *output* yang mendapatkan skala tepat. Jangkauan dari temperatur yang dapat diukur mulai -55°C sampai dengan $+150^{\circ}\text{C}$. keunggulan lain dari LM35 adalah konsumsi arus yang kurang dari $60\mu\text{A}$. Bagan komponen dari LM 35 seperti terlihat pada gambar 2.4.

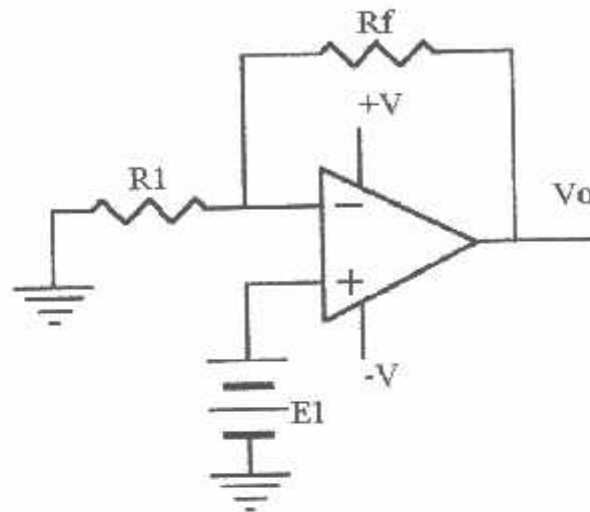


Gambar 2.4 Sensor Temperatur

Sumber : National Semiconductor LM35 Precision Centigrated Temperature Sensors, Data Sheet

2.4. Penguat Tidak Membalik (Non Inverting Amplifier)

OP – Amp dapat di pakai sebagai penguat tak membalik, penguat tak membalik adalah penguat dimana tegangan *output* sefasa dengan tegangan *input*. Gambar 2.5 merupakan rangkaian dari penguat tak membalik.



Gambar 2.5 Rangkaian Penguat Tidak Membalik

Sumber : Wasito S. Vademekum Elektronika, 2001.

Apabila tegangan antara terminal *input* (-) dengan terminal *input* (+) menunjukkan 0 (nol) volt pada gambar 2.5, maka besar tegangan *input* (-) sama dengan tegangan *input* (+) terhadap *ground* (GND) yaitu sebesar $E1$ volt. Arus yang melewati tahanan $R1$ sebesar :

$$I = \frac{E1}{R1} \text{ ampere ...1)}$$

Arah arus tergantung dari *polaritas* tegangan $E1$. Arus akan melewati tahanan umpan balik Rf , sehingga tegangan pada tahanan Rf diperoleh :

$$V_{RF} = I \cdot Rf \text{ volt ...2)}$$

Dengan mensubstitusikannya persamaan (1) dan (2), maka didapatkan :

$$V_{RF} = \frac{E1}{R1} \cdot Rf \text{ volt}$$

Tegangan *output* (V_o) diperoleh dari penjumlahan tegangan pada $R1$ dengan tegangan pada Rf , yaitu :

$$V_o = E1 + V_{RF}$$

$$V_o = E1 + \frac{Rf}{R1} \cdot E1 \text{ volt}$$

$$V_o = \left(1 + \frac{Rf}{R1} \right) E1 \text{ volt}$$

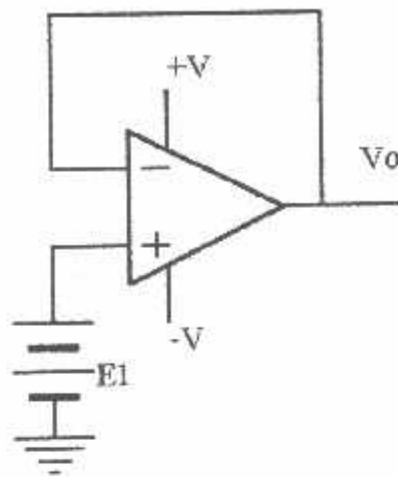
Besar penguatan diperoleh dari tegangan *output* berbanding dengan tegangan *input*, dimana diperoleh :

$$A_o = \frac{V_o}{E1}$$

$$A_o = \left(1 + \frac{Rf}{R1} \right)$$

2.5. Pengikut Tegangan (*Voltage Follower*)

Pengikut tegangan biasanya didefinisikan sebagai rangkaian dengan penguatan satu atau kurang dengan keluaran mengikuti masukan. Diantara masukan dan keluaran terdapat isolasi impedansi. Op-amp pada khususnya berguna sebagai pengikut tegangan, seperti terlihat pada Gambar 2.6.



Gambar 2.6 Rangkaian Pengikut Tegangan
 Sumber : Wasito S. Vademekum Elektronika, 2001.

dengan pengikut tegangan tak membalik, keluaran terhubung langsung pada masukan membalik dengan tegangan masukan dikenakan pada masukan tak membalik. Resistansi umpan balik sama dengan nol. Karena itu, penguatan pengikut tegangan sama dengan satu. Dengan kata lain bila umpan balik diberikan umpan balik 100%, maka keluaran akan mengikuti masukannya. Sehingga besar tegangan *output* (V_o) adalah :

$$V_o = E1 \text{ volt}$$

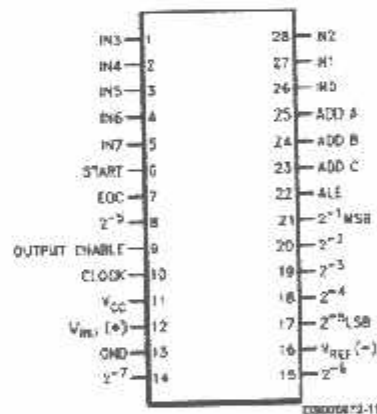
Dapat diperhatikan bahwa tegangan masukan membalik selalu menyamai tegangan masukan tak membalik. Jadi, selisih tegangan antara kedua masukan kira-kira selalu nol. Rangkaian ini memiliki impedansi masukan yang tinggi serta impedansi keluaran yang rendah. Keuntungan ini menjadikannya sangat ideal untuk menyangga atau mengisolasi rangkaian.

2.6. ANALOG TO DIGITAL CONVERTER (ADC)

ADC adalah suatu perangkat yang dapat merubah masukan analog secara multiplex yang menjadi keluaran digital 8 *bit*.

Spesifikasi ADC 0809 adalah

- ◆ Supply tegangan yang dibutuhkan sebesar 5 volt.
- ◆ Waktu konversi adalah 100 μ detik.
- ◆ Mudah diinterfacekan dengan mikrokontroller / berdiri sendiri.
- ◆ Tegangan masuk analog adalah 0 – 5 volt.
- ◆ Pengaturan kenaikan tegangan *per-bit* dapat diatur dengan mengukur tegangan V_{ref} .
- ◆ Frekuensi *clock input* 10 – 1280 KHZ.
- ◆ Konsumsi daya yang rendah.



Gambar 2.7 Pin konfigurasi ADC

Sumber : National Semiconductor, ADC0808/ADC0809 8-bit μ P Compatible A/D Converters Data Sheet.

* $In0 - In7$ (*input analog*)

Ada sejumlah 8 bit analog yang dapat mengatur kombinasi *bit* pada pin Add A,B,C.

* Add A,B,C (*Address*)

Untuk mengatur pemilihan *analog input* yang akan dikonversikan.

* Clock

Pin *clock* adalah tempat memberikan pengaturan keserempakan kerja internal circuit ADC. Typical yang disarankan 640 KHZ. Dan maksimumnya adalah 1280 KHZ.

* Ref (+) dan Ref (-)

Tegangan referensi untuk menentukan *bit* keluaran misalnya diberikan tegangan referensi 5 volt. Kombinasi yang mungkin dari 8 *bit* keluaran adalah 256 (2^8) maka kenaikan tegangan per *bit* adalah $5/(2^8-1) = 19,6$ mvolt. Sehingga tegangan *input* yang bisa dideteksi adalah 19,6 mvolt dengan keluaran digital 00000001₂ akan naik menjadi 00000010₂ jika tegangan naik menjadi 39,2 mvolt demikian seterusnya.

* 2⁰ sampai 2⁷

Tempat keluarannya data digital hasil konversi yang dihubungkan dengan data bus sistem jika di *interface* dengan mikroprosesor.

* ALE (Address Latch Enable)

Untuk *Latch* / pengunci alamat yang telah ada pada Add A, B, C sesuai dengan analog *input* yang akan dikonversikan. Pin *input* ini adalah aktif *high*.

* Start

Untuk membantu agar ADC memulai konversi tegangan *input* yang telah dipilih dengan memberi kombinasi pada 3 *bit* alamat dan mengenainya dengan ALE, pin ini aktif *high*.

* EOC

Pin keluaran ini akan memberikan sinyal *low* jika ADC telah selesai mengkonversikan tegangan analog yang diberikan. Pin ini dapat dihubungkan ke suatu *port* sebagai status / ke pin *interrupt* dari prosesor sebagai tanda pemberitahuan agar *cpu* mengambil data yang telah siap.

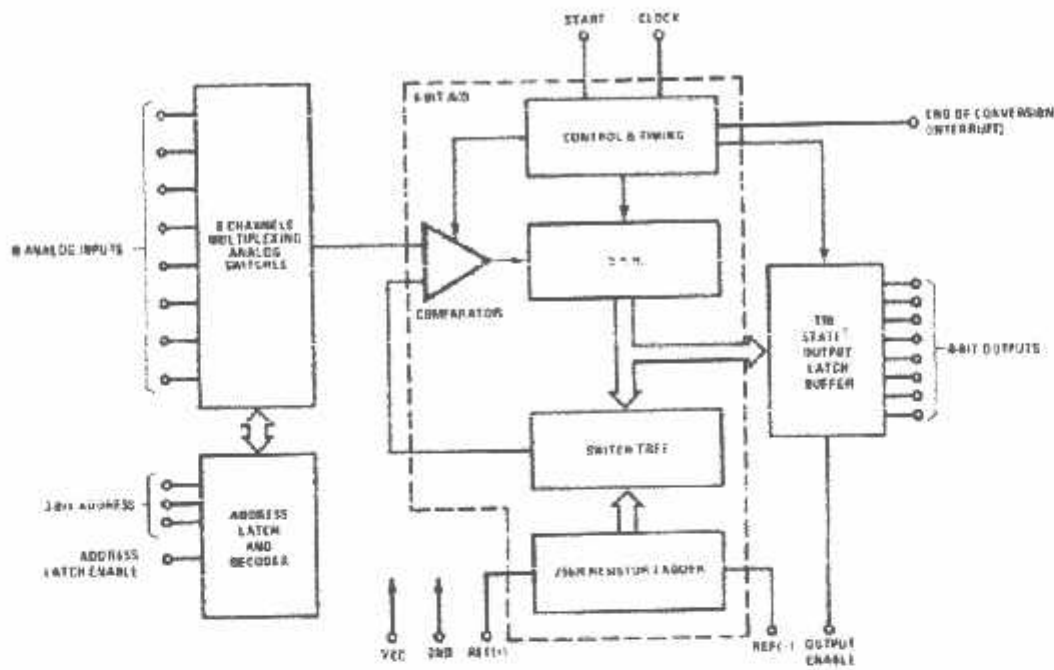
* OE (*Output Enable*)

Setelah EOC memberikan pulsa *low* sejenak maka berarti data telah siap di *buffer internal* ADC untuk mengambil yang masih ada di *buffer* agar keluaran ke data bus perlu memberikan pulsa *high* pada pin OE.

Dapat digambar secara garis besar, disini urutan proses konversi dari besaran analog ke digital dengan menggunakan ADC 0809 :

- Memberikan analog *input* yang akan dikonversikan dengan memberikan kombinasi *bit* pada *address*.
- Memberikan pulsa ALE untuk menguji pilihan tersebut analog.
- Memberikan pulsa *start* untuk memulai konversi.
- Menanti pulsa EOC dari ADC sebagai tanda selesainya konversi
- Memberikan pulsa OE untuk aktifkan *output*.

Untuk lebih jelasnya lihat pada gambar 2.8 tentang karakteristik kerja ADC.



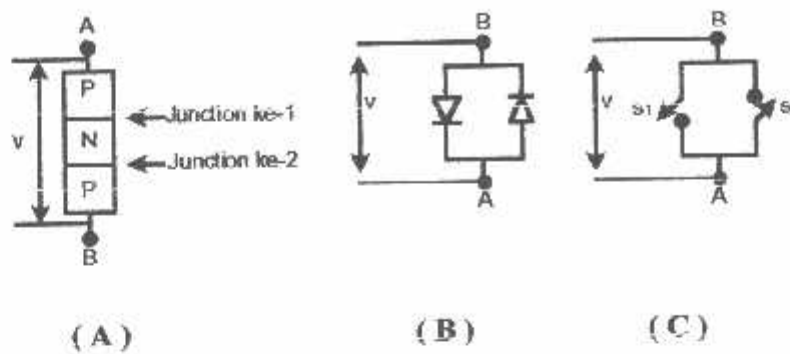
See Ordering
Information

Gambar 2.8 Karakteristik Kerja ADC

Sumber : National Semiconductor, ADC0808/ADC0809 8-bit μ P Compatible A/D Converters Data Sheet.

2.7. 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 hampir sama dengan transistor, namun elektrodanya ada 2 dan mempunyai 2 sambungan (*junction*) seperti gambar 2.9.



GAMBAR 2.9

(A) *Susunan Diac*(B) *Rangkaian Diac*(C) *Rangkaian Pengganti Diac*

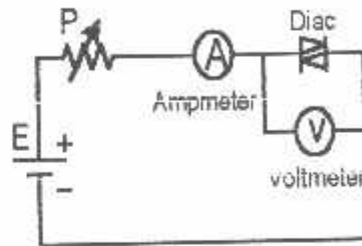
Sumber : Malvino, Prinsip-Prinsip Elektronika, 1994.

Apabila titik A adalah titik muatan positif, maka *junction* ke-1 pada bias maju sedangkan *junction* ke-2 pada keadaan bias mundur. Pada saat titik A tegangan positif terhadap titik B, maka setelah pada tegangan tertentu dapat menembus tegangan dadal (*break down*) sehingga arus mengalir pada diac. Demikian juga apabila titik B tegangannya lebih positif terhadap titik A.

Sampai menembus *junction* ke-1, maka arus mengalir melalui diac. untuk lebih jelasnya dapat dilihat pada gambar 2.9c, yaitu apabila titik A pada keadaan bias maju, maka saklar S_1 pada kondisi *on* sedangkan pada saklar S_2 pada kondisi *off*. Sebaliknya, jika titik B pada keadaan bias maju, maka saklar S_2 pada kondisi *on* dan saklar S_1 pada kondisi *off*. Dengan demikian jelaslah bahwa prinsip kerja dari diac hampir sama dengan arus bolak-balik, yaitu bergantian *forward* bias dan *reverse* biasnya apabila diberi tegangan arus bolak-balik (AC).

2.7.1. Karakteristik diac

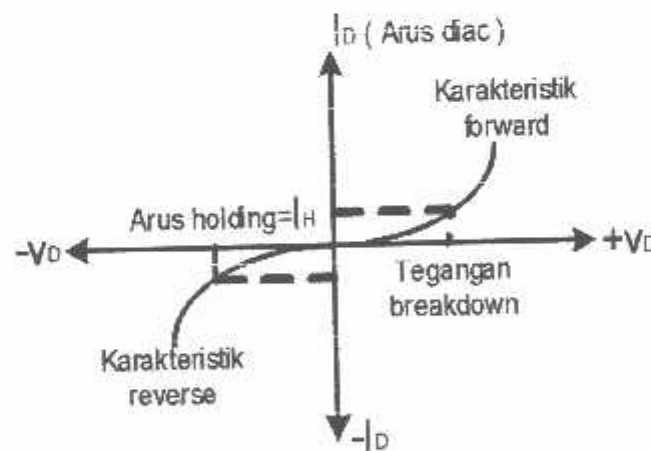
Rangkaian percobaan untuk karakteristik *diac* ini dapat di lihat seperti gambar 2.10.



GAMBAR 2.10 Rangkaian Percobaan Karakteristik Diac

Sumber : Malvino, Prinsip-Prinsip Elektronika, 1994

Pada waktu di berikan *forward* bias terhadap diac, penunjukan ampere meter dan voltmeter di amati, dan hasilnya di gambarkan pada sebuah koordinat sumbu. Kemudian potensiometer diatur, lalu di amati lagi kedua meter tersebut dan lakukan pengaturan potensio berulang-ulang sehingga didapat titik yang tepat.



Gambar 2.11 Kurva Karakteristik

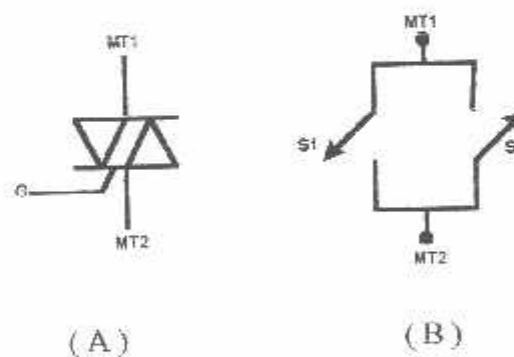
Sumber : Malvino, Prinsip-Prinsip Elektronika, 1994

kemudian sewaktu pemberian *reverse* bias pelaksanaan penggambarannya pun seperti *forward* bias tadi, sehingga dari hasil pengukuran kedua meter yang

berulang-ulang diamati dengan pemutaran potensiometer dapat dibuat gambarnya seperti pada gambar 2.11, demikian juga untuk menentukan tegangan *holding* maupun arus *holding* dan tegangan *breakdown* dari diac secara tepat harus dicobakan berulang-ulang. Diac ini digunakan untuk *trigger* SCR dan untuk mengatur daya. Sebagai *trigger* pada SCR, fungsinya seolah-olah sebagai saklar elektronik, demikian juga untuk mengatur daya.

2.8. Triac (Triode Alternating Current)

Triac adalah saklar triode untuk arus bolak-balik. Berdasarkan gambar 2.12 triac tersusun oleh 2 buah SCR secara paralel. Simbol triac dan rangkaian pengganti sebagai saklar seperti gambar 2.12.



GAMBAR 2.12

(A) Simbol Triac

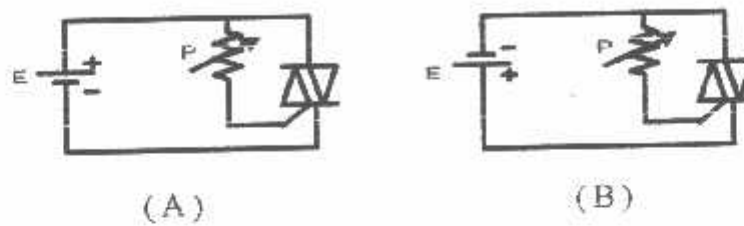
(B) Rangkaian Penggantinya Sebagai Saklar

Sumber : Malvino, Prinsip Prinsip Elektronika.1994

Pada gambar 2.12 triac terdiri dari 3 kaki yaitu: Gate; MT1; MT2, dengan prinsip kerja apabila MT1 diberi *forward* bias, maka saklar S1 menutup

(ON), dan sebaliknya jika MT1 diberi *reverse* bias menyebabkan saklar S2 menutup, dengan kata lain triac bekerja secara bergantian.

Skema pemberian *forward* bias maupun *reverse* bias adalah seperti gambar 2.13.



GAMBAR 2.13

(A) *Forward Bias*

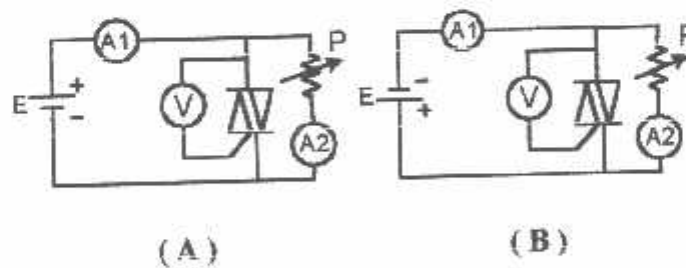
(B) *Reverse Bias*

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.

2.8.1 Karakteristik Triac

Rangkaian percobaan untuk karakteristik triac adalah seperti pada gambar 2.14.



GAMBAR 2.14 Rangkaian Percobaan Karakteristik Triac

(A) *Rangkaian Untuk Karakteristik Forward*

(B) *Rangkaian Untuk Karakteristik Reverse*

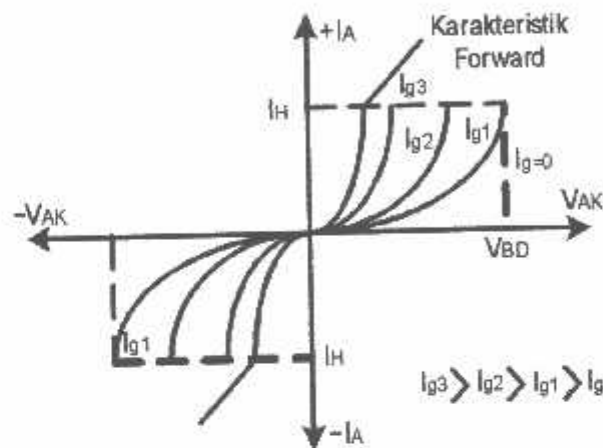
A1 = Amperemeter Untuk Mengukur Arus Melalui Triac

A_2 = Amperemeter Untuk Mengukur Arus Gate

V = Voltmeter Untuk Mengukur V Breakdown antara MT1 dan MT2

E = Sumber Arus

Sumber : Malvino, Prinsip-Prinsip Elektronika, 1994



Gambar 2.15 Kurva Karakteristik Triac. Tidak Ada Perbedaan Antara

Karakteristik Forward Dan Reverse-nya

Sumber : Malvino, Prinsip-Prinsip Elektronika, 1994

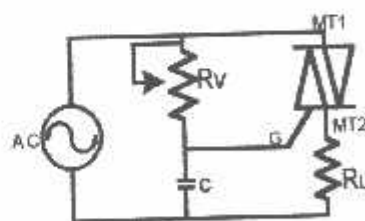
V_{BD} = Tegangan BreakDown

I_g = Arus Gate

I_H = Arus Holding

V_{AK} = Tegangan MT1 Triac

Rangkain dasarnya dapat dijelaskan pada gambar 2.16



AC = Sumber arus bolak-balik

R_v = resistor variabel

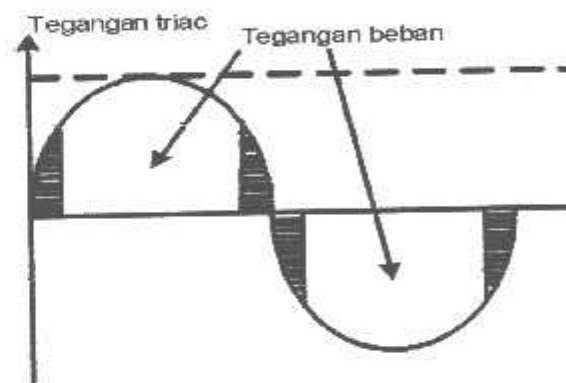
R_L = Tahanan Beban

C = condensator

GAMBAR 2.16 Rangkaian Dasar Kontrol

Sumber : Malvino, Prinsip-Prinsip Elektronika, 1994

Jika resistor (Tahanan) variable (R_v) diatur pada posisi minimum, maka kerugian tegangan pada R_v besar dibandingkan dengan pada *gate*. sekarang jika R_v diatur pada posisi maksimum maka tegangan pada *gate* akan bertambah besar. Apabila tegangan *trigger* diperbesar maka pada saat tegangan tertentu triac akan menghantar sehingga ada arus melalui beban. Oleh karena itu pada beban terdapat daya. Bentuk gelombang yang terdapat pada beban adalah seperti pada gambar 2.17.



GAMBAR 2.17

Bentuk Gelombang Pada Beban Rangkaian Dasar Kontrol

Sumber : Malvino, Prinsip-Prinsip Elektronika, 1994

Dari gambar 2.17 dapat dilihat bahwa tegangan yang terdapat pada beban tidak gelombang penuh, tetapi dikurangi tegangan pada triac itu sendiri.

2.9 Display Seven-Segment

Display seven segment merupakan gabungan dari beberapa LED (*Light Emitting Diode*) yang dapat dicatu secara individu atau masing-masing. Warna yang ditampilkan pada *display* ini umumnya adalah warna merah. LED-LED tersebut tersusun menyerupai angka delapan dan dicatu semuanya sehingga

akan menampilkan angka delapan. Seperti namanya, terdapat tujuh segment LED yang dapat diatur kombinasinya untuk menampilkan angka dan huruf.

Ada dua macam hubungan pada *display seven-segment*, yaitu:

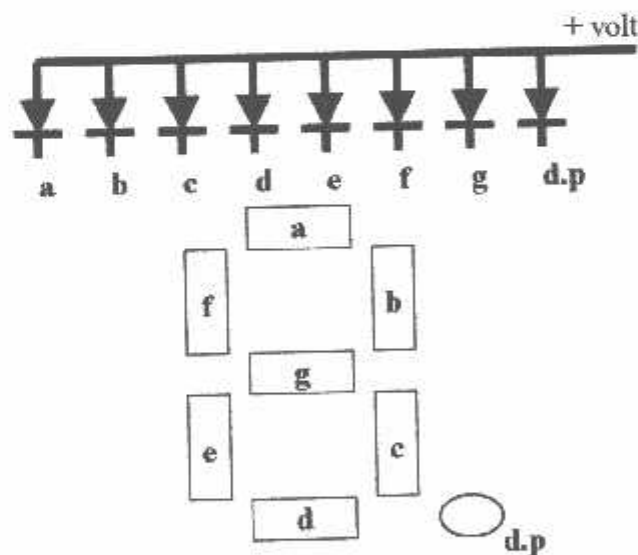
1. Common Anoda

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

2. Common Katoda

Pada hubungan ini semua katoda dihubungkan menjadi satu ke *ground*, sedangkan anodanya difungsikan sebagai masukan.

Dalam penggunaan *display seven-segment* ini harus dipasang resistor seri terhadap setiap LED yang berfungsi untuk membatasi arus yang mengalir. Adapun jenis seven segment yang digunakan disini adalah tipe common anoda.



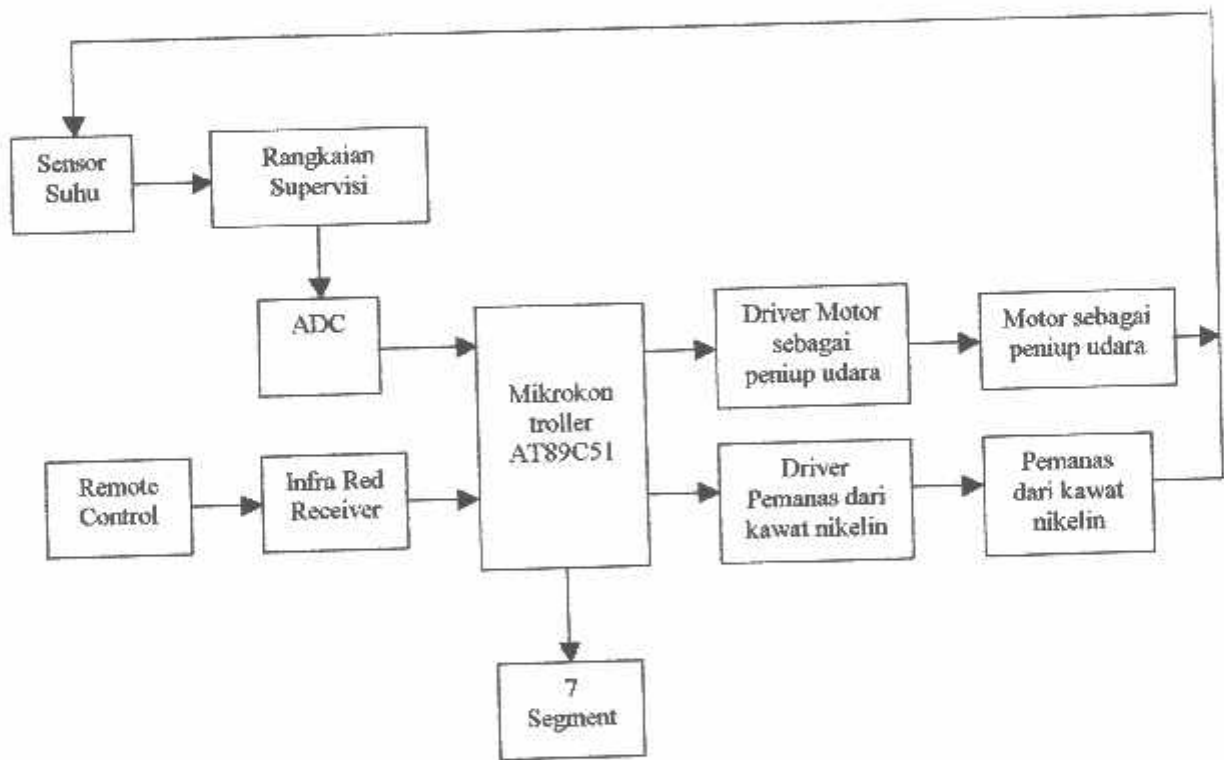
Gambar 2.18 Seven Segment Common Anoda

BAB III

PERENCANAAN DAN PEMBUATAN ALAT

Untuk mendapatkan keseluruhan sistem pada kontrol suhu pada susu, di perlukan tahapan – tahapan perencanaan yang nantinya sedapat mungkin terwujud hasil yang diharapkan. Diagram blok rangkaian terlihat pada gambar 3.1

3.1 Diagram Blok Rangkaian



Gambar 3.1 Diagram Pengaturan Gelembung Udara Mandi Spa

Cara kerja blok diagram gambar 3.1 adalah sebagai berikut:

- Sensor suhu, berfungsi untuk mendeteksi temperatur udara yang ditiup oleh fan yang di panaskan oleh kawat nikelin, sehingga perubahan temperatur udara akan dideteksi oleh sensor ini.
- 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.
- ADC, merupakan piranti yang di gunakan untuk mengubah data yang berbentuk analog menjadi data yang berbentuk digital.
- AT89C51, digunakan sebagai kontrol utama yang mengerakkan keseluruhan sistem, dengan bantuan *software*.
- Remote Control, untuk memberikan masukan angka / level yang di tentukan.
- Infra Red Receiver, berfungsi sebagai penerima sinyal dari remote control.
- 7 Segment, berfungsi untuk menunjukkan nilai perubahan level, nilai level gelembung, dan juga nilai panas gelembung.

3.2. Perencanaan Hardware

Dalam perencanaan ini rancangan *hardware* yang dibuat tujuannya adalah untuk mendukung dan memberikan kemudahan proses kerja pada rancangan *software* agar nantinya dapat sesuai dengan kondisi yang diinginkan. Sedangkan perancangan *hardware* ini dibagi menjadi lima bagian :

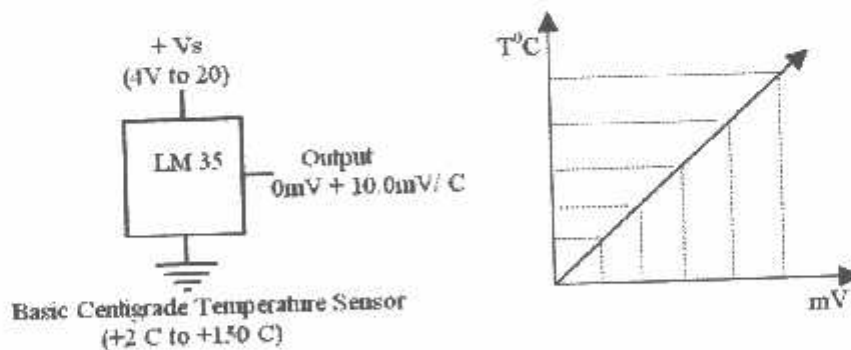
a. Sensor

- b. Rangkaian Supervisi
- c. Rangkaian ADC
- d. Rangkaian AT89C51
- e. Driver

3.2.1. 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.

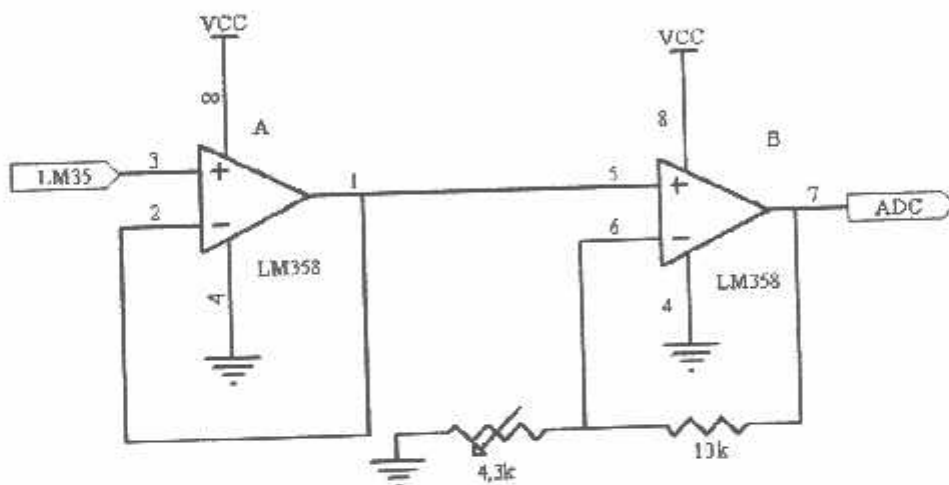
Disini sensor disupply dengan tegangan (V_s) 5 Volt DC. Tegangan yang di keluarkan oleh sensor ini dimaksimalkan pada suhu 150°C dengan nilai tegangan sekitar 1 Volt Dc pada V_{out} sensor. Gambar sensor suhu LM 35 seperti gambar 3.2.



Gambar 3.2 Sensor Suhu

3.2.2. Rangkaian Supervisi Suhu

Pada rangkaian ini terdapat dua buah *operasional amplifier* yang menggunakan satu buah IC LM 358 dimana terdapat dua buah op amp didalamnya. Op Amp yang pertama dikondisikan sebagai *buffer* (pengikut tegangan) dan yang kedua difungsikan sebagai Penguat Diferensial dengan penguatan yang dibutuhkan sebesar 3,3 kali penguatan. Rangkaian supervisi suhu seperti pada gambar 3.3.



Gambar 3.3. Rangkaian Supervisi Suhu

Nilai R_1 pada gambar 3.3 ditentukan sebesar $4,3 \text{ k}\Omega$ sedangkan nilai R_F didapat dari persamaan sebagai berikut :

$$\frac{R_F}{R_1} = AV - 1$$

$$\begin{aligned} \frac{R_F}{R_1} &= 3,3 - 1 \\ &= 2,3 \end{aligned}$$

Maka

$$\begin{aligned}
 R_F &= 2,3 R_1 \\
 &= 2,3 \cdot (4,3 \text{ k}\Omega) \\
 R_F &= 9,89 \text{ k}\Omega
 \end{aligned}$$

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

Untuk menguji apakah penguatan sebesar 3,3 kali, setelah didapat nilai R_F sebesar 9,89k Ω dan R_1 sebesar 4,3k Ω maka untuk mencari penguatan apakah sesuai dengan yang diinginkan, adalah sebagai berikut:

$$A_V = \frac{R_F}{R_1} + 1$$

Dimana :

$$A_V = \frac{9,89}{4,3} + 1$$

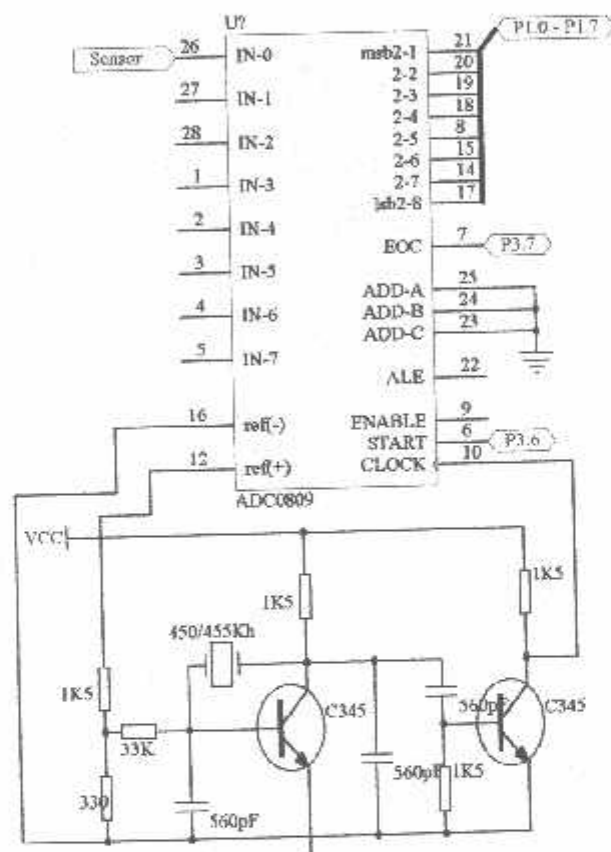
$$A_V = 3,3 \text{ Kali}$$

3.2.3. Perancangan ADC 0809 (Analog To Digital Converter)

Dalam pembuatan alat ini juga dibutuhkan pengubah sinyal analog menjadi sinyal digital / disebut juga *Analog To Digital Converter* (ADC), hal ini disebabkan karena sinyal – sinyal yang didapat dari sensor temperatur berupa sinyal analog sedangkan rangkaian *controller* menggunakan sistem digital sehingga membutuhkan masukan berupa sinyal digital. ADC yang digunakan adalah 0809. ADC 0809 ini dapat menerima hingga 8 *input* tetapi yang digunakan pada alat ini hanya 1 *input* dan sisa *input* yang lain di *ground* kan (di tanahkan).

Karena hanya menggunakan 1 *input* pada IN0 (Pin 26) maka EOC (Pin 7) dan START (Pin 6) yang dihubungkan ke μC sedangkan untuk ADD A(Pin 25), ADD B(pin 24) dan ADD C (pin 23) diberi nilai *low* dengan cara di *ground* kan.

Gambar dari rangkaian ADC 0809 seperti terlihat pada gambar 3.4:



Gambar 3.4 Rangkaian ADC 0809

- *Input* 0 (pin 26) merupakan masukan yang berupa sinyal analog dari sensor temperatur
- Pin 2 - 1 sampai pin 2 - 8 dipergunakan untuk mengirim data digital ke Mikrokontroller AT89C51.

- EOC (*End Of Conversion*) Pin 7 akan *high* jika proses konversi telah selesai.

Ic ADC ini dapat dioperasikan pada *time conversion* maksimum yaitu $100\mu s$ dan membutuhkan frekuensi sebesar 100 MHz . Dengan frekuensi yang dibangun dari rangkaian clock:

$$f = \frac{1}{1.1 \times R1 \times C1}$$

$$f = \frac{1}{1.1 \times 1,5 \cdot 10^3 \times 560 \cdot 10^{-9}}$$

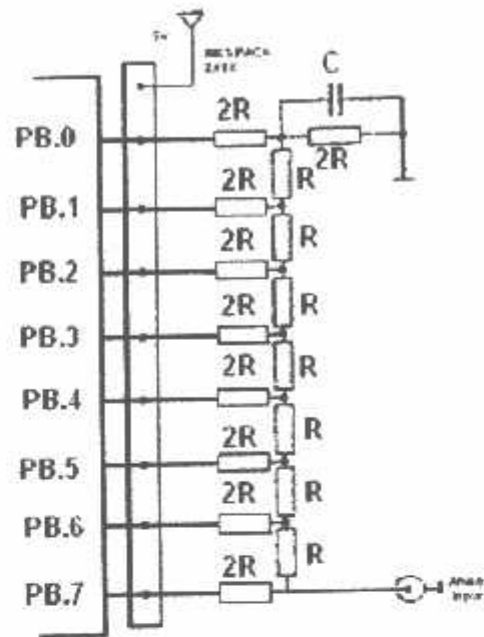
$$f = 1MHz$$

Untuk *resolusi* dari ADC diatur untuk V_{ref} sebesar 5 Volt, maka besar *resolusi* adalah sbb:

$$Resolusi = \frac{V_{ref}}{(2^8 - 1)} = \frac{5}{(256 - 1)} = 19.6mVolt$$

3.2.4. Digital 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 3.5 di bawah ini :



Gambar 3.5 Rangkaian Tangga R-2R DAC

Rangkaian DAC pada gambar 3.5 mendapatkan *input* digital sehingga perbandingan tegangan keluaran yang di hasilkan adalah :

$$V_{out} : \frac{\text{decimal_input}}{\text{decimal_maksimum}} \cdot V_{ref}$$

Rumus diatas berlaku untuk rangkaian tanpa beban, jika pada keluaran diberikan beban, maka beban harus diperhitungkan jika ingin mendapatkan hasil yang sesuai. Untuk mengatasi permasalahan tersebut maka ditambahkan penyangga atau rangkaian op amp.

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

DAC 4bit ; $V_{ref} = 5$ volt

$$\text{Nilai skala penuh} = 2^4 = 16$$

$$\text{Resolusi} = \left(\frac{1}{16}\right) \cdot 5 = 0,315 \text{ volt}$$

Sedangkan pada 8bit :

$$\text{DAC 8bit ; } V_{\text{ref}} = 5 \text{ volt}$$

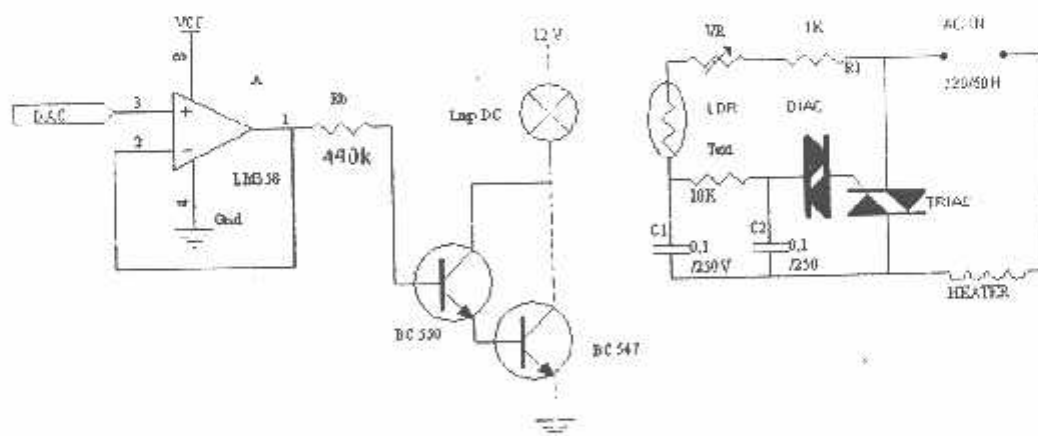
$$\text{Nilai skala penuh} = 2^8 = 256$$

$$\text{Resolusi} = \left(\frac{1}{256}\right) \cdot 5 = 0,0039 \text{ volt}$$

Jika diamati DAC 8bit memiliki *resolusi* lebih kecil dari pada DAC 4bit hal ini berarti jika tegangan referensi dimasukkan sebesar 5 volt akan memiliki kenaikan sebesar 0,0039 volt perbit sedangkan 4bit jauh lebih kasar kenaikan perbitnya.

3.2.5. Driver Pemanas

Berikut ini adalah gambar dari *driver* pemanas lihat pada gambar 3.6:



Gambar 3.6 Driver Pemanas

Output dari DAC mempunyai tegangan maksimal 5 Volt. Dimana tegangan ini merupakan tegangan *input driver* lampu. Tegangan ini dilewatkan terlebih dahulu ke rangkaian *buffer* LM 358 yang diaplikasikan sebagai rangkaian pengikut tegangan (*Voltage Follower*), dimana tegangan *Output* nya :

$$V_{in} = V_{out}$$

Didalam (*Internal*) satu IC LM 358 ini memiliki 2 buah rangkaian op-amp yang mana pada aplikasinya hanya dipakai 1 buah op-amp yang kemudian keluaran dari IC LM 358 ini di *inputkan* ke basis transistor untuk mengaktifkan transistor.

Diketahui dari gambar rangkaian diatas keluaran dari DAC masuk pada basis transistor penguat darlington BC550 dan BC547, dengan penguatan (H_{FE}) $\beta = \beta_1 \cdot \beta_2$. Dimana terlebih dahulu melewati R_b , yang digunakan untuk mengontrol cahaya pada lampu DC. Untuk menghitung analisa rangkaian *driver* lampu adalah sebagai berikut:

Dari data *sheet* transistor BC550 dan BC547 diperoleh:

- H_{FE} : 110 (BC550) : 110 (BC547)
- V_{CC} : 12 Volt
- I_c : 100 mA (BC550 & BC547)
- V_{BE} : 0,7 Volt

untuk arus yang mengalir pada basis (I_b) :

$$\begin{aligned}
 I_b &= \frac{I_c}{H_{fe}} \\
 &= \frac{100mA}{110 * 110} \\
 &= 8,26 \mu A
 \end{aligned}$$

Maka nilai Rb dapat dicari :

$$\begin{aligned}
 R_b &= \frac{V_B - 2V_{BE}}{I_b} \\
 &= \frac{5V - 2.0,7V}{8,26 \mu A} \\
 &= 435,835 K\Omega
 \end{aligned}$$

Pada aplikasinya nilai resistansi diatas tidak terdapat dipasaran oleh karena itu untuk mendapatkan nilai resistansi yang mendekati nilai Rb diatas maka resistor (Rb) dipasang 440K Ω .

Pada rangkaian gambar 3.6 terdapat rangkaian peredup lampu (*Dimmer Lamp*) yang menggunakan Diac Triac Q4006LT. Prinsip kerjanya ketika cahaya lampu dc jatuh pada sensor cahaya (LDR) berada pada harga terendahnya (Cahaya yang jatuh pada LDR besar), kapasitor C1 mengisi penguatan dengan cepat pada permulaan dari masing-masing setengah siklus tegangan AC. Jika tegangan antara C1 mencapai tegangan lebih triac (*over*) dari diac, maka C1 mengosongkan muatan atau membuang muatan pada gerbang triac. Jadi triac hidup (*ON*) lebih awal pada setiap setengah siklus dan mempertahankan kondisi sampai akhir setengah siklus berikutnya. Oleh karena itu, arus akan mengalir pada *heater* untuk sebagian besar dari setengah siklus diac

dan menghasilkan kecerahan (terang) yang penuh pada 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 berkurang.

Untuk menentukan besarnya daya yang diperlukan oleh elemen pemanas, kita harus mengetahui dulu rugi – rugi daya yang terjadi.

Adapun rugi daya tersebut adalah sebagai berikut :

a. Rugi daya untuk memanaskan udara dalam ruang

Kebutuhan daya untuk memanaskan udara dalam ruang untuk mencapai suhu maksimum dapat dicari sebagai berikut :

- ρ udara = $1,228 \text{ kg/m}^3$
- c udara = $1,0057 \text{ kJ/kg } ^\circ\text{C}$
- suhu yang diinginkan (maks) = $50 \text{ } ^\circ\text{C}$

Jika diketahui :

- Diameter (d) : 5 cm
- Luas alas (L) : 70,65 cm
- Tinggi (t) : 13 cm

$$\begin{aligned}
 \text{Maka besar volume ruang} &= L \cdot t \\
 &= 70,65 \cdot 13 \\
 &= 9,1845 \text{ m}^3
 \end{aligned}$$

Jadi energi kalor yang dibutuhkan untuk memanaskan udara di dalam ruang sampai dengan suhu 50 °C dapat dihitung dengan persamaan sebagai berikut :

$$Q = m \cdot c \cdot \Delta t$$

Dimana :

$$m = \rho \cdot v$$

Sehingga persamaannya menjadi :

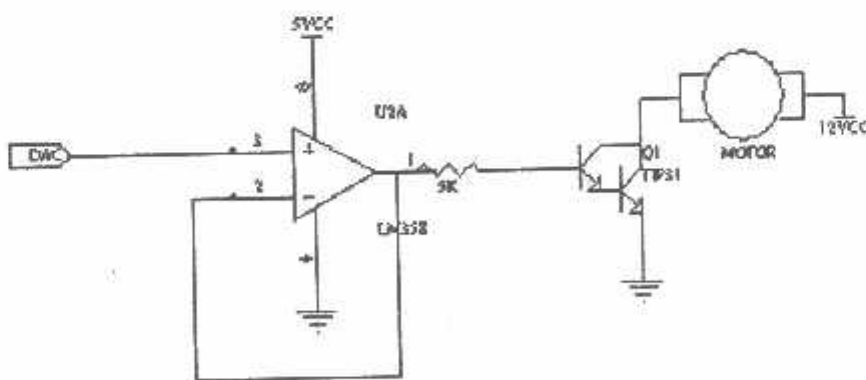
$$\begin{aligned} Q &= \rho \cdot v \cdot c \cdot \Delta t \\ &= 1,22 \cdot 9,18 \cdot 1,0057 \cdot (50 - 24) \\ &= 0,292 \text{ kJ} \end{aligned}$$

Jika untuk mencapai suhu tersebut diperlukan waktu ± 2 menit, maka dibutuhkan daya besar :

$$\begin{aligned} P &= 292 / 120 \\ &= 2,43 \text{ Watt} \end{aligned}$$

3.2.6. Driver Kipas

Rangkaian driver untuk kipas ditunjukkan pada gambar berikut :



Gambar 3.7. Rangkaian Driver Kipas

Kipas akan bekerja jika mendapat perintah dari sistem utama atau mikrokontroller yang mendapat masukan/input dari remote control yang diterima IR Receiver. Sebagai driver untuk motor dc pada kipas, digunakan transistor dengan tipe TIP31, dimana besar tahanan R_B yang diperlukan jika tegangan keluaran dari Mikro (V_H) = 5 Volt adalah:

Dari data sheet transistor:

❖ TIP31 dengan $h_{FE} = 50$

Data fan : $I = 2.26A / 12V$

Maka pada saat jenuh (saturation) besar arus $I_{B\ total}$ adalah:

$$\begin{aligned} I_{B\ total} &= \frac{I_C}{h_{FE}} \\ &= \frac{2.26}{50 \times 50} \\ &= 904\ \mu A \end{aligned}$$

Dengan demikian besar tahanan R_B yang diperlukan jika $V_H = 5\text{ Volt}$, $V_{BE} = 1.8\text{ Volt}$ (hasil pengukuran) adalah:

$$\begin{aligned} R_B &= \frac{V_H - 2.V_{BE}}{I_B} \\ &= \frac{5V - 2.1.8V}{904\ \mu A} \\ &= 1548.672\ \Omega \end{aligned}$$

Pada aplikasinya nilai resistansi diatas tidak terdapat dipasaran oleh karena itu untuk mendapatkan nilai resistansi yang mendekati nilai R_B diatas maka resistor (R_B) dipasang $2\text{ K}\Omega$.

3.2.7. Minimum System AT89C51

Mikrokontroller AT89C51 dirancang untuk dapat berdiri sendiri, karena sudah terdapat EPROM, RAM serta port *I/O internal*, tetapi dalam perancangan ini masih ditambah EEPROM *eksternal*, PPI dan perlengkapan lainnya dengan tujuan menambah kefleksibelan dalam aplikasinya dan keluwesan dalam perancangan *software*nya.

Untuk berhubungan dengan peralatan luar chip dibutuhkan 3 bus yaitu :

1. Data Bus

Yaitu jalur untuk *input – output* data yang lebarnya sesuai dengan lebar data yang diolah oleh mikrokontroller, yaitu 8 *bit*.

2. Address Bus

Yaitu jalur untuk alamat dari *input – output* atau *memory* yang dihubungi, sehingga pada suatu saat hanya ada satu *device* yang berhubungan dengan CPU. Lebar *address bus* Mikrokontroller AT89C51 adalah 16 *bit* (A0-A15).

3. Control Bus

Control bus berfungsi untuk mengatur sinkronisasi antara CPU dengan *device* luar.

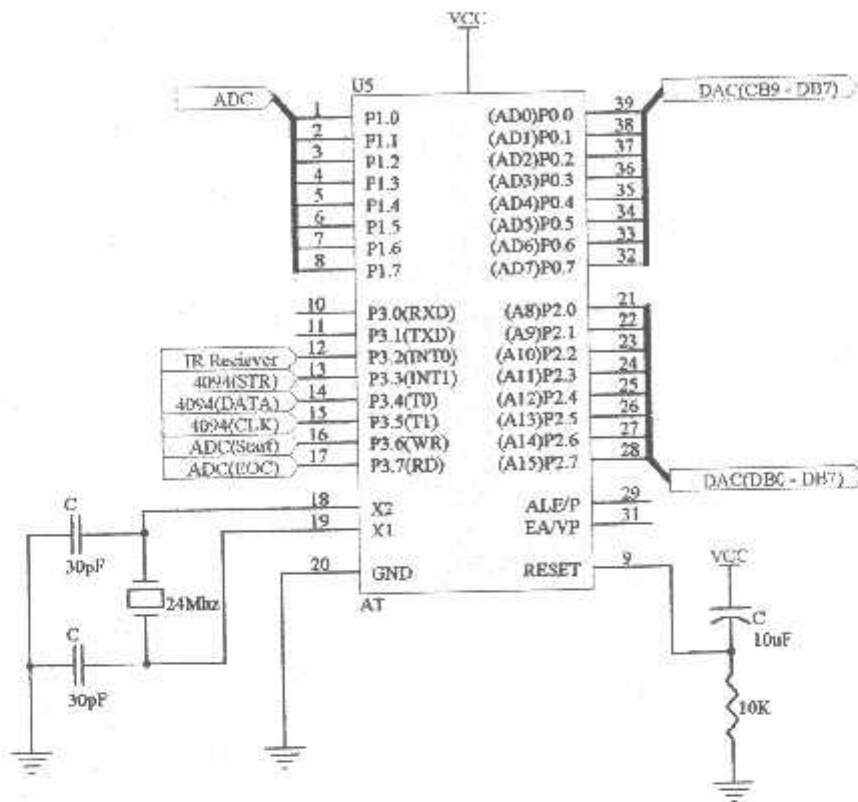
3.2.7.1. Konfigurasi Pin Mikrokontroler AT89C51

Penentuan port – portnya dan sinyal – sinyal yang digunakan untuk mendukung proses yang akan dilakukan adalah sangat penting. Mikrokontroller

AT89C51 adalah suatu chip IC yang terdiri dari 40 pin, dalam perancangan alat ini pin-pin yang digunakan adalah sebagai berikut :

1. Pin 1 - 7 / Port(1.0 – 1.6) digunakan sebagai inputan dari ADC
2. Pin 32 - 39 / Port(0.0 – 0.7) digunakan sebagai inputan DAC untuk driver pemanas.
3. Pin 21 – 28 / Port(2.0 – 2.7) digunakan sebagai inputan DAC untuk driver motor / fan.
4. Pin 9 / Port (RST) digunakan sebagai reset sistem.
5. Pin 12 / port (3.2) dihubungkan pada Infra Red Reciever sebagai masukan / inputan remote control .
6. Pin 13 / Port (3.3) dihubungkan pada pin 1 dari IC 4094 yang berfungsi sebagai Strobe.
7. Pin 14 / Port (3.4) dihubungkan pada pin 2 dari IC 4094 yang berfungsi sebagai Data.
8. Pin 15 / Port (3.5) dihubungkan pada pin 3 dari IC 4094 yang berfungsi sebagai Clock
9. Pin 16 / Port (3.6) digunakan untuk memberi logika pada port WR dari ADC 0809.
10. Pin 17 / Port (3.7) digunakan untuk memberi logika pada port RD dari ADC 0809.

Dari uraian diatas tentang pin atau port agar lebih jelasnya dapat dilihat pada gambar 3.8



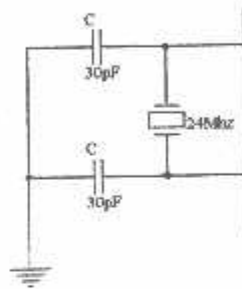
Gambar 3.8. Rangkaian Minimum Sistem AT89C51

3.2.7.2. Rangkaian Clock Minimum Sistem

Kecepatan proses pengolahan data pada mikrokontroller ditentukan oleh Clock (pewaktu) yang dikendalikan oleh Mikrokontroller tersebut. Pada Mikrokontroller AT 89C51 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 18 dan 19 pada AT 89C51.

Dalam Perancangan rangkaian ini menggunakan.

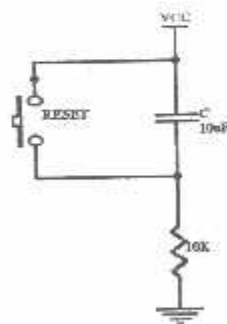
1. $C = 30 \text{ pF}$. Penentuan besarnya kapasitansi disesuaikan dengan spesifikasi pada data sheet AT 89C51.
2. Kristal 24 MHZ (berdasarkan data sheet AT 89C51) adapun gambar rangkaian clock tampak seperti pada gambar 3.9.



Gambar 3.9. Rangkaian Clock minimum sistem

3.2.7.3. Rangkaian Reset

Reset pada Mikrokontroller merupakan masukan aktif High '1' Pulsa transisi dari rendah '0' ke tinggi '1' akan mereset Mikrokontroller menuju alamat 0000H. Pin reset dihubungkan dengan rangkaian power on reset seperti pada gambar 3.10.



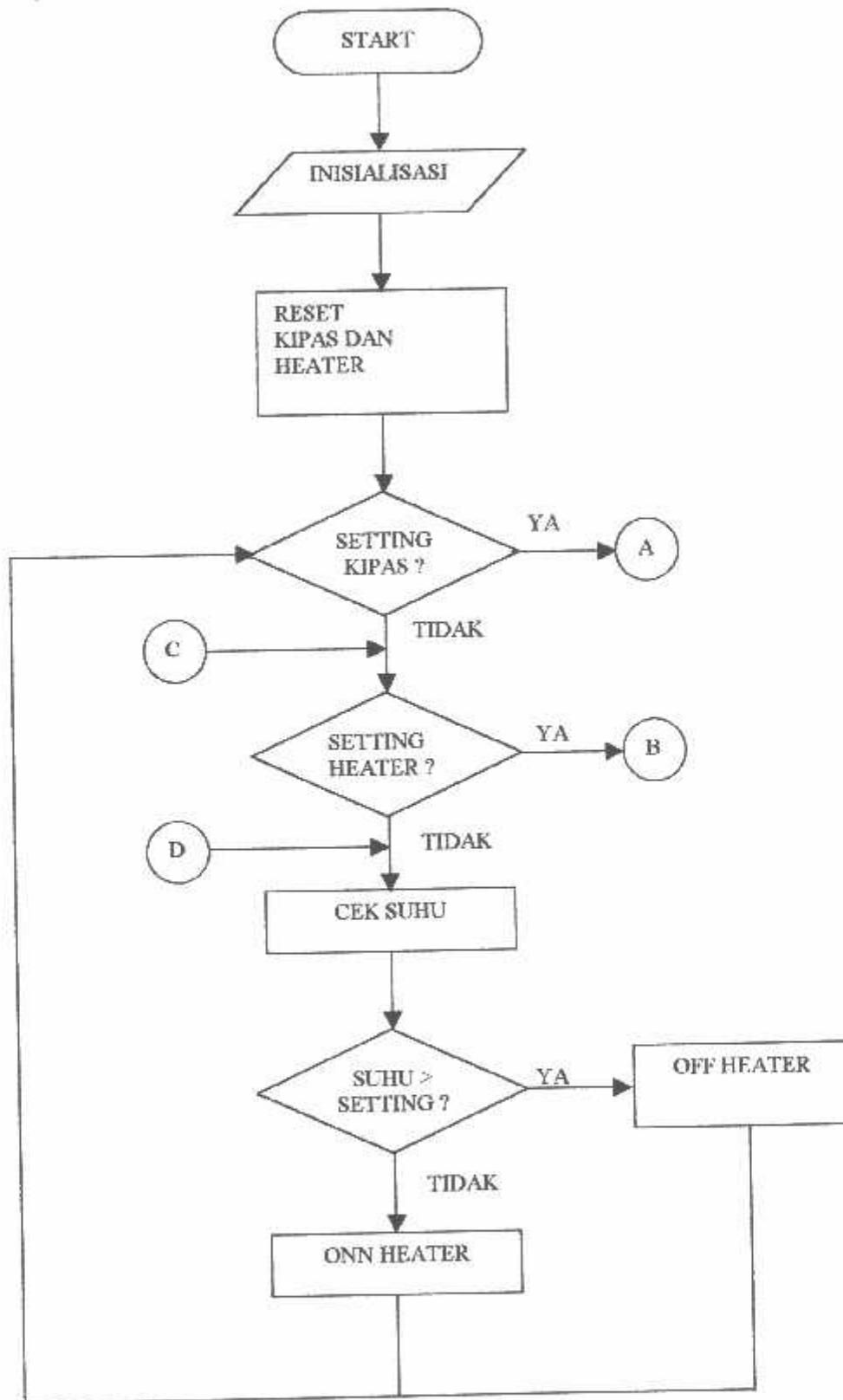
Gambar 3.10. Rangkaian Power On Reset

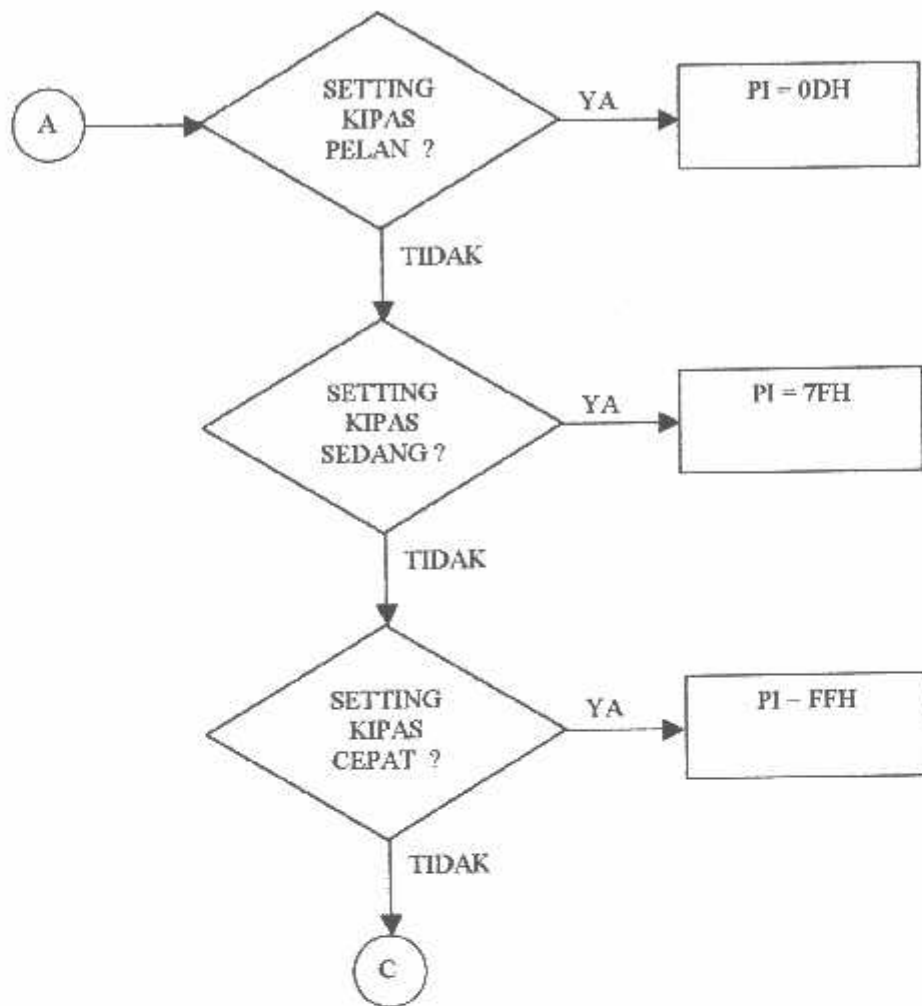
Rangkaian reset bertujuan agar Mikrokontroller dapat menjalankan proses dari awal. Rangkaian reset untuk Mikrokontoller dirancang agar mempunyai kemampuan power on reset, yaitu reset yang terjadi pada saat sistem dinyalakan untuk pertama kalinya. Reset juga dapat dilakukan secara manual dengan menekan tombol reset yang berupa switch push button.

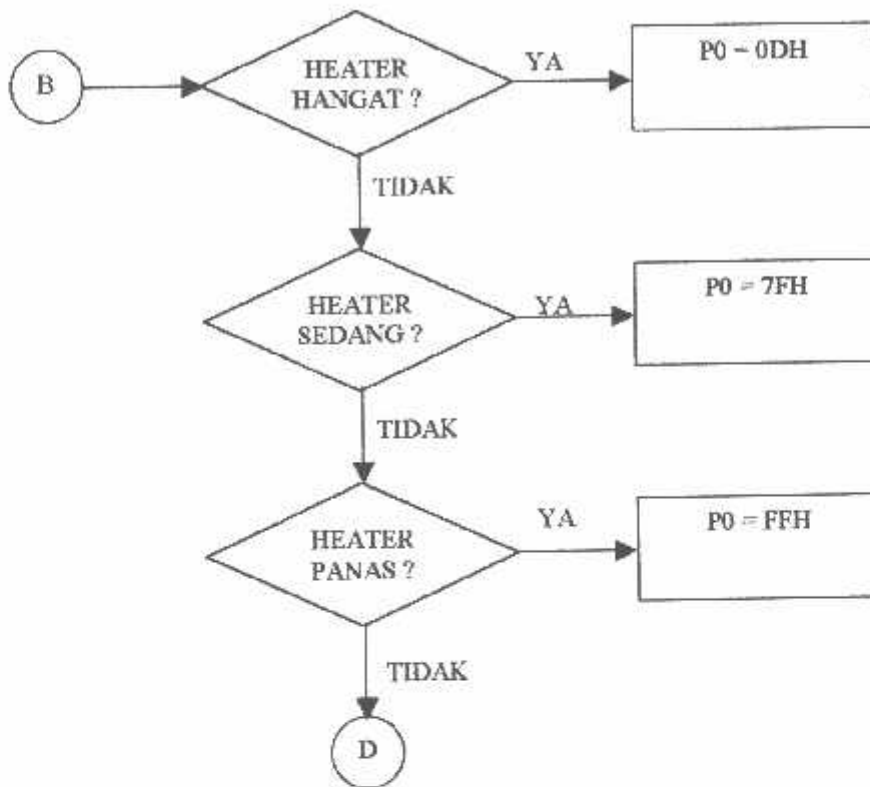
Gambar 3.10 merupakan gambar rangkaian reset yang bekerja secara manual dan otomatis saat sumber daya diaktifkan. Pada saat sumber daya diaktifkan, maka kapasitor C1 akan terhubung singkat pada saat itu sehingga arus mengalir dari Vcc langsung ke kaki reset (RST) sehingga pada kaki tersebut berlogika 1 (High). Kemudian kapasitor terisi hingga tegangan pada kapasitor (Vc) yaitu tegangan antara Vcc dan titik antara C1 dan R2 atau tegangan RST akan turun menjadi 0 sehingga kaki reset berlogika 0 (Low) dan proses reset selesai. Jika saklar S1 ditekan, reset bekerja secara manual, aliran arus akan mengalir dari Vcc melalui R1 menuju ke kaki RST. Tegangan pada kaki RST atau VR2 akan berubah menjadi:

$$\begin{aligned}VR2 &= \frac{R2 \times Vcc}{R1 + R2} \\&= \frac{8k2 \times 5}{100 + 8k2} \\&= 4,94 \text{ Volt}\end{aligned}$$

Tegangan 4,49 volt pada kaki RST menyebabkan kaki ini berlogika 1 (High) pada saat saklar ditekan. Saat saklar dilepas, aliran arus dari Vcc melalui R1 akan terhanti dan tegangan pada kaki RST akan turun menuju ke ground melalui R2 sehingga kaki ini akan berlogika 0 dan proses reset selesai.

FLOWCHART ALAT PENGATUR GELEMBUNG UDARA MANDI SPA**Pada Gambar 3.11 :**





Gambar 3.11. Flowchart Gelembung Udara Mandi Spa

BAB IV

PENGUJIAN ALAT

4.1. Tujuan

Pada bab ini akan dibahas tentang pengujian alat yang telah dirancang dengan tujuan agar antara 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.

Pada pengujian yang dilakukan batas range awal pada suhu 24°C sampai 50°C didapatkan tegangan yang bervariasi mulai dari 0,245 volt sampai 0,402 volt. Dimana besarnya kenaikan tegangan pada IC LM35 tanpa penguatan adalah $\pm 10\text{ mV}/^{\circ}\text{C}$. Sehingga :

$$V_{\text{out}} = \text{Suhu } (^{\circ}\text{C}) \times 10\text{ mV}$$

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

Tabel 4.1

Hasil Pengukuran Dan Perhitungan Tegangan Sensor Suhu

NO	SUHU ($^{\circ}\text{C}$)	HASIL PENGUKURAN (Volt)	HASIL PERHITUNGAN (Volt)
1	24	0,245	0,24
2	26	0,263	0,26
3	28	0,284	0,28
4	30	0,302	0,30
5	31	0,312	0,31
6	32	0,324	0,32
7	33	0,333	0,33
8	34	0,341	0,34
9	35	0,357	0,35
10	36	0,362	0,36
11	37	0,375	0,37
12	38	0,385	0,38
13	39	0,393	0,39
14	40	0,402	0,40
15	42	0,425	0,42
16	44	0,441	0,44
17	46	0,465	0,46
18	48	0,485	0,48
19	50	0,501	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 penguatan (Volt)
1	24	0,245	0,24	0,79
2	26	0,263	0,26	0,87
3	28	0,284	0,28	0,92
4	30	0,302	0,30	0,99
5	31	0,312	0,31	1,02
6	32	0,324	0,32	1,06
7	33	0,333	0,33	1,09
8	34	0,341	0,34	1,12
9	35	0,357	0,35	1,17
10	36	0,362	0,36	1,19
11	37	0,375	0,37	1,23
12	38	0,385	0,38	1,27
13	39	0,393	0,39	1,29
14	40	0,402	0,40	1,32
15	42	0,425	0,42	1,39
16	44	0,441	0,44	1,47
17	46	0,465	0,46	1,56
18	48	0,485	0,48	1,62
19	50	0,501	0,50	1,73

Analisa kesalahan / *error* tegangan keluaran pada sensor suhu LM35 dari Tabel 4.1 diatas, adalah sebagai berikut :

$$\% \text{ kesalahan (k)} = \frac{\text{Selisih Hasil Pengukuran Dan Hasil Perhitungan}}{\text{Hasil Perhitungan}} \times 100\%$$

Dari rumus diatas maka didapatkan kesalahan / *error* antara hasil pengukuran dengan hasil perhitungan tegangan keluaran sensor suhu LM35 seperti pada tabel 4.3 berikut ini :

Tabel 4.3.
Kesalahan / Error Antara Hasil Pengukuran Dengan Hasil Pengujian
Sensor Suhu

NO	Suhu (C°)	Hasil Pengukuran (Volt)	Hasil Perhitungan (Volt)	Kesalahan/Error (%)
1	24	0,245	0,24	0,71
2	26	0,263	0,26	0,69
3	28	0,284	0,28	0,68
4	30	0,302	0,30	0,66
5	31	0,312	0,31	0,64
6	32	0,324	0,32	0,62
7	33	0,333	0,33	0,60
8	34	0,341	0,34	0,58
9	35	0,351	0,35	0,57
10	36	0,362	0,36	0,55
11	37	0,372	0,37	0,54
12	38	0,385	0,38	0,52
13	39	0,393	0,39	0,51
14	40	0,402	0,40	0,50
15	42	0,425	0,42	0,48
16	44	0,441	0,44	0,47
17	46	0,465	0,46	0,45
18	48	0,485	0,48	0,43
19	50	0,501	0,50	0,42

4.2.2. Pengujian ADC (Analog To Digital Conversion)

Dalam pengujian ADC menggunakan led yang disusun pada PCB. Selain itu menggunakan LM 35 beserta penguatanya sebagai *input* yang

didekatkan dengan thermometer untuk mengetahui berada pada suhu berapa untuk mendapatkan output digital. Pengukuran dari ADC di tunjukan pada tabel 4.4

Tabel 4.4.

Hasil Pengukuran ADC Dengan Menggunakan Led Berdasarkan Suhu

NO	Temperatur (C°)	Output Led								Tegangan ouput Supervisi (Volt)
		D7	D6	D5	D4	D3	D2	D1	D0	
1	28	0	0	1	1	0	1	1	1	1,06
2	30	0	0	1	1	1	0	0	0	1,09
3	32	0	0	1	1	1	0	1	0	1,13
4	34	0	0	1	1	1	0	1	1	1,15

Hasil analisa didapatkan :

Pada suhu 30 C° didapat tegangan masukan sebesar 1,09, maka hasil analisa didapat sebagai berikut

$$\begin{aligned}
 V_o &= \frac{V_{in}}{V_{ref}} \times 255 \\
 &= \frac{1,09}{5} \times 255 \\
 &= 55,59 \text{ Dec} = 00110111 \text{ bin}
 \end{aligned}$$

Maka didapat perbedaan nilai antara pengukuran dan perhitungan, dimana nilai pengukuran sebesar 00111000 bin = 56 Dec sedangkan hasil perhitungan sebesar 00110111 bin = 55,59 Dec. Dengan menggunakan rumus untuk mencari *error*, sehingga didapat *error* sebesar 0,73%.

Tabel 4.6

Hasil Pengukuran Rangkaian Heater

Level	Vin (volt)	Vout (volt)	Keterangan Lamp 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 semakin bertambah tahapan maka nyala lampu lamp dc akan semakin terang. Keadaan lamp dc yang terang akan membuat LDR pada dimmer lamp mencapai tahanan terendahnya, sehingga tegangan yang menuju kawat nikelin/ heater menjadi besar.

4.2.5. Pengujian Rangkaian Penggerak Fan

Dalam pengujian rangkaian penggerak ini dilakukan perangkaian alat seperti pada gambar 4.3 dibawah ini :



Gambar 4.3. Blok diagram pengujian rangkaian penggerak fan.

Sumber : Perancangan

- Pada basis transistor rangkaian diberi tegangan, kemudian keluaran kolektor transistor diukur dengan voltmeter.

BAB V

PENUTUP

5.1. Kesimpulan

Setelah melakukan perencanaan dan pembuatan alat pengatur gelembung udara untuk mandi spa dengan menggunakan mikrokontroller AT89C51 maka pada bab ini diberikan kesimpulan :

- a. Pada pengujian sensor suhu, dimana pada pengujian diambil data suhu antara 24°C sampai 50°C diperoleh range tegangan keluaran sebesar 0,245 volt sampai 0,50 volt, dengan kesalahan relatif yang terjadi rata-rata sebesar 0,55%.
- b. Pada pengujian ADC 0809, dimana pada pengujian dilakukan percobaan dengan range suhu antara 28°C – 34°C , dari data yang dihasilkan dengan menggunakan rumus didapatkan kesalahan relatif yang terjadi rata-rata sebesar 0,73%.
- c. Dari hasil pengujian DAC, dimana percobaan dengan nilai/data 00h – FFh diperoleh range nilai/data analog/tegangan keluaran sebesar 0,34 volt – 4,92volt. Dapat disimpulkan bahwa kenaikan nilai digit keluaran dari mikro diikuti pula naiknya nilai/data analog setelah dikonversi oleh DAC sebagai masukan / inputan untuk rangkaian driver.
- d. Pada pengujian driver heater, disimpulkan bahwa naiknya nilai tegangan (1,65 volt, 1,76 volt, 1,85 volt) yang mengalir pada lamp dc, membuat lamp dc menyala dari redup, sedang, terang. Dimana

keadaan lamp dc akan diterima LDR pada dimmer lump yang menyebabkan tegangan mengalir pada kawat nikelin, sehingga menimbulkan kondisi hangat, agak panas dan panas.

- e. Pada pengujian driver kipas/fan, didapatkan bahwa naiknya nilai tegangan (9,43 volt; 10,45 volt; 11,57 volt) yang masuk pada kipas/fan, sehingga kipas berputar dari pelan, sedang, cepat.

5.2. Saran - Saran

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

DAFTAR PUSTAKA

Data Sheet AT89C51, www.Atmel.com.

Richard Blocher, Dipl. Phys, *Dasar Elektronika*, Andi, 2003.

Wasito S, *Vademekum Elektronika*, PT. Gramedia Pustaka Utama, Jakarta, 2001.

Paulus Andi Nalwan, *Panduan Praktis Teknik Antarmuka dan Pemrograman*, PT. Elex Media Komputindo, Jakarta, 2003.

Agfianto Eko Putra, *Belajar Mikrokontroler AT89C51/52/55 (Teori dan Aplikasi)*, Gava Media, Yogyakarta, 2004.

Henri S.V. Simanjuntak, *Dasar-Dasar Mikroprosesor*, Kanisius (Anggota IKAPI), Yogyakarta, 2001.

National Semiconductor, *LM35 Precision Centigrade Temperature Sensors Datasheet*.

National Semiconductor, *ADC0808/ADC0809 8-bit μ P Compatible A/D Converters Datasheet*.

Malvino, *Prinsip-Prinsip Elektronika*, Erlangga, 1994.

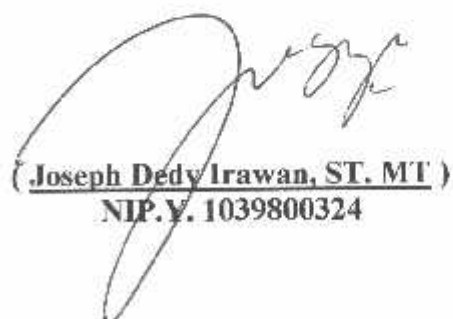


LEMBAR BIMBINGAN SKRIPSI

Nama Mahasiswa : Yudi Agung Prasetyo
Nim : 99.17.249
Jurusan : Teknik Elektro (S-1)
Judul Skripsi : Perencanaan Dan Pembuatan Alat Pengatur
Gelembung Udara Untuk Mandi Spa Berbasis
Mikrokontroller AT89C51.
Tanggal Mengajukan Skripsi : 28 Januari 2005
Selesai Mengerjakan Skripsi : 04 Oktober 2005
Dosen Pembimbing : Joseph Dedy Irawan, ST, MT
Telah Diuji dengan nilai : 87 (A) *g*

Malang, Oktober 2005


Mengetahui
Ketua Jurusan Teknik Elektro S-1
(Ir. F. Yudi Limpraptono, MT)
NIP.Y. 1039500274

Disetujui
Dosen Pembimbing

(Joseph Dedy Irawan, ST, MT)
NIP.Y. 1039800324



PERSETUJUAN PERBAIKAN SKRIPSI

Dari hasil ujian Skripsi Jenjang Strata Satu (S-1) jurusan Teknik Elektronika
pada :

Hari : Selasa

Tanggal : 04 Oktober 2005

Telah dilaksanakan perbaikan skripsi oleh saudara

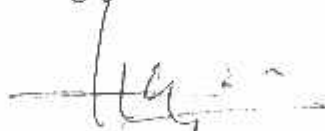
Nama : Yudi Agung Prasetyo

Nim : 99.17.249

Perbaikan tersebut meliputi :

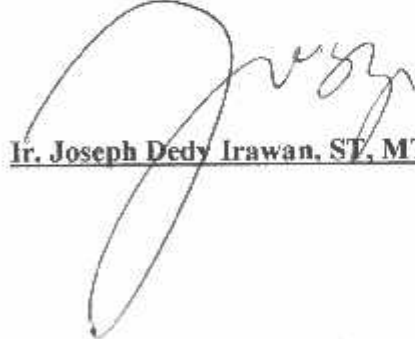
No	Materi Perbaikan	Keterangan
1.	Kesimpulan disempurnakan, bukan diambil dari teori (data sheet).	

Disetujui
Penguji Pertama



Ir. Sidik Noertjahjono, MT

Mengetahui
Dosen Pembimbing



Ir. Joseph Dedy Irawan, ST, MT



PERSETUJUAN PERBAIKAN SKRIPSI

Dari hasil ujian Skripsi Jenjang Strata Satu (S-I) jurusan Teknik Elektronika
pada :

Hari : Selasa

Tanggal : 04 Oktober 2005

Telah dilaksanakan perbaikan skripsi oleh saudara

Nama : Yudi Agung Prasetyo

Nim : 99.17.249

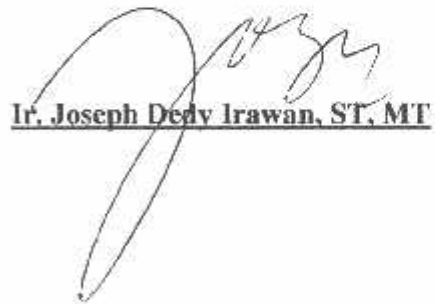
Perbaikan tersebut meliputi :

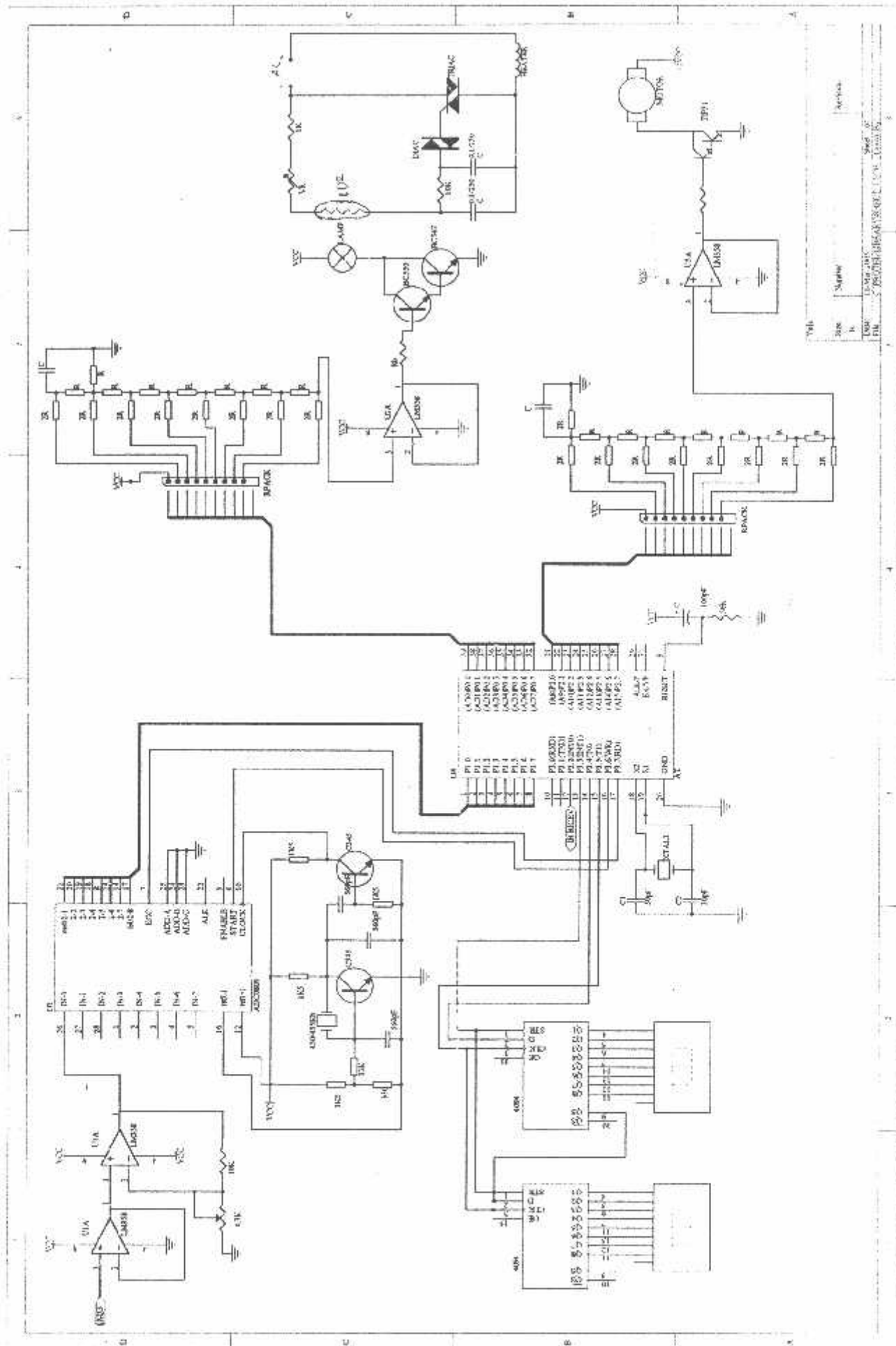
No	Materi Perbaikan	Keterangan
1.	• Perbaikan the design dengan (μ C) elektronik circuit	

Disetujui
Penguji Kedua


Ir. Cahyo Crysdian, MSc

Mengetahui
Dosen Pembimbing


Ir. Joseph Dedy Irawan, ST, MT



LAMPIRAN

```

;software kontrol heater dan blower,dengan menggunakan sensor suhu lm35
;adc yang digunakan 0809,dengan addr.tetap line 0.driver display 4094
;kontroler adalah remote SONY rm827t Trinitron,x-tal 12Mhz
;tombol "power" untuk onn/off"
;tombol "mute " untuk select setting yang diinginkan
;tombol "display" untuk enter setting

```

```

org 00h
ljmp start

```

```

org 03h
ljmp reem

```

```

org 1bh
clr tr1
inc r4
mov r5,#0ffh
reti

```

```

org 0bh
ljmp t_rel

```

```

org 50h
upper_limit equ 30h ;buffer limit atas suhu
lower_limit equ 31h ;buffer limit bawah suhu
adc_buffer equ 32h
finrem1 equ 33h ;buffer data final remote
finrem2 equ 34h
mode_blower equ 35h ;buffer mode untuk blower
mode_heater equ 36h ;buffer mode heater
jump_ind equ 37h
set_buffer equ 38h ;buffer setting
heat_buffer equ 39h ;buffer untuk setting heat
rem bit p3.2
disbuff equ 40h
stak equ 64h
ADC_WR bit P3.6
ADC_INT bit P3.7
adc_ale bit p3.1
adc_read bit p3.0
data_cek equ 7fh ;bit tanda ada penekanan remote

```

```

strobe      bit    p3.3
clock       bit    p3.5
dat         bit    p3.4
heater      equ    p0
blower      equ    p2
start:
    mov     tmod,#11h
    mov     ie,#8ah          ;set off semua heater dan kipas
                                ;dan clear semua display

    mov     blower,#00
    mov     heater,#00
    mov     set_buffer,#00    ;buffer sementara mode
    mov     mode_heater,#00   ;mode off
    mov     mode_blower,#00   ;mode off
    mov     heat_buffer,#00
    clr     adc_wr            ;reset adc 0809
    clr     adc_read

mode_steady:
    mov     jump_ind,#00      ;tanda ret.setelah ada int
    mov     dissbuff,mode_blower
    mov     41h,mode_heater
    call    display
ms0:  setb   ex0
    mov     a,mode_heater     ;cek mode heater
    cjne    a,#00,ms2         ;cek heater off/onn
ms1:  sjmp   ms0
ms2:  call   ambil_adc        ;heater onn,cek suhu
    call    olah_adc
    cjne    a,lower_limit,ms3 ;bandingkan dengan batas bawah
ms3:  jnc    ms4
    mov     heater,heat_buffer ;suhu rendah heater onn kan
    sjmp    ms0               ;cek kembali
ms4:  cjne    a,upper_limit,ms5 ;bandingkan dengan upper limit
ms5:  jc     ms0               ;lebih kecil dari batas atas,looping cek
    mov     heater,#00        ;melebihi batas atas ,heater off
    sjmp    ms0

addr_back:
;routine untuk cek alamat return setelah penekanan remote
    mov     r0,#jump_ind
    cjne    @r0,#00,adb
    mov     a,finrem1
    cjne    a,#14h,adb0        ;cek apakah tombol select ditekan
    ljmp    setting_blower     ;loncat ke cek setting

```

```

sjm4:
    cjne    a,#15h,sb
    ljmp    power_off
dsp_ind:                                ;displaykan indikator selama 2 s
    call    indikator_proses
    call    display
    call    times_2                      ;delay2 s
    ljmp    sb0

;-----;
setting_heater:
    mov     jump_ind,#02                ;indikator jump
hsb0:  call    clear_dissbuff
    mov     dissbuff,mode_heater        ;tampilkan mode heater
hsb1:  call    display
hsb:   call    tomb_release              ;tunggu tombol remote lepas
    jnb     rem,$                       ;tunggu tekan
set_heat:
    mov     a,finrem1
hsjm1: cjne    a,#03ah,hsjm5              ;apakah tombol enter ditekan
    mov     mode_heater,set_buffer
    mov     a,mode_heater               ;cek mode heater
    cjne    a,#01,hsedang
    mov     heat_buffer,#01h            ;set heater hangat
    mov     heater,heat_buffer
    mov     upper_limit,#30             ;setting batas arus
    mov     lower_limit,#20
    sjmp    hdsp_ind
hsedang:
    cjne    a,#02,hbesar
    mov     heat_buffer,#07h            ;set heater sedang
    mov     heater,heat_buffer
    mov     upper_limit,#40             ;setting batas arus
    mov     lower_limit,#30
    sjmp    hdsp_ind
hbesar: cjne    a,#03,houtr
    mov     heat_buffer,#0ffh           ;set heater besar
    mov     heater,heat_buffer
    mov     upper_limit,#50             ;setting batas arus
    mov     lower_limit,#60
    sjmp    hdsp_ind
houtr: sjmp    hsb

hsjm5: cjne    a,#03,hsjm2              ;cek apa data <4
hsjm2: jnc     hsjm3

```

inc	a	
mov	set_buffer,a	;masukkan set ke set buffer
mov	dissbuff,set_buffer	
ljmp	hsb1	
hsjm3:	cjne a,#14h,hsjm4	
	ljmp cek_adc	
;	call tomb_release	
;	ljmp mode_steady	;select ditekan?looping ke mode_steady
hsjm4:		
	cjne a,#15h,hsb	
	ljmp power_off	
hdsp_ind:		;displaykan indikator selama 2 s
	call indikator_proses	
	call display	
	call times_2	;delay2 s
	ljmp hsb0	
cek_adc:		
	mov jump_ind,#04	
	call clear_dissbuff	
	call ambil_adc	
	call olah_adc	
	mov r0,#adc_buffer	
	mov r1,#dissbuff	
	call konversi	
	call display	
ssjm1:	call tomb_release	
slm0:		
	call clear_dissbuff	
	call ambil_adc	
	call olah_adc	
	mov r0,#adc_buffer	
	mov r1,#dissbuff	
	call konversi	
	call display	
	call delay	
	sjmp slm0	
cek_suhu:		
	mov a,finrem1	
	cjne a,#014h,ssm5	;apakah tombol select ditekan
	call tomb_release	
	ljmp mode_steady	;select ditekan?looping ke mode_steady

```
ssm5: cjne    a,#15h,ssjml
      ljmp    power_off
```

```
olah_adc:
      mov     b,#2
      mov     a,adc_buffer
      div     ab
      mov     adc_buffer,a
      ret
```

```
power_off:
;routine untuk offkan semua
      mov     jump_ind,#03
      call    clear_dissbuff
      call    display
      mov     blower,#00
      mov     heater,#00
      mov     set_buffer,#00      ;buffer sementara mode
      mov     mode_heater,#00    ;mode off
      mov     mode_blower,#00    ;mode off
      mov     heat_buffer,#00h
pore:  call    tomb_release
      sjmp    $
power_onn:
      mov     a,finrem1
      cjne    a,#15h,pore
      mov     jump_ind,#00      ;tanda ret.setelah ada int
      mov     dissbuff,mode_blower
      mov     41h,mode_heater
      call    display
      call    tomb_release
      ljmp    ms1              ;onnkan semua
```

```
konversi:
      mov     r2,#3
      mov     a,@r0
konv:  mov     b,#10
      div     ab
      xch     a,@r1
      mov     a,b
      xch     a,@r1
      inc     r1
```

```

djnz r2,konv
mov @r1,a
ret

```

```

ambil_adc:
;routine ambil data adc 0809
    setb    adc_wr                ;start konversi
    nop
    clr     adc_wr
    jb     adc_int,$
    nop
    nop
    nop
    setb    adc_read              ;baca adc
    call    delay
    mov     adc_buffer,p1
    clr     adc_read
    ret

```

```

display:
;routine displaykan data yang diambil dari rtc atau adc
    mov     dptr,#angka
    mov     r0,#dissbuff          ;addr. data yang akan didisply
    mov     r7,#2
    clr     strobe
    clr     clock
dsp1:    mov     a,@r0
        move    a,@a+dptr

    mov     r2,#08                ;counter geser
lagi:    rlc     a
        jc     tes
        clr     dat
        sjmp    clk
tes:     setb    dat
clk:     setb    clock
        clr     clock
        djnz    r2,lagi
        inc     r0
        djnz    r7,dsp1
        setb    strobe
        ret

```

```

tomb_release:                ;tunggu tombol dilepas

```

```

        setb    pt0                ;timer 0, highest priority
        jnb     rem,$              ;ukur pulsa high apakah lebih dari 65 ms
        mov     th0,#00
        mov     tl0,#00
        setb    tr0
        jnb     rem,$
        clr     tr0
        sjmp    tomb_release
trel:   clr     pt0                ;priority reset
        setb    ex0               ;external int.enable
        ret

t_rel:
        clr     tr0
        mov     tl0,#00           ;reset timer 0
        mov     th0,#00
        dec     sp
        dec     sp
        mov     dptr,#trel
        push    dpl               ;timer 0 overflow,indikasi tombol telah
        push    dph               ;dilepas
        reti

;-----
;routine ambil data remote
;-----
reem:
        clr     ex0              ;disable int
        mov     r5,#02           ;counter paket data yang diambil
reem1:
        MOV     A,#00H
        mov     finrem1,a        ;clear dta final
        mov     finrem2,a

reem0:
        jnb     rem,$
        mov     th0,#00
        mov     tl0,#00
        jnb     rem,$
        setb    tr0
        jnb     rem,$
        clr     tr0              ;disable counter
        mov     a,th0
        cjne    a,#02,remr
        clr     c
        sjmp    rem5

```

```

remr:
    cjne    a,#06,remm
remm: jnc    kembali           ;data selesai diterima
      setb   c
rem5: mov    r1,#finrem2       ;data remote digeser sebagai 16 byte
      mov    r4,#2
shb:  mov    a,@r1
      rrc    a
      mov    @r1,a
      dec    r1
      djnz   r4,shb
      sjmp   rem0

kembali:
      djnz   r5,rem1           ;data kedua yang diambil

      mov    r7,#3
sdf:  mov    r1,#finrem2       ;diambil 7 bit awal,geser 3 kali
      mov    r4,#2
shb1: mov    a,@r1
      rrc    a
      mov    @r1,a
      dec    r1
      djnz   r4,shb1
      djnz   r7,sdf
      mov    a,finrem1         ;geser 1 kali,jadi 8 bit
      clr    c
      rrc    a
      mov    finrem1,a

      mov    dptr,#addr_back   ;reti ke addr_back untuk cek alamat kembali
      mov    sp,#07
      push   dpl
      push   dph
      reti

times_2:
      mov    r4,#00h           ;timer 2 s
per0r: mov    r5,#00h
      mov    th1,#04bh
      mov    tl1,#0ffh
      setb   tr1
      cjne   r5,#0ffh,$
      cjne   r4,#40,per0r
      rct

```

indikator_proses:

;isi display dengan tampilan -,sebagai indikator proses

```
    mov    r1,#dissbuff
    mov    @r1,#0bh          ;disi dengan 0bh
    inc    r1
    mov    @r1,#0bh
    ret
```

clear_dissbuff:

```
    mov    r1,#dissbuff
    mov    @r1,#0ah          ;disi dengan 0ah
    inc    r1
    mov    @r1,#0ah
    ret
```

```
delay: mov    R3,#0ffh
delay1: mov    R5,#0ffh
        djnz   R5,$
        djnz   R3,delay1
        ret
```

angka:

```
db 0c0h,0f9h,0a4h,0b0h,099h,092h,082h,0f8h,080h,090h,0ffh,0bfh
end
```

DATA SHEET

LM35 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 $\pm 1/4^{\circ}\text{C}$ at room temperature and $\pm 3/4^{\circ}\text{C}$ over a full -55° to $+150^{\circ}\text{C}$ 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 $+150^{\circ}\text{C}$ temperature range, while the LM35C is rated for a -40° to $+110^{\circ}\text{C}$ range (-10° with improved accuracy). The LM35 series is available packaged in

hermetic TO-48 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 $+ 10.0 \text{ mV}/^{\circ}\text{C}$ scale factor
- 0.5°C accuracy guaranteeable (at $+25^{\circ}\text{C}$)
- Rated for full -55° to $+150^{\circ}\text{C}$ 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 $\pm 1/4^{\circ}\text{C}$ typical
- Low impedance output, 0.1Ω for 1 mA load

Typical Applications

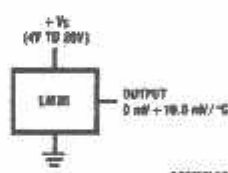
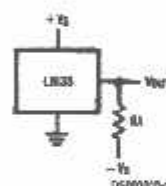


FIGURE 1. Basic Centigrade Temperature Sensor
($+2^{\circ}\text{C}$ to $+150^{\circ}\text{C}$)



Choose $R_1 = -V_- / 50 \mu\text{A}$
 $V_{\text{OUT}} = +1.500 \text{ mV}$ at $+150^{\circ}\text{C}$
 $= +250 \text{ mV}$ at $+25^{\circ}\text{C}$
 $= -550 \text{ mV}$ at -55°C

FIGURE 2. Full-Range Centigrade Temperature Sensor

TRISTATE is a registered trademark of National Semiconductor Corporation.

Connection Diagrams

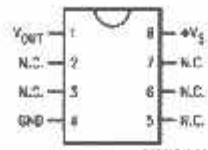
TO-46
Metal Can Package*



BOTTOM VIEW
050966/15-1

*Cape is connected to negative pin (GND).
Order Number LM35H, LM35AH, LM35CH, LM35CAH or LM35DH
See NS Package Number H03H

SO-8
Small Outline Molded Package



00889/15-21

N.C. = No Connection

Top View
Order Number LM35DM
See NS Package Number M08A

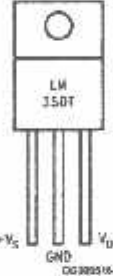
TO-92
Plastic Package



BOTTOM VIEW
050966/15-2

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

TO-220
Plastic Package*



003895/15-24

*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, 8)

Parameter	Conditions	LM35A			LM35CA			Units (Max.)
		Typical	Tested Limit (Note 4)	Design Limit (Note 5)	Typical	Tested Limit (Note 4)	Design Limit (Note 5)	
Accuracy (Note 7)	$T_A = +25^\circ\text{C}$	± 0.2	± 0.5		± 0.2	± 0.5		$^\circ\text{C}$
	$T_A = -10^\circ\text{C}$	± 0.3			± 0.3		± 1.0	$^\circ\text{C}$
	$T_A = T_{MAX}$	± 0.4	± 1.0		± 0.4	± 1.0		$^\circ\text{C}$
	$T_A = T_{MIN}$	± 0.4	± 1.0		± 0.4		± 1.5	$^\circ\text{C}$
Nonlinearity (Note 8)	$T_{MIN} \leq T_A \leq T_{MAX}$	± 0.18		± 0.35	± 0.16		± 0.3	$^\circ\text{C}$
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/ $^\circ\text{C}$
Load Regulation (Note 3) $0 \leq I_L \leq 1 \text{ mA}$	$T_A = +25^\circ\text{C}$	± 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)	$T_A = +25^\circ\text{C}$	± 0.01	± 0.05		± 0.01	± 0.05		mV/V
	$4 \text{ V} \leq V_S \leq 30 \text{ V}$	± 0.02		± 0.1	± 0.02		± 0.1	mV/V
Quiescent Current (Note 9)	$V_B = +5 \text{ V}$, $+25^\circ\text{C}$	56	67		56	67		μA
	$V_S = +5 \text{ V}$	105		131	91		114	μA
	$V_S = +30 \text{ V}$, $+25^\circ\text{C}$	56.2	68		56.2	68		μA
	$V_S = +30 \text{ V}$	105.5		133	91.5		116	μA
Change of Quiescent Current (Note 3)	$4 \text{ V} \leq V_B \leq 30 \text{ V}$, $+25^\circ\text{C}$	0.2	1.0		0.2	1.0		μA
	$4 \text{ V} \leq V_S \leq 30 \text{ V}$	0.5		2.0	0.5		2.0	μA
Temperature Coefficient of Quiescent Current		$+0.39$		$+0.5$	$+0.39$		$+0.5$	$\mu\text{A}/^\circ\text{C}$
Minimum Temperature for Rated Accuracy	In circuit of Figure 1, $I_L = 0$	$+1.5$		$+2.0$	$+1.5$		$+2.0$	$^\circ\text{C}$
Long Term Stability	$T_A = T_{MAX}$, for 1000 hours	± 0.08			± 0.08			$^\circ\text{C}$

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, LM35, LM35C (Note 7)	$T_A = +25^{\circ}\text{C}$	± 0.4	± 1.0		± 0.4	± 1.0		$^{\circ}\text{C}$
	$T_A = -10^{\circ}\text{C}$	± 0.5			± 0.5		± 1.5	$^{\circ}\text{C}$
	$T_A = T_{\text{MAX}}$	± 0.8	± 1.5		± 0.8		± 1.5	$^{\circ}\text{C}$
	$T_A = T_{\text{MIN}}$	± 0.8		± 1.5	± 0.8		± 2.0	$^{\circ}\text{C}$
Accuracy, LM35D (Note 7)	$T_A = +25^{\circ}\text{C}$				± 0.6	± 1.5		$^{\circ}\text{C}$
	$T_A = T_{\text{MAX}}$				± 0.9		± 2.0	$^{\circ}\text{C}$
	$T_A = T_{\text{MIN}}$				± 0.9		± 2.0	$^{\circ}\text{C}$
Nonlinearity (Note 8)	$T_{\text{MIN}} \leq T_A \leq T_{\text{MAX}}$	± 0.3		± 0.5	± 0.2		± 0.5	$^{\circ}\text{C}$
Sensor Gain (Average Slope)	$I_{\text{MIN}} \leq I_A \leq I_{\text{MAX}}$	$+10.0$	$+9.8$, $+10.2$		$+10.0$		$+9.8$, $+10.2$	$\text{mV}/^{\circ}\text{C}$
Load Regulation (Note 3) $0 \leq I_L \leq 1 \text{ mA}$	$T_A = +25^{\circ}\text{C}$	± 0.4	± 2.0		± 0.4	± 2.0		mV/mA
	$T_{\text{MIN}} \leq T_A \leq T_{\text{MAX}}$	± 0.5		± 5.0	± 0.5		± 5.0	mV/mA
Line Regulation (Note 3)	$T_A = +25^{\circ}\text{C}$	± 0.01	± 0.1		± 0.01	± 0.1		mV/V
	$4 \text{ V} \leq V_S \leq 30 \text{ V}$	± 0.02		± 0.2	± 0.02		± 0.2	mV/V
Quiescent Current (Note 9)	$V_S = +5 \text{ V}$, $+25^{\circ}\text{C}$	56	80		56	80		μA
	$V_S = +5 \text{ V}$	105		138	91		138	μA
	$V_S = +30 \text{ V}$, $+25^{\circ}\text{C}$	56.2	82		56.2	82		μA
	$V_S = +30 \text{ V}$	105.5		161	91.5		141	μA
Change of Quiescent Current (Note 3)	$4 \text{ V} \leq V_S \leq 30 \text{ V}$, $+25^{\circ}\text{C}$	0.2	2.0		0.2	2.0		μA
	$4 \text{ V} \leq V_S \leq 30 \text{ V}$	0.5		3.0	0.5		3.0	μA
Temperature Coefficient of Quiescent Current		$+0.39$		$+0.7$	$+0.39$		$+0.7$	$\mu\text{A}/^{\circ}\text{C}$
Minimum Temperature for Rated Accuracy	In circuit of Figure 1, $I_L = 0$	$+1.5$		$+2.0$	$+1.5$		$+2.0$	$^{\circ}\text{C}$
Long Term Stability	$T_A = T_{\text{MAX}}$ for 1000 hours	± 0.08			± 0.08			$^{\circ}\text{C}$

Note 1: Unless otherwise noted, these specifications apply: $-55^{\circ}\text{C} \leq T_J \leq +150^{\circ}\text{C}$ for the LM35 and LM35A; $-40^{\circ}\text{C} \leq T_J \leq +110^{\circ}\text{C}$ for the LM35C and LM35CA; and $0^{\circ}\text{C} \leq T_J \leq +100^{\circ}\text{C}$ for the LM35D. $V_S = +5 \text{ V}$ and $I_{\text{LOAD}} = 50 \mu\text{A}$ in the circuit of Figure 2. These specifications also apply from $+2^{\circ}\text{C}$ 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 $400^{\circ}\text{C}/\text{W}$ junction to ambient, and $24^{\circ}\text{C}/\text{W}$ junction to case. Thermal resistance of the TO-92 package is $180^{\circ}\text{C}/\text{W}$ junction to ambient. Thermal resistance of the small outline molded package is $220^{\circ}\text{C}/\text{W}$ junction to ambient. Thermal resistance of the TO-220 package is $30^{\circ}\text{C}/\text{W}$ 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 $10 \text{ mV}/^{\circ}\text{C}$ times the device's case temperature, at specified conditions of voltage, current, and temperature (expressed in $^{\circ}\text{C}$).

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.

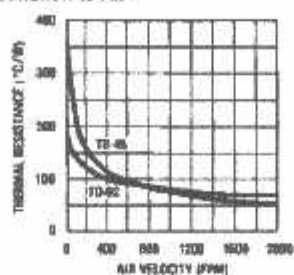
Note 10: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions. See Note 1.

Note 11: Human body model, 100 pF discharged through a $1.5 \text{ k}\Omega$ 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.

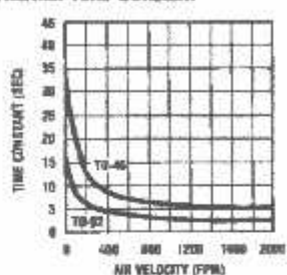
Typical Performance Characteristics

**Thermal Resistance
Junction to Air**



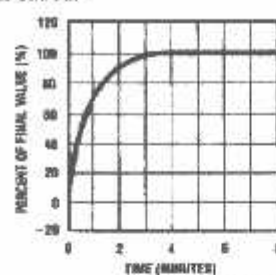
1-800-345-28

Thermal Time Constant



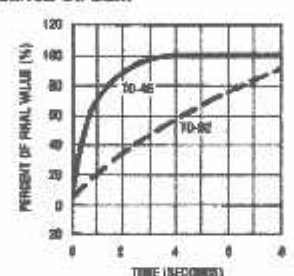
(20090518-79)

Thermal Response in Still Air



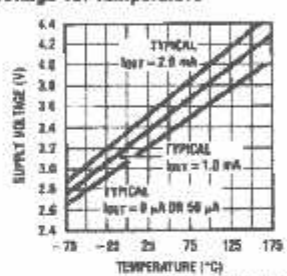
OSAMUS, 21

Thermal Response in Stirred Oil Bath



186205-578-299

Minimum Supply Voltage vs. Temperature



Quintid 16-28

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

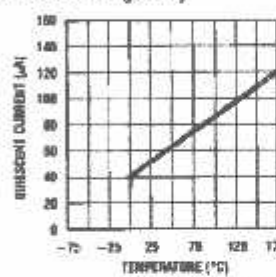
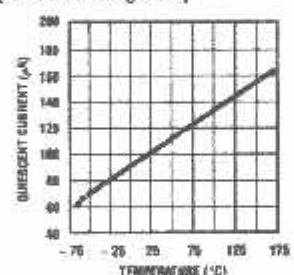


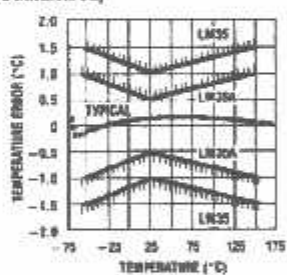
TABLE 6-1

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



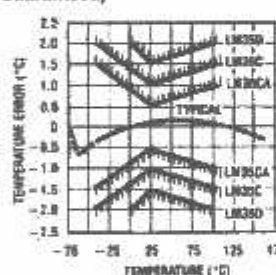
00006214-3*

Accuracy vs. Temperature (Guaranteed)



029 00001 0-312

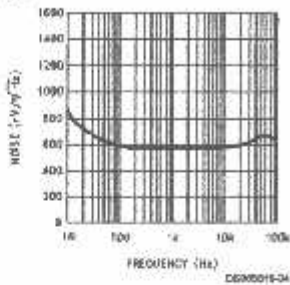
Accuracy vs. Temperature (Guaranteed)



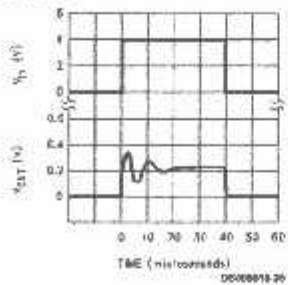
DELPH-3

Typical Performance Characteristics (Continued)

Noise Voltage



Start-Up Response



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 especially 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	540°C/W	220°C/W	110°C/W	26°C/W
Moving air	100°C/W	40°C/W	90°C/W	70°C/W	105°C/W	80°C/W	25°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)							
		20°C/W				55°C/W	

*Waterfield 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

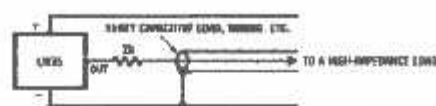


FIGURE 3. LM35 with Decoupling from Capacitive Load

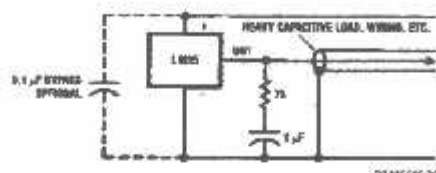


FIGURE 4. LM35 with R-C Dumper

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.

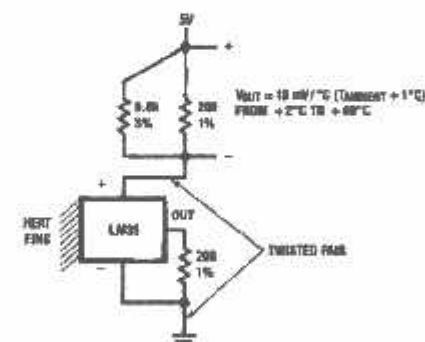


FIGURE 5. Two-Wire Remote Temperature Sensor (Grounded Sensor)

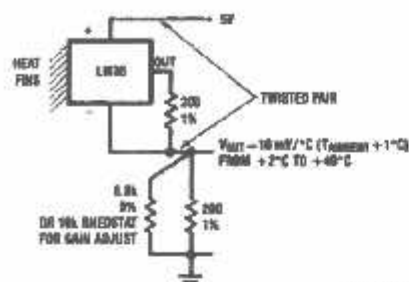


FIGURE 6. Two-Wire Remote Temperature Sensor (Output Referred to Ground)

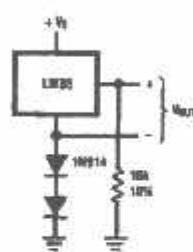


FIGURE 7. Temperature Sensor, Single Supply, -55° to +150°C

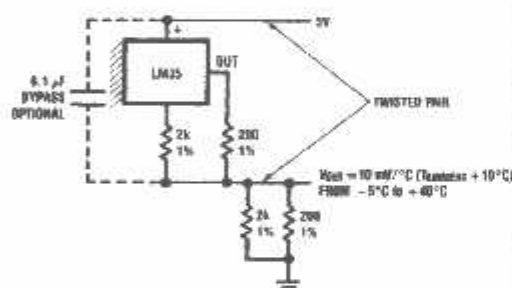


FIGURE 8. Two-Wire Remote Temperature Sensor (Output Referred to Ground)

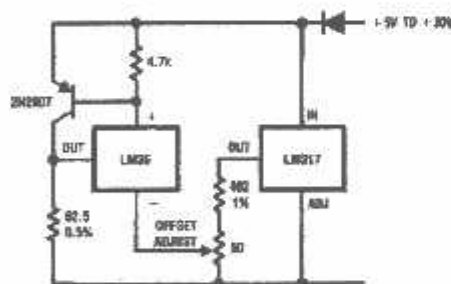


FIGURE 9. 4-To-20 mA Current Source (0°C to +100°C)

Typical Applications (Continued)

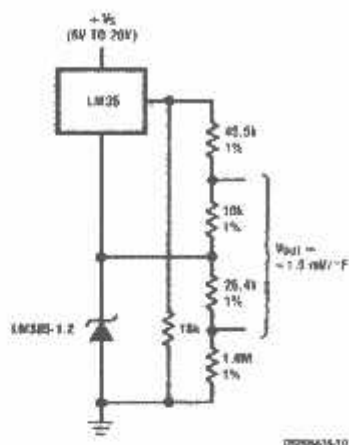


FIGURE 10. Fahrenheit Thermometer

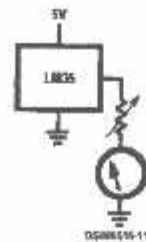


FIGURE 11. Centigrade Thermometer (Analog Meter)

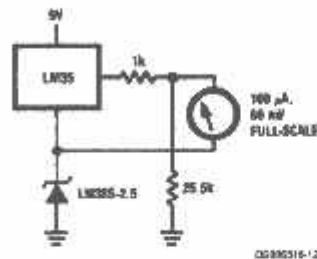


FIGURE 12. Fahrenheit Thermometer Expanded Scale Thermometer (50° to 80° Fahrenheit, for Example Shown)

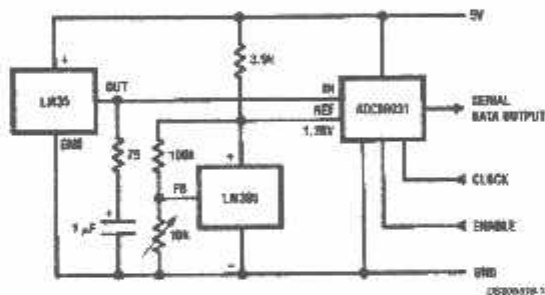


FIGURE 13. Temperature To Digital Converter (Serial Output) (+128°C Full Scale)

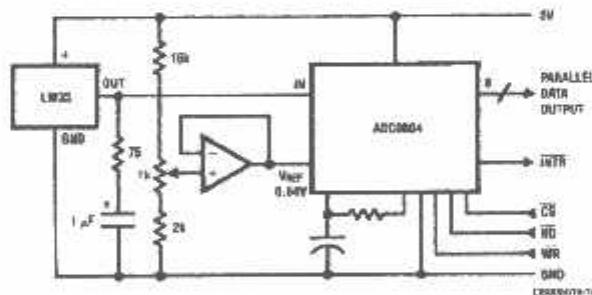
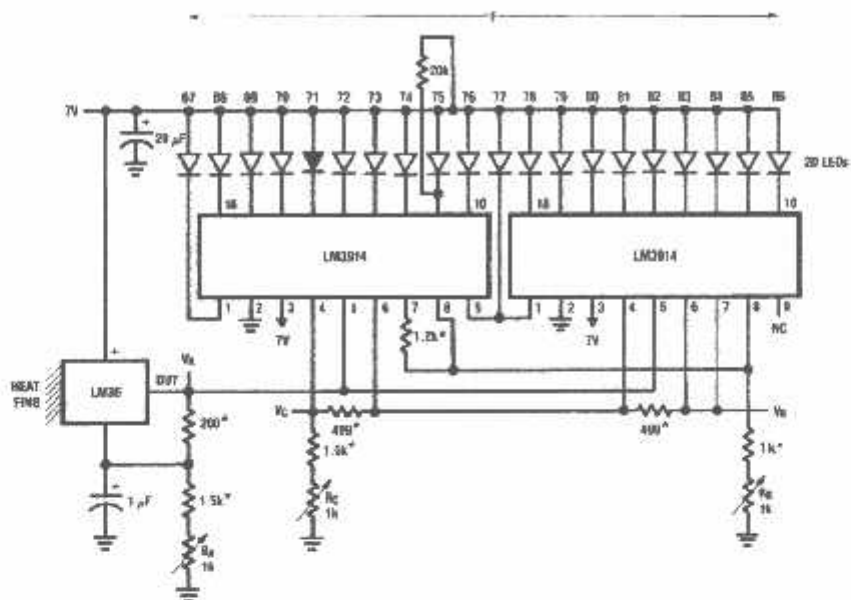


FIGURE 14. Temperature To Digital Converter (Parallel TRI-STATE™ Outputs for Standard Data Bus to μP Interface) (128°C Full Scale)

Typical Applications (Continued)



~1% to 2% trim resistor
 Trim R_B for $V_B = 3.075V$
 Trim R_C for $V_C = 1.055V$
 Trim R_A for $V_A = 0.075V + 100mV/^\circ C \times T_{ambient}$
 Example: $V_A = 2.275V$ at $22^\circ C$

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

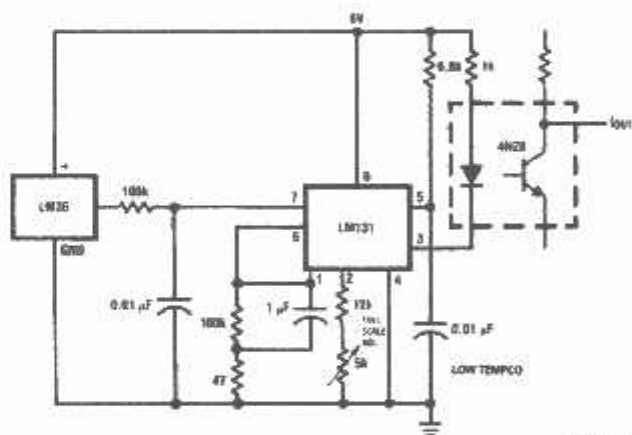
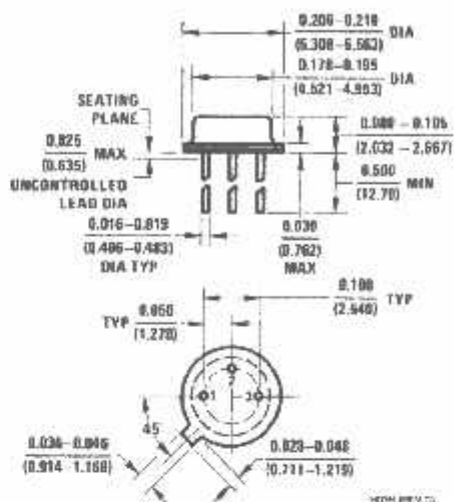


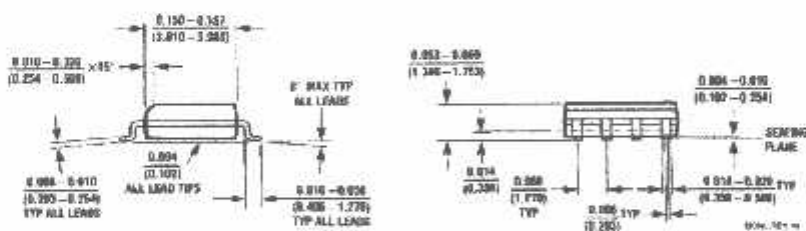
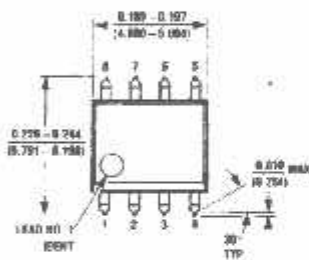
FIGURE 16. LM35 With Voltage-To-Frequency Converter And Isolated Output
(2°C to +150°C; 20 Hz to 1500 Hz)

Block Diagram

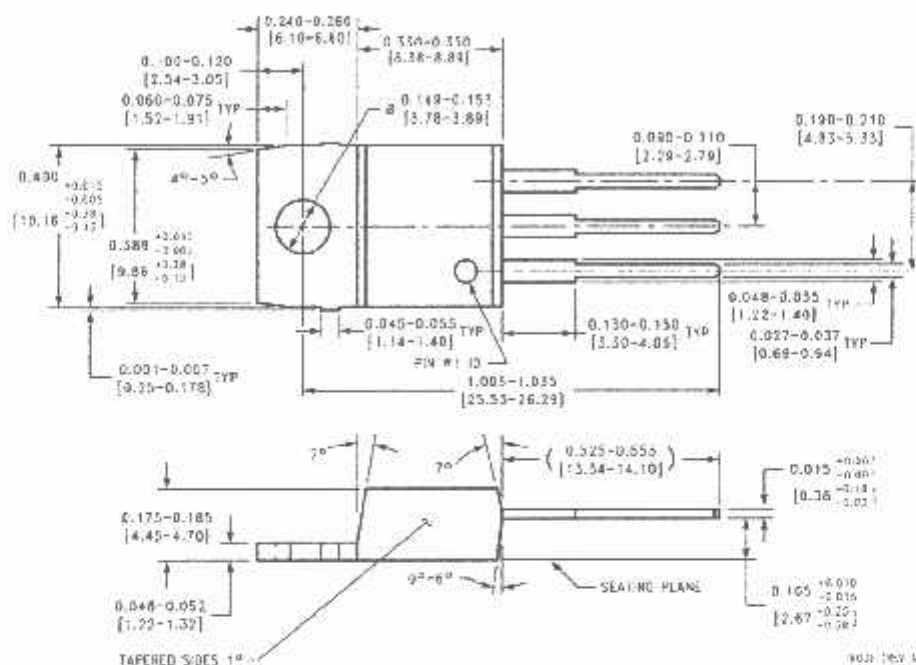


Physical Dimensions inches (millimeters) unless otherwise noted

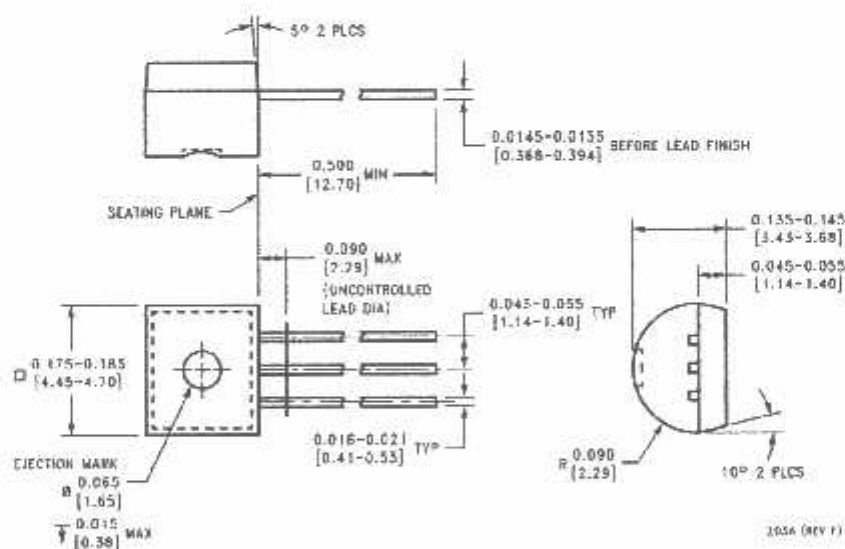
TO-46 Metal Can Package (H)
Order Number LM35H, LM35AH, LM35CH,
LM35CAH, or LM35DH
NS Package Number H03H



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-62 Plastic Package (Z)
Order Number LM35CZ, LM35CAZ or LM35DZ
NS Package Number Z03A

Notes

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
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.

 **National Semiconductor Corporation**
Americas
Tel: 1-800-272-6659
Fax: 1-800-737-7015
Email: support@nsc.com
www.national.com

National Semiconductor Europe
Fax: +49 (0) 1 89-530 85 85
Email: europe.support@nsc.com
Deutsch: Tel: +49 (0) 1 89-530 85 85
English: Tel: +49 (0) 1 89-532 78 32
Français: Tel: +49 (0) 1 89-532 88 88
Italiano: Tel: +49 (0) 1 89-534 76 80

National Semiconductor Asia Pacific Customer Response Group
Tel: 65-2564466
Fax: 65-2504466
Email: ase.support@nsc.com

National Semiconductor Japan Ltd.
Tel: 81-3-5538-7560
Fax: 81-3-5538-7507

National does not assume any responsibility for use of any circuitry described, no circuit patent licenses are implied and National reserves the right at any time without notice to change said circuitry and specifications.

LM158/LM258/LM358/LM2904

Low Power Dual Operational Amplifiers

General Description

The LM158 series consists of two independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltages. 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 amplifiers, dc gain blocks and all the conventional op amp circuits which now can be more easily implemented in single power supply systems. For example, the LM158 series can be directly operated off of the standard +5V power supply voltage which is used in digital systems and will easily provide the required interface electronics without requiring the additional $\pm 15V$ power supplies.

The LM358 is also available in a chip sized package (8-Bump micro SMD) using National's micro SMD package technology.

Unique Characteristics

- In the linear mode the input common-mode voltage range includes ground and the output voltage can also swing to ground, even though operated from only a single power supply voltage.
- The unity gain cross frequency is temperature compensated.
- The input bias current is also temperature compensated.

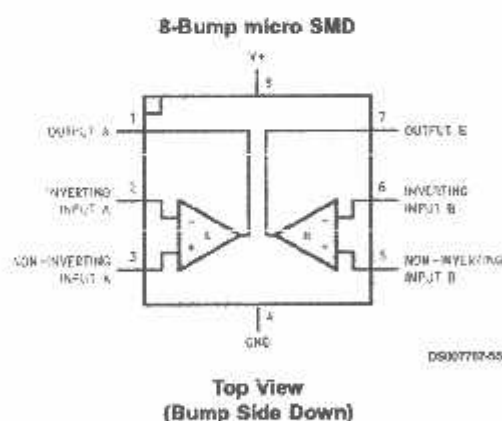
Advantages

- Two internally compensated op amps
- Eliminates need for dual supplies
- Allows direct sensing near GND and V_{OUT} also goes to GND
- Compatible with all forms of logic
- Power drain suitable for battery operation
- Pin-out same as LM1558/LM1458 dual op amp

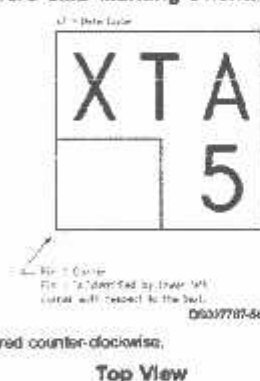
Features

- Available in 8-Bump micro SMD chip sized package, (See AN-1112)
- Internally frequency compensated for unity gain
- Large dc voltage gain: 100 dB
- Wide bandwidth (unity gain): 1 MHz (temperature compensated)
- Wide power supply range:
 - Single supply: 3V to 32V
 - or dual supplies: $\pm 1.5V$ to $\pm 16V$
- Very low supply current drain (500 μA)— essentially independent of supply voltage
- Low input offset voltage: 2 mV
- Input common-mode voltage range includes ground
- Differential input voltage range equal to the power supply voltage
- Large output voltage swing: 0V to $V^+ - 1.5V$

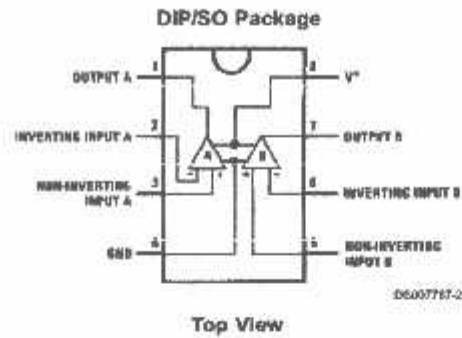
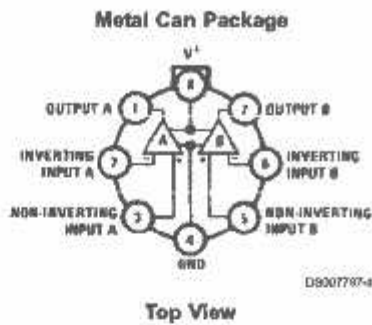
Connection Diagrams



micro SMD Marking Orientation



Connection Diagrams (Continued)



Ordering Information

Package	Temperature Range				NSC Drawing
	-55°C to 125°C	-25°C to 85°C	0°C to 70°C	-40°C to 85°C	
SO-8			LM358AM LM358M	LM2904M	M08A
8-Pin Molded DIP			LM358AN LM358N	LM2904N	N08E
8-Pin Ceramic DIP	LM158AJ/883(Note 1) LM158J/883(Note 1) LM158J LM158AJLQML(Note 2) LM158AJQMLV(Note 2)				J08A
TO-5, 8-Pin Metal Can	LM158AH/883(Note 1) LM158H/883(Note 1) LM158AJI LM158H LM158AHLQML(Note 2) LM158AHLQMLV(Note 2)	LM258H	LM358H		H08C
8-Bump micro SMD			LM358BP LM358BPX		BPA08AAA

Note 1: LM158 is available per SMD #5962-8771001
LM158A is available per SMD #5962-8771002
Note 2: See STD MIL DWG 5962L87710 for Radiation Tolerant Devices

Absolute Maximum Ratings (Note 11)

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

	LM158/LM258/LM358 LM158A/LM258A/LM358A	LM2904
Supply Voltage, V^+	32V	26V
Differential Input Voltage	32V	26V
Input Voltage	-0.3V to +32V	-0.3V to +26V
Power Dissipation (Note 3)		
DIP	830 mW	830 mW
Metal Can	550 mW	
Small Outline Package (M)	530 mW	530 mW
Micro SMD	435mW	
Output Short-Circuit to GND One Amplifier (Note 4)		
$V^+ \leq 15V$ and $T_A = 25^\circ C$	Continuous	Continuous
Output Current ($V_{IN} < -0.3V$) (Note 5)	50 mA	50 mA
Operating Temperature Range		
LM358	0°C to +70°C	-40°C to +85°C
LM258	-25°C to +85°C	
LM158	-55°C to +125°C	
Storage Temperature Range	-65°C to +150°C	-65°C to +150°C
Lead Temperature, DIP		
Soldering, 10 seconds	260°C	260°C
Lead Temperature, Metal Can		
Soldering, 10 seconds	300°C	300°C
Soldering Information		
Dual-In-Line Package		
Soldering (10 seconds)	260°C	260°C
Small Outline Package		
Vapor Phase (60 seconds)	215°C	215°C
Infrared (15 seconds)	220°C	220°C
See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.		
Input Tolerance (Note 12)	250V	250V

Electrical Characteristics

+5.0V, unless otherwise stated

Parameter	Conditions	LM158A			LM358A			LM158/LM258			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Offset Voltage	(Note 7), $T_A = 25^\circ C$		1	2		2	3		2	5	mV
Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$, $T_A = 25^\circ C$, $V_{CM} = 0V$, (Note 8)		20	50		45	100		45	150	nA
Offset Current	$I_{IN(+)} - I_{IN(-)}$, $V_{CM} = 0V$, $T_A = 25^\circ C$		2	10		5	30		3	30	nA
Common-Mode Voltage Range	$V^+ = 30V$, (Note 9) (LM2904, $V^+ = 26V$), $T_A = 25^\circ C$	0		$V^+ - 1.5$	0		$V^+ - 1.5$	0		$V^+ - 1.5$	V
Input Current	Over Full Temperature Range $R_L = \infty$ on All Op Amps $V^+ = 30V$ (LM2904 $V^+ = 26V$) $V^- = 5V$		1 0.5	2 1.2		1 0.5	2 1.2		1 0.5	2 1.2	mA mA

Electrical Characteristics

V* = +5.0V, unless otherwise stated

Parameter	Conditions	LM358			LM2904			Units
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	(Note 7), $T_A = 25^\circ\text{C}$		2	7		2	7	mV
Input Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$, $T_A = 25^\circ\text{C}$, $V_{CM} = 0\text{V}$, (Note 8)		45	250		45	250	nA
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$, $V_{CM} = 0\text{V}$, $T_A = 25^\circ\text{C}$		5	50		5	50	nA
Input Common-Mode Voltage Range	$V^* = 30\text{V}$, (Note 9) (LM2904, $V^* = 26\text{V}$), $T_A = 25^\circ\text{C}$	0		$V^* - 1.5$	0		$V^* - 1.5$	V
Supply Current	Over Full Temperature Range $R_L = \infty$ on All Op Amps $V^* = 30\text{V}$ (LM2904 $V^* = 26\text{V}$) $V^* = 5\text{V}$							
			1 0.5	2 1.2		1 0.5	2 1.2	mA mA

Electrical Characteristics

V* = +5.0V, (Note 6), unless otherwise stated

Parameter	Conditions	LM158A			LM358A			LM158/LM258			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Large Signal Voltage Gain	$V^* = 15\text{V}$, $T_A = 25^\circ\text{C}$, $R_L \geq 2\text{ k}\Omega$, (For $V_O = 1\text{V}$ to 11V)	50	100		25	100		50	100		V/mV
Common-Mode Rejection Ratio	$T_A = 25^\circ\text{C}$, $V_{CM} = 0\text{V}$ to $V^* - 1.5\text{V}$	70	85		65	85		70	85		dB
Power Supply Rejection Ratio	$V^* = 5\text{V}$ to 30V (LM2904, $V^* = 5\text{V}$ to 26V), $T_A = 25^\circ\text{C}$	65	100		65	100		65	100		dB
Amplifier-to-Amplifier Coupling	$f = 1\text{ kHz}$ to 20 kHz , $T_A = 25^\circ\text{C}$ (Input Referred), (Note 10)	-120			-120			-120			dB
Output Current	Source $V_{IN+} = 1\text{V}$, $V_{IN-} = 0\text{V}$, $V^* = 15\text{V}$, $V_O = 2\text{V}$, $T_A = 25^\circ\text{C}$	20	40		20	40		20	40		mA
	Sink $V_{IN-} = 1\text{V}$, $V_{IN+} = 0\text{V}$ $V^* = 15\text{V}$, $T_A = 25^\circ\text{C}$, $V_O = 2\text{V}$	10	20		10	20		10	20		mA
	$V_{IN-} = 1\text{V}$, $V_{IN+} = 0\text{V}$ $T_A = 25^\circ\text{C}$, $V_O = 200\text{ mV}$, $V^* = 15\text{V}$	12	50		12	50		12	50		μA
Short Circuit to Ground	$T_A = 25^\circ\text{C}$, (Note 4), $V^* = 15\text{V}$	40	60		40	60		40	60		mA
Input Offset Voltage	(Note 7)		4			5			7		mV
Input Offset Voltage Drift	$R_S = 0\Omega$		7	15		7	20		7		$\mu\text{V}/^\circ\text{C}$
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$			30			75			100	nA
Input Offset Current Drift	$R_S = 0\Omega$		10	200		10	300		10		$\text{pA}/^\circ\text{C}$
Input Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$		40	100		40	200		40	300	nA
Input Common-Mode Voltage Range	$V^* = 30\text{V}$, (Note 9) (LM2904, $V^* = 26\text{V}$)	0		$V^* - 2$	0		$V^* - 2$	0		$V^* - 2$	V

Electrical Characteristics (Continued)

±5.0V, (Note 6), unless otherwise stated

Parameter	Conditions	LM158A			LM358A			LM158/LM258			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Signal Voltage	$V^+ = +15V$ ($V_O = 1V$ to $11V$) $R_L \geq 2\text{ k}\Omega$	25			15			25			V/mV
Output Voltage	V_{OH}	$V^+ = +30V$ (LM2904, $V^+ = 26V$)			$R_L = 2\text{ k}\Omega$			26			V
					$R_L = 10\text{ k}\Omega$			27 28			V
	V_{IL}	$V^+ = 5V, R_L = 10\text{ k}\Omega$			5 20			5 20			mV
Output Current	Source	$V_{IN}^+ = +1V, V_{IN}^- = 0V$, $V^+ = 15V, V_O = 2V$			10 20			10 20			mA
	Sink	$V_{IN}^- = +1V, V_{IN}^+ = 0V$, $V^+ = 15V, V_O = 2V$			10 15			5 8			mA

Electrical Characteristics

±5.0V, (Note 6), unless otherwise stated

Parameter	Conditions	LM358			LM2904			Units
		Min	Typ	Max	Min	Typ	Max	
Signal Voltage	$V^+ = 15V, T_A = 25^\circ\text{C}$, $R_L \geq 2\text{ k}\Omega$, (For $V_O = 1V$ to $11V$)	25	100		25	100		V/mV
Common-Mode Rejection Ratio	$T_A = 25^\circ\text{C}$, $V_{CM} = 0V$ to $V^+ - 1.5V$	65	85		50	70		dB
Power Supply Rejection Ratio	$V^+ = 5V$ to $30V$ (LM2904, $V^+ = 5V$ to $26V$), $T_A = 25^\circ\text{C}$	65	100		50	100		dB
Common-Mode Input Impedance	$f = 1\text{ kHz}$ to 20 kHz , $T_A = 25^\circ\text{C}$ (Input Referred), (Note 10)		-120			-120		dB
Output Current	Source	$V_{IN}^+ = 1V$, $V_{IN}^- = 0V$, $V^+ = 15V$, $V_O = 2V, T_A = 25^\circ\text{C}$			20 40			mA
	Sink	$V_{IN}^- = 1V, V_{IN}^+ = 0V$, $V^+ = 15V, T_A = 25^\circ\text{C}$, $V_O = 2V$			10 20			mA
		$V_{IN}^- = 1V$, $V_{IN}^+ = 0V$, $T_A = 25^\circ\text{C}, V_O = 200\text{ mV}$, $V^+ = 15V$			12 50			μA
Circuit to Ground	$T_A = 25^\circ\text{C}$, (Note 4), $V^+ = 15V$		40 60			40 60		mA
Offset Voltage	(Note 7)			9			10	mV
Offset Voltage	$R_S = 0\Omega$		7			7		$\mu\text{V}/^\circ\text{C}$
Offset Current	$I_{IN(+)} - I_{IN(-)}$			150		45 200		nA
Offset Current	$R_S = 0\Omega$		10			10		$\text{pA}/^\circ\text{C}$
Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$		40 500			40 500		nA
Common-Mode Input Voltage Range	$V^+ = 30V$, (Note 9) (LM2904, $V^+ = 26V$)	0		$V^+ - 2$	0		$V^+ - 2$	V

Electrical Characteristics (Continued)

$V^+ = +5.0V$, (Note 6), unless otherwise stated

Parameter	Conditions	LM358			LM2904			Units
		Min	Typ	Max	Min	Typ	Max	
Large Signal Voltage Gain	$V^+ = +15V$ ($V_O = 1V$ to $11V$) $R_L \geq 2 k\Omega$	15			15			V/mV
Output Voltage Swing	V_{OH} $V^+ = +30V$ (LM2904, $V^+ = 26V$)	26			22			V
	$R_L = 2 k\Omega$	27	28		23	24		V
	$R_L = 10 k\Omega$							
	V_{OL} $V^+ = 5V, R_L = 10 k\Omega$		5	20		5	100	mV
Output Current	Source $V_{IN}^+ = +1V, V_{IN}^- = 0V$ $V^+ = 15V, V_O = 2V$	10	20		10	20		mA
	Sink $V_{IN}^- = +1V, V_{IN}^+ = 0V$ $V^+ = 15V, V_O = 2V$	5	8		5	8		mA

Note 3: For operating at high temperatures, the LM358/LM358A, LM2904 must be derated based on a $+125^\circ C$ maximum junction temperature and a thermal resistance of $120^\circ C/W$ for MDIP, $182^\circ C/W$ for Metal Can, $189^\circ C/W$ for Small Outline package, and $230^\circ C/W$ for micro SMD, which applies for the device soldered in a printed circuit board, operating in a still air ambient. The LM258/LM258A and LM158/LM158A can be derated based on a $+150^\circ C$ maximum junction temperature. The deration is the total of both amplifiers—use external resistors, where possible, to allow the amplifier to separate or to reduce the power which is dissipated in the integrated circuit.

Note 4: Short circuits from the output to V^+ can cause excessive heating and eventual destruction. When considering short circuits to ground, the maximum output current is approximately 40 mA independent of the magnitude of V^+ . At values of supply voltage in excess of $+15V$, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

Note 5: This input current will only exist when the voltage at any of the input leads is driven negative. It is due to the collector-base junction of the input PNP transistors becoming forward biased and thereby acting as input diode clamps. In addition to this diode action, there is also lateral NPN parasitic transistor action on the IC chip. This transistor action can cause the output voltages of the op amps to go to the V^+ voltage level (or to ground for a large overdrive) for the time duration that an input is driven negative. This is not destructive and normal output states will re-establish when the input voltage, which was negative, again returns to a value greater than $-0.3V$ (at $25^\circ C$).

Note 6: These specifications are limited to $-55^\circ C \leq T_A \leq +125^\circ C$ for the LM158/LM158A. With the LM258/LM258A, all temperature specifications are limited to $-25^\circ C \leq T_A \leq +85^\circ C$, the LM358/LM358A temperature specifications are limited to $0^\circ C \leq T_A \leq +70^\circ C$, and the LM2904 specifications are limited to $-40^\circ C \leq T_A \leq +85^\circ C$.

Note 7: $V_{O1} = 1.4V, R_S = 0\Omega$ with V^+ from $5V$ to $30V$; and over the full input common-mode range ($0V$ to $V^+ - 1.5V$) at $25^\circ C$. For LM2904, V^+ from $5V$ to $26V$.

Note 8: The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the input lines.

Note 9: The input common-mode voltage of either input signal voltage should not be allowed to go negative by more than $0.3V$ (at $25^\circ C$). The upper end of the common-mode voltage range is $V^+ - 1.5V$ (at $25^\circ C$), but either or both inputs can go to $+32V$ without damage ($+26V$ for LM2904), independent of the magnitude of V^+ .

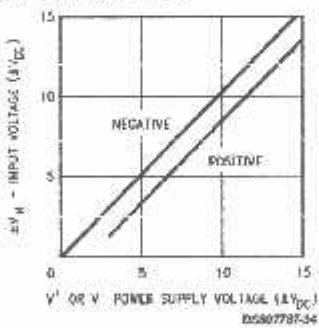
Note 10: Due to proximity of external components, insure that coupling is not originating via stray capacitance between these external parts. This typically can be detected as this type of capacitance increases at higher frequencies.

Note 11: Refer to RET3158AX for LM158A military specifications and to RET3158X for LM158 military specifications.

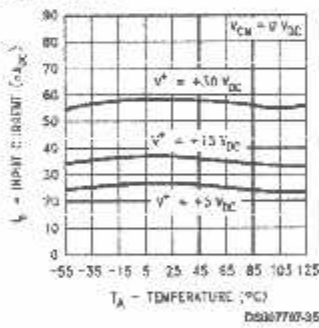
Note 12: Human body model, $1.5 k\Omega$ in series with $100 pF$.

Typical Performance Characteristics

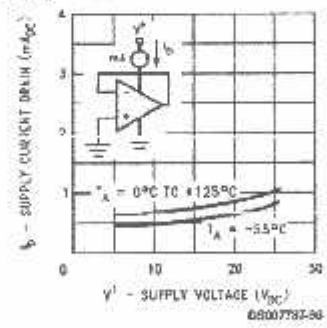
Input Voltage Range



Input Current

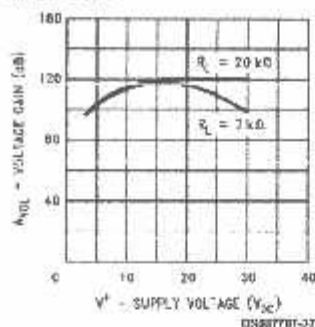


Supply Current

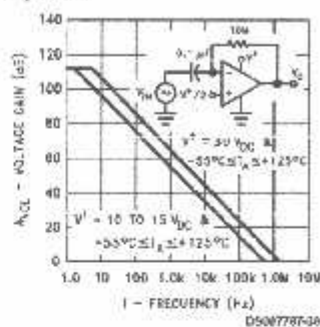


Typical Performance Characteristics (Continued)

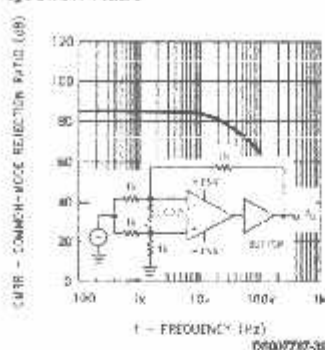
Voltage Gain



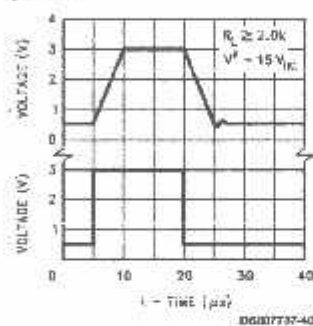
Open Loop Frequency Response



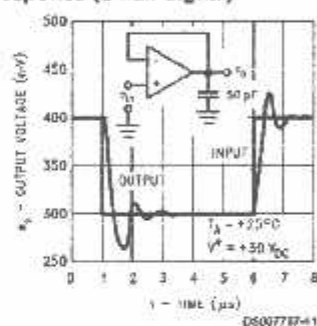
Common-Mode Rejection Ratio



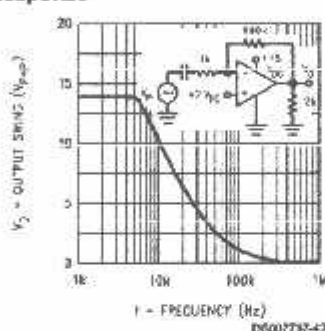
Voltage Follower Pulse Response



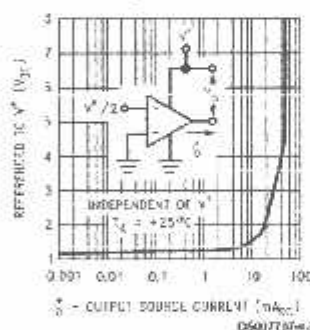
Voltage Follower Pulse Response (Small Signal)



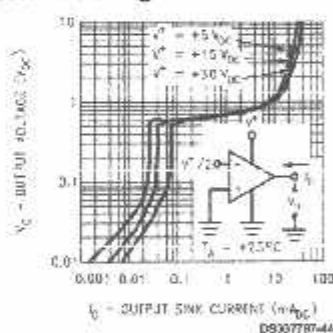
Large Signal Frequency Response



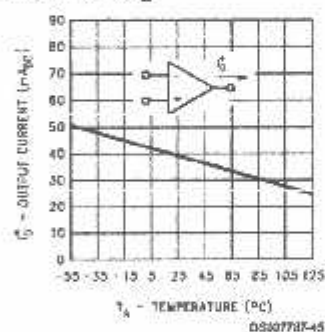
Output Characteristics Current Sourcing



Output Characteristics Current Sinking

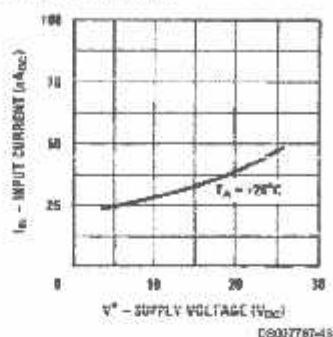


Current Limiting

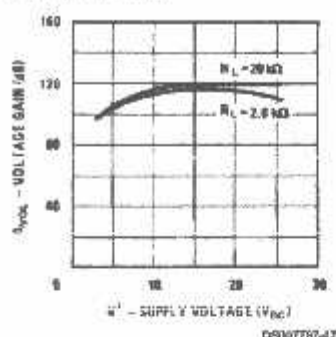


Typical Performance Characteristics (Continued)

Input Current (LM2902 only)



Voltage Gain (LM2902 only)



Application Hints

The LM158 series are op amps which operate with only a single power supply voltage, have true-differential inputs, and remain in the linear mode with an input common-mode voltage of $0 V_{DC}$. These amplifiers operate over a wide range of power supply voltage with little change in performance characteristics. At $25^{\circ}C$ amplifier operation is possible down to a minimum supply voltage of $2.3 V_{DC}$.

Precautions should be taken to insure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a test socket as an unlimited current surge through the resulting forward diode within the IC could cause fusing of the internal conductors and result in a destroyed unit.

Large differential input voltages can be easily accommodated and, as input differential voltage protection diodes are not needed, no large input currents result from large differential input voltages. The differential input voltage may be larger than V^{+} without damaging the device. Protection should be provided to prevent the input voltages from going negative more than $-0.3 V_{DC}$ (at $25^{\circ}C$). An input clamp diode with a resistor to the IC input terminal can be used.

To reduce the power supply current drain, the amplifiers have a class A output stage for small signal levels which converts to class B in a large signal mode. This allows the amplifiers to both source and sink large output currents. Therefore both NPN and PNP external current boost transistors can be used to extend the power capability of the basic amplifiers. The output voltage needs to raise approximately 1 diode drop above ground to bias the on-chip vertical PNP transistor for output current sinking applications.

For ac applications, where the load is capacitively coupled to the output of the amplifier, a resistor should be used, from the output of the amplifier to ground to increase the class A bias current and prevent crossover distortion. Where the load is directly coupled, as in dc applications, there is no crossover distortion.

Capacitive loads which are applied directly to the output of the amplifier reduce the loop stability margin. Values of 50 pF can be accommodated using the worst-case non-inverting unity gain connection. Large closed loop gains or resistive isolation should be used if larger load capacitance must be driven by the amplifier.

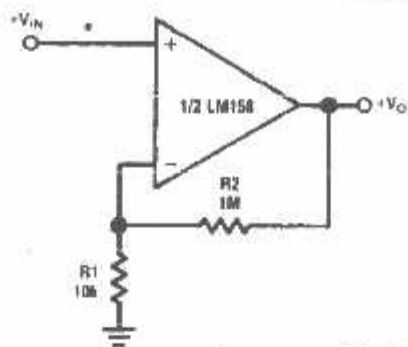
The bias network of the LM158 establishes a drain current which is independent of the magnitude of the power supply voltage over the range of $3 V_{DC}$ to $30 V_{DC}$.

Output short circuits either to ground or to the positive power supply should be of short time duration. Units can be destroyed, not as a result of the short circuit current causing metal fusing, but rather due to the large increase in IC chip dissipation which will cause eventual failure due to excessive junction temperatures. Putting direct short-circuits on more than one amplifier at a time will increase the total IC power dissipation to destructive levels, if not properly protected with external dissipation limiting resistors in series with the output leads of the amplifiers. The larger value of output source current which is available at $25^{\circ}C$ provides a larger output current capability at elevated temperatures (see typical performance characteristics) than a standard IC op amp.

The circuits presented in the section on typical applications emphasize operation on only a single power supply voltage. If complementary power supplies are available, all of the standard op amp circuits can be used. In general, introducing a pseudo-ground (a bias voltage reference of $V^{+}/2$) will allow operation above and below this value in single power supply systems. Many application circuits are shown which take advantage of the wide input common-mode voltage range which includes ground. In most cases, input biasing is not required and input voltages which range to ground can easily be accommodated.

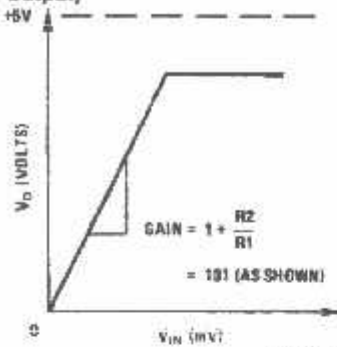
ypical Single-Supply Applications ($V^+ = 5.0 V_{DC}$)

Non-Inverting DC Gain (0V Output)



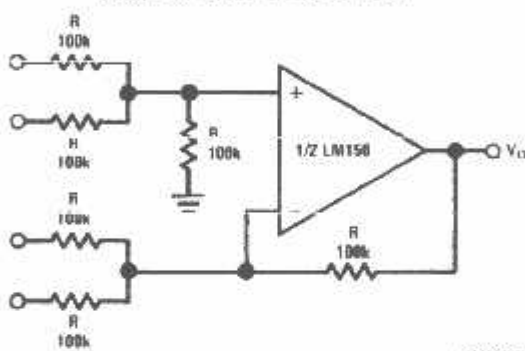
DS007787-6

not needed due to temperature independent I_{B1}



DS007787-7

DC Summing Amplifier
($V_{IN's} \geq 0 V_{DC}$ and $V_O \geq 0 V_{DC}$)

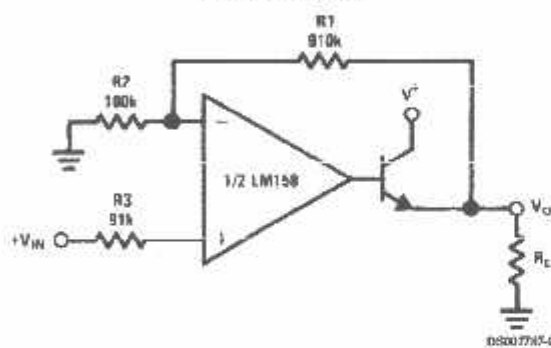


DS007787-8

$$V_O = V_1 + V_2 + V_3 + V_4$$

$$-V_2 \geq (V_3 + V_4) \text{ to keep } V_O \geq 0 V_{DC}$$

Power Amplifier



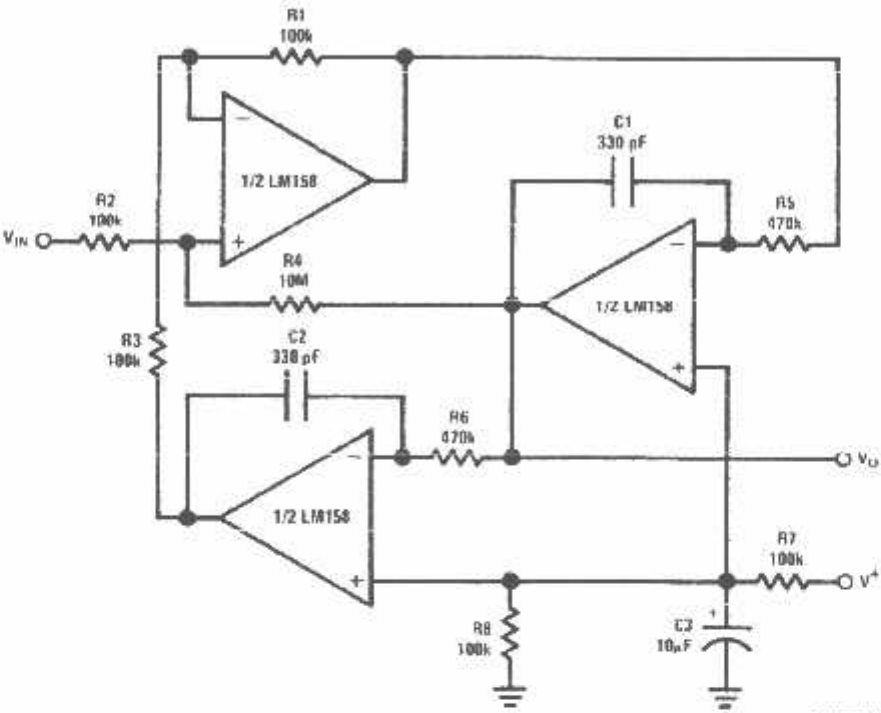
DS007787-9

$$V_O = 0 V_{DC} \text{ for } V_{IN} = 0 V_{DC}$$

$$A_V = 10$$

Typical Single-Supply Applications ($V^+ = 5.0\text{ V}_{OC}$) (Continued)

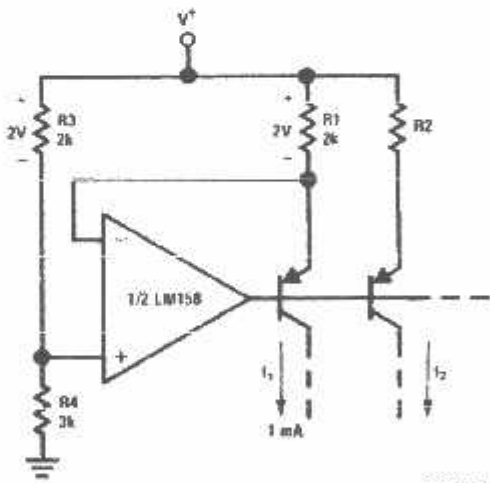
"BI-QUAD" RC Active Bandpass Filter



D9907797-10

$f_n = 1\text{ kHz}$
 $Q = 50$
 $A_v = 100\text{ (40 dB)}$

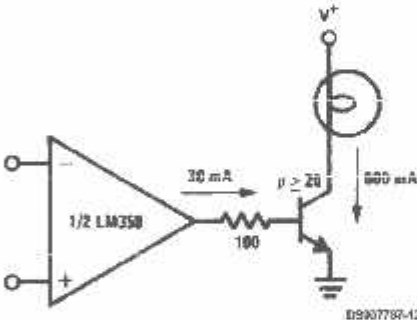
Fixed Current Sources



D9907797-11

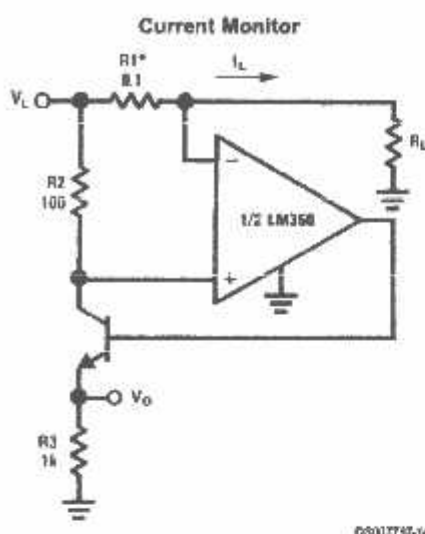
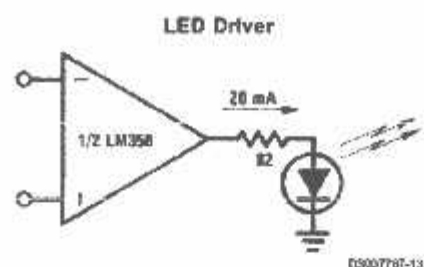
$$I_2 = \left(\frac{R1}{R2} \right) I_1$$

Lamp Driver



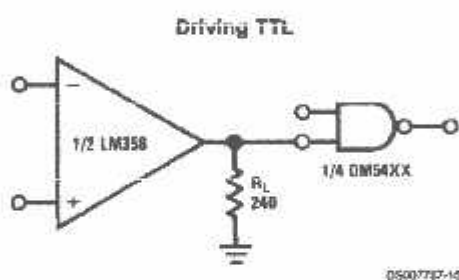
D9907797-12

Typical Single-Supply Applications ($V^+ = 5.0\text{ V}_{\text{DC}}$) (Continued)

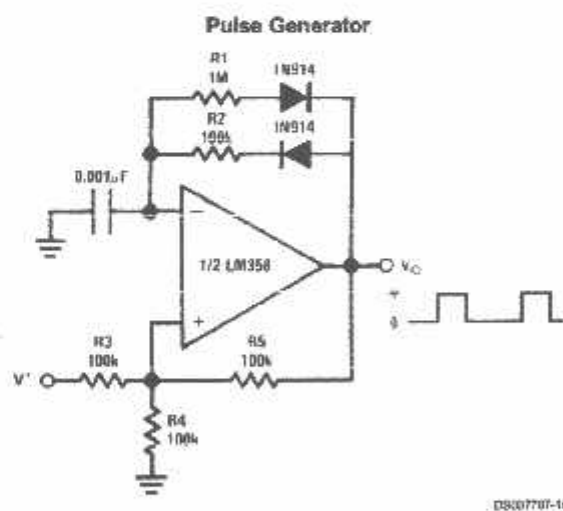
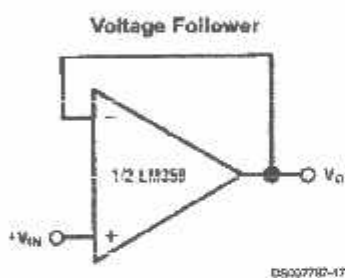


$$V_O = \frac{1V(I_L)}{1A}$$

(Increase R1 for I_L small)
 $V_L < V^+ - 2V$

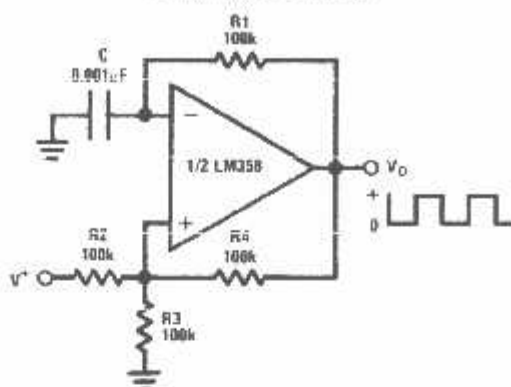


$$V_O = V_{IN}$$



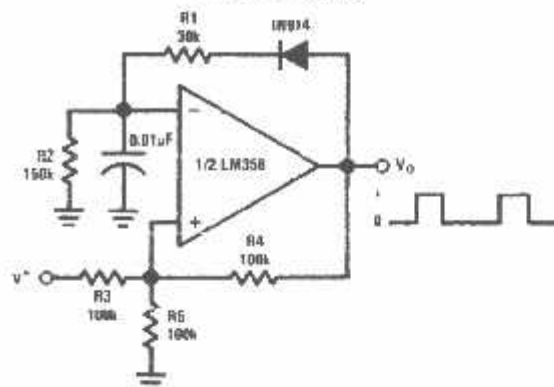
Typical Single-Supply Applications ($V^- = 5.0 V_{DC}$) (Continued)

Squarewave Oscillator



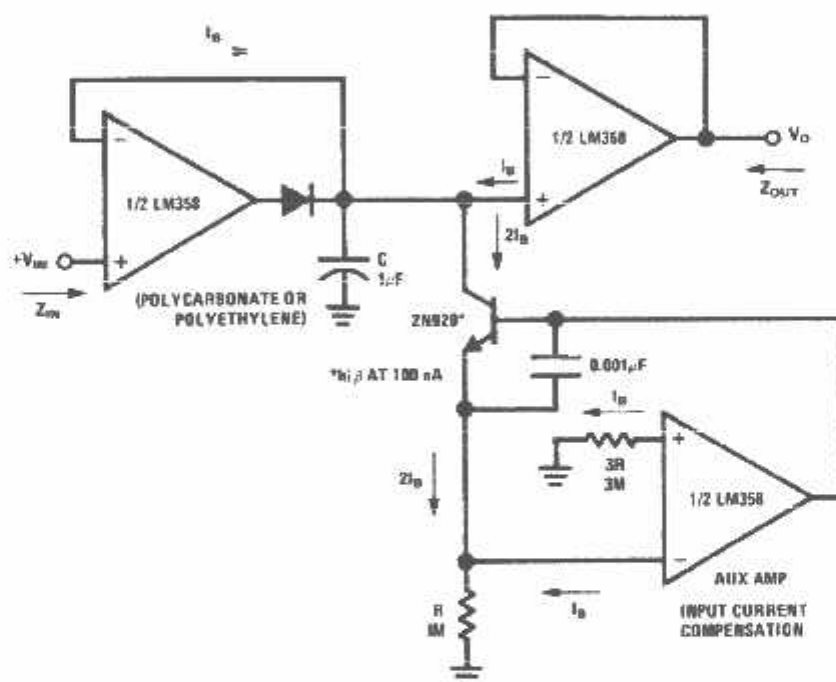
DS027757-16

Pulse Generator



DS027757-18

Low Drift Peak Detector

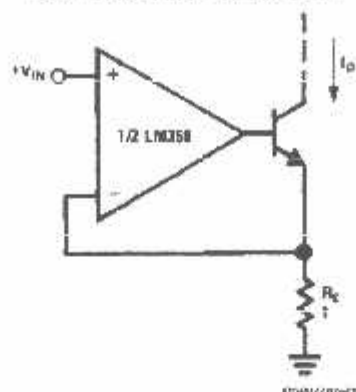


DS027757-20

HIGH Z_{IN}
LOW Z_{OUT}

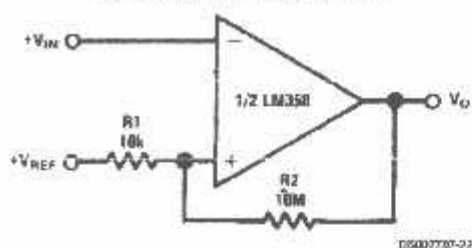
Typical Single-Supply Applications ($V^* = 5.0\text{ V}_{\text{DC}}$) (Continued)

High Compliance Current Sink



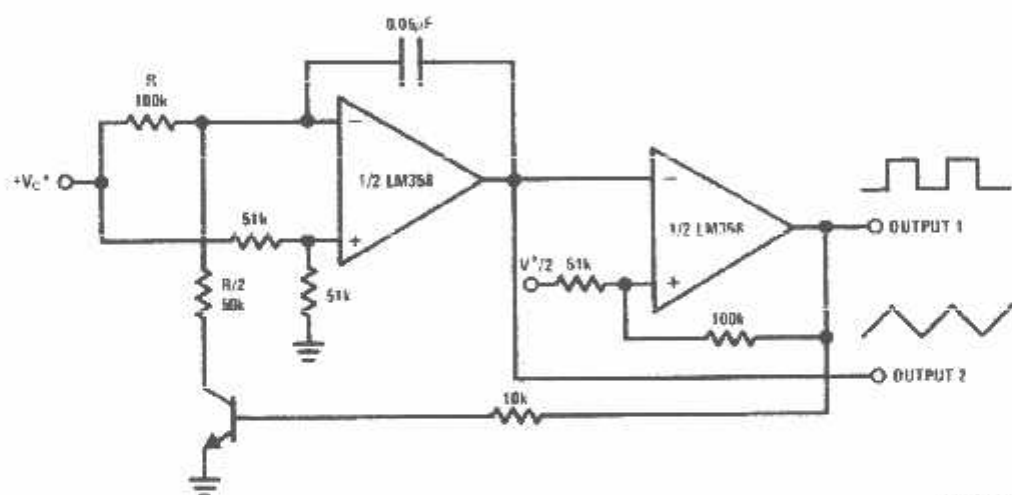
1 amp/volt V_{IN}
 base R_E for I_D small)

Comparator with Hysteresis



D8007787-22

Voltage Controlled Oscillator (VCO)

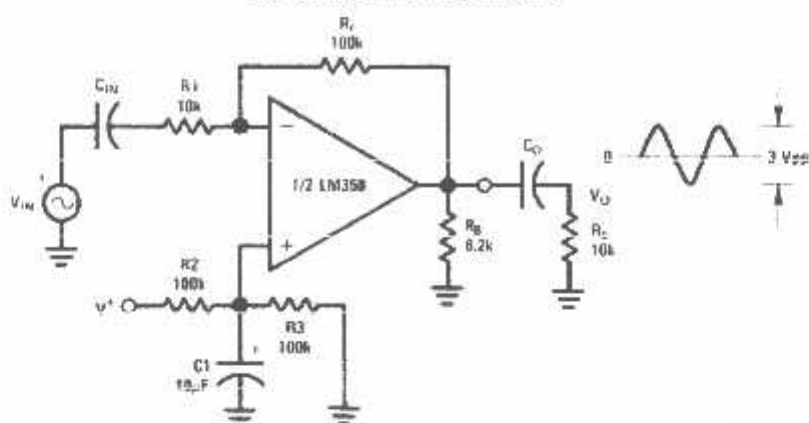


D8007787-23

CONTROL VOLTAGE RANGE: $0\text{ V}_{\text{DC}} \leq V_C \leq 2\text{ V}^* - 1.5\text{ V}_{\text{DC}}$

Typical Single-Supply Applications ($V^+ = 5.0\text{ V}_{DC}$) (Continued)

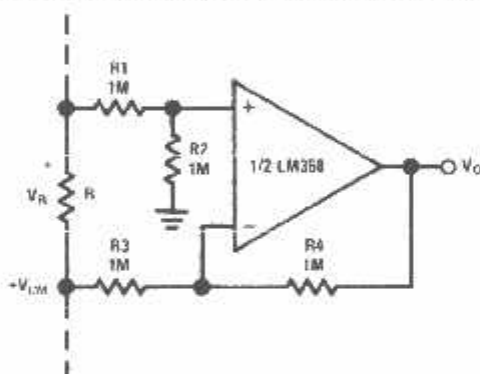
AC Coupled Inverting Amplifier



DS007737-24

$$A_V = \frac{R_f}{R_1} \quad (\text{As shown, } A_V = 10)$$

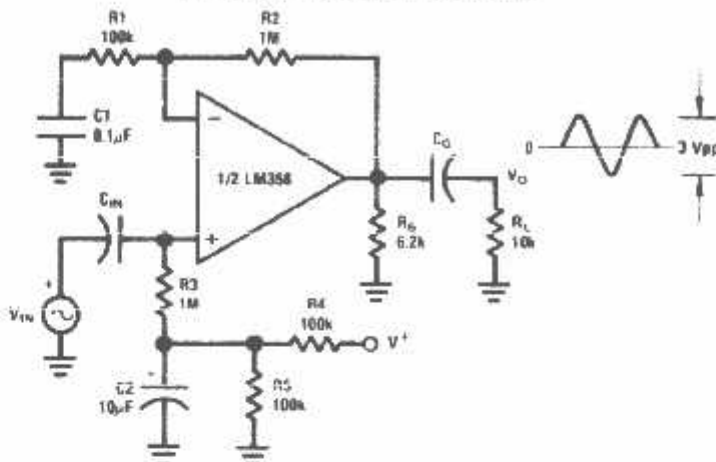
Ground Referencing a Differential Input Signal



DS007737-25

Typical Single-Supply Applications ($V^+ = 5.0\text{ V}_{\text{DC}}$) (Continued)

AC Coupled Non-Inverting Amplifier

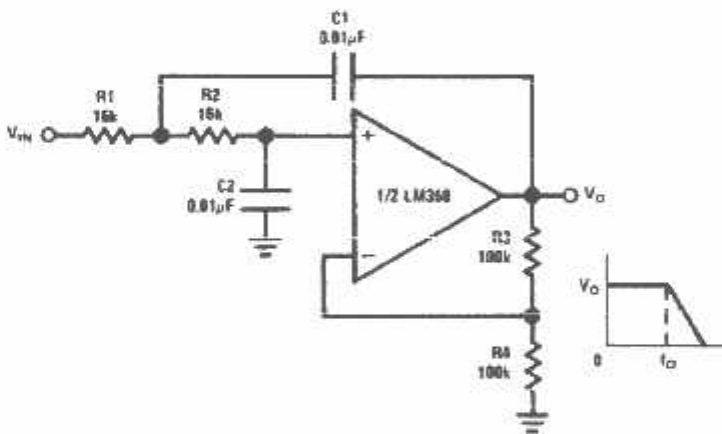


DS307767-26

$$-1 + \frac{R2}{R1}$$

11 (As Shown)

DC Coupled Low-Pass RC Active Filter



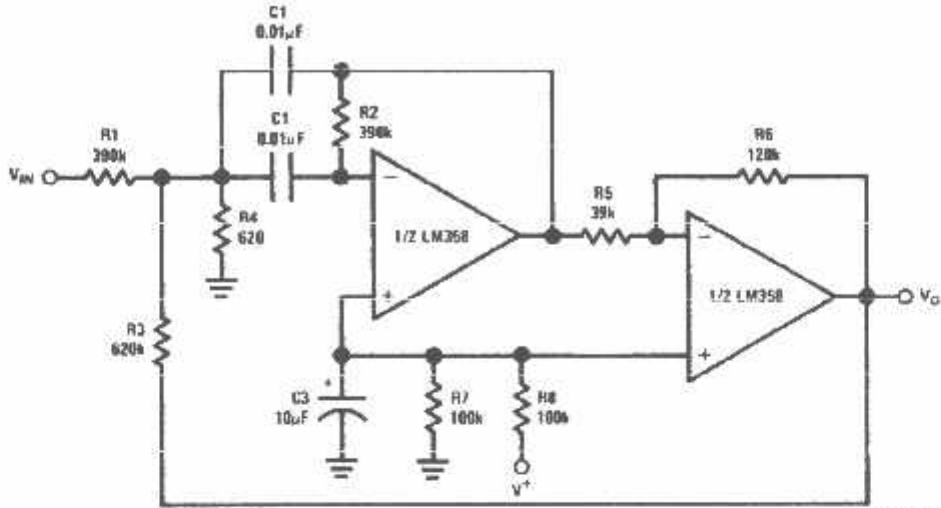
DS307767-27

kHz

2

Typical Single-Supply Applications ($V^+ = 5.0 V_{DC}$) (Continued)

Bandpass Active Filter

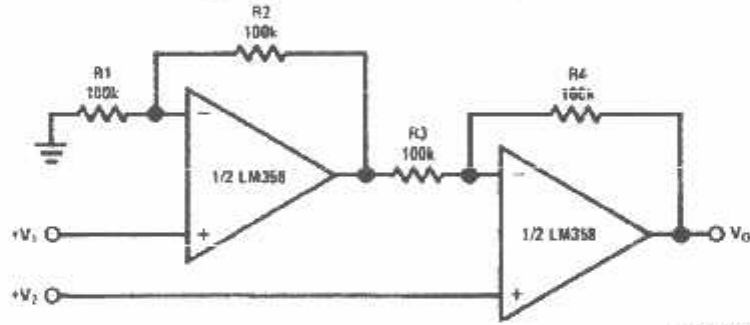


DS007757-26

$$f_o = 1 \text{ kHz}$$

$$Q = 25$$

High Input Z, DC Differential Amplifier



DS007757-29

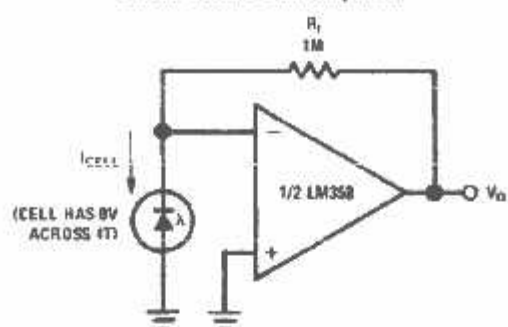
$$F_{CMR} = \frac{R1}{R2} - \frac{R4}{R3} \quad (\text{CMRR depends on this resistor ratio match})$$

$$V_O = 1 + \frac{R4}{R3} (V_2 - V_1)$$

$$\text{As Shown: } V_O = 2 (V_2 - V_1)$$

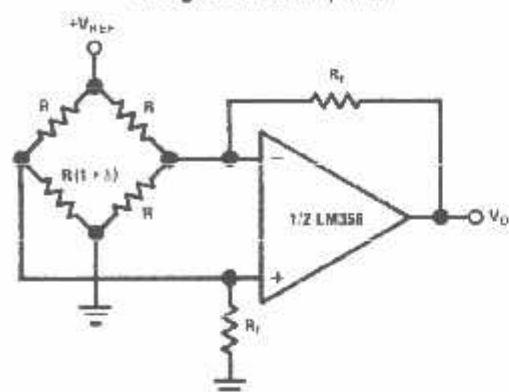
Typical Single-Supply Applications ($V^+ = 5.0 V_{DC}$) (Continued)

Photo Voltaic-Cell Amplifier



DS007787-38

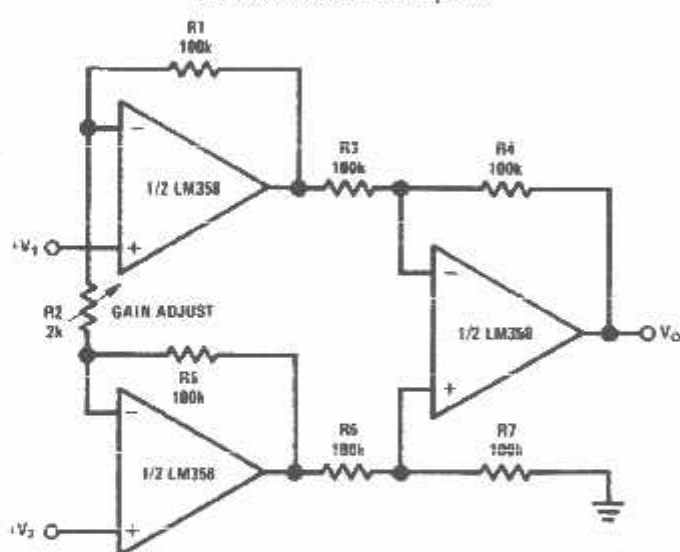
Bridge Current Amplifier



DS007787-39

For $\delta \ll 1$ and $R_f \gg R$

$$V_O = V_{REF} \left(\frac{\delta}{2} \right) \frac{R_f}{R}$$

High Input Z Adjustable-Gain
DC Instrumentation Amplifier

DS007787-34

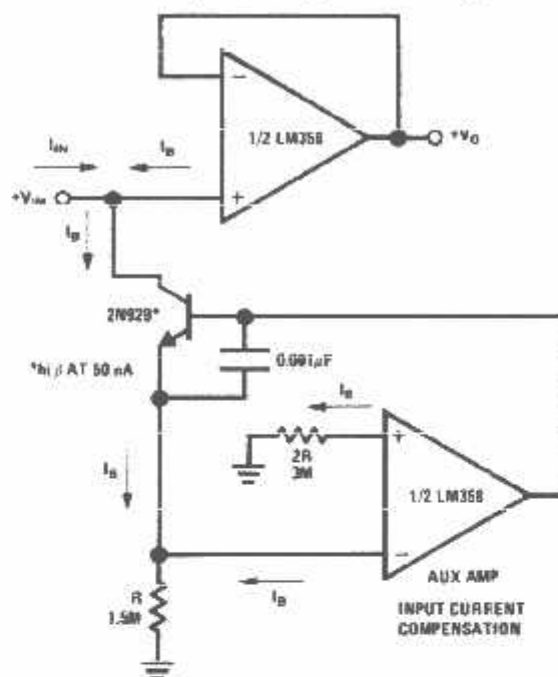
- $R5 \text{ \& } R3 = R4 = R6 = R7$ (CMRR depends on match)

$$V_O = 1 + \frac{2R1}{R2} (V_2 - V_1)$$

As shown $V_O = 101 (V_2 - V_1)$

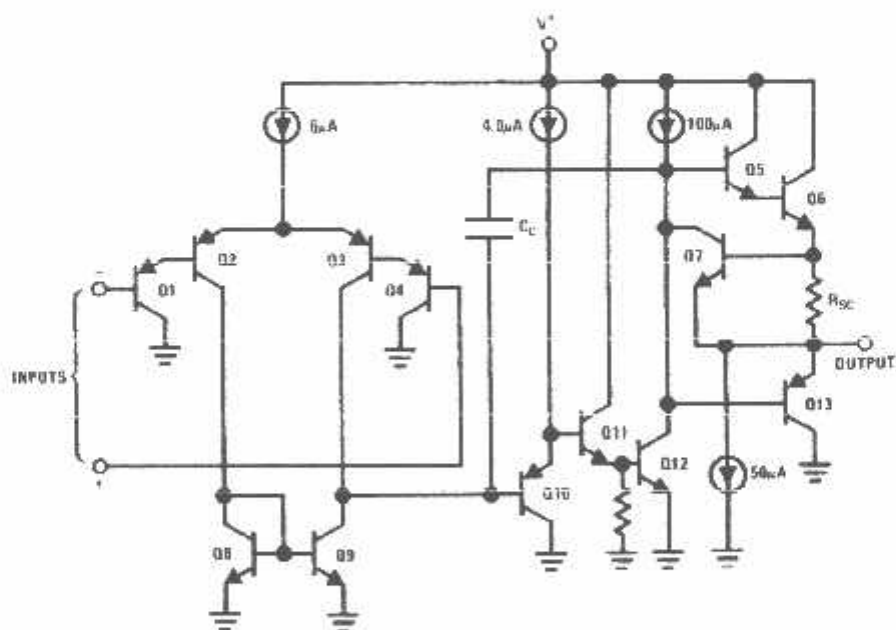
Typical Single-Supply Applications $(V^+ = 5.0 \text{ V}_{\text{DC}})$ (Continued)

Using Symmetrical Amplifiers to Reduce Input Current (General Concept)



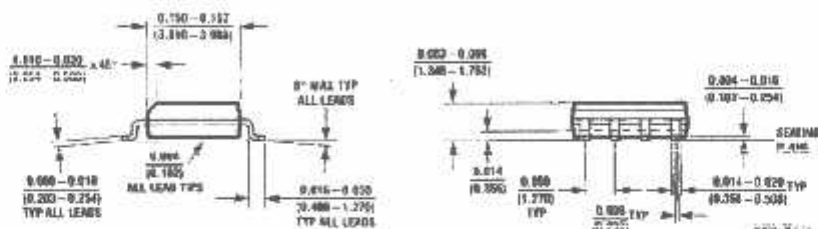
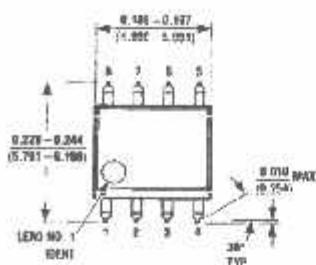
DS007760-31

Schematic Diagram (Each Amplifier)



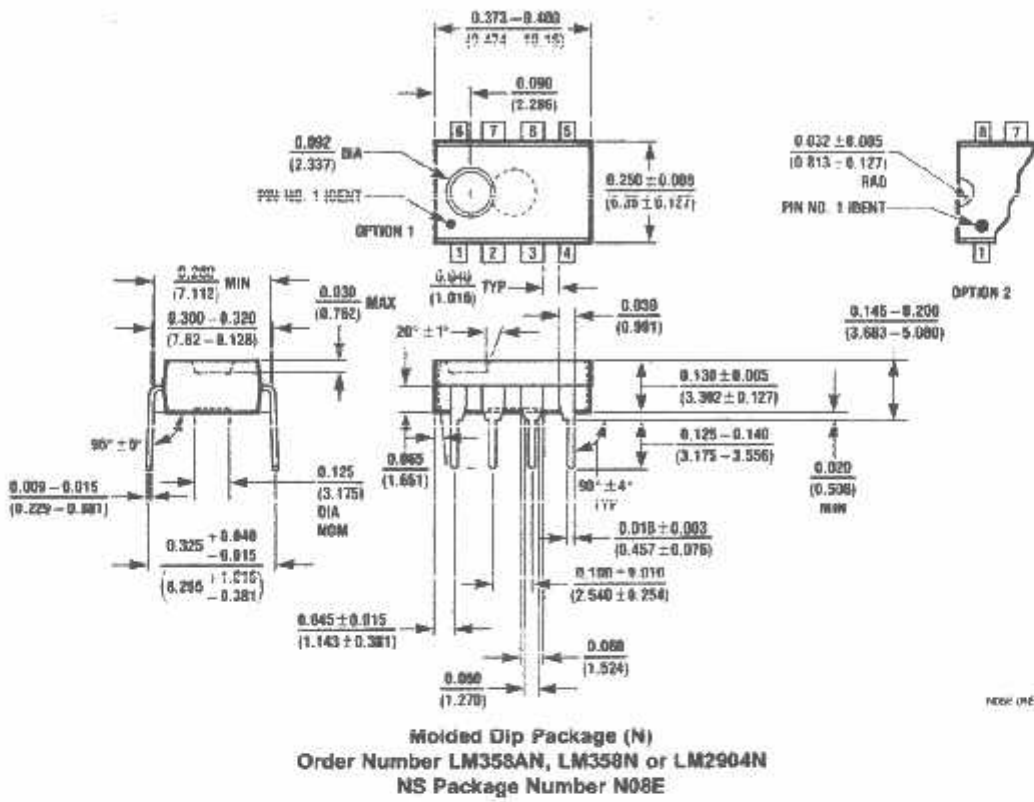
DS007760-3

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

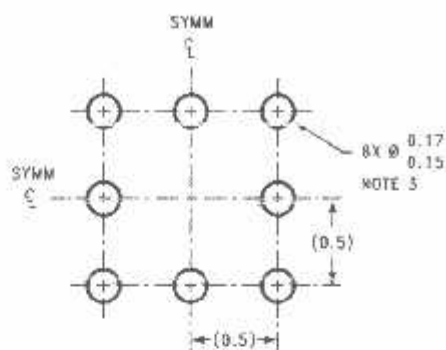


S.O. Package (M)
Order Number LM358M, LM358AM or LM2904M
NS Package Number M08A

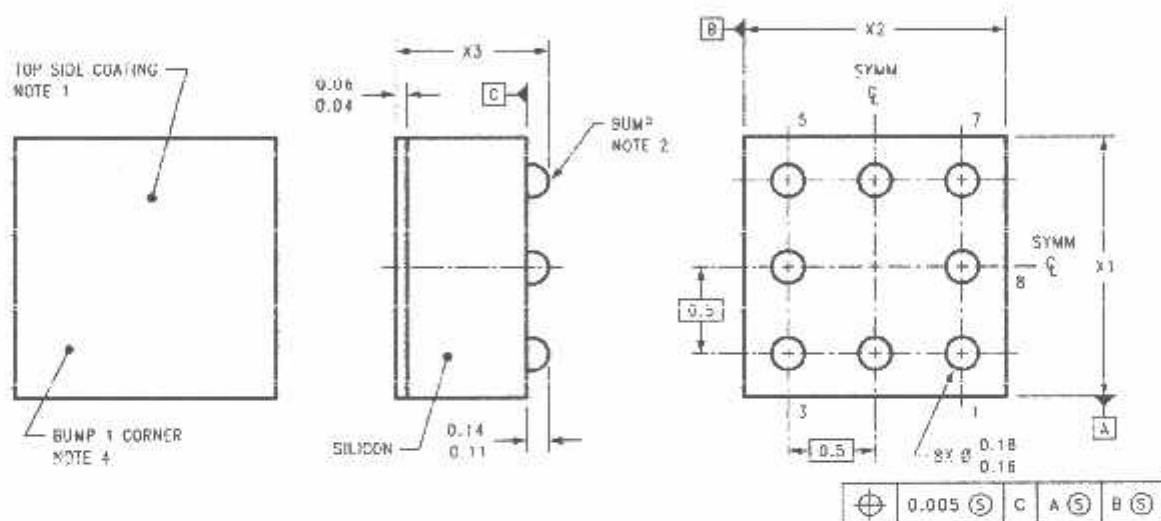
Physical Dimensions (inches (millimeters) unless otherwise noted) (Continued)



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



LAND PATTERN RECOMMENDATION



DIMENSIONS ARE IN MILLIMETERS

BPA08/13 (REV. A)

NOTES: UNLESS OTHERWISE SPECIFIED

1. EPOXY COATING
2. 63Sn/37Pb EUTECTIC BUMP
3. RECOMMEND NON-SOLDER MASK DEFINED LANDING PAD.
4. PIN 1 IS ESTABLISHED BY LOWER LEFT CORNER WITH RESPECT TO TEXT ORIENTATION REMAINING PINS ARE NUMBERED COUNTERCLOCKWISE.
5. XXX IN DRAWING NUMBER REPRESENTS PACKAGE SIZE VARIATION WHERE X_1 IS PACKAGE WIDTH, X_2 IS PACKAGE LENGTH AND X_3 IS PACKAGE HEIGHT.
6. REFERENCE JEDEC REGISTRATION MO-211, VARIATION BC.

8-Bump micro SMD
NS Package Number BPA08AAA
 $X_1 = 1.285$ $X_2 = 1.285$ $X_3 = 0.700$

Notes

SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL MANAGER OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. A life support device or system is a device or system which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the accompanying literature, can be reasonably expected to result in a significant injury to the user.

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.

National Semiconductor
Corporation
Americas
Tel: 1 (800) 272-9969
Fax: 1-800-737-7018
Email: support@nsc.com
nscl.com

National Semiconductor
Europe
Fax: +49 (0) 1 80-630 85 86
Email: europe.support@nsc.com
Deutsch Tel: +49 (0) 1 80-630 85 85
English Tel: +49 (0) 1 80-632 78 32
Français Tel: +49 (0) 1 80-632 93 88
Italiano Tel: +49 (0) 1 80-634 15 80

National Semiconductor
Asia Pacific Customer
Response Group
Tel: 65 2544444
Fax: 65-2504466
Email: asa.support@nsc.com

National Semiconductor
Japan Ltd.
Tel: 81-3-5630-7660
Fax: 81-3-5630-7667

National Semiconductor does not assume any responsibility for use of any product described, no circuit patent licenses are implied and National reserves the right at any time without notice to change said circuitry and specifications.

ADC0808/ADC0809 8-Bit μ P Compatible A/D Converters with 8-Channel Multiplexer

General Description

The ADC0808, ADC0809 data acquisition component is a monolithic CMOS device with an 8-bit analog-to-digital converter, 8-channel multiplexer and microprocessor compatible control logic. The 8-bit A/D converter uses successive approximation as the conversion technique. The converter features a high impedance chopper stabilized comparator, a 256R voltage divider with analog switch tree and a successive approximation register. The 8-channel multiplexer can directly access any of 8 single-ended analog signals.

The device eliminates the need for external zero and full-scale adjustments. Easy interfacing to microprocessors is provided by the latched and decoded multiplexer address inputs and latched TTL TRI-STATE® outputs.

The design of the ADC0808, ADC0809 has been optimized by incorporating the most desirable aspects of several A/D conversion techniques. The ADC0808, ADC0809 offers high speed, high accuracy, minimal temperature dependence, excellent long-term accuracy and repeatability, and consumes minimal power. These features make this device ideally suited to applications from process and machine control to consumer and automotive applications. For 16-channel multiplexer with common output (sample/hold port) see ADC0816 data sheet. (See AN-247 for more information.)

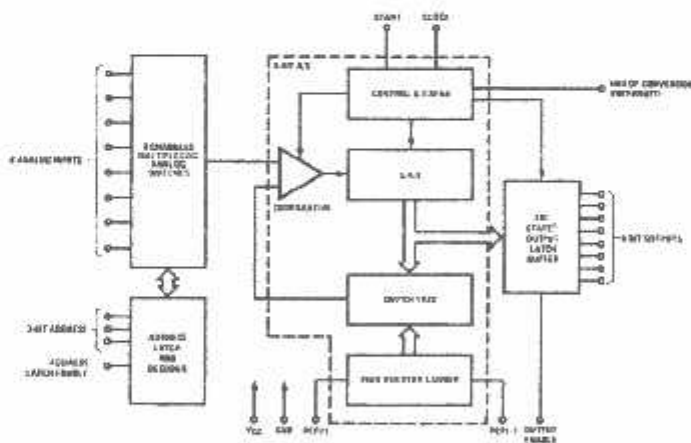
Features

- Easy interface to all microprocessors
- Operates ratiometrically or with 5 V_{DC} or analog span adjusted voltage reference
- No zero or full-scale adjust required
- 8-channel multiplexer with address logic
- 0V to 5V input range with single 5V power supply
- Outputs meet TTL voltage level specifications
- Standard hermetic or molded 28-pin DIP package
- 28-pin molded chip carrier package
- ADC0808 equivalent to MM74C949
- ADC0809 equivalent to MM74C949-1

Key Specifications

■ Resolution	8 Bits
■ Total Unadjusted Error	$\pm 1/2$ LSB and ± 1 LSB
■ Single Supply	5 V _{DC}
■ Low Power	15 mW
■ Conversion Time	100 μ s

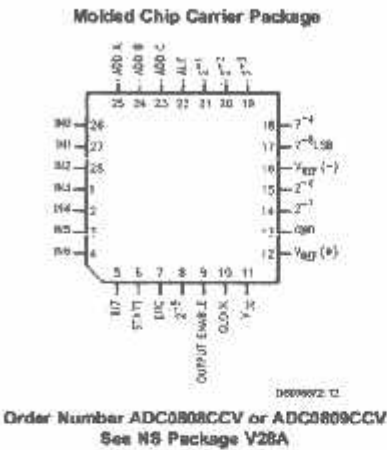
Block Diagram



See Ordering
Information

TRI-STATE® is a registered trademark of National Semiconductor Corp.

Connection Diagrams



Ordering Information

TEMPERATURE RANGE		-40°C to +85°C			-55°C to +125°C
Error	±1/2 LSB Unadjusted	ADC0808CCN	ADC0808CCV	ADC0808CCJ	ADC0808CJ
	±1 LSB Unadjusted	ADC0809CCN	ADC0809CCV		
Package Outline		N28A Molded DIP	V28A Molded Chip Carrier	J28A Ceramic DIP	J28A Ceramic DIP

Absolute Maximum Ratings (Notes 2, 1)

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

Supply Voltage (V_{CC}) (Note 3)	6.5V
Voltage at Any Pin	-0.3V to ($V_{CC}+0.3V$)
Except Control Inputs	
Voltage at Control Inputs (START, OE, CLOCK, ALE, ADD A, ADD B, ADD C)	-0.3V to +15V
Storage Temperature Range	-65°C to +160°C
Package Dissipation at $T_A=25^\circ\text{C}$	875 mW
Lead Temp. (Soldering, 10 seconds)	
Dual-In-Line Package (plastic)	260°C

Dual-In-Line Package (ceramic)	300°C
Molded Chip Carrier Package	
Vapor Phase (60 seconds)	215°C
Infrared (15 seconds)	270°C
ESD Susceptibility (Note 8)	400V

Operating Conditions (Notes 1, 2)

Temperature Range (Note 1)	$T_{MIN} \leq T_A \leq T_{MAX}$
ADC0808CCN, ADC0809CCN	-40°C $\leq T_A \leq$ +85°C
ADC0808CCV, ADC0809CCV	40°C $\leq T_A \leq$ +135°C
Range of V_{CC} (Note 1)	4.5 V_{CC} to 6.0 V_{CC}

Electrical Characteristics

Converter Specifications: $V_{DD}=5V$, $V_{REF+}=V_{REF-}=GND$, $T_{MIN} \leq T_A \leq T_{MAX}$ and $f_{CLK}=840$ kHz unless otherwise stated.

Symbol	Parameter	Conditions	Min	Typ	Max	Units
	ADC0808					
	Total Unadjusted Error (Note 5)	25°C T_{MIN} to T_{MAX}			$\pm 1/2$ $\pm 1/2$	LSB LSB
	ADC0809					
	Total Unadjusted Error (Note 5)	0°C to 70°C T_{MIN} to T_{MAX}			± 1 $\pm 1 1/2$	LSB LSB
	Input Resistance	From Ref(+) to Ref(-)	1.0	2.5		k Ω
	Analog Input Voltage Range	(Notes 4) V(+) or V(-)	GND-0.10		$V_{CC}-0.10$	V_{CC}
V_{REF+}	Voltage, Top of Ladder	Measured at Ref(+)		V_{CC}	$V_{CC}+0.1$	V
$\frac{V_{REF+} + V_{REF-}}{2}$	Voltage, Center of Ladder		$V_{CC}/2-0.1$	$V_{CC}/2$	$V_{CC}/2+0.1$	V
V_{REF-}	Voltage, Bottom of Ladder	Measured at Ref(-)	-0.1	0		V
I_{IH}	Comparator Input Current	$f_{CLK}=840$ kHz, (Note 6)	-2	± 0.5	2	μA

Electrical Characteristics

Digital Levels and DC Specifications: ADC0808CCN, ADC0808CCV, ADC0809CCN and ADC0809CCV, 4.75 $\leq V_{CC} \leq$ 5.25V, -40°C $\leq T_A \leq$ +85°C unless otherwise noted

Symbol	Parameter	Conditions	Min	Typ	Max	Units
ANALOG MULTIPLEXER						
$I_{OFF(+)}$	OFF Channel Leakage Current	$V_{CC}=5V$, $V_{IN}=5V$, $T_A=25^\circ\text{C}$ T_{MIN} to T_{MAX}		10 1.0	200 1.0	nA μA
$I_{OFF(-)}$	OFF Channel Leakage Current	$V_{CC}=5V$, $V_{IN}=0$, $T_A=25^\circ\text{C}$ T_{MIN} to T_{MAX}	-200 -1.0	-10		nA μA
CONTROL INPUTS						
V_{INH1}	Logical "1" Input Voltage		$V_{CC}-1.5$			V
V_{IN01}	Logical "0" Input Voltage				1.5	V
I_{INH1}	Logical "1" Input Current (The Control Inputs)	$V_{CC}=15V$			1.0	μA
I_{IN01}	Logical "0" Input Current (The Control Inputs)	$V_{IN}=0$	-1.0			μA
I_{CC}	Supply Current	$f_{CLK}=840$ kHz		0.3	3.0	mA

Electrical Characteristics (Continued)						
Digital Levels and DC Specifications: ADC0808CCN, ADC0808CCV, ADC0809CCN and ADC0809CCV, 4.75≤V _{DD} ≤5.25V, -40°C≤T _A ≤+85°C unless otherwise noted						
Symbol	Parameter	Conditions	Min	Typ	Max	Units
DATA OUTPUTS AND EOC (INTERRUPT)						
V _{OUT(1)}	Logical "1" Output Voltage	V _{DD} = 4.75V I _{OUT} = 200µA I _{OUT} = -10µA		2.4 4.5		V(min)
V _{OUT(0)}	Logical "0" Output Voltage	I _O = 1.6 mA			0.45	V
V _{OUT(EO)}	Logical "0" Output Voltage EOC	I _O = 1.2 mA			0.45	V
I _{OUT}	TRI-STATE Output Current	V _O = 5V V _O = 0	-3		3	µA µA
Electrical Characteristics						
Timing Specifications: V _{DD} = 5V, V _{SS} = 0V, f _{CLOCK} = 500 kHz and T _A = 25°C unless otherwise noted						
Symbol	Parameter	Conditions	Min	Typ	Max	Units
t _{WS}	Minimum Start Pulse Width	(Figure 5)		100	200	ns
t _{WALE}	Minimum ALE Pulse Width	(Figure 5)		100	200	ns
t _S	Minimum Address Set-Up Time	(Figure 5)		25	50	ns
t _H	Minimum Address Hold Time	(Figure 5)		25	50	ns
t _D	Analog MUX Delay Time From ALE	R _{SA} = 0Ω (Figure 6)		1	2.5	µs
t _{OE} , t _{OH}	OE Control to Q Logic State	C _I = 50 pF, R _I = 10k (Figure 8)		125	250	ns
t _{TH} , t _{OT}	OE Control to Hi-Z	C _I = 10 pF, R _I = 10k (Figure 8)		125	250	ns
t _C	Conversion Time	f _C = 640 kHz, (Figure 5) (Note 7)		100	116	µs
f _C	Clock Frequency		10	640	1280	kHz
t _{EOC}	EOC Delay Time	(Figure 5)	0		8+2 µS	Clock Periods
C _{IN}	Input Capacitance	At Conversion Inputs		10	15	pF
C _{OUT}	TRI-STATE Output Capacitance	At TRI-STATE Outputs		10	15	pF
Note 1: 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 specified operating conditions.						
Note 2: All voltages are measured with respect to GND, unless otherwise specified.						
Note 3: A corner discharge exists internally from V _{DD} to GND and has a typical breakdown voltage of 7 V _{DD} .						
Note 4: Two on-chip diodes are tied to each analog input which will forward conduct for analog input voltages one diode drop below ground or one diode drop greater than the V _{DD} supply. The spec allows 100 mV forward bias of either diode. This means that as long as the analog V _{IN} does not exceed the supply voltage by more than 100 mV, the output code will be correct. To achieve an absolute V _{DD} to 5V _{DD} input voltage range will therefore require a minimum supply voltage of 4.200 V _{DD} over temperature variations, initial tolerances and loading.						
Note 5: Total unadjusted error includes offset, full-scale, linearity, and multiplexer errors. See Figure 3. None of these ADs requires a zero or full-scale adjust. However, if an all-zero code is desired for an analog input other than 0.0V, or if a narrow full-scale span exists (for example, 0.5V to 4.5V full-scale) the reference voltages can be adjusted to achieve this. See Figure 13.						
Note 6: Comparator input currents exhibit corner bits at each of the change in absolute temperature. The bits corner codes directly with clock frequency and test temperature dependence (Figure 6). See paragraph 4.0.						
Note 7: The outputs of the data register are updated one clock cycle before the rising edge of EOC.						
Note 8: Human body model, 100 pF discharged through a 1.5 kΩ resistor.						

Functional Description

Multiplexer. The device contains an 8-channel single-ended analog signal multiplexer. A particular input channel is selected by using the address decoder. Table 1 shows the input states for the address lines to select any channel. The address is latched into the decoder on the low-to-high transition of the address latch enable signal.

TABLE 1.

SELECTED ANALOG CHANNEL	ADDRESS LINE		
	C	B	A
IN0	L	L	L
IN1	L	L	H
IN2	L	H	L
IN3	L	H	H
IN4	H	L	L
IN5	H	L	H
IN6	H	H	L
IN7	H	H	H

CONVERTER CHARACTERISTICS

The Converter

The heart of the eight chip data acquisition system is its 8-bit analog-to-digital converter. The converter is designed to give fast, accurate, and repeatable conversions over a wide range of temperatures. The converter is partitioned into 3 major sections: the 256R ladder network, the successive approximation register, and the comparator. The converter's digital outputs are positive true.

The 256R ladder network approach (Figure 7) was chosen over the conventional R/2R ladder because of its inherent monotonicity, which guarantees no missing digital codes. Monotonicity is particularly important in closed loop feedback control systems. A non-monotonic relationship can cause oscillations that will be catastrophic for the system. Additionally, the 256R network does not cause load variations on the reference voltage.

The bottom resistor and the top resistor of the ladder network in Figure 7 are not the same value as the remainder of the network. The difference in these resistors causes the output characteristic to be symmetrical with the zero and full-scale points of the transfer curve. The first output transition occurs when the analog signal has reached $+1/2$ LSB and succeeding output transitions occur every 1 LSB later up to full-scale.

The successive approximation register (SAR) performs 8 iterations to approximate the input voltage. For any SAR type converter, n-iterations are required for an n-bit converter. Figure 2 shows a typical example of a 3-bit converter. In the ADC0808, ADC0809, the approximation technique is extended to 8 bits using the 256R network.

The A/D converter's successive approximation register (SAR) is reset on the positive edge of the start conversion (SC) pulse. The conversion is begun on the falling edge of the start conversion pulse. A conversion in process will be interrupted by receipt of a new start conversion pulse. Continuous conversion may be accomplished by tying the end-of-conversion (EOC) output to the SC input. If used in this mode, an external start conversion pulse should be applied after power up. End-of-conversion will go low between 0 and 8 clock pulses after the rising edge of start conversion.

The most important section of the A/D converter is the comparator. It is this section which is responsible for the ultimate accuracy of the entire converter. It is also the comparator drift which has the greatest influence on the repeatability of the device. A chopper-stabilized comparator provides the most effective method of satisfying all the converter requirements.

The chopper-stabilized comparator converts the DC input signal into an AC signal. This signal is then fed through a high gain AC amplifier and has the DC level restored. This technique limits the drift component of the amplifier since the drift is a DC component which is not passed by the AC amplifier. This makes the entire A/D converter extremely insensitive to temperature, long term drift and input offset errors.

Figure 4 shows a typical error curve for the ADC0808 as measured using the procedure outlined in AN-12a.

Functional Description (Continued)

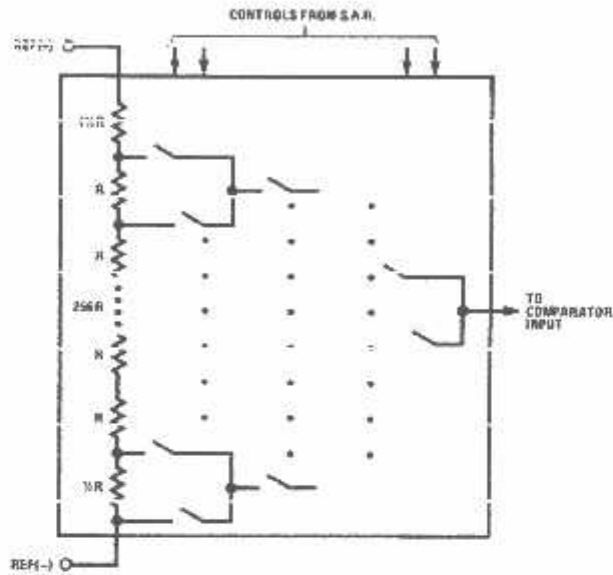


FIGURE 1. Resistor Ladder and Switch Tree

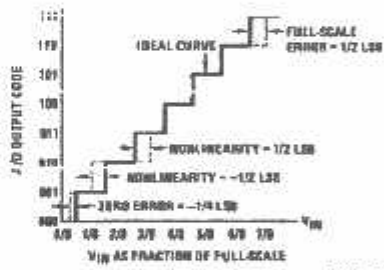


FIGURE 2. 3-Bit A/D Transfer Curve

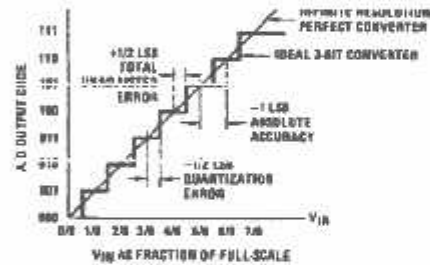


FIGURE 3. 3-Bit A/D Absolute Accuracy Curve

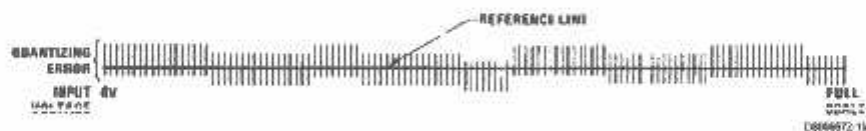


FIGURE 4. Typical Error Curve

Timing Diagram

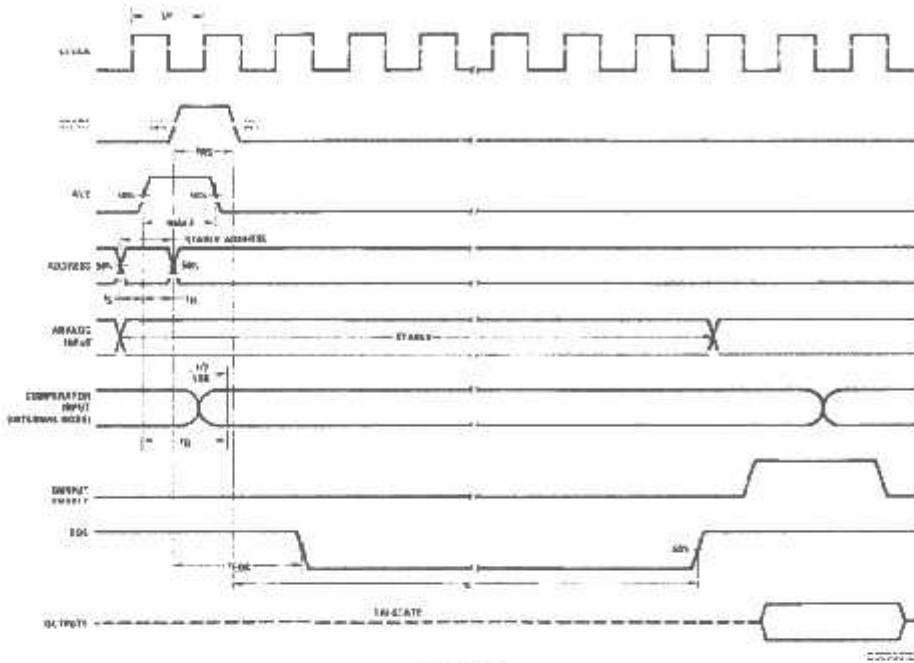


FIGURE 5.

Typical Performance Characteristics

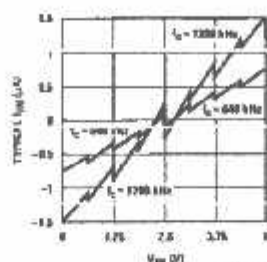


FIGURE 6. Comparator I_M vs V_{IN}
($V_{CC}=V_{REF}=5V$)

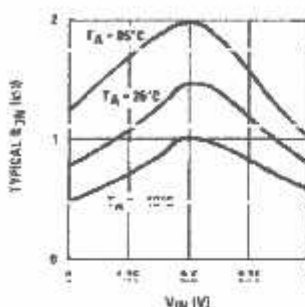


FIGURE 7. Maximum S_N vs V_{IN}
($V_{CC}=V_{REF}=5V$)

TRI-STATE Test Circuits and Timing Diagrams

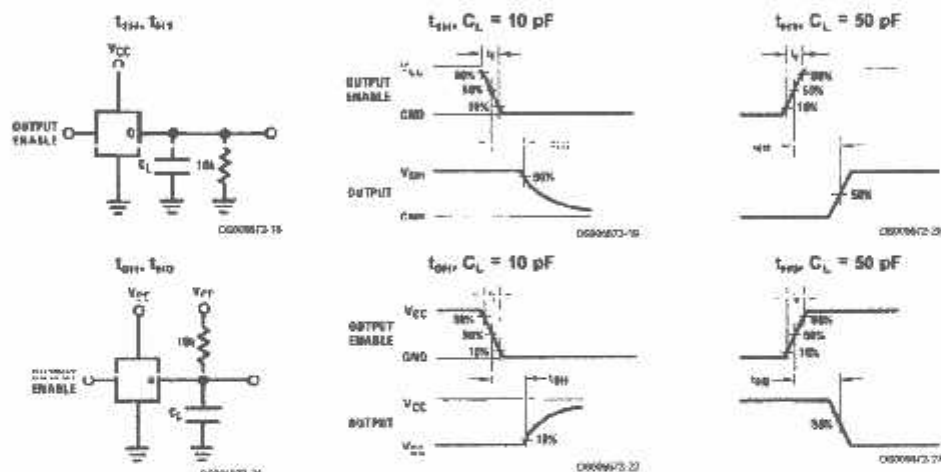


FIGURE 8.

Applications information

OPERATION

1.0 RATIO-METRIC CONVERSION

The ADC0808, ADC0809 is designed as a complete Data Acquisition System (DAS) for ratio-metric conversion systems. In ratio-metric systems, the physical variable being measured is expressed as a percentage of full-scale which is not necessarily related to an absolute standard. The voltage input to the ADC0808 is expressed by the equation

$$\frac{V_{IN}}{V_{FS}-V_{Z}} = \frac{D_X}{D_{MAX}-D_{MIN}} \quad (1)$$

V_{IN} = Input voltage into the ADC0808

V_{FS} = Full-scale voltage

V_Z = Zero voltage

D_X = Data point being measured

D_{MAX} = Maximum data limit

D_{MIN} = Minimum data limit

A good example of a ratio-metric transducer is a potentiometer used as a position sensor. The position of the wiper is directly proportional to the output voltage which is a ratio of the full-scale voltage across it. Since the data is represented as a proportion of full-scale, reference requirements are greatly reduced, eliminating a large source of error and cost for many applications. A major advantage of the ADC0808, ADC0809 is that the input voltage range is equal to the supply range so the transducers can be connected directly across the supply and their outputs connected directly into the multiplexer inputs, (Figure 9).

Ratio-metric transducers such as potentiometers, strain gauges, thermistor bridges, pressure transducers, etc., are suitable for measuring proportional relationships; however, many types of measurements must be referred to an absolute standard such as voltage or current. This means a sys-

Applications Information (Continued)

tem reference must be used which relates the full-scale voltage to the standard volt. For example, if $V_{CC} = V_{REF} = 5.12V$, then the full-scale range is divided into 256 standard steps. The smallest standard step is 1 LSB which is then 20 mV.

2.0 RESISTOR LADDER LIMITATIONS

The voltages from the resistor ladder are compared to the selected into 8 times in a conversion. These voltages are coupled to the comparator via an analog switch tree which is referenced in the circuit. The voltages at the top, center and bottom of the ladder must be controlled to maintain proper operation.

The top of the ladder, Ref(+), should not be more positive than the supply, and the bottom of the ladder, Ref(-), should not be more negative than ground. The center of the ladder voltage must also be near the center of the supply because the analog switch tree changes from N-channel switches to P-channel switches. These limitations are automatically satisfied in ratiometric systems and can be easily met in ground referenced systems.

Figure 10 shows a ground referenced system with a separate supply and reference. In this system, the supply must be trimmed to match the reference voltage. For instance, if a 5.12V is used, the supply should be adjusted to the same voltage within 0.1V.

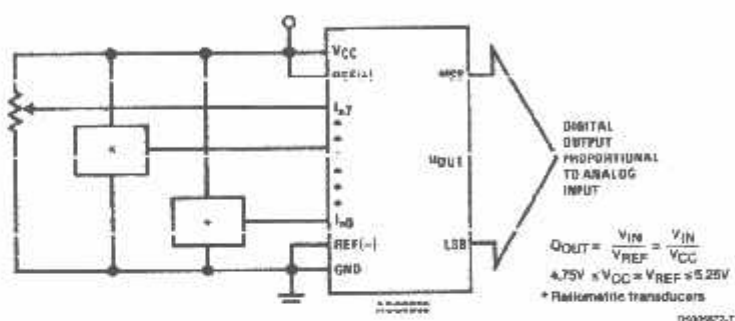
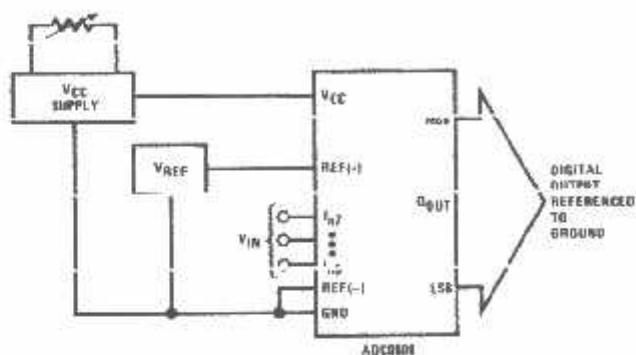


FIGURE 9. Ratiometric Conversion System

The ADC0808 needs less than a milliamp of supply current so developing the supply from the reference is readily accomplished. In Figure 11 a ground referenced system is shown which generates the supply from the reference. The buffer shown can be an op amp of sufficient drive to supply the milliamp of supply current and the desired bus drive, or if a capacitive bus is driven by the outputs a large capacitor will supply the transient supply current as seen in Figure 12. The LM301 is overcompensated to insure stability when loaded by the 10 μF output capacitor.

The top and bottom ladder voltages cannot exceed V_{CC} and ground, respectively, but they can be symmetrically less than V_{CC} and greater than ground. The center of the ladder voltage should always be near the center of the supply. The sensitivity of the converter can be increased, (i.e., size of the LSB steps decreased) by using a symmetrical reference system. In Figure 13, a 2.5V reference is symmetrically centered about $V_{CC}/2$ since the same current flows in identical resistors. This system with a 2.5V reference allows the LSB bit to be half the size of a 5V reference system.

Applications Information (Continued)

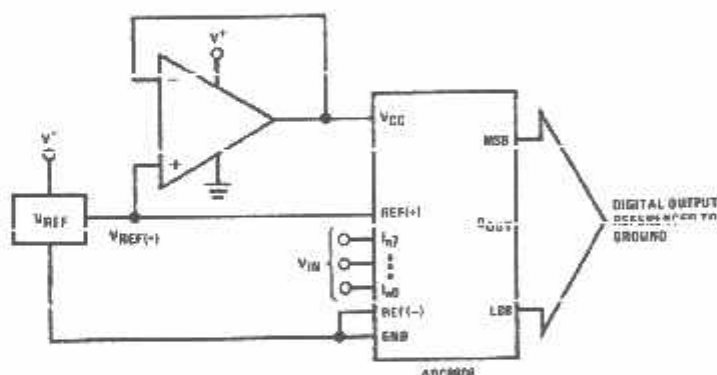


02030572-24

$$Q_{OUT} = \frac{V_{IN}}{V_{REF}}$$

$$4.75V \leq V_{CC} = V_{REF} \leq 5.25V$$

FIGURE 10. Ground Referenced Conversion System Using Trimmed Supply



02030672-26

$$Q_{OUT} = \frac{V_{IN}}{V_{REF}}$$

$$4.75V \leq V_{CC} = V_{REF} \leq 5.25V$$

FIGURE 11. Ground Referenced Conversion System with Reference Generating VCC Supply

Applications Information (Continued)

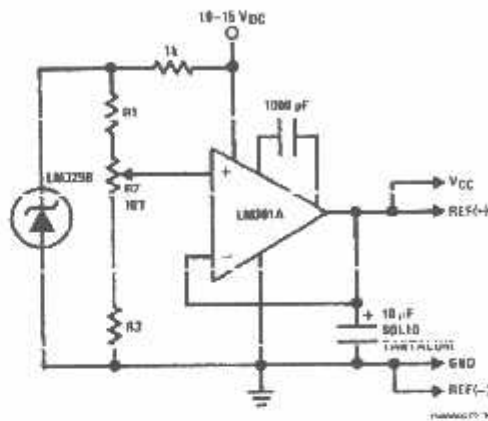
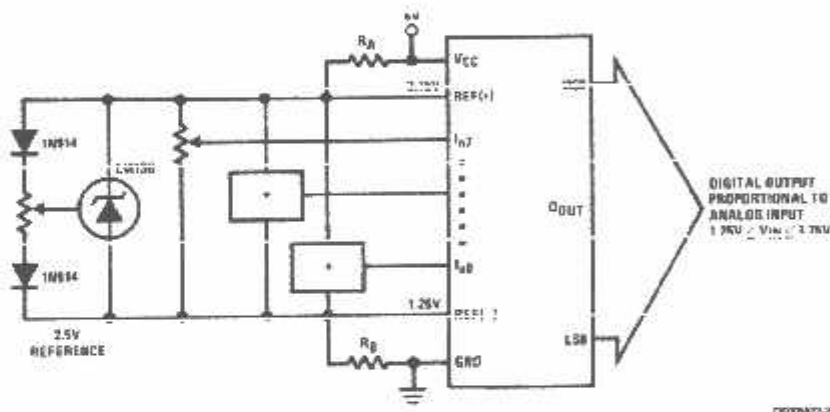


FIGURE 12. Typical Reference and Supply Circuit



00000000-0000-0000-0000-000000000000

 $\mu_1 = \mu_2$

*Ratiometric transducers

FIGURE 13. Symmetrically Centered Reference

3.1 CONVERTER EQUATIONS

The transition between adjacent codes N and $N+1$ is given by:

$$V_{N+1} = \left[(V_{\text{REF}(N)} - V_{\text{REF}}) \cdot \left(\left[\frac{N}{256} + \frac{1}{512} \right] \pm V_{\text{TRIP}} \right) \right] + V_{\text{REF}(N-1)} \quad (2)$$

The center of an output code N is given by:

$$V_{IN} \left[(V_{REF1}) - V_{REF1} - \mu \left(\frac{N}{200} \right) \pm V_{IUE} \right] + V_{REF1} \quad (3)$$

The output code n for an arbitrary input are the integers within the range:

$$N = \frac{V_{\text{REF}} - V_{\text{REF}(-)}}{V_{\text{REF}(+)}} \times 256 \pm \text{Absolute Accuracy} \quad (4)$$

1.8. The following table shows the number of people who attended the 2004 Summer Olympic Games in Athens, Greece, and the 2008 Summer Olympic Games in Beijing, China.

$V_{REF(+)}$ = Voltage at Ref(+)

$V_{REF(-)}$ = Voltage at Ref(-)

វិធានការ = បែងចែក ធនធានសំបាប់ ចំពោះ មន្ត្រីរដ្ឋបាល ប្រែប្រួលជំនាញ

Applications Information (Continued)

4.0 ANALOG COMPARATOR INPUTS

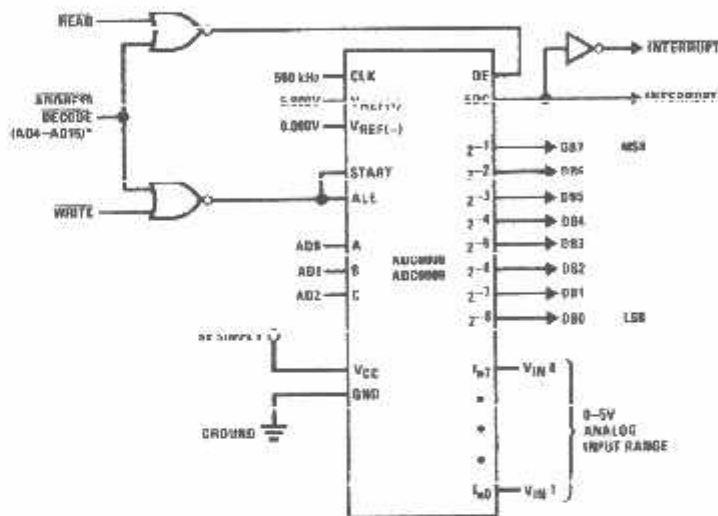
The dynamic comparator input current is caused by the periodic switching of on-chip delay capacitances. These are connected alternately to the output of the resistor ladder/switch tree network and to the comparator input as part of the operation of the chopper stabilized comparator.

The average value of the comparator input current varies directly with clock frequency and with V_{REF} as shown in Figure 6.

If no filter capacitors are used at the analog inputs and the signal source impedances are low, the comparator input current should not introduce converter errors, as the transient created by the capacitance discharge will die out before the comparator output is strobed.

If input filter capacitors are desired for noise reduction and signal conditioning they will tend to average out the dynamic comparator input current. It will then take on the characteristics of a DC bias current whose effect can be predicted conventionally.

Typical Application

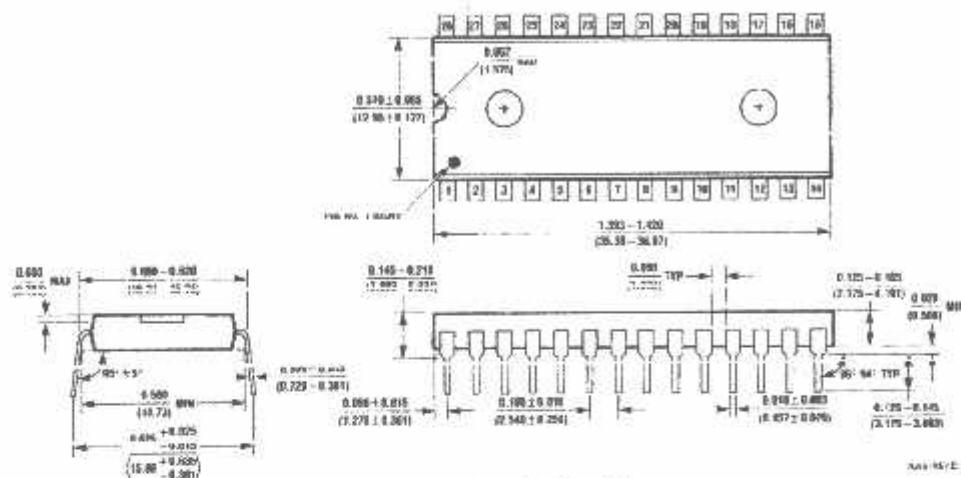


*Address lines 16-15 are for 8086 and SCAMP interfaces to the ADC0809 in a microprocessor.

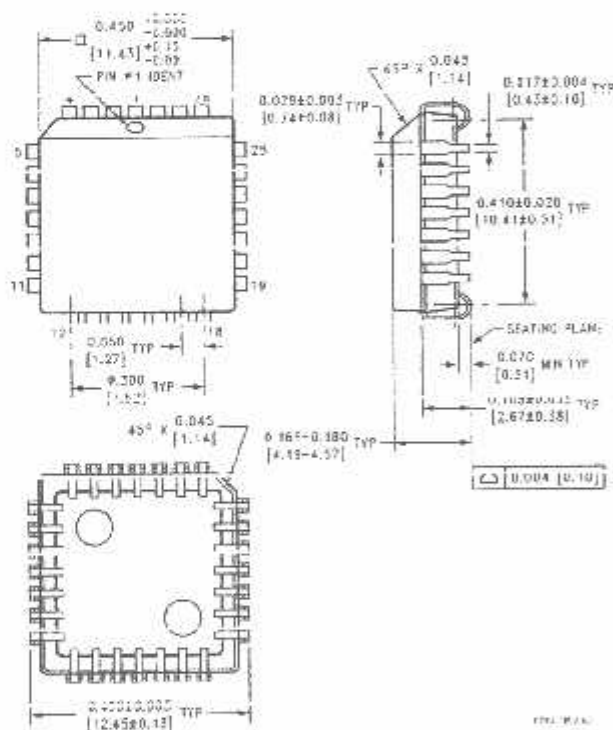
TABLE 2. Microprocessor Interface Table

PROCESSOR	READ	WRITE	INTERRUPT (COMMENT)
8080	MEMR	MEMW	INTR (Thru RST Circuit)
8085	RD	WR	INTR (Thru RST Circuit)
Z-80	RD	WR	INT (Thru RST Circuit, Mode 0)
SC/MP	NRDS	NWDS	SA (Thru Sense A)
6800	VMA-q2-R/W	VMA-q-R/W	IRQA or IRQB (Thru PIA)

Physical Dimensions (millimeters) unless otherwise noted



Molded Dual-In-Line Package (N)
Order Number ADC0808CCN or ADC0809CCN
NS Package Number N28B



Molded Chip Carrier (V)
Order Number ADC0808CCV or ADC0809CCV
NS Package Number V28A

Notes

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which: (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
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.

 National Semiconductor
Corporation
America
Tel: 1-800-272-9098
Fax: 1-800-737-7018
Email: corporate@nsc.com

www.national.com

National Semiconductor
Europe
Fax: +49 (0) 1 80-530 85 85
Email: europesupport@nsc.com
Deutsch: Tel: +49 (0) 1 80-530 85 85
English: Tel: +49 (0) 1 80-530 85 85
Français: Tel: +49 (0) 1 80-530 85 85
Italiano: Tel: +49 (0) 1 80-530 85 85

National Semiconductor
Asia Pacific Customer
Response Group
Tel: 65-2544400
Fax: 65-2544400
Email: asia@nsc.com

National Semiconductor
Japan Ltd.
Tel: 81-3-5639-7560
Fax: 81-3-5639-7597

National does not assume any responsibility for use of any circuit described in this data sheet where no circuit diagram is provided and where no reference is made to the specific circuit diagram.

Features

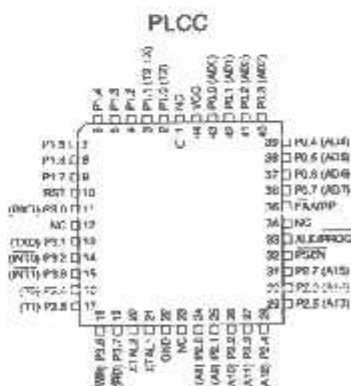
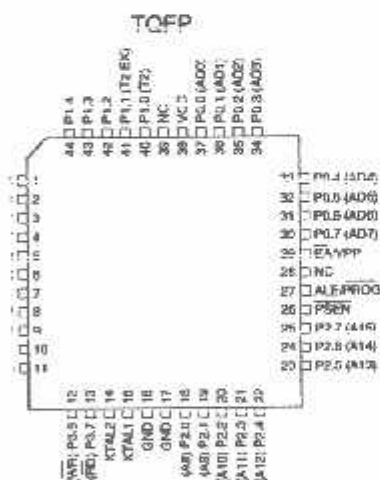
- Compatible with MCS-51™ Products
- 1024 Bytes of Reprogrammable Flash Memory
- Endurance: 1000 Write/Erase Cycles
- 5.5V Operating Range
- Static Operation: 0 Hz to 33 MHz
- Write-Level Program Memory Lock
- 8-bit Internal RAM
- Reprogrammable I/O Lines
- Two 16-bit Timer/Counters
- Multiple Interrupt Sources
- Reprogrammable Serial Channel
- Power-Save and Power-down Modes
- Fast Recovery from Power-down Mode
- Software Watchdog Timer
- Data Pointer
- Power-off Flag

Description

AT89C51RC is a low-power, high-performance CMOS 8-bit microcomputer with 1024 bytes of Flash programmable read only memory and 512 bytes of RAM. The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry-standard 80C51 and 80C52 instruction set and pin configurations.

(continued)

Configurations



Rev. 1920A-08/00



8-bit Microcontroller with 32K Bytes Flash

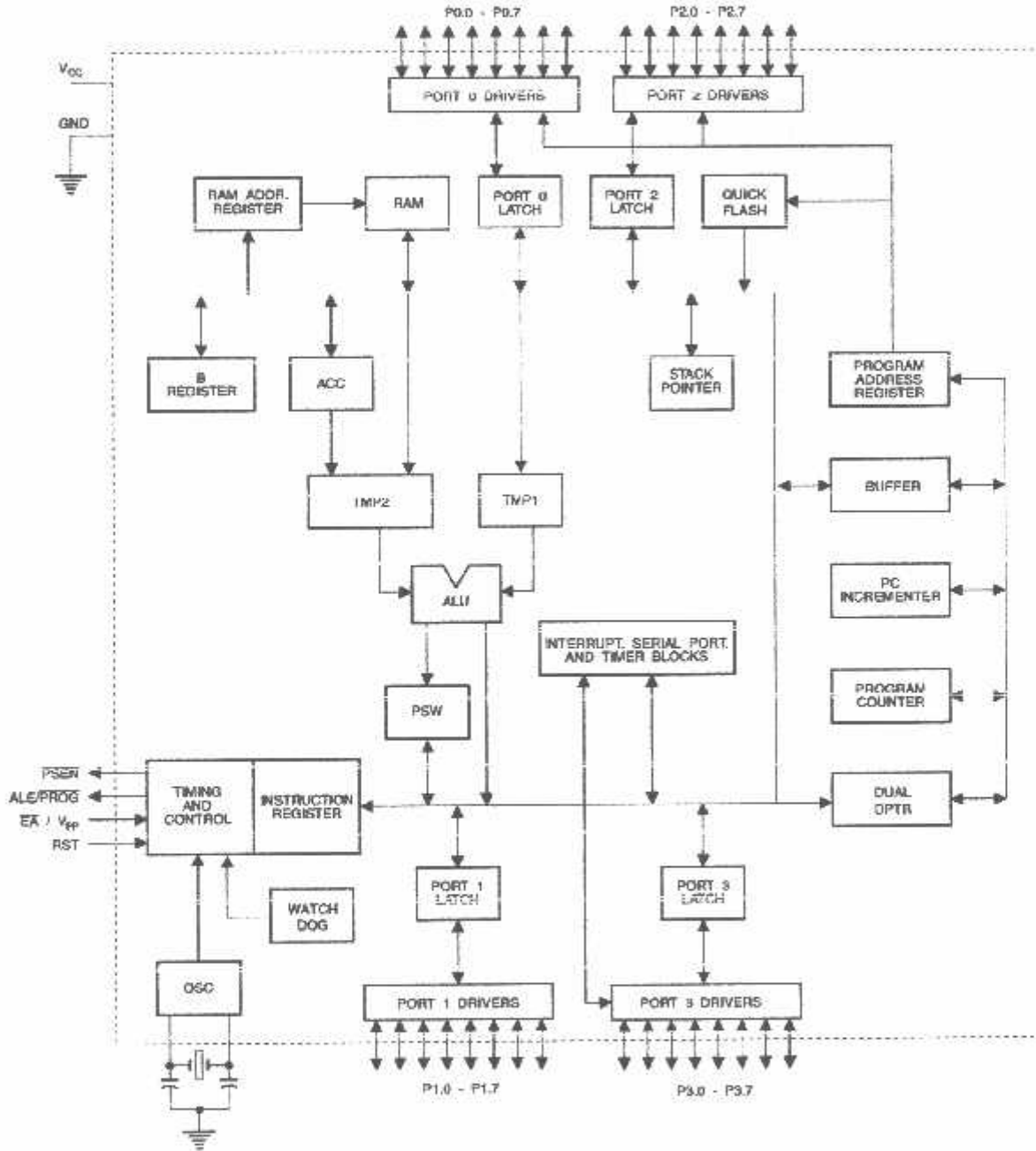
AT89C51RC



The on-chip Flash allows the program memory to be programmed by a conventional nonvolatile memory programmer. A total of 512 bytes of internal RAM are available in the AT89C51RC. The 256-byte expanded internal RAM is accessed via MOVX instructions after clearing bit 1 of the SFR located at address 8EH. The other 256-byte

RAM segment is accessed the same way as the Atmel AT89-series and other 8052-compatible products. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C51RC is a powerful microcomputer which provides a highly-flexible and cost-effective solution to many embedded control applications.

Block Diagram



AT89C51RC

AT89C51RC provides the following standard features: 1 Kbytes of Flash, 512 bytes of RAM, 32 I/O lines, three timer/counters, a six-vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator, and circuitry. In addition, the AT89C51RC is designed with logic for operation down to zero frequency and has two software selectable power saving modes. The Idle mode stops the CPU while allowing the RAM, timer/counters, serial port, and interrupt system to continue running. The Power-down mode saves the RAM content but freezes the oscillator, disabling all other chip functions until the next external interrupt or hardware reset.

Description

voltage.

1.

Port 0 is an 8-bit open drain bidirectional I/O port. As an output port, each pin can sink eight TTL inputs. When 1s are written to Port 0 pins, the pins can be used as high-impedance inputs.

Port 0 can also be configured to be the multiplexed low-address/data bus during accesses to external program memory and data memory. In this mode, Port 0 has internal pull-ups.

Port 0 also receives the code bytes during Flash programming and outputs the code bytes during program verification. External pull-ups are required during program verification.

Port 1 is an 8-bit bidirectional I/O port with internal pull-ups. The Port 1 output buffers can sink/source four TTL inputs. When 1s are written to Port 1 pins, they are pulled high by the internal pull-ups and can be used as inputs. As inputs, Port 1 pins that are externally being pulled low will source current (I_{IL}) because of the internal pull-ups.

In addition, P1.0 and P1.1 can be configured to be the Timer/Counter 2 external count input (P1.0/T2) and the Timer/Counter 2 trigger input (P1.1/T2EX), respectively, as shown in the following table.

Port 1 also receives the low-order address bytes during Flash programming and verification.

Pin	Alternate Functions
P1.0	T2 (external count input to Timer/Counter 2), clock-out
P1.1	T2EX (Timer/Counter 2 capture/reload trigger and direction control)

Port 2

Port 2 is an 8-bit bidirectional I/O port with internal pull-ups. The Port 2 output buffers can sink/source four TTL inputs. When 1s are written to Port 2 pins, they are pulled high by the internal pull-ups and can be used as inputs. As inputs, Port 2 pins that are externally being pulled low will source current (I_{IL}) because of the internal pull-ups.

Port 2 emits the high-order address byte during fetches from external program memory and during accesses to external data memory that use 16-bit addresses (MOVX @ DPTR). In this application, Port 2 uses strong internal pull-ups when emitting 1s. During accesses to external data memory that use 8-bit addresses (MOVX @ R1), Port 2 emits the contents of the P2 Special Function Register.

Port 2 also receives the high-order address bits and some control signals during Flash programming and verification.

Port 3

Port 3 is an 8-bit bidirectional I/O port with internal pull-ups. The Port 3 output buffers can sink/source four TTL inputs. When 1s are written to Port 3 pins, they are pulled high by the internal pull-ups and can be used as inputs. As inputs, Port 3 pins that are externally being pulled low will source current (I_{IL}) because of the pull-ups.

Port 3 also serves the functions of various special features of the AT89C51RC, as shown in the following table.

Port 3 also receives some control signals for Flash programming and verification.

Port Pin	Alternate Functions
P3.0	RXD (serial input port)
P3.1	TXD (serial output port)
P3.2	INT0 (external interrupt 0)
P3.3	INT1 (external interrupt 1)
P3.4	T0 (timer 0 external input)
P3.5	T1 (timer 1 external input)
P3.6	WR (external data memory write strobe)
P3.7	RD (external data memory read strobe)

RST

Reset input. A high on this pin for two machine cycles while the oscillator is running resets the device. This pin drives High for 96 oscillator periods after the Watchdog times out. The DISRST0 bit in SFR AUXR (address 8EH) can be used to disable this feature. In the default state of bit DISTRO, the RESET HIGH out feature is enabled.

ALE/PROG

Address Latch Enable is an output pulse for latching the low byte of the address during accesses to external



ry. This pin is also the program pulse input ($\overline{\text{PROG}}$) Flash programming.

nal operation, ALE is emitted at a constant rate of 1/6 oscillator frequency and may be used for external or clocking purposes. Note, however, that one pulse is skipped during each access to external data memory.

ed, ALE operation can be disabled by setting bit 0 of location 8EH. With the bit set, ALE is active only during MOVX or MOVC instruction. Otherwise, the pin is pulled high. Setting the ALE-disable bit has no effect if the microcontroller is in external execution mode.

m Store Enable is the read strobe to external program memory.

the AT89C51RC is executing code from external program memory, $\overline{\text{PSEN}}$ is activated twice each machine

cycle, except that two $\overline{\text{PSEN}}$ activations are skipped during each access to external data memory.

EA/VPP

External Access Enable. EA must be strapped to GND in order to enable the device to fetch code from external program memory locations starting at 0000H up to FFFFH. Note, however, that if lock bit 1 is programmed, EA will be internally latched on reset.

EA should be strapped to V_{CC} for internal program executions.

This pin also receives the 12-volt programming enable voltage (V_{PP}) during Flash programming.

XTAL1

Input to the inverting oscillator amplifier and input to the internal clock operating circuit.

XTAL2

Output from the inverting oscillator amplifier.

1. AT89C51RC SFR Map and Reset Values

							0FFH
B 00000000							0F7H
							0EFH
ACC 00000000							0E7H
							0DFH
PSW 00000000							0D7H
T2CON 00000000	T2MOD XXXXXX00	RCAP2L 00000000	RCAP2H 00000000	TL2 00000000	TH2 00000000		0CFH
							0C7H
IP XX000000							0BFH
P3 11111111							0B7H
IE 0X000000							0AFH
P2 11111111		AUXR1 XXXXXXXX0				WDTRST XXXXXXXX	0A7H
SCON 00000000	SBUF XXXXXXXXX						9FH
P1 11111111							97H
TCON 00000000	TMOD 00000000	TL0 00000000	TL1 00000000	TH0 00000000	TH1 00000000	AUXR XX000000	8FH
P0 11111111	SP 00000111	DP0L 00000000	DP0H 00000000	DP1L 00000000	DP1H 00000000		87H
						PCON 0XX00000	

AT89C51RC

Special Function Registers

of the on-chip memory area called the Special Function Register (SFR) space is shown in Table 1.

Not all of the addresses are occupied, and unoccupied addresses may not be implemented on the chip. Accesses to these addresses will in general return random data, and write accesses will have an indeterminate effect.

Software should not write 1s to these unlisted locations since they may be used in future products to invoke

new features. In that case, the reset or inactive values of the new bits will always be 0.

Timer 2 Registers: Control and status bits are contained in registers T2CON (shown in Table 2) and T2MOD (shown in Table 4) for Timer 2. The register pair (RCAP2H, RCAP2L) are the Capture/Reload registers for Timer 2 in 16-bit capture mode or 16-bit auto-reload mode.

Interrupt Registers: The individual interrupt enable bits are in the IE register. Two priorities can be set for each of the six interrupt sources in the IP register.

2. T2CON – Timer/Counter 2 Control Register

T2CON Address = 0C8H

Reset Value = 0000 0000B

Bit Addressable

Bit	TF2	EXF2	RCLK	TCLK	EXEN2	TR2	C/T2	CP/RL2
7								
6								
5								
4								
3								
2								
1								
0								

Bit	Function
7	Timer 2 overflow flag set by a Timer 2 overflow and must be cleared by software. TF2 will not be set when either RCLK = 1 or TCLK = 1.
6	Timer 2 external flag set when either a capture or reload is caused by a negative transition on T2EX and EXEN2 = 1. When Timer 2 interrupt is enabled, EXF2 = 1 will cause the CPU to vector to the Timer 2 interrupt routine. EXF2 must be cleared by software. EXF2 does not cause an interrupt in up/down counter mode (DCEN = 1).
5	Receive clock enable. When set, causes the serial port to use Timer 2 overflow pulses for its receive clock in serial port Modes 1 and 3. RCLK = 0 causes Timer 1 overflow to be used for the receive clock.
4	Transmit clock enable. When set, causes the serial port to use Timer 2 overflow pulses for its transmit clock in serial port Modes 1 and 3. TCLK = 0 causes Timer 1 overflows to be used for the transmit clock.
3	Timer 2 external enable. When set, allows a capture or reload to occur as a result of a negative transition on T2EX if Timer 2 is not being used to clock the serial port. EXEN2 = 0 causes Timer 2 to ignore events at T2EX.
2	Start/Stop control for Timer 2. TR2 = 1 starts the timer.
1	Timer or counter select for Timer 2. C/T2 = 0 for timer function. C/T2 = 1 for external event counter (falling edge triggered).
0	Capture/Reload select. CP/RL2 = 1 causes captures to occur on negative transitions at T2EX if EXEN2 = 1. CP/RL2 = 0 causes automatic reloads to occur when Timer 2 overflows or negative transitions occur at T2EX when EXEN2 = 1. When either RCLK or TCLK = 1, this bit is ignored and the timer is forced to auto-reload on Timer 2 overflow.



3a. AUXR: Auxiliary Register

Address = 8EH Reset Value = XXX00X00B

Not Bit Addressable

	—	—	—	WDIDLE	DISRTO	—	EXTRAM	DISALE
Bit	7	6	5	4	3	2	1	0

Reserved for future expansion

.E Disable/Enable ALE

DISALE Operating Mode

0 ALE is emitted at a constant rate of 1/6 the oscillator frequency

1 ALE is active only during a MOVX or MOVC instruction

AM Internal External RAM (00H-FFH) access using MOVX @ Ri/DPTR

EXTRAM Operating Mode

0 Internal ERAM (00H-FFH) access using MOVX @ Ri/DPTR

1 External data memory access

O Disable/Enable Reset out

DISRTO

0 Reset pin is driven High after WDT times out

1 Reset pin is input only

.E Disable/Enable WDT in IDLE mode

WDIDLE

0 WDT continues to count in IDLE mode

1 WDT halts counting in IDLE mode

Data Pointer Registers: To facilitate accessing both internal and external data memory, two banks of 16-bit Data Pointer Registers are provided: DP0 at SFR address is 82H-83H and DP1 at 84H-85H. Bit DPS = 0 in AUXR1 selects DP0 and DPS = 1 selects DP1. The user should always initialize the DPS bit to the appropriate

value before accessing the respective Data Pointer Register.

Power Off Flag: The Power Off Flag (POF) is located at bit 4 (PCON.4) in the PCON SFR. POF is set to "1" during power up. It can be set and reset under software control and is not affected by reset.

b. AUXR1: Auxiliary Register 1

Address = A2H

Reset Value = XXXXXXX0B

Not Bit Addressable

	—	—	—	—	—	—	—	DPS
Bit	7	6	5	4	3	2	1	0

Reserved for future expansion

Data Pointer Register Select

DPS

0 Selects DPTR Registers DP0L, DP0H

1 Selects DPTR Registers DP1L, DP1H

AT89C51RC

Memory Organization

51 devices have a separate address space for Program and Data Memory. Up to 64K bytes each of external Program and Data Memory can be addressed.

Program Memory

EA pin is connected to GND, all program fetches are directed to external memory.

For AT89C51RC, if EA is connected to V_{CC}, program fetches to addresses 0000H through 7FFFH are directed to internal memory and fetches to addresses 8000H through FFFFH are to external memory.

Data Memory

AT89C51RC has internal data memory that is mapped in separate segments: the lower 128 bytes of RAM, 128 bytes of RAM, 128 bytes special function registers (SFRs) and 256 bytes expanded RAM (ERAM).

These segments are:

- Lower 128 bytes of RAM (addresses 00H to 7FH) are directly and indirectly addressable.
- Upper 128 bytes of RAM (addresses 80H to FFH) are indirectly addressable only.
- Special Function Registers, SFRs, (addresses 00H to FFH) are directly addressable only.
- 256-byte expanded RAM (ERAM, 00H-FFH) is directly accessed by MOVX instructions, and with EXTRAM bit cleared.

Lower 128 bytes can be accessed by either direct or indirect addressing. The Upper 128 bytes can be accessed by indirect addressing only. The Upper 128 bytes occupy the same address space as the SFRs. This means they have the same address, but are physically separate from SFR space.

An instruction accesses an internal location above 7FH, the CPU knows whether the access is to the lower 128 bytes of data RAM or to SFR space by the addressing mode used in the instruction. Instructions that use direct addressing access SFR space. For example:

```
MOVB 0A0H, # data
```

Accesses the SFR at location 0A0H (which is P2). Instructions that use indirect addressing access the Upper 128 bytes of data RAM. For example:

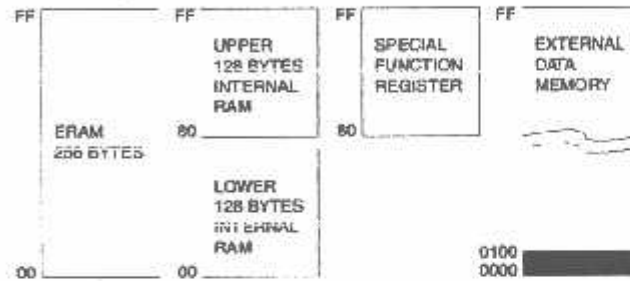
```
MOVX @R0, # data
```

If R0 contains 0A0H, accesses the data byte at 0A0H, rather than P2 (whose address is 0A0H).

Note that stack operations are examples of indirect addressing, so the upper 128 bytes of data RAM are available as stack space.

The 256 bytes of ERAM can be accessed by indirect addressing, with EXTRAM bit cleared and MOVX instructions. This part of memory is physically located on-chip, logically occupying the first 256 bytes of external data memory.

Figure 1. Internal and External Data Memory Address (with EXTRAM = 0)



With EXTRAM = 0, the ERAM is indirectly addressed, using the MOVX instruction in combination with any of the registers R0, R1 of the selected bank or DPTR. An access to ERAM will not affect ports P0, P2, P3.6 (WR), and P3.7 (RD). For example, with EXTRAM = 0,

```
MOVX @R0, # data
```

where R0 contains 0A0H, accesses the ERAM at address 0A0H rather than external memory. An access to external data memory locations higher than FFH (i.e. 0100H to FFFFH) will be performed with the MOVX DPTR instructions in the same way as in the standard MCS-51, i.e., with P0 and P2 as data/address bus, and P3.6 and P3.7 as write and read timing signals. Refer to Figure 1.

With EXTRAM = 1, MOVX @Ri and MOVX@DPTR will be similar to the standard MCS-51. MOVX@Ri will provide an 8-bit address multiplexed with data on Port 0 and any output port pins can be used to output higher-order address bits. This is to provide the external paging capability. MOVX@DPTR will generate a 16-bit address. Port 2 outputs the high-order 8 address bits (the contents of DP0H), while Port 0 multiplexes the low-order 8 address bits (the contents of DP0L) with data. MOVX@Ri and MOVX@DPTR will generate either read or write signals on P3.6 (WR) and P3.7 (RD).

The stack pointer (SP) may be located anywhere in the 256 bytes RAM (lower and upper RAM) internal data memory. The stack may not be located in the ERAM.



Low-Power Watchdog Timer (Time Enabled with Reset-out)

The WDT is intended as a recovery method in situations where the CPU may be subjected to software upsets. The WDT consists of a 14-bit counter and the WatchDog Timer (WDTRST) SFR. The WDT is defaulted to disable exiting reset. To enable the WDT, a user must write 01EH and 0E1H in sequence to the WDTRST register (SFR location 0A6H). When the WDT is enabled, it will increment every machine cycle while the oscillator is running. There is no way to disable the WDT except through either hardware reset or WDT overflow reset. When it overflows, it will drive an output RESET HIGH pulse at the RST pin.

Enabling the WDT

To enable the WDT, a user must write 01EH and 0E1H in sequence to the WDTRST register (SFR location 0A6H). Once the WDT is enabled, the user needs to service it by writing 01EH and 0E1H to WDTRST to avoid a WDT overflow. The 14-bit counter overflows when it reaches 16383 (0x3FFF), and this will reset the device. When the WDT is disabled, it will increment every machine cycle while the oscillator is running. This means the user must reset the WDT at least every 16383 machine cycles. To reset the WDT, the user must write 01EH and 0E1H to WDTRST. WDTRST is a write-only register. The WDT counter cannot be read or written. When WDT overflows, it will generate an RESET pulse at the RST pin. The RESET pulse width is 98xTOSC, where TOSC=1/FOSC. To make the most use of the WDT, it should be serviced in those sections of code that will periodically be executed within the application to prevent a WDT reset.

During Power-down and Idle

In Power-down mode the oscillator stops, which means the WDT also stops. While in Power-down mode, the user must still need to service the WDT. There are two methods of servicing the WDT in Power-down mode: by a hardware reset or via a configured external interrupt which is enabled prior to entering Power-down mode. When Power-down is exited, either through hardware reset, servicing the WDT should occur as it does whenever the AT89C51RC is reset. Exiting Power-down with an interrupt is significantly different. The interrupt pin is held low long enough for the oscillator to stabilize. When the interrupt is brought high, the interrupt is serviced. To prevent the WDT from resetting the device while the interrupt pin is held low, the WDT is not started until the interrupt pin is pulled high. It is suggested that the WDT be serviced during the interrupt service for the interrupt used to exit Power-down mode.

To ensure that the WDT does not overflow within a few states of exiting Power-down, it is best to reset the WDT just before entering Power-down mode.

Before going into the IDLE mode, the WDIDLE bit in SFR AUXR is used to determine whether the WDT continues to count if enabled. The WDT keeps counting during IDLE (WDIDLE bit = 0) as the default state. To prevent the WDT from resetting the AT89C51RC while in IDLE mode, the user should always set up a timer that will periodically exit IDLE, service the WDT, and reenter IDLE mode.

With WDIDLE bit enabled, the WDT will stop to count in IDLE mode and resumes the count upon exit from IDLE.

UART

The UART in the AT89C51RC operates the same way as the UART in the AT89C51 and AT89C52. For further information, see the December 1997 Microcontroller Data Book, page 2-48, section titled, "Serial Interface".

Timer 0 and 1

Timer 0 and Timer 1 in the AT89C51RC operate the same way as Timer 0 and Timer 1 in the AT89C51 and AT89C52.

Timer 2

Timer 2 is a 16-bit Timer/Counter that can operate as either a timer or an event counter. The type of operation is selected by bit C/T2 in the SFR T2CON (shown in Table 2). Timer 2 has three operating modes: capture, auto-reload (up or down counting), and baud rate generator. The modes are selected by bits in T2CON, as shown in Table 4. Timer 2 consists of two 8-bit registers, TH2 and TL2. In the Timer function, the TL2 register is incremented every machine cycle. Since a machine cycle consists of 12 oscillator periods, the count rate is 1/12 of the oscillator frequency.

Table 4. Timer 2 Operating Modes

RCLK +TCLK	CP/RL2	TR2	MODE
0	0	1	16-bit Auto-reload
0	1	1	16-bit Capture
1	X	1	Baud Rate Generator
X	X	0	(Off)

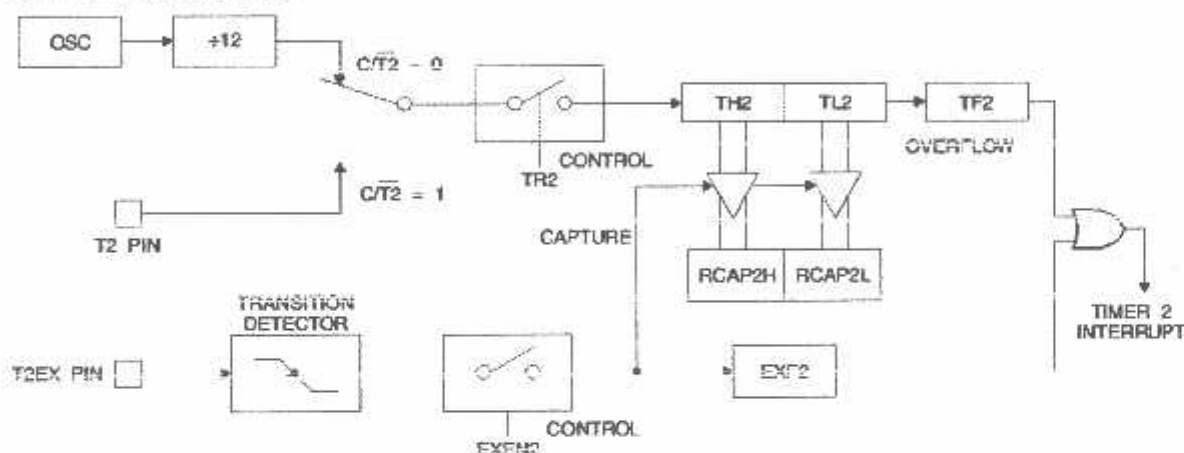
In the Counter function, the register is incremented in response to a 1-to-0 transition at its corresponding external input pin, T2. In this function, the external input is sampled during S5P2 of every machine cycle. When the samples show a high in one cycle and a low in the next cycle, the count is incremented. The new count value appears in the register during S5P1 of the cycle following the one in which

nition was detected. Since two machine cycles (24
tor periods) are required to recognize a 1-to-0 transi-
ie maximum count rate is 1/24 of the oscillator fre-
y. To ensure that a given level is sampled at least
efore it changes, the level should be held for at least
1 machine cycle.

ire Mode

capture mode, two options are selected by bit 2 in T2CON. If EXEN2 = 0, Timer 2 is a 16-bit timer counter which upon overflow sets bit TF2 in T2CON. It can then be used to generate an interrupt. If EXEN2 = 1, Timer 2 performs the same operation, but a transition at external input T2EX also causes the

2. Timer in Capture Mode



3 shows Timer 2 automatically counting up when 0. In this mode, two options are selected by bit 1 in T2CON. If EXEN2 = 0, Timer 2 counts up to 4 and then sets the TF2 bit upon overflow. The 7 also causes the timer registers to be reloaded with bit value in RCAP2H and RCAP2L. The values in 1 Capture Mode RCAP2H and RCAP2L are preset rare. If EXEN2 = 1, a 16-bit reload can be triggered y an overflow or by a 1-to-0 transition at external EX. This transition also sets the EXF2 bit. Both the 1 EXF2 bits can generate an interrupt if enabled.

The DCEN bit enables Timer 2 to count up or down, as shown in Figure 3. In this mode, the T2EX pin controls

current value in TH2 and TL2 to be captured into RCAP2H and RCAP2L, respectively. In addition, the transition at T2EX causes bit EXF2 in T2CON to be set. The EXF2 bit, like TF2, can generate an interrupt. The capture mode is illustrated in Figure 2.

Auto-Reload (Up or Down Counter)

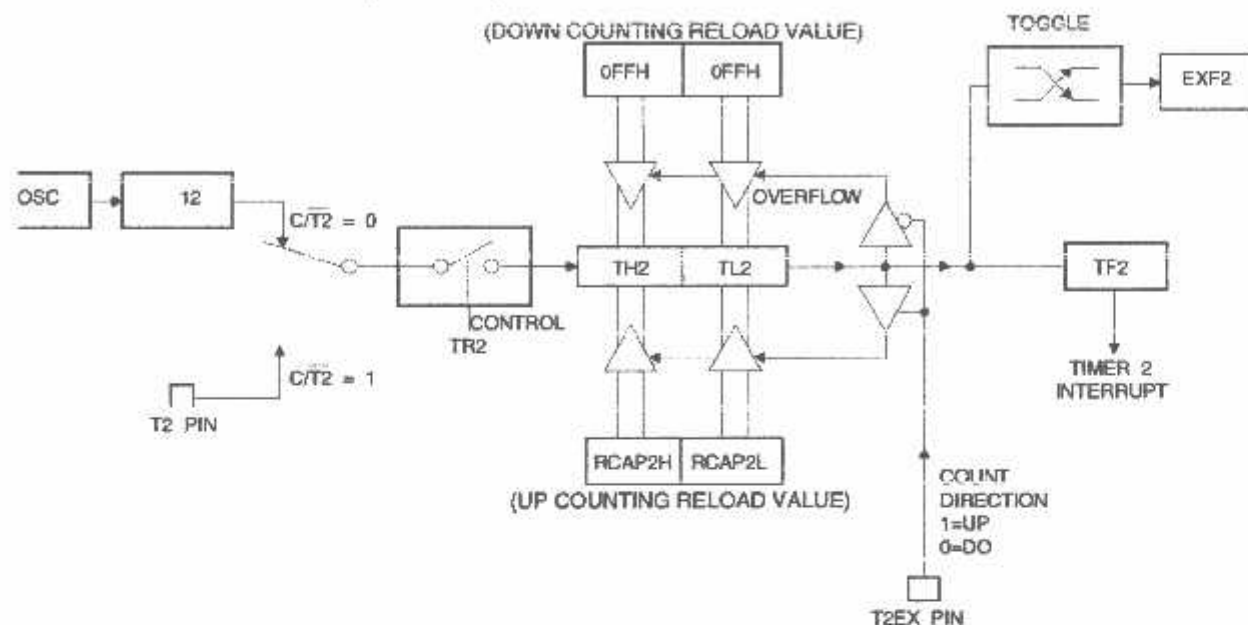
Timer 2 can be programmed to count up or down when configured in its 16-bit auto-reload mode. This feature is invoked by the DCEN (Down Counter Enable) bit located in the SFR T2MOD (see Table 5). Upon reset, the DCEN bit is set to 0 so that timer 2 will default to count up. When DCEN is set, Timer 2 can count up or down, depending on the value of the T2EX pin.

the direction of the count. A logic 1 at T2EX makes Timer 2 count up. The timer will overflow at 0FFFFH and set the TF2 bit. This overflow also causes the 16-bit value in RCAP2H and RCAP2L to be reloaded into the timer registers, TH2 and TL2, respectively.

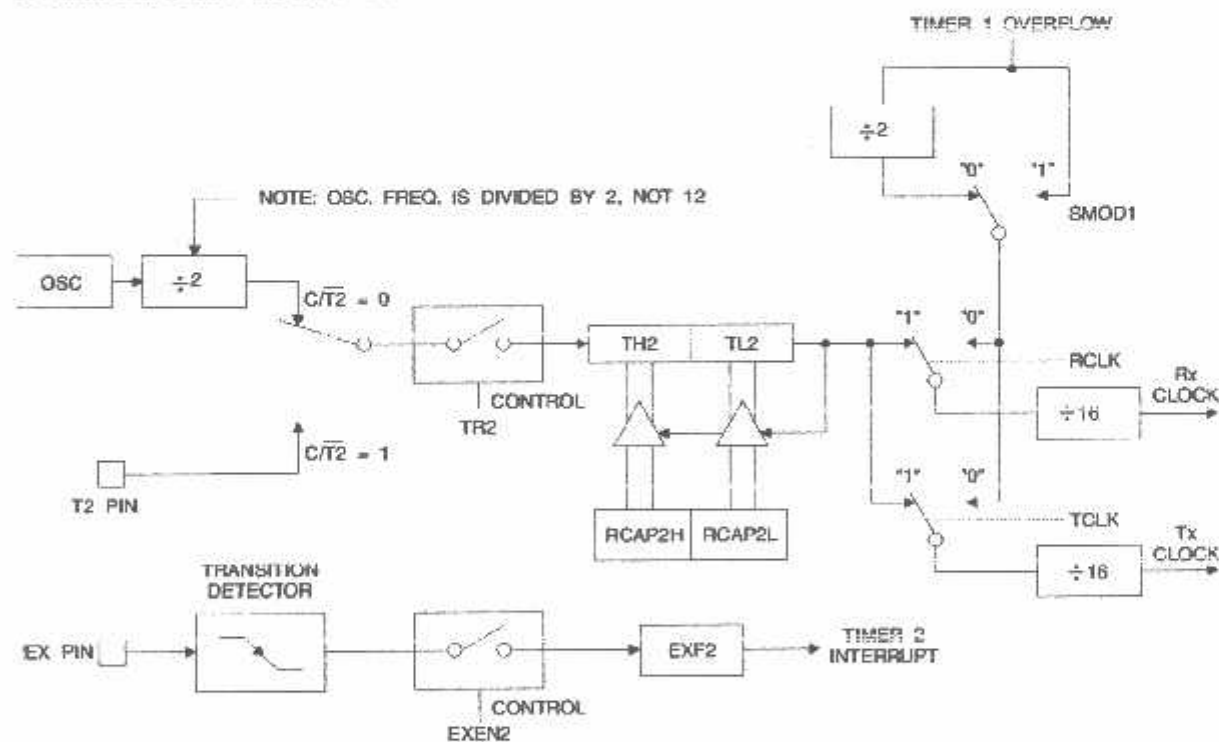
A logic 0 at T2EX makes Timer 2 count down. The timer underflows when TH2 and TL2 equal the values stored in RCAP2H and RCAP2L. The underflow sets the TF2 bit and causes 0FFFFH to be reloaded into the timer registers.

The EXF2 bit toggles whenever Timer 2 overflows or underflows and can be used as a 17th bit of resolution. In this operating mode, EXF2 does not flag an interrupt.

4. Timer 2 Auto Reload Mode (DCEN = 1)



5. Timer 2 in Baud Rate Generator Mode



Rate Generator

2 is selected as the baud rate generator by setting and/or RCLK in T2CON (Table 2). Note that the rates for transmit and receive can be different if Timer 2 is used for the receiver or transmitter and Timer 1 is used for other function. Setting RCLK and/or TCLK puts Timer 2 into its baud rate generator mode, as shown in Table 2.

Reload rate generator mode is similar to the auto-reload in that a rollover in TH2 causes the Timer 2 registers loaded with the 16-bit value in registers RCAP2H and RCAP2L, which are preset by software.

ud rates in Modes 1 and 3 are determined by Timer
rflow rate according to the following equation.

$$\text{5, 1 and 3 Baud Rates} = \frac{\text{Timer 2 Overflow Rate}}{16}$$

ner can be configured for either timer or counter operation. In most applications, it is configured for timer operation ($CP/T2 = 0$). The timer operation is different from when it is used as a baud rate generator. Normally, the timer increments every machine cycle (at $1/2$ the crystal frequency). As a baud rate generator, however, it

increments every state time (at 1/2 the oscillator frequency). The baud rate formula is given below.

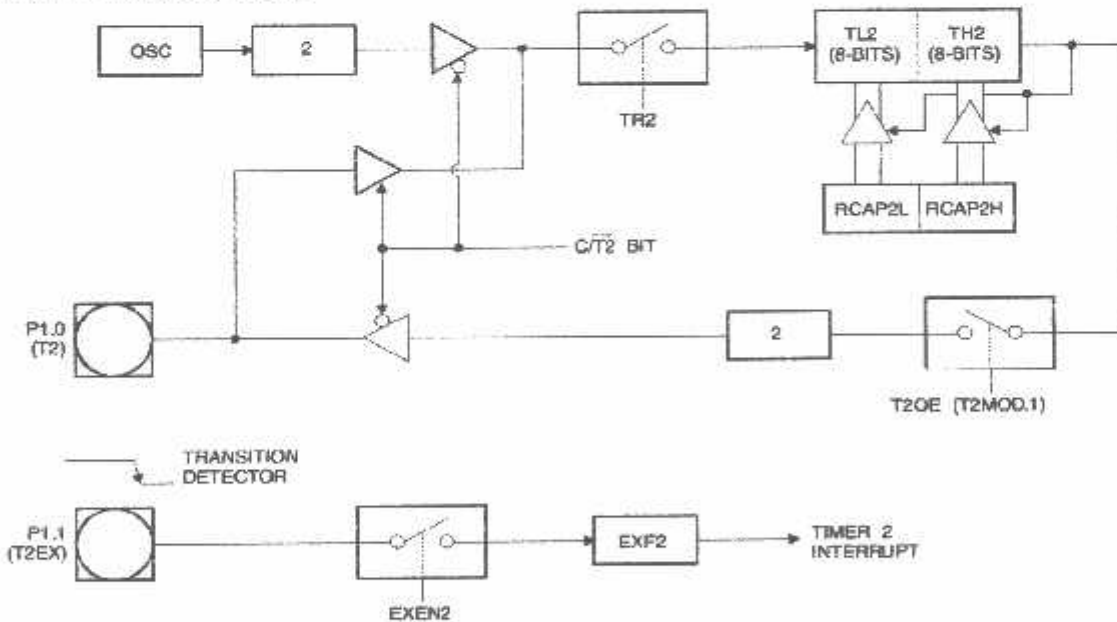
$$\frac{\text{Modes 1 and 3}}{\text{Baud Rate}} = \frac{\text{Oscillator Frequency}}{32 \times (65536 - \text{RCAP2H}, \text{RCAP2L})}$$

where (RCAP2H, RCAP2L) is the content of RCAP2H and RCAP2L taken as a 16-bit unsigned integer.

Timer 2 as a baud rate generator is shown in Figure 5. This figure is valid only if RCLK or TCLK = 1 in T2CON. Note that a rollover in TH2 does not set TF2 and will not generate an interrupt. Note too, that if EXEN2 is set, a 1-to-0 transition in T2EX will set EXP2 but will not cause a reload from (RCAP2H, RCAP2L) to (TH2, TL2). Thus when Timer 2 is in use as a baud rate generator, T2EX can be used as an extra external interrupt.

Note that when Timer 2 is running ($TR2 = 1$) as a timer in the baud rate generator mode, TH2 or TL2 should not be read from or written to. Under these conditions, the Timer is incremented every state time, and the results of a read or write may not be accurate. The RCAP2 registers may be read but should not be written to, because a write might overlap a reload and cause write and/or reload errors. The timer should be turned off (clear TR2) before accessing the Timer 2 or RCAP2 registers.

5. Timer 2 in Clock-Out Mode



Programmable Clock Out

A 50% duty cycle clock can be programmed to come out on pin 1, besides being a regular pin, has two alternate functions. It can be programmed to input the external clock for Timer/Counter 2 or output a 50% duty cycle clock ranging from 61 Hz to 4 kHz at a 16 MHz operating frequency.

Configure the Timer/Counter 2 as a clock generator, bit T2CON.1 must be cleared and bit T2OE (T2MOD.1) be set. Bit TR2 (T2CON.2) starts and stops the timer. Clock-out frequency depends on the oscillator frequency and the reload value of Timer 2 capture registers 2H, RCAP2L, as shown in the following equation.

$$\text{Clock-Out Frequency} = \frac{\text{Oscillator Frequency}}{4 \times [65536 - (RCAP2H, RCAP2L)]}$$

In clock-out mode, Timer 2 roll-overs will not generate an interrupt. This behavior is similar to when Timer 2 is used as a baud-rate generator. It is possible to use Timer 2 as a baud-rate generator and a clock generator simultaneously. Note, however, that the baud-rate and clock-out frequencies cannot be determined independently from one another since they both use RCAP2H and RCAP2L.

Interrupts

The AT89C51RC has a total of six interrupt vectors, two external interrupts (INT0 and INT1), three timer interrupts (Timer 0, 1, and 2), and the serial port interrupt. These interrupts are all shown in Figure 7.

Each of these interrupt sources can be individually enabled or disabled by setting or clearing a bit in the Special Function Register IE. IE also contains a global disable bit, EA, which disables all interrupts at once.

As Table 5 shows that bit position IE.6 is unimplemented in the AT89C51RC, bit position IE.5 is also unimplemented. User software should not write 1s to these bits, since they may be used in future AT89 products. The interrupt is generated by the logical OR of bits TF2, TF1, and EXF2 in register T2CON. Neither of these flags is set by hardware when the service routine is vectored to it, the service routine may have to determine if it was TF2 or EXF2 that generated the interrupt, and the bit will have to be cleared in software.

Timer 0 and Timer 1 flags, TF0 and TF1, are set at the end of the cycle in which the timers overflow. The values are polled by the circuitry in the next cycle. However, for Timer 2 flag, TF2, is set at S2P2 and is polled in the next cycle in which the timer overflows.

Table 5. Interrupt Enable (IE) Register

(MSB)
(LSB)

EA	—	ET2	ES	ET1	EX1	ET0	EX0
----	---	-----	----	-----	-----	-----	-----

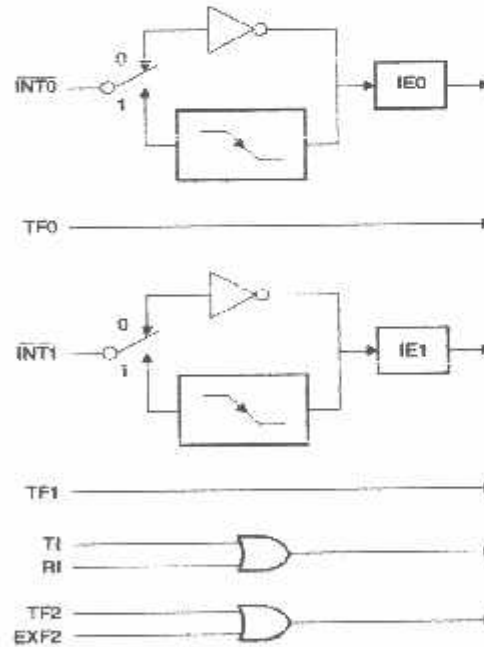
Enable Bit = 1 enables the interrupt.

Enable Bit = 0 disables the interrupt.

Symbol	Position	Function
EA	IE.7	Disables all interrupts. If EA = 0, no interrupt is acknowledged. If EA = 1, each interrupt source is individually enabled or disabled by setting or clearing its enable bit.
—	IE.6	Reserved.
ET2	IE.5	Timer 2 interrupt enable bit.
ES	IE.4	Serial Port interrupt enable bit.
ET1	IE.3	Timer 1 interrupt enable bit.
EX1	IE.2	External interrupt 1 enable bit.
ET0	IE.1	Timer 0 interrupt enable bit.
EX0	IE.0	External interrupt 0 enable bit.

User software should never write 1s to unimplemented bits, because they may be used in future AT89 products.

Figure 7. Interrupt Sources



Oscillator Characteristics

and XTAL2 are the input and output, respectively, inverting amplifier that can be configured for use as chip oscillator, as shown in Figure 8. Either a quartz or ceramic resonator may be used. To drive the from an external clock source, XTAL2 should be left unconnected while XTAL1 is driven, as shown in Figure 9. There are no requirements on the duty cycle of the external signal, since the input to the internal clocking circuitry is a divide-by-two flip-flop, but minimum and maximum high and low time specifications must be added.

Idle Mode

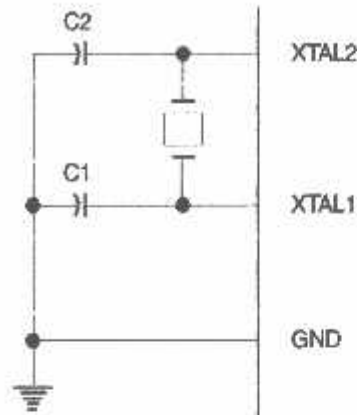
In idle mode, the CPU puts itself to sleep while all the on-chip peripherals remain active. The mode is invoked by executing the content of the on-chip RAM and all the special function registers remain unchanged during this mode. The idle mode can be terminated by any enabled interrupt or by a hardware reset.

When idle mode is terminated by a hardware reset, the device normally resumes program execution where it left off, up to two machine cycles before the reset algorithm takes control. On-chip hardware access to internal RAM in this event, but access to I/O pins is not inhibited. To eliminate the possibility of unexpected writes to a port pin when idle mode is terminated by a reset, the instruction following the one that enters idle mode should not write to a port pin or to external memory.

Power-down Mode

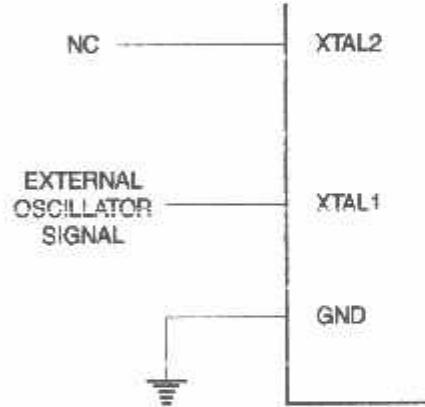
In power-down mode, the oscillator is stopped, and the on-chip oscillator is the last instruction executed. The on-chip RAM and Special Function Registers retain their values until the Power-down mode is terminated. Exit from Power-down can be initiated either by a hardware reset or by an enabled external interrupt. Reset resets the SFRs but does not change the on-chip RAM. It should not be activated before V_{CC} is restored to its normal operating level and must be held active long enough to allow the oscillator to restart and stabilize.

Figure 8. Oscillator Connections



Note: C1, C2 = 30 pF $\pm$ 10 pF for Crystals
= 40 pF $\pm$ 10 pF for Ceramic Resonators

Figure 9. External Clock Drive Configuration



Status of External Pins During Idle and Power-down Modes

	Program Memory	ALE	PSEN	PORT0	PORT1	PORT2	PORT3
	Internal	1	1	Data	Data	Data	Data
	External	1	1	Float	Data	Address	Data
Power-down	Internal	0	0	Data	Data	Data	Data
Power-down	External	0	0	Float	Data	Data	Data

Program Memory Lock Bits

AT89C51RC has three lock bits that can be left unprogrammed (U) or can be programmed (P) to obtain the additional features listed in the following table.

1. Lock Bit Protection Modes

Program Lock Bits			Protection Type
LB1	LB2	LB3	
U	U	U	No program lock features
P	U	U	MOVX instructions executed from external program memory are disabled from fetching code bytes from internal memory, EA is sampled and latched on reset, and further programming of the Flash memory is disabled
P	P	U	Same as mode 2, but verify is also disabled
P	P	P	Same as mode 3, but external execution is also disabled

Lock bit 1 is programmed, the logic level at the EA pin is latched and latched during reset. If the device is powered without a reset, the latch initializes to a random level and holds that value until reset is activated. The value of EA must agree with the current logic level in order for the device to function properly.

Programming the Flash

AT89C51RC is shipped with the on-chip Flash memory ready to be programmed. The programming interface is a high-voltage (12-volt) program enable signal compatible with conventional third-party Flash programmers.

AT89C51RC code memory array is programmed byte-by-byte.

Programming Algorithm: Before programming the AT89C51RC, the address, data, and control signals should be set according to the Flash programming mode table in Figures 10 and 11. To program the AT89C51RC, take the following steps:

1. Set the desired memory location on the address lines.
2. Set the appropriate data byte on the data lines.

3. Activate the correct combination of control signals.
4. Raise $\overline{EA}/V_{PP}$ to 12V.
5. Pulse ALE/PROG once to program a byte in the Flash array or the lock bits. The byte-write cycle is self-timed and typically takes no more than 50 μ s. Repeat steps 1 through 5, changing the address and data for the entire array or until the end of the object file is reached.

Chip Erase Sequence: Before the AT89C51RC can be reprogrammed, a Chip Erase operation needs to be performed. To erase the contents of the AT89C51RC, follow this sequence:

1. Pulse ALE/PROG once and wait for 150 ms.
2. Power the device down and up again.
3. Pulse ALE/PROG once again and wait for 150 ms.
4. Power the device down and up again.

Data Polling: The AT89C51RC features Data Polling to indicate the end of a write cycle. During a write cycle, an attempted read of the last byte written will result in the complement of the written data on P0.7. Once the write cycle has been completed, true data is valid on all outputs, and the next cycle may begin. Data Polling may begin any time after a write cycle has been initiated.

Ready/Busy: The progress of byte programming can also be monitored by the RDY/BSY output signal. P3.0 is pulled low after ALE goes high during programming to indicate BUSY. P3.0 is pulled high again when programming is done to indicate READY.

Program Verify: If lock bits LB1 and LB2 have not been programmed, the programmed code data can be read back via the address and data lines for verification. The lock bits cannot be verified directly. Verification of the lock bits is achieved by observing that their features are enabled.

Reading the Signature Bytes: The signature bytes are read by the same procedure as a normal verification of locations 000H, 100H, and 200H, except that P3.6 and P3.7 must be pulled to a logic low. The values returned are as follows:

- (000H) = 1EH indicates manufactured by Atmel
- (100H) = 51H
- (200H) = 07H indicates 89C51RC



Programming Interface

code byte in the Flash array can be programmed by the appropriate combination of control signals. The operation cycle is self-timed and once initiated, will automatically time itself to completion.

All major programming vendors offer worldwide support for the Atmel microcontroller series. Please contact your local programming vendor for the appropriate software revision.

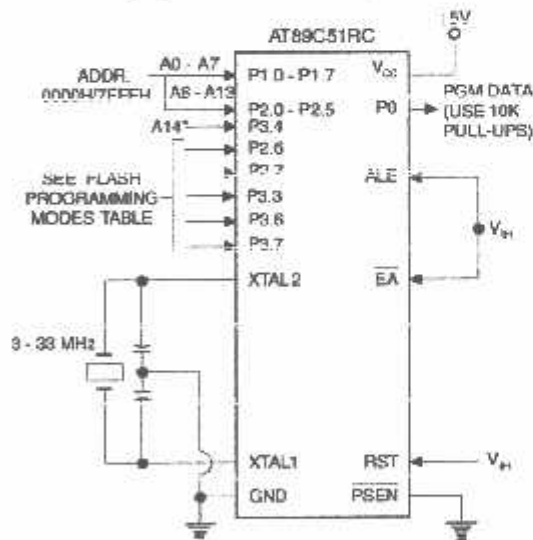
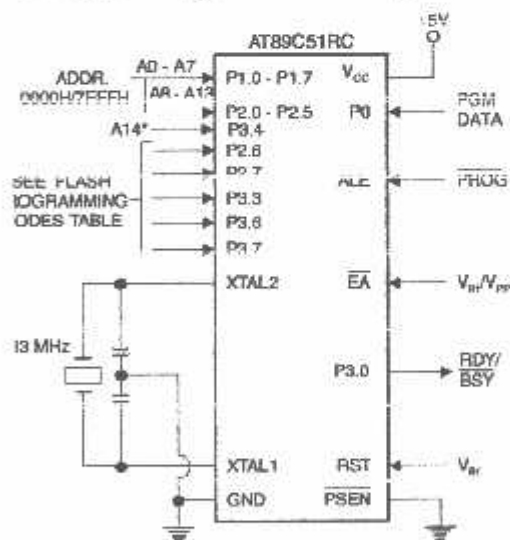
1. Flash Programming Modes

	V _{cc}	RST	PSEN	ALE/ PROG	EA/ V _{pp}	P2.6	P2.7	P3.3	P3.6	P3.7	P0.7-0 Data	P3.4	P2.5-0	P1.7-0
												Address		
Code Data	5 V	H	L		12 V	L	H	H	H	H	D _{IN}	A14	A13-8	A7-0
Code Data	5 V	H	L	H	H/12V	L	L	L	H	H	D _{OUT}	A14	A13-8	A7-0
Lock Bit 1	6.5 V	H	L		12 V	H	H	H	H	H	X	X	X	X
Lock Bit 2	6.5 V	H	L		12 V	H	H	H	L	L	X	X	X	X
Lock Bit 3	6.5 V	H	L		12 V	H	L	H	H	L	X	X	X	X
Lock Bits	5 V	H	L	H	H	H	H	L	H	L	D2, 3, 4	X	X	X
Erase	6.5V	H	L		12V	H	L	H	L	L	X	X	X	X
Device ID	5 V	H	L	H	H	L	L	L	L	L	1EH	X	X	000H
Device ID	5 V	H	L	H	H	L	L	L	L	L	51H	X	X	100H
Device ID	5 V	H	L	H	H	L	L	L	L	L	07H	X	X	200H

1. Write Code Data requires a 200 ns $\overline{\text{PROG}}$ pulse.
2. Write Lock Bits requires a 100 μs $\overline{\text{PROG}}$ pulse.
3. Chip Erase requires a 200 ns - 500 ns $\overline{\text{PROG}}$ pulse.
4. RDY/BSY signal is output on P3.0 during programming.

10. Programming the Flash Memory

Figure 11. Verifying the Flash Memory



Programming address line A14 (P3.4) is not the same as the external memory address line A14 (P2.6).

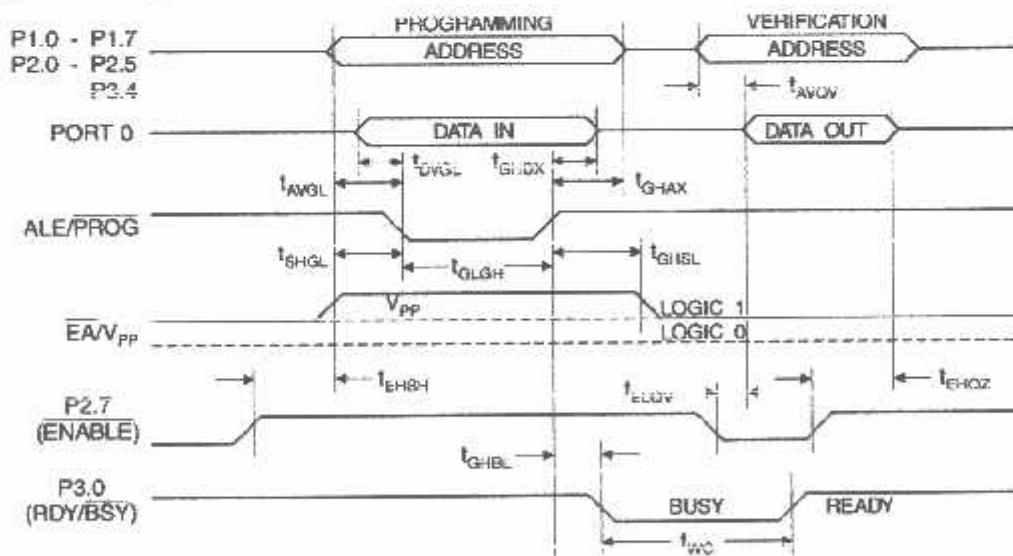
AT89C51RC

1 Programming and Verification Characteristics

1°C to 30°C, $V_{CC} = 4.5V$ to $5.5V$

SI	Parameter	Min	Max	Units
	Programming Supply Voltage	11.5	12.5	V
	Programming Supply Current		10	mA
	V _{CC} Supply Current		30	mA
	Oscillator Frequency	3	33	MHz
	Address Setup to $\overline{\text{PROG}}$ Low	48t _{CLCL}		
	Address Hold after $\overline{\text{PROG}}$	48t _{CLCL}		
	Data Setup to $\overline{\text{PROG}}$ Low	48t _{CLCL}		
	Data Hold after $\overline{\text{PROG}}$	48t _{CLCL}		
	P2.7 (ENABLE) High to V _{pp}	48t _{CLCL}		
	V _{pp} Setup to $\overline{\text{PROG}}$ Low	10		μs
	V _{pp} Hold after $\overline{\text{PROG}}$	10		μs
	$\overline{\text{PROG}}$ Width	0.2	1	μs
	Address to Data Valid		48t _{CLCL}	
	ENABLE Low to Data Valid		48t _{CLCL}	
	Data Float after ENABLE	0	48t _{CLCL}	
	$\overline{\text{PROG}}$ High to BUSY Low		1.0	μs
	Byte Write Cycle Time		80	μs

Programming and Verification Waveforms





Absolute Maximum Ratings*

Storage Temperature.....	-55°C to +125°C
Operating Temperature	-65°C to +150°C
Voltage on Any Pin with respect to Ground	-1.0V to +7.0V
Maximum Operating Voltage	6.6V
Maximum Output Current.....	15.0 mA

*NOTICE: Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Electrical Characteristics

Values shown in this table are valid for T_A = -40°C to 85°C and V_{CC} = 4.0V to 5.5V, unless otherwise noted.

Parameter	Condition	Min	Max	Units
Input Low-voltage	(Except EA)	-0.5	0.2 V _{CC} -0.1	V
Input Low-voltage (EA)		-0.5	0.2 V _{CC} -0.3	V
Input High-voltage	(Except XTAL1, RST)	0.2 V _{CC} +0.9	V _{CC} +0.5	V
Input High-voltage	(XTAL1, RST)	0.7 V _{CC}	V _{CC} +0.5	V
Output Low-voltage ⁽¹⁾ (Ports 1,2,3)	I _{OL} = 1.6 mA		0.45	V
Output Low-voltage ⁽¹⁾ (Port 0, ALE, PSEN)	I _{OL} = 3.2 mA		0.45	V
Output High-voltage (Ports 1,2,3, ALE, PSEN)	I _{OHI} = -60 µA, V _{CC} = 5V ± 10%	2.4		V
	I _{OHI} = -25 µA	0.75 V _{CC}		V
	I _{OHI} = -10 µA	0.9 V _{CC}		V
Output High-voltage (Port 0 in External Bus Mode)	I _{OHI} = -800 µA, V _{CC} = 5V ± 10%	2.4		V
	I _{OHI} = -300 µA	0.75 V _{CC}		V
	I _{OHI} = -80 µA	0.9 V _{CC}		V
Logical 0 Input Current (Ports 1,2,3)	V _{IN} = 0.45V		-50	µA
Logical 1 to 0 Transition Current (Ports 1,2,3)	V _{IN} = 2V, V _{CC} = 5V ± 10%		-850	µA
Input Leakage Current (Port 0, EA)	0.45 < V _{IN} < V _{CC}		±10	µA
Reset Pull-down Resistor		50	300	KΩ
Pin Capacitance	Test Freq. = 1 MHz, T _A = 25°C		10	pF
Power Supply Current	Active Mode, 12 MHz		25	mA
	Idle Mode, 12 MHz		8.5	mA
Power-down Mode ⁽¹⁾	V _{CC} = 5.5V		100	µA

1. Under steady state (non-transient) conditions, I_{OL} must be externally limited as follows:
Maximum I_{OL} per port pin: 10 mA
Maximum I_{OL} per 8-bit port:
Port 0: 26 mA Ports 1, 2, 3: 15 mA
Maximum total I_{OL} for all output pins: 71 mA
If I_{OL} exceeds the test condition, V_{OL} may exceed the related specification. Pins are not guaranteed to sink current greater than the listed test conditions.
2. Minimum V_{CC} for Power-down is 2V.

Characteristics

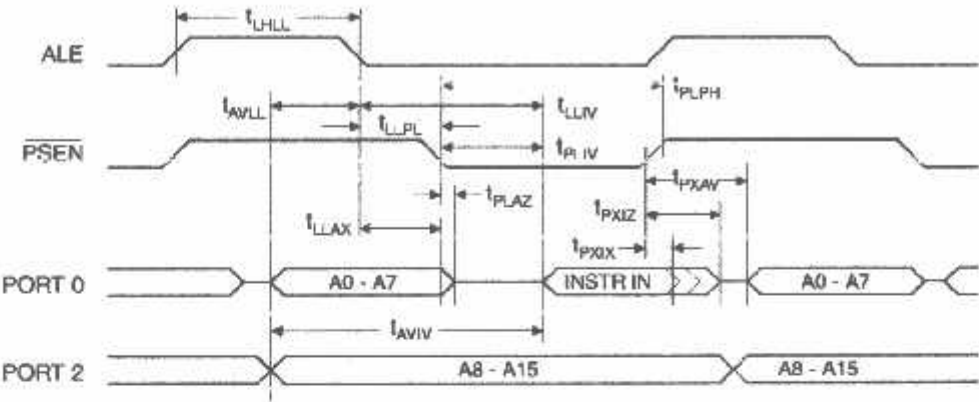
operating conditions, load capacitance for Port 0, ALE/PROG, and PSEN = 100 pF; load capacitance for all other ports = 80 pF.

Normal Program and Data Memory Characteristics

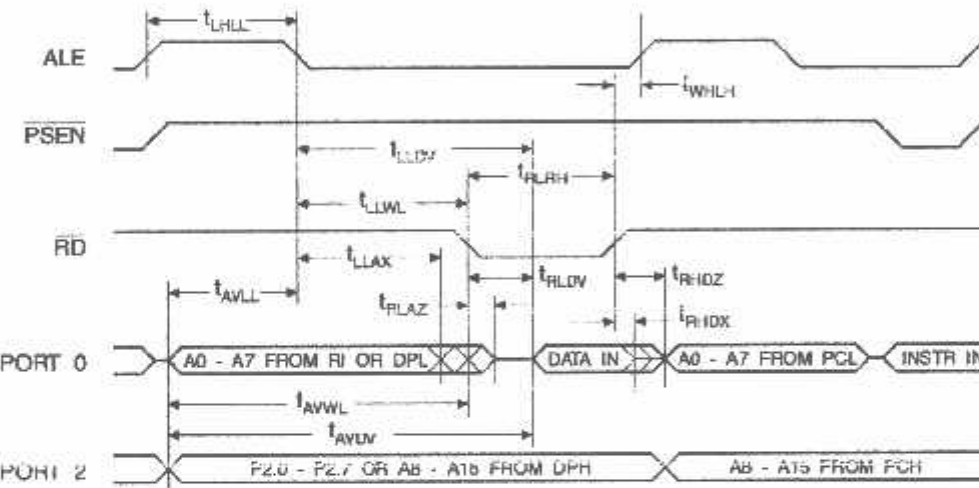
No.	Parameter	12 MHz Oscillator		Variable Oscillator		Units
		Min	Max	Min	Max	
	Oscillator Frequency			0	33	MHz
	ALE Pulse Width	127		$2t_{CLCL}-40$		ns
	Address Valid to ALE Low	43		$t_{CLCL}-25$		ns
	Address Hold after ALE Low	48		$t_{CLCL}-25$		ns
	ALE Low to Valid Instruction In		233		$4t_{CLCL}-65$	ns
	ALE Low to PSEN Low	43		$t_{CLCL}-25$		ns
	PSEN Pulse Width	205		$3t_{CLCL}-45$		ns
	PSEN Low to Valid Instruction In		145		$3t_{CLCL}-60$	ns
	Input Instruction Hold after PSEN	0		0		ns
	Input Instruction Float after PSEN		59		$t_{CLCL}-25$	ns
	PSEN to Address Valid	75		$t_{CLCL}-8$		ns
	Address to Valid Instruction In		312		$5t_{CLCL}-80$	ns
	PSEN Low to Address Float		10		10	ns
	RD Pulse Width	400		$8t_{CLCL}-100$		ns
	WR Pulse Width	400		$6t_{CLCL}-100$		ns
	RD Low to Valid Data In		252		$5t_{CLCL}-90$	ns
	Data Hold after RD	0		0		ns
	Data Float after RD		97		$2t_{CLCL}-28$	ns
	ALE Low to Valid Data In		517		$8t_{CLCL}-150$	ns
	Address to Valid Data In		585		$9t_{CLCL}-165$	ns
	ALE Low to RD or WR Low	200	300	$3t_{CLCL}-50$	$3t_{CLCL}+50$	ns
	Address to RD or WR Low	203		$4t_{CLCL}-75$		ns
	Data Valid to WR Transition	23		$t_{CLCL}-30$		ns
	Data Valid to WR High	433		$7t_{CLCL}-130$		ns
	Data Hold after WR	33		$t_{CLCL}-25$		ns
	RD Low to Address Float		0		0	ns
	RD or WR High to ALE High	43	123	$t_{CLCL}-25$	$t_{CLCL}+25$	ns



nal Program Memory Read Cycle



nal Data Memory Read Cycle



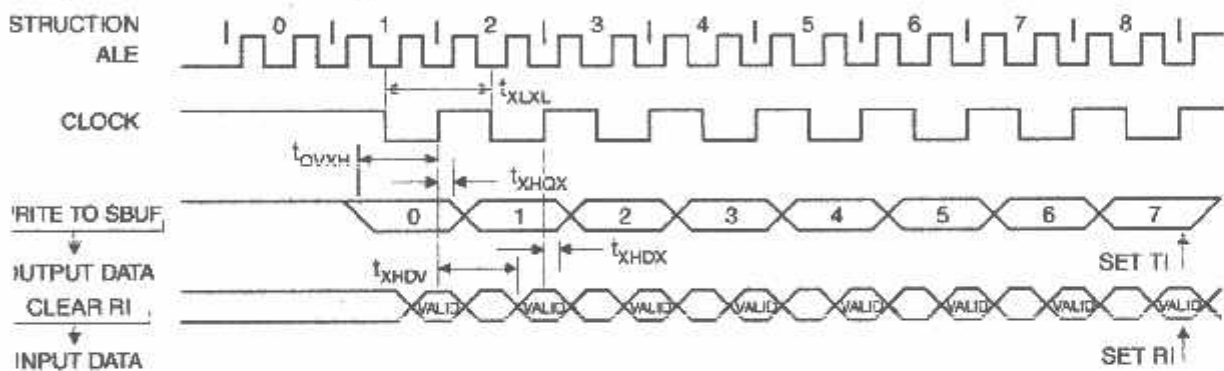


II Port Timing: Shift Register Mode Test Conditions

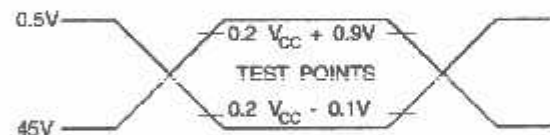
Values in this table are valid for $V_{CC} = 4.0V$ to $5.5V$ and Load Capacitance = 80 pF .

SI	Parameter	12 MHz Osc		Variable Oscillator		Units
		Min	Max	Min	Max	
	Serial Port Clock Cycle Time	1.0		$12t_{CCL}$		μs
	Output Data Setup to Clock Rising Edge	700		$10t_{CCL} - 133$		ns
	Output Data Hold after Clock Rising Edge	50		$2t_{ClG} - 80$		ns
	Input Data Hold after Clock Rising Edge	0		0		ns
	Clock Rising Edge to Input Data Valid		700		$10t_{CCL} - 133$	ns

Register Mode Timing Waveforms

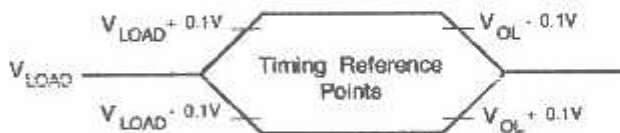


Testing Input/Output Waveforms⁽¹⁾



1. AC Inputs during testing are driven at $V_{CC} - 0.5V$ for a logic 1 and $0.45V$ for a logic 0. Timing measurements are made at V_{IH} min. for a logic 1 and V_{IL} max. for a logic 0.

Float Waveforms⁽¹⁾



- Note: 1. For timing purposes, a port pin is no longer floating when a 100 mV change from load voltage occurs. A port pin begins to float when a 100 mV change from the loaded V_{OH}/V_{OL} level occurs.

Ordering Information

Ordering Code	Power Supply	Ordering Code	Package	Operation Range
	4.0V to 5.5V	AT89C51RC-24AC	44A	Commercial (0°C to 70°C)
		AT89C51RC-24JC	44J	
		AT89C51RC-24PC	40PB	
		AT89C51RC-24AI	44A	Industrial (-40°C to 85°C)
		AT89C51RC-24JI	44J	
		AT89C51RC-24PI	40PB	
	4.5V to 5.5V	AT89C51RC-33AC	44A	Commercial (0°C to 70°C)
		AT89C51RC-33JC	44J	
		AT89C51RC-33PC	40PB	

Shaded area indicates preliminary availability.

Package Type

- 44-lead, Thin Plastic Gull Wing Quad Flatpack (TQFP)
- 44-lead, Plastic J-leaded Chip Carrier (PLCC)
- 40-lead, 0.600" Wide, Plastic Dual In-line Package (PDIP)





AT89C51RC



Atmel Headquarters

Corporate Headquarters
5 Orchard Parkway
Folsom, CA 95631
(408) 441-0311
(408) 487-2600

Atmel U.K., Ltd.
Atmel Business Centre
The Old Waterworks
Berkeley, Surrey GU15 3YL
England
(44) 1276-886-677
(44) 1276-886-697

Atmel Asia, Ltd.
Room 1219
The Metropole Hotel
100 Nathan Road
Tsimshatsui
Kowloon
Hong Kong
(852) 2721-9778
(852) 2722-1369

Atmel Japan K.K.
Fujitsu Shinkawa Bldg.
5F Shinkawa
Chiyoda-ku, Tokyo 104-0033
Japan
(81) 3-3523-3551
(81) 3-3523-7581

Atmel Operations

Atmel Colorado Springs
1150 E. Cheyenne Mtn. Blvd.
Colorado Springs, CO 80906
TEL (719) 576-3300
FAX (719) 540-1759

Atmel Rousset
Zone Industrielle
13106 Rousset Cedex
France
TEL (33) 4-4253-6000
FAX (33) 4-4253-6001

Fax-on-Demand

North America:
1-(800) 292-8635

International:
1-(408) 441-0732

e-mail
literature@atmel.com

Web Site
<http://www.atmel.com>

BBS
1-(408) 436-4309

Atmel Corporation 2000.

Atmel Corporation makes no warranty for the use of its products, other than those expressly contained in the Company's standard warranty which is detailed in Atmel's Terms and Conditions located on the Company's web site. The Company assumes no responsibility for errors which may appear in this document, reserves the right to change devices or specifications detailed herein at any time without notice and does not make any commitment to update the information contained herein. No licenses to patents or other intellectual property are granted by the Company in connection with the sale of Atmel products, expressly or by implication. Atmel's products are not intended for use as critical components in life support devices or systems.

Atmel, Atmel logo and/or [®] are registered trademarks and trademarks of Atmel Corporation.

All other product names in this document may be trademarks of others.



Printed on recycled paper.

1920A-08/00/XM

BC546/547/548/549/550

Switching and Amplifier

- High Voltage: BC546, $V_{CE0}=85V$
- Low Noise: BC549, BC550
- Complement to BC556 ... BC560



NPN Epitaxial Silicon Transistor

Absolute Maximum Ratings $T_a=25^{\circ}C$ unless otherwise noted

Symbol	Parameter	Value	Units
V_{CB0}	Collector-Base Voltage	BC546	80 V
		BC547/550	50 V
		BC548/549	30 V
V_{CE0}	Collector-Emitter Voltage	BC546	85 V
		BC547/550	45 V
		BC548/549	30 V
V_{EB0}	Emitter-Base Voltage	BC546/547	6 V
		BC548/549/550	5 V
I_C	Collector Current (DC)	100	mA
P_C	Collector Dissipation	500	mW
T_J	Junction Temperature	150	$^{\circ}C$
T_{STG}	Storage Temperature	-65 ~ 150	$^{\circ}C$

Electrical Characteristics $T_a=25^{\circ}C$ unless otherwise noted

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Units
I_{CBO}	Collector Cut-off Current	$V_{CB}=30V, I_E=0$			15	nA
h_{FE}	DC Current Gain	$V_{CE}=5V, I_C=2mA$	110		800	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_C=10mA, I_B=0.5mA$		90	250	mV
		$I_C=100mA, I_B=5mA$		200	600	mV
$V_{BE(sat)}$	Base-Emitter Saturation Voltage	$I_C=10mA, I_B=0.5mA$		700		mV
		$I_C=100mA, I_B=5mA$		900		mV
$V_{BE(on)}$	Base-Emitter On Voltage	$V_{CE}=5V, I_C=2mA$	580	680	700	mV
		$V_{CE}=5V, I_C=10mA$			720	mV
f_T	Current Gain Bandwidth Product	$V_{CE}=5V, I_C=10mA, f=100MHz$		300		MHz
C_{ob}	Output Capacitance	$V_{CB}=10V, I_E=0, f=1MHz$		3.5	6	pF
C_{ib}	Input Capacitance	$V_{EB}=0.5V, I_C=0, f=1MHz$		9		pF
NF	Noise Figure	BC546/547/548		2	10	dB
		BC549/550		1.2	4	dB
		BC549		1.4	4	dB
		BC550		1.4	3	dB

h_{FE} Classification

Classification	A	B	C
h_{FE}	110 ~ 220	200 ~ 450	420 ~ 800

Typical Characteristics

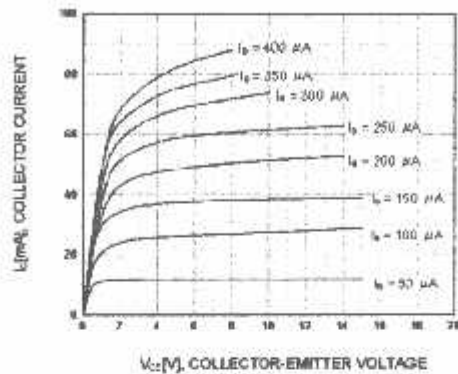


Figure 1. Static Characteristic

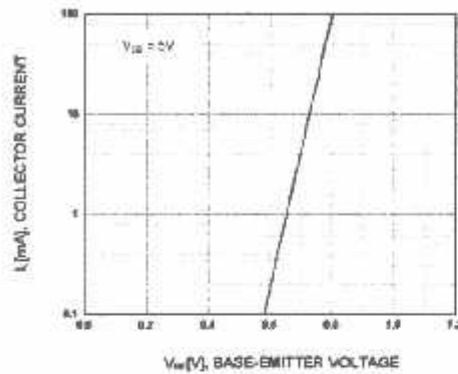


Figure 2. Transfer Characteristic

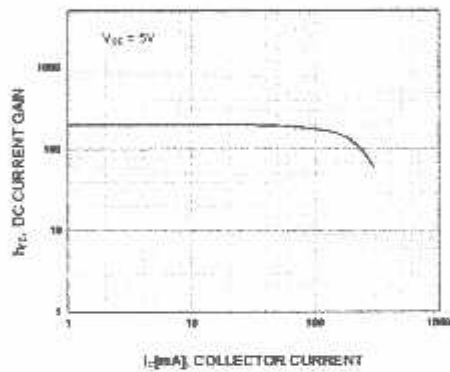


Figure 3. DC current Gain

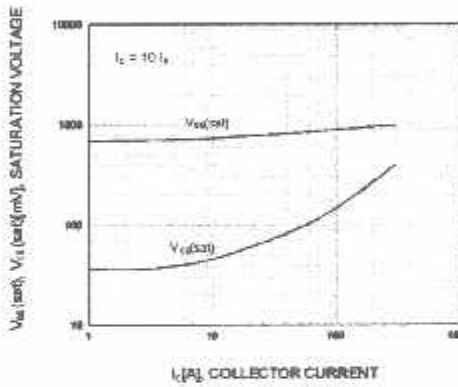


Figure 4. Base-Emitter Saturation Voltage
Collector-Emitter Saturation Voltage

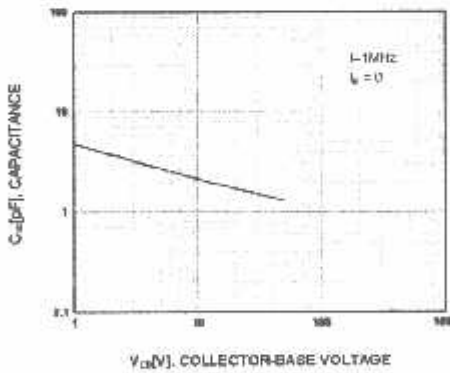


Figure 5. Output Capacitance

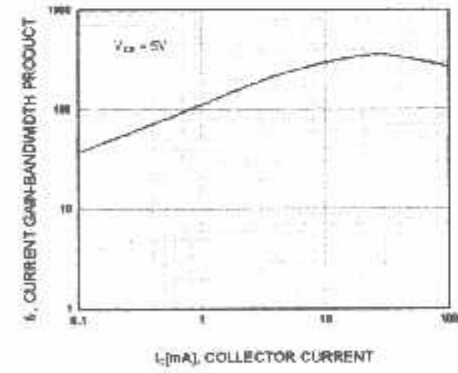
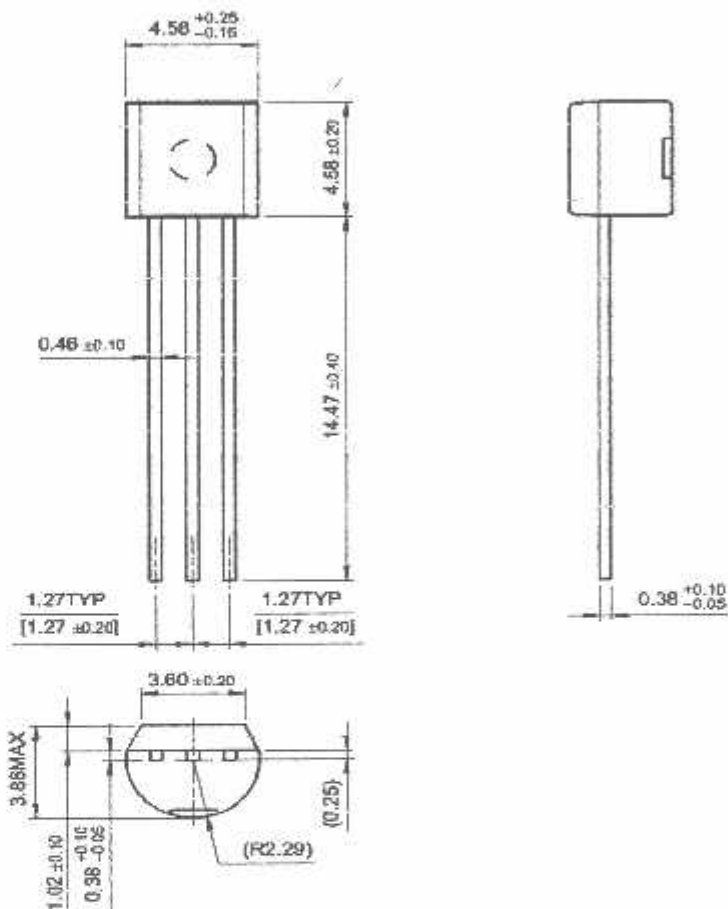


Figure 6. Current Gain Bandwidth Product

Package Demensions

BC546/547/548/549/550

TO-92



Dimensions in Millimeters

TRADEMARKS

The following are registered and unregistered trademarks Fairchild Semiconductor owns or is authorized to use and is not intended to be an exhaustive list of all such trademarks.

ACE [™]	HiSeC [™]	SuperSOT [™] -8
Bottomless [™]	ISOP [™]	SyncFET [™]
CoolFET [™]	MICROWIRE [™]	TinyLogic [™]
CROSSVOLT [™]	POP [™]	UHC [™]
E ² CMOS [™]	PowerTrench [®]	VCX [™]
FACT [™]	QFET [™]	
FACT Quiet Series [™]	QS [™]	
FAST [®]	Quiet Series [™]	
FAST [™]	SuperSOT [™] -3	
GTO [™]	SuperSOT [™] -6	

DISCLAIMER

FAIRCHILD SEMICONDUCTOR RESERVES THE RIGHT TO MAKE CHANGES WITHOUT FURTHER NOTICE TO ANY PRODUCTS HEREIN TO IMPROVE RELIABILITY, FUNCTION OR DESIGN. FAIRCHILD DOES NOT ASSUME ANY LIABILITY ARISING OUT OF THE APPLICATION OR USE OF ANY PRODUCT OR CIRCUIT DESCRIBED HEREIN; NEITHER DOES IT CONVEY ANY LICENSE UNDER ITS PATENT RIGHTS, NOR THE RIGHTS OF OTHERS.

LIFE SUPPORT POLICY

FAIRCHILD'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF FAIRCHILD SEMICONDUCTOR INTERNATIONAL.

As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, or (c) whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in significant injury to the user.
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.



TIP31A/31C TIP32A/32B/32C

COMPLEMENTARY SILICON POWER TRANSISTORS

APPLICATION

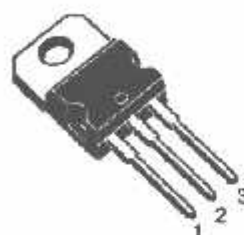
- LINEAR AND SWITCHING INDUSTRIAL EQUIPMENT

DESCRIPTION

The TIP31A and TIP31C are silicon Epitaxial-Base NPN transistors mounted in Jedec TO-220 plastic package. They are intended for use in medium power linear and switching applications.

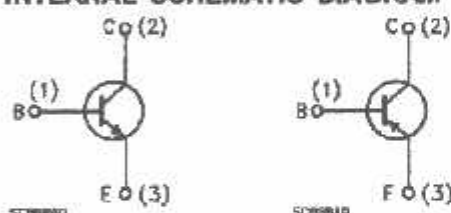
The complementary PNP types are TIP32A and TIP32C respectively.

Also TIP32B is a PNP type.



TO-220

INTERNAL SCHEMATIC DIAGRAM



ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value				Unit
		NPN	TIP31A		TIP31C	
V_{CB0}	Collector-Base Voltage ($I_C = 0$)		60	80	100	V
V_{CE0}	Collector-Emitter Voltage ($I_B = 0$)		60	80	100	V
V_{EB0}	Emitter-Base Voltage ($I_C = 0$)			5		V
I_C	Collector Current			3		A
I_{CM}	Collector Peak Current			5		A
I_B	Base Current			1		A
P_{tot}	Total Dissipation at $T_{case} \leq 25^\circ C$ $T_{amb} \leq 25^\circ C$			40 2		W W
T_{sig}	Storage Temperature			-65 to 150		$^\circ C$
T_j	Max. Operating Junction Temperature			150		$^\circ C$

or PNP types voltage and current values are negative

TIP31A/TIP31C/TIP32A/TIP32B/TIP32C

THERMAL DATA

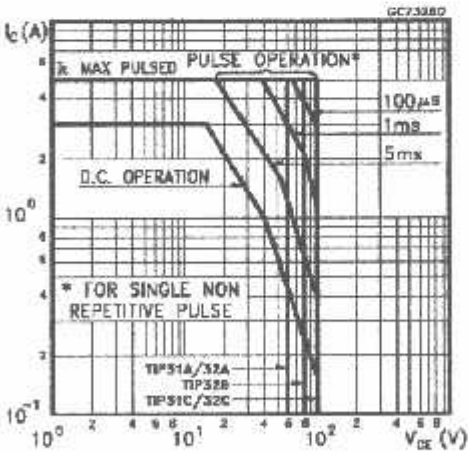
$R_{th(j-case)}$	Thermal Resistance Junction-case	Max	3.12	$^{\circ}C/W$
$R_{th(j-amb)}$	Thermal Resistance Junction-ambient	Max	62.5	$^{\circ}C/W$

ELECTRICAL CHARACTERISTICS ($T_{case} = 25^{\circ}C$ unless otherwise specified)

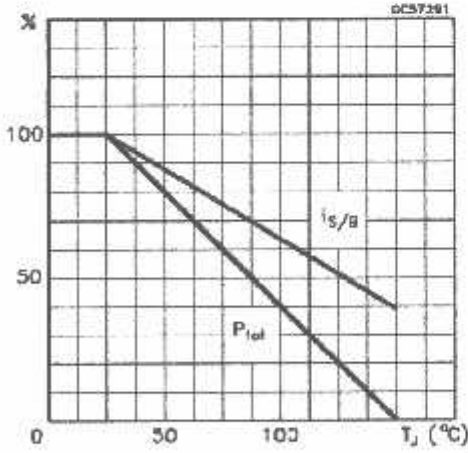
Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
I_{CEO}	Collector Cut-off Current ($I_B = 0$)	for TIP31A/32A $V_{CE} = 30\text{ V}$ for TIP31C/32B/32C $V_{CE} = 60\text{ V}$			0.3 0.3	mA mA
I_{CES}	Collector Cut-off Current ($V_{BE} = 0$)	for TIP31A/32A $V_{CE} = 60\text{ V}$ for TIP32B $V_{CE} = 80\text{ V}$ for TIP31C/32C $V_{CE} = 100\text{ V}$			0.2 0.2 0.2	mA mA mA
I_{EBO}	Emitter Cut-off Current ($I_C = 0$)	$V_{EB} = 5\text{ V}$			1	mA
$V_{CEO(sus)*}$	Collector-Emitter Sustaining Voltage ($I_B = 0$)	$I_C = 30\text{ mA}$ for TIP31A/32A for TIP32B for TIP31C/32C	60 80 100			V V V
$V_{CE(sat)*}$	Collector-Emitter Saturation Voltage	$I_C = 3\text{ A}$ $I_B = 375\text{ mA}$			1.2	V
$V_{BE(on)*}$	Base-Emitter Voltage	$I_C = 3\text{ A}$ $V_{CE} = 4\text{ V}$			1.8	V
h_{FE}^{α}	DC Current Gain	$I_C = 1\text{ A}$ $V_{CE} = 4\text{ V}$ $I_C = 3\text{ A}$ $V_{CE} = 4\text{ V}$	25 10		50	
h_{fe}	Small Signal Current Gain	$I_C = 0.5\text{ A}$ $V_{CE} = 10\text{ V}$ $f = 1\text{ KHz}$ $I_C = 0.5\text{ A}$ $V_{CE} = 10\text{ V}$ $f = 1\text{ MHz}$	20 3			

Pulsed : pulse duration = 300 μs , duty cycle $\leq 2\%$
for PNP types voltage and current values are negative.

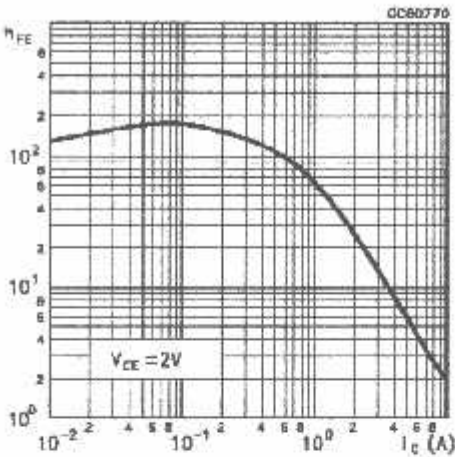
Safe Operating Area



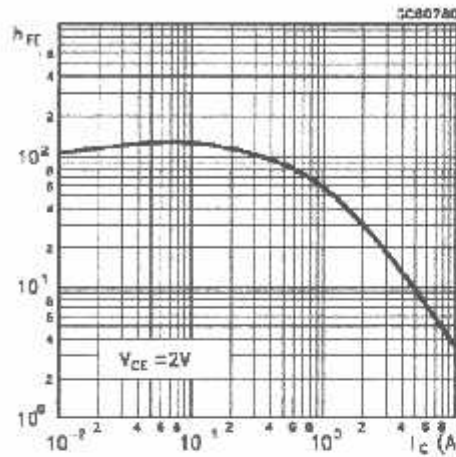
Derating Curves



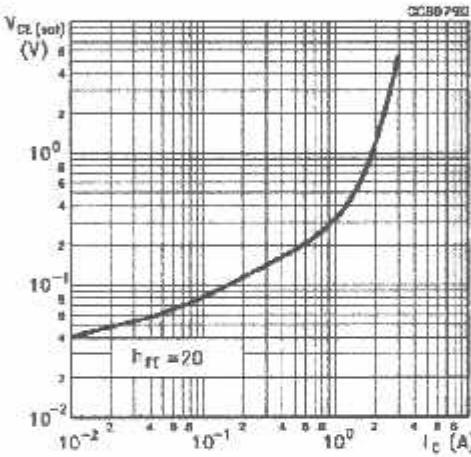
DC Current Gain (NPN type)



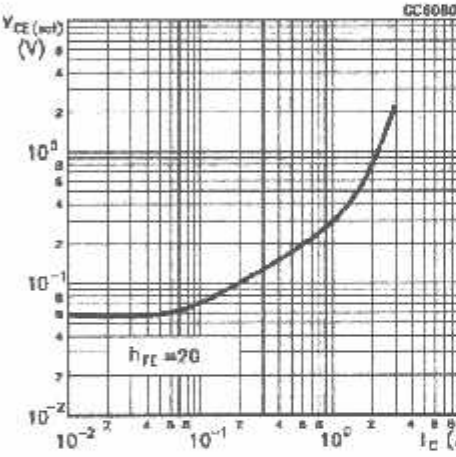
DC Current Gain (PNP type)



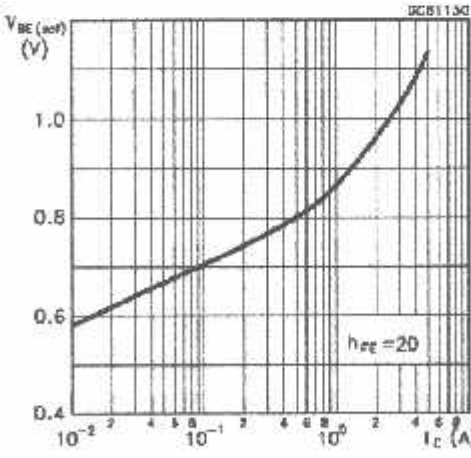
Collector-Emitter Saturation Voltage (NPN type)



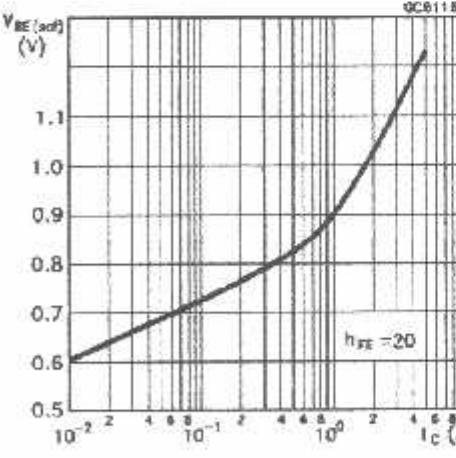
Collector-Emitter Saturation Voltage (PNP type)



Base-Emitter Saturation Voltage (NPN type)



Collector-Base Capacitance (PNP type)



TO-220 MECHANICAL DATA

DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A	4.40		4.60	0.173		0.181
C	1.23		1.32	0.048		0.051
D	2.40		2.72	0.094		0.107
D1		1.27			0.050	
E	0.49		0.70	0.019		0.027
F	0.61		0.88	0.024		0.034
F1	1.14		1.70	0.044		0.067
F2	1.14		1.70	0.044		0.067
G	4.95		5.15	0.194		0.203
G1	2.4		2.7	0.094		0.106
H2	10.0		10.40	0.393		0.409
L2		16.4			0.645	
L4	13.0		14.0	0.511		0.551
L5	2.65		2.95	0.104		0.116
L6	15.25		15.75	0.600		0.620
L7	6.2		6.6	0.244		0.260
L9	3.5		3.93	0.137		0.154
DIA.	3.75		3.85	0.147		0.151

