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

SKRIPSI

PERENCANAAN DAN PEMBUATAN ALAT KONTROL SUHU PADA INKUBATOR BAYI DENGAN MENGGUNAKAN AT89S8252 YANG TERMONITOR DENGAN PC

Disusun Oleh :

FIFI ERIYATI

02 17 127

MARET 2007

LEMBAR PERSETUJUAN

PERENCANAAN DAN PEMBUATAN ALAT KONTROL SUHU PADA INKUBATOR BAYI DENGAN MENGGUNAKAN AT89S8252 YANG TERMONITOR DENGAN PC

SKRIPSI

Diajukan Sebagai Salah Satu Syarat Untuk Memperoleh Gelar Sarjana Teknik Pada Jurusan Teknik Elektro Strata Satu (S-1) Konsentrasi Elektronika

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2007

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ABSTRAKSI

Judul: Perencanaan Dan Pembuatan Alat Kontrol Suhu Pada Inkubator Bayi Dengan Menggunakan AT89S8252 Yang Termonitor Dengan PC.

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Kata Kunci: Kontol Suhu, AT89S8252, Driver DC dan AC, Delphi.

Dengan semakin berkembangnya penggunaan alat-alat elektronika dibidang medis untuk memudahkan aktifitas perawatan. Inkubator bayi berfungsi untuk menjaga bayi premature dalam suhu 32°C - 35°C, yang ada sekarang masih banyak menggunakan campur tangan perawat dalam aktifitas monitoring bayi, perawat harus ke ruang inkubator berada untuk mengecek satu per satu inkubator setiap waktu, dan belum bisa dimonitor secara keseluruhan dari ruangan lain.

Dengan mikrokontroller AT89S8252 dirancang suatu sistem yang dapat mengontrol suhu dan memonitoring kelembaban pada inkubator bayi yang hasil pengukurannya ditampilkan pada LCD, sedangkan dengan Software Delphi dibuat tampilan hasil pengukuran suhu, kelembaban (hasil pengukuran sama dengan tampilan LCD) dan webcam secara real time pada PC.

Pada alat ini input suhu bisa diset antara 32°C - 35°C, sedangkan kelembaban sebatas pengukuran/monitoring. Dengan outputan berupa driver AC untuk heater sebagai pemanas dan driver DC untuk fan.

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Alhamdulillah, puji syukur kehadirat-Mu Ya Allah yang telah memberikan rahmat dan hidayah-Nya, sehingga dapat menyelesaikan skripsi yang berjudul "PERENCANAAN DAN PEMBUATAN ALAT KONTROL SUHU PADA INKUBATOR BAYI DENGAN MENGGUNAKAN AT89S8252 YANG TERMONITOR DENGAN PC" ini dengan lancar. Skripsi ini merupakan persyaratan kelulusan Studi di Jurusan Teknik Elektro S-1 Konsentrasi Teknik Elektronika ITN Malang dan untuk mencapai gelar Sarjana Teknik.

Keberhasilan peyelesaian laporan skripsi ini tidak lepas dari dukungan dan bantuan berbagai pihak. Untuk itu penyusun menyampaikan terima kasih kepada :

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3. Bapak Sotyohadi, ST. MSc selaku Dosen Pembimbing II.
4. Ayah dan Ibu serta keluarga besar yang telah memberikan do'a restu, dorongan, semangat, dan biaya.
5. Rekan-rekan mahasiswa/i Elektronika S-1.

Penyusun menerima saran dan kritik yang membangun dari pembaca demi kesempurnaan laporan ini.

Malang, Maret 2007

Penyusun

BAB V. KESIMPULAN DAN SARAN

DAFTAR GAMBAR

DAFTAR TABEL

DAFTAR GRAFIK

BAB I

PENDAHULUAN

1.1. Latar Belakang

Perkembangan teknologi dijaman ini mengalami kemajuan yang sangat pesat seiring dengan perkembangan pola pikir manusia. Suatu ide untuk melakukan penelitian di bidang medis yang nilai banyak sekali peralatan-peralatan yang perlu dikembangkan untuk memudahkan aktifitas perawatan. Dalam hal ini topik yang diamati adalah inkubator bayi, berfungsi untuk menjaga bayi prematur dalam suhu 32° - 35°C. Berdasarkan pengamatan perawatan bayi dalam inkubator sekarang masih membutuhkan campur tangan perawat yang harus mengecek satu per satu suhu inkubator sesuai yang diinginkan, hal tersebut dinilai kurang efisien karena suhu inkubator tidak bisa dimonitor secara keseluruhan oleh satu perawat. Padahal perawat juga manusia biasa yang kadang juga bisa lalai, ketiduran, lupa, teledor, yang nantinya membahayakan bayi. Bila suhu inkubator tidak sesuai dengan yang ditentukan, akibatnya terhadap bayi:

- Bila suhunya kurang dari 32°C bayi akan kedinginan dan bisa terkena penyakit hipotermia (kedinginan yang berlebihan).
- Bila suhunya lebih dari 35°C tidak nyaman untuk bayi.

Hal tersebut yang mendasari pembuatan suatu alat kontrol suhu inkubator bayi yang termonitor dengan PC. Perawat bisa memonitoring suhu, kelembaban, tangisan bayi dan aktifitas / keadaan bayi dalam inkubator melalui PC (*Personal Computer*).

1.2. Tujuan

Penulisan skripsi ini bertujuan untuk merencanakan dan membuat alat kontrol suhu inkubator bayi yang dilengkapi sistem monitoring suhu, kelembaban, tangisan bayi dan aktifitas/keadaan bayi dalam inkubator melalui PC

1.3. Rumusan Masalah

Berdasarkan latar belakang yang telah diuraikan pada bagian sebelumnya, maka dapat dirumuskan beberapa masalah yang akan dibahas yaitu :

1. Bagaimana merancang dan membuat hardware beserta software yang dapat mengontrol suhu inkubator.
2. Bagaimana merancang dan membuat software untuk memonitor inkubator yang ditampilkan pada PC.

1.4. Batasan Masalah

Dalam menyusun skripsi ini diperlukan suatu batasan masalah agar tidak menyimpang dari ruang lingkup yang akan dibahas, batasan masalahnya meliputi:

1. Sistem dapat mengontrol suhu pada range 30°C - 36°C.
2. Menggunakan software delphi sebagai interface.
3. Miniatur dirancang untuk 1 bayi (1 inkubator).

1.5. Metodologi

Metodologi yang dipakai dalam pembuatan skripsi ini adalah:

1. Studi Literatur

   Dengan mencari referensi-referensi yang berhubungan dengan perencanaan dan pembuatan alat yang akan dibuat.

2. *Field Research*

   Dengan melakukan penelitian secara langsung mengenai objek-objek yang berhubungan langsung dengan perencanaan alat yang akan dibuat.

3. *Design* dan Pembuatan Alat

   Yaitu meliputi pembuatan PCB, perakitan komponen serta penyolderan dan pembuatan perangkat lunak.

4. Pengujian Alat

   Dengan melakukan pengujian perblok rangkaian dan kerja seluruh sistem pada alat tersebut.

5. Penyusunan Laporan Skripsi

   Membuat laporan yang terdiri dari: Pendahuluan, Landasan Teori, Perencanaan dan Pembuatan Alat, Pengujian Alat dan Penutup.

1.6. Sistematika Penulisan

Penulisan skripsi ini terbagi menjadi lima bab dengan sistematika sebagai berikut:

BAB I PENDAHULUAN

Membahas tentang latar belakang, rumusan masalah, tujuan, batasan masalah, metodologi dan sistematika penulisan.

BAB II LANDASAN TEORI

Membahas teori dasar penunjang perancangan dan pembuatan alat.

BAB III PERENCANAAN DAN PEMBUATAN ALAT

Membahas tentang perancangan alat yang terdiri dari perancangan perangkat keras dan perangkat lunak.

BAB IV PENGUJIAN ALAT

Membahas tentang pengujian peralatan secara keseluruhan dan analisa hasil pengujian.

BAB V PENUTUP

Berisikan kesimpulan dan saran.

BAB II

DASAR TEORI

2.1. Mikrokontroler AT89S8252

2.1.1. Pendahuluan

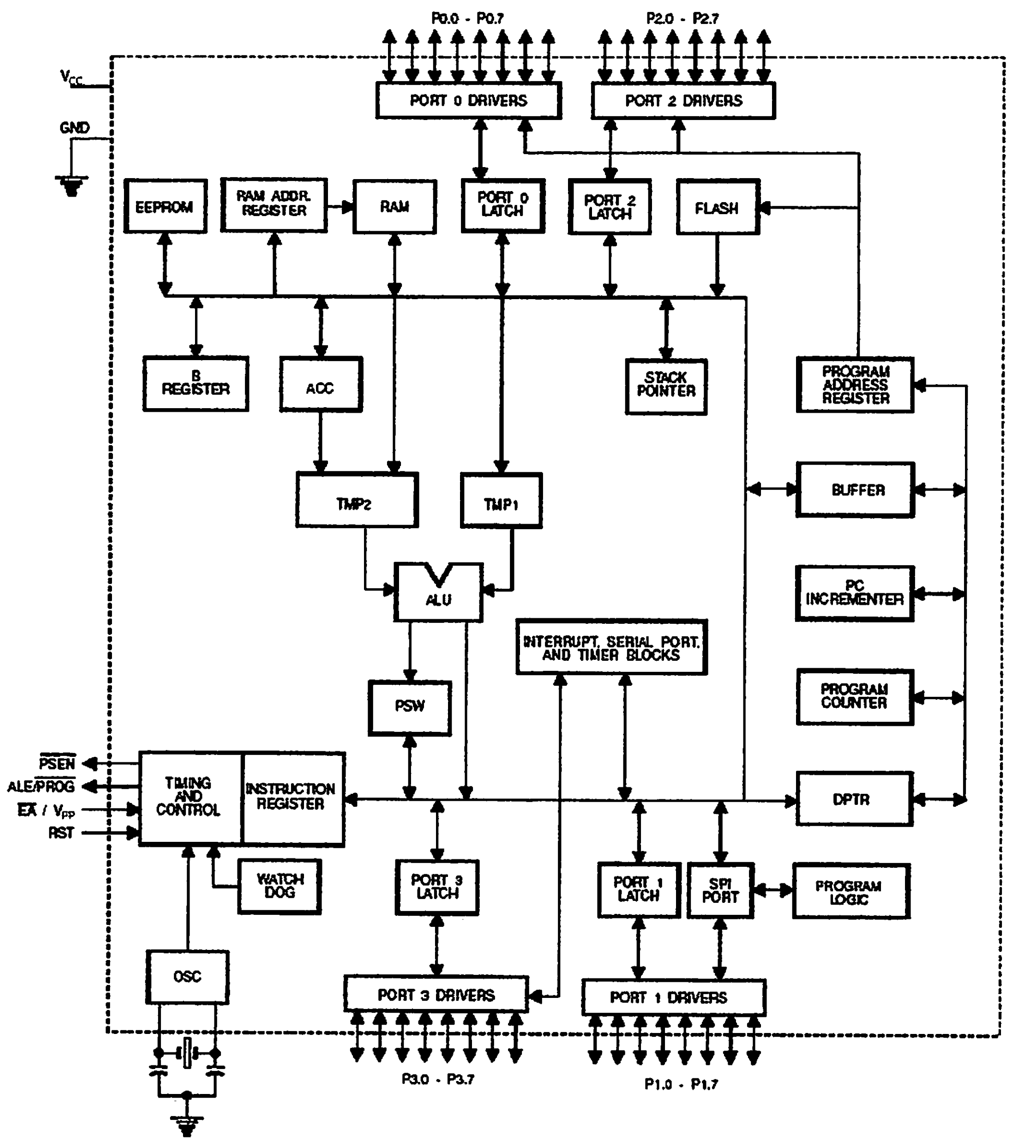
Mikrokontroler AT89S8252 merupakan mikrokontroller 8 bit kompatibel dengan standart industri MCS-51 baik atas segi pemrograman maupun atas kaki tiap pin. Mikrokontroller AT89S8252 mempunyai 8Kbyte PEROM (*Flash Programmable and Eraseble Read Only Memory*). Pada dasarnya adalah terdiri atas mikroprosesor, *timer* dan *counter*, perangkat I/O dan internal memori. Mikrokontroller termasuk perangkat yang sudah didesain dalam bentuk *chip* tunggal.

Pada dasarnya mikrokontroller mempunyai fungsi yang sama dengan mikroprosesor yaitu untuk mengontrol suatu kerja sistem. Selain itu mikrokontroller juga dikemas dalam satu *chip* (*single chip*). Didalam mikrokontroller juga terdapat CPU, ALU, PC, SP dan register seperti dalam mikroprosesor, tetapi juga ditambah dengan perangkat-perangkat lain seperti POM, PAM, SIO, *counter* dan juga ditambah rangkaian *clock*. Mikrokontroller di desain instruksi-instruksi lebih luas dan 8 bit instruksi yang digunakan membaca data instruksi dari internal memory ke ALU. Sebagai suatu sistem kontrol mikrokontroller bila dibandingkan mikroprosesor memiliki kemampuan dari segi ekonomis yang bisa diandalkan karena dalam mikrokontroller sudah terdapat RAM dan ROM sedangkan mikroprosesor didalamnya tidak terdapat keduanya. Terlihat bahwa mikrokontroller AT89S8252 memiliki banyak fitur yang menguntungkan. Dipakainya Downloadable flash memungkinkan mikrokontroller ini bekerja sendiri tanpa diperlukan tambahan chip lainnya. Sementara flash memorinya mampu diprogram hingga seribu kali. Hal ini yang menguntungkan adalah sistem pemrograman menjadi lebih sederhana dan tidak memerlukan rangkaian yang rumit. Secara umum konfigurasi yang dimiliki mikrokontroller AT89S8252 adalah sebagai berikut :

- Sebuah CPU 8 bit dengan menggunakan teknologi dari Atmel
- 8 Kbyte Downloadable Flash Memory (PEROM)
- 2 Kbyte EEPROM
- 256 byte RAM internal
- 32 *Programmable I/O lines*
- 3 buah timer / counter 16 bit
- Sebuah port serial dengan control *full duplex* UART (*Universal Asynchronous Receiver Transmiter*)
- SPI Serial Interface
- Programmable Watchdog Timer
- Dual Data Pointer

- Frekuensi kerja 0 sampai 24 MHz
- Tegangan operasi 2,7 sampai 6 Volt
- Kemampuan melaksanakan operasi *Boolean* (bit)

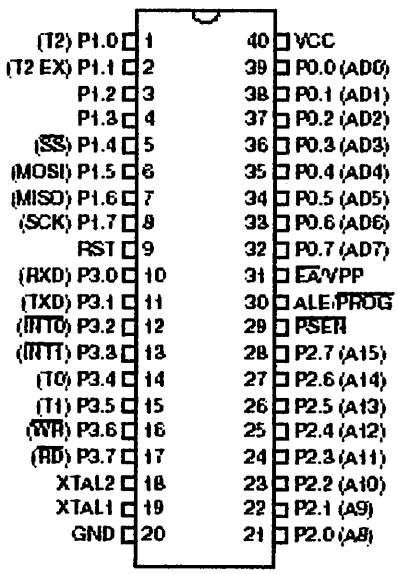
Sedangkan untuk blok diagram AT89S8252 diperlihatkan dalam Gambar 2.1.



Gambar 2-1
Blok Diagram AT89S8252
(Sumber : Data Sheet Atmel AT89S8252)

2.1.2. Penjelasan Fungsi Pin AT89S8252

Mikrokontroller AT89S8252 mempunyai 40 pin seperti yang ditunjukkan dalam Gambar 2.2. fungsi-fungsi pin dijelaskan sebagai berikut:



Gambar 2-2
Konfigurasi Pin-Pin AT89S8252
(Sumber : Data Sheet Atmel AT89S8252)

Fungsi tiap pin-nya adalah sebagai berikut :

1. Pin 1 Sampai 8 (Port 1 → P1.0 – P1.7)

   Merupakan port input – output dua arah dengan *pull-up*. Port ini berfungsi sebagai input atau output dan bekerja baik untuk operasi bit maupun byte, tergantung dari pengaturan software.

2. Pin 9 (Reset)

   Input Reset merupakan reset master untuk AT89S8252.

3. Pin 10 sampai 17 (Port 3 → P3.0 – P3.7)

Merupakan port input-output dengan internal pull-up, dimana Port 3 juga memiliki fungsi khusus dan dapat dilihat pada tabel berikut ini:

Tabel 2-1
Fungsi Khusus Pada Port 3

Pin Port	Fungsi Khusus
Port 3.0	RxD (Port masukan serial)
Port 3.1	TxD (Port keluaran Serial)
Port 3.2	$\overline{INT0}$ (Masukan Interupsi Eksternal 0)
Port 3.3	$\overline{INT1}$ (Masukan Interupsi Eksternal 1)
Port 3.4	T0 (Masukan Pewaktu Eksternal 0)
Port 3.5	T1 (Masukan Pewaktu Eksternal 1)
Port 3.6	$\overline{WR}$ (sinyal tulis memori data eksternal)
Port 3.7	$\overline{RW}$ (sinyal baca memori data eksternal)

(Sumber : Data Sheet Atmel AT89S8252)

4. Pin 18 dan 19

$XTAL_1$ dan $XTAL_2$ merupakan saluran untuk mengatur pewaktu sistem. Untuk pewaktu dapat menggunakan pewaktu internal maupun eksternal.

5. Pin 20 (Gnd)

Dihubungkan dengan ground rangkaian.

6. Pin 21 sampai 28 (Port 2 → P2.0 – P2.7)

Port 2 yang terdiri atas pin 21 sampai 28 merupakan saluran masukan/keluaran dua arah. Port ini merupakan 8 bit bagian alamat tinggi (A8 – A15) selama pengambilan instruksi dari memori eksternal yang menggunakan mode pengalamatan 16 bit.

7. Pin 29 (PSEN)

PSEN (*Program Store Enable*) merupakan sinyal pengontrol yang memperbolehkan program memori eksternal masuk kedalam bus.

8. Pin 30 (ALE/PROG)

ALE/PROG (*Addres latch Enable*) merupakan pulsa yang berfungsi untuk menahan alamat rendah (A0 – A7) dalam port 0. selama proses baca/tulis memori eksternal. Frekuensi ALE adalah 1/6 kali frekuensi oscillator, dan dapat digunakan sebagai pewaktu. Pin ini juga berfungsi sebagai saluran program selama dilakukan pemrograman jika menggunakan memori program internal.

9. Pin 31 (EA/VPP)

EA/VPP (*External Access Enable*) untuk mengatur penggunaan memori program eksternal dan internal. Pin ini harus dihubungkan dengan ground bila menggunakan memori program eksternal dan dihubungkan dengan VPP sebesar 12 Volt jika menggunakan memori program eksternal.

10. Pin 32 sampai 39 (Port 0 → P0.0 – P0.1)

Port 0 yang terdiri atas pin 32 sampai 39 merupakan saluran masukan/keluaran. Port 0 merupakan saluran rendah (A0 – A7) yang dimultipleks dengan saluran *bus* data (D0 – D7).

11. Pin 40 (Vcc)

Vcc merupakan saluran masukan untuk catu daya positif sebesar 5 Volt DC dengan toleransi kurang lebih 10%.

2.1.3. SFR (*Special Fungtion Register*)

Special Fungtion Register merupakan register dengan tugas khusus. SFR pada mikrokontroller AT89S8252 kompatible dengan mikrokontroller keluarga MCS-51 dan memiliki alamat 80h sampai FFh sehingga terdapat 128 lokasi alamat untuk SFR. Namun demikian pada mikrokontroller ini tidak berarti memiliki SFR sebanyak 128 buah.

Tidak semua *address* diterapkan dalam bentuk chip. Akses pembacaan dari semua address akan diwujudkan dalam bentuk random data, dan penulisan akses diwujudkan dalam bentuk (efek) tidak tentu. Area memori AT89S8252 disebut dengan *Special Fungtion Register* (SFR) seperti pada Tabel 2.2.

Selain itu mikrokontroller AT89S8252 memiliki tambahan SFR. Hal ini tidak lain karena terdapatnya tambahan fitur pada mikrokontroller ini. SFR tambahan ini meliputi : T2CON (*Timer 2 Register* dengan alamat 0C8h), T2MOD (*Timer 2 Mode* dengan alamat 0C9h), WMCON (*Watchdog and Memory Control Register* dengan alamat D5h), SPSR (SPI Status Register dengan alamat AAh), SPDR (SPI Data Register dengan alamat 86h).

Table 2-2
AT89S8252 SFR Map dan Reset Values

0F8H									0FFH
0F0H	B 00000000								0F7H
0E8H									0EFH
0E0H	ACC 00000000								0E7H
0D8H									0DFH
0D0H	PSW 00000000					SPCR 000001XX			0D7H
0C8H	T2CON 00000000	T2MOD XXXXXX00	RCAP2L 00000000	RCAP2H 00000000	TL2 00000000	TH2 00000000			0CFH
0C0H									0C7H
0B8H	IP XX000000								0BFH
0B0H	P3 11111111								0B7H
0A8H	IE 0X000000		SPSR 00XXXXXX						0AFH
0A0H	P2 11111111								0A7H
98H	SCON 00000000	SBUF XXXXXXXX							9FH
90H	P1 11111111						WMCON 00000010		97H
88H	TCON 00000000	TMOD 00000000	TL0 00000000	TL1 00000000	TH0 00000000	TH1 00000000			8FH
80H	P0 11111111	SP 00000111	DP0L 00000000	DP0H 00000000	DP1L 00000000	DP1H 00000000	SPDR XXXXXXXX	PCON 0XXX0000	87H

(Sumber : Data Sheet ATMEL Mikrokontroller AT89S8252)

2.1.4. Data Memori EEPROM dan RAM

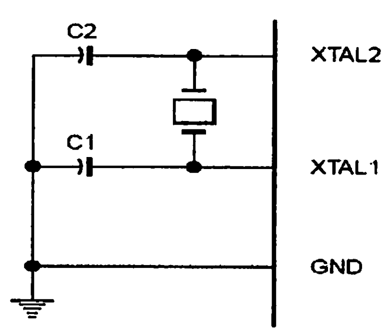
Untuk AT89S8252 terdapat 2 Kbyte dalam EEPROM untuk data dan 256 byte untuk RAM. Dibagian atas 128 byte RAM ditempati parallel untuk *Special Function Register*. Tetapi bagian atas 128 byte mempunyai alamat sama sebagai SFR, tetapi secara fisik terpisah dari SFR. Ketika suatu instruksi mengakses suatu penempatan internal diatas menunjukkan 7Fh, alamat yang digunakan di dalam instruksi menetapkan apakah CPU mengakses yang bagian atas 128 byte RAM atau SFR. Instruksi yang digunakan langsung menunjukkan akses SFR.

Didalam EEPROM data memori terpilih dengan pengaturan EEMEN didalam WMCON yang terdaftar pada SFR dan alamat penempatannya adalah 96h. Alamat EEPROM adalah dari 0000h sampai 7FFFh. Dan selama SSPROM memprogram, yang dibaca dari EEPROM akan mengambil byte yang sedang ditulis dengan melengkapi MSB.

2.1.5. Oscillator

Mikrokontroller AT89S8252 memiliki osilator internal (*on chip oscillator*) yang dapat digunakan sebagai sumber pewaktu (*clock*) bagi CPU. Untuk menggunakan internal diperlukan sebuah kristal atau resonator keramik antara pin $XTAL_1$ dan pin $XTAL_2$ dan sebuah kapasitor ke *ground.* Untuk kristalnya digunakan dengan frekuensi dari 6 – 24 MHz, sedangkan kapasitor dapat bernilai 27 – 33 pF.

f : 11,0592 MHz
1 clock = 12 T
$= 12 \times \frac{1}{11{,}0592 . 10^6}$
= 1,085 μs



Gambar 2-3
Osilator Eksternal AT89S8252
(Sumber : Data Sheet Atmel AT89S8252)

2.1.6. Sistem Interrupt

AT89S8252 mempunyai 5 buah sumber interupsi, 2 eksternal interupsi (INT0 dan INT1), 2 timer interupsi (Timer 0 dan Timer1), dan serial port interupsi.

- INT0 : Interrupt pada P3.2 (pin 12)
- INT1 : Interrupt pada P3.3 (pin 13)
- Timer0 : Timer pada P3.4 (pin 14)
- Timer1 : Timer pada P3.5 (pin 15)
- Port Serial : Jika pengiriman/penerimaan satu frame telah lengkap.

Saat terjadinya interrupt mikrokontroller secara otomatis akan menuju ke subrutin pada alamat tersebut. Setelah interrupt servise selesai dikerjakan mikrokontroller akan mengerjakan program semula. Dua sumber external adalah INT0 dan INT1 pada register TCON. Interrupt T0 dan T1 aktif pada saat timer yang sesuai mengalami roll over. Interrupt serial dibangkitkan dengan melakukan operasi OR pada R1 dan T1. tiap-tiap sumber interrupsi dapat enable atau disable secara software. Tingkat prioritas semua sumber interupsi dapat diprogram sendiri-sendiri dengan set atau clear bit pada SFRS IP (interrupt Priority). Register yang berperan dalam mengatur aktif tidaknya adalah interrupt enable register.

2.1.7. Timer / Counter

Pengendalian kerja dari timer/counter dilakukan dengan pengaturan register yang berhubungan dengan kerja dari *timer/counter* yang melalui sebuah *timer/counter* mode control. Untuk mengaktifkan *timer/counter* yang meliputi penentuan fungsi sebagai *timer* atau sebagai *counter* serta pemilihan operasi yang dapat diatur melalui TMOD.

(Sumber: Belajar Mikrokontroller ATMEL AT89S8252,2003)

2.2. ADC 0808 (Ananlog to Digital Converter)

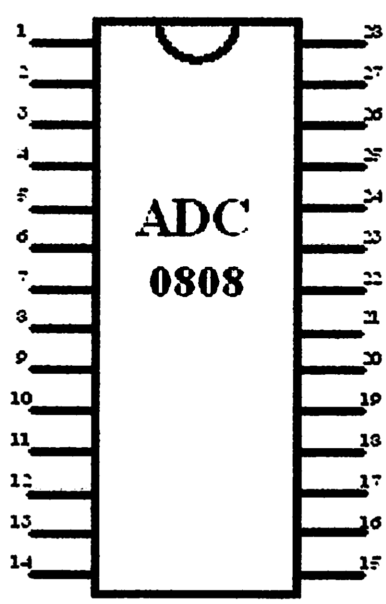
Analog to Digital Converter 0808 dikemas dalam IC *monolitik*, ADC ini menggunakan metode pengubah berturut-turut (*Successifve Approximation*) dengan 8 saluran *input analog* dan dilengkapi dengan beberapa kontrol logika yang sesuai dengan *standart microprocessor.* Blok diagram ADC 0808 memperlihatkan bahwa ADC 0808 terdiri dari 3 bagian utama, yaitu:

- MUX *Analog* 8 *Channel*
- *Analog to Digital Converter* ADC 8 bit
- *Three – State Latch Buffer* (penyangga terkunci 3 kanal)

Multiplekser analog 8 *chanel* berfungsi untuk mengolah 8 *input* data *analog* secara bergantian. Untuk memilih *input* mana yang dikehendaki pada *output multiplekser* disediakan 3 bit kontrol pemilih saluran *input. Analog to Digital Converter* (ADC) merupakan *successive approximation register* 8 bit yang terdiri dari komparator, SAR dan *Clock Three – State Latch Buffer* berfungsi untuk menampung keluaran ADC 8 bit.

ADC ini merupakan *level* terbatas untuk sinyal *input*-nya yang tergantung pada *input* referensi yang digunakan. Dalam hal ini yang membatasi adalah tegangan referensi *positif* Vref (+) dan tegangan *negatif* Vref (-). Jika *input* referensi *negatif* diberi tegangan *negatif* dan input referensi *positif* diberi tegangan *positif* sehingga tegangan *input analog* dapat berharga diantara kedua tegangan referensi tadi dan ini disebut *bipolar*, artinya kedua *input* mempunyai polaritas *positif* dan *negative*. Jika *input* referensi *positif* diberi tegangan *positif* dan referensi *negative* diberi tegangan 0 Volt, maka dapat disebut *unipolar* karena *analog*-nya berada diatas 0 Volt (berharga *positif* saja). ADC yang dipakai dalam sistem ini dirancang untuk jenis *unipolar*. Gambar struktur pin ADC 0808 sebagai berikut:

(Sumber: Vijay Sidharta, 2006)



Gambar 2-4
Struktur Pin IC ADC 0808
(Sumber: Anonimous, National Data Sheet, 1995)

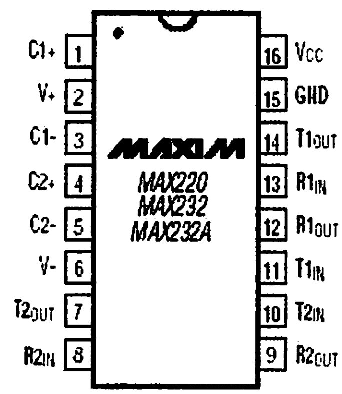
Table 2-3
Keterangan Pin IC ADC 0808

Pin	Nama	Keterangan
1	IN_3	Masukan 3
2	IN_4	Masukan 4
3	IN_5	Masukan 5
4	IN_6	Masukan 6
5	IN_7	Masukan 7
6	Start	Mulai Konversi
7	EOC	*End of Convertion*
8	Out 2^{-5}	Keluaran 5
9	*Output Enable*	Menghidupkan *Output*
10	*Clock*	*Clock*
11	Vcc	*Supply* tegangan
12	Vref (+)	Tegangan refernsi (+)
13	GND	*Ground*
14	Out 2^{-7}	Keluaran 7
15	Out 2^{-6}	Keluaran 6
16	Vref (-)	Tegangan referensi (-)
17	Out $2^{-8}{}_{(LSB)}$	Keluaran 8
18	Out 2^{-4}	Keluaran 4
19	Out 2^{-3}	Keluaran 3
20	Out 2^{-2}	Keluaran 2
21	Out $2^{-1}{}_{(MSB)}$	Keluaran 1
22	ALE	*Address Latch Enable*
23	ADD-C	*Control* A
24	ADD-B	*Control* B
25	ADD-A	*Control* C
26	IN_0	Masukan 0
27	IN_1	Masukan 1
28	IN_2	Masukan 2

(Sumber: Anonimous, National Data Sheet, 1995)

2.3. Komunikasi Serial

Untuk mengirimkan data dari AT89S8252 ke PC (*Personal Computer*), digunakan port serial RS-232 yabg terdapat pada PC, dimana pada port ini terdapat fungsi-fungsi untuk Tx (pengiriman data), Rx (penerimaan data) dan TX/RX (pemilihan mode Tx atau Rx). Untukmelakukan transfer data dari mikrokontroller ke PC digunakan IC MAX232, yang merupakan rangkaian terpadu untuk antarmuka komunikasi serial. Selain secara hardware diperlukan pula inisialisasi secara software guna mendukung unjuk kerja komunikasi serial ini. Secara software terdapat empat buah register khusus yang harus diinisialisasikan, yaitu: SMOD, TMOD, TCON, TH1 dan baudrate yang digunakan. Pertama akan dibahas secara hardware.



Gambar 2-5
RS 232 (MAXIM)
(Sumber : Data Sheet RS 232)

RS MAX232 tersusun dari 2 bagian yaitu *RS232 Line Driver* yang berfungsi mengubah level tegangan TTL ke level tegangan RS232 dan *RS232 Line Receiver* yang berfungsi mengubah level tegangan RS232 ke level tagangan TTL.

Standart RS232 ditetapkan oleh Electronic Industry Association dan Telecomunication Industry Association pada tahun 1962. Standart ini hanya menyangkut komunikasi data antara komputer (*Data Terminal Equipment* – DTE) dengan alat-alat pelengkap komputer maupun alat-alat digital lainnya

(*Data Circuit-Terminating Equipment* – DCE). Arus masukkan yang dibutuhkan oleh IC MAX232 rata sebesar 5mA.

Ada 3 hal pokok yang diatur dalam standart RS232 antara lain:

1. Bentuk sinyal dan level tegangan yang dipakai.

   Dalam standart RS232, tegangan antara +3 sampai +25 Volt baik pada input *Line Receiver* maupun *Line Driver* dianggap sebagai level tegangan '0' dan tegangan antara -3 sampai -25 Volt dianggap sebagai level tegangan '1'.

2. Penentuan jenis sinyal dan konektor yang dipakai serta susunan sinyal pada kaki-kaki di konektor.

   Jenis-jenis sinyal dipakai mengatur pertukaran informasi antara DTE dan DCE semuanya terdapat 24 jenis sinyal tapi umum dipakai hanyalah 9 jenis sinyal.

3. Penentuan tata cara pertukaran informasi antara computer dan alat-alat pelengkapnya maupun alat-alat digital.

Alat ini merupakan standart yang dipakai untuk mengirimkan aliran bit seri antar interface. Komunikasi serial dapat dibagi menjadi dua sifat dasar pola komunikasi. Yang pertama adalah komunikasi asinkron, dimana pola-pola bit tertentu dipakai untuk memisahkan bit-bit karakter. Yang kedua adalah komunikasi seri sinkron, yang memungkinkan karakter dikirim secara berurutan, namun membutuhkan karakter sinkronisasi khusus pada awal setiap karakter dan karakter semu khusus untuk dikirimkan ketika tidak ada informasi yang sedang dikirim.

2.3.1. Antarmuka Port Serial RS232

Pada PC terdapat antarmuka untuk komunikasi data secara serial yang mengikuti standart antarmuka RS232. Antarmuka ini menggunakan rangkaian terintegrasi UART (*Universal Asynchronous Receiver/Transmitter*) INS 8250 atau persamaannya. PC mempunyai beberapa antarmuka serial, dan dua yang biasanya dipakai dan paling penting adalah *primary asynchronous communication adaptor* (port COM1) dan *secondary asynchronous communication adaptor* (port COM2). Untuk jelasnya, alamat-alamat register yang digunakan pada UART 8250 adalah seperti terdapat pada tabel berikut:

(Sumber: Raden Fadhil Fadhli, 2006)

Table 2-4
Address Register RS232

NAMA REGISTER	COM1	COM2
TX BUFFER	03F8H	02F8H
RX BUFFER	03F8H	02F8H
BAUD RATE DIVISOR LATCH LSB	03F8H	02F8H
BAUD RATE DIVISOR LATCH MSB	03F9H	02F9H
INTERRUPT ENABLE REGISTER	03F9H	02F9H
INTERRUPT IDENTIFICATION REGISTER	03FAH	02FAH
LINE CONTROL REGISTER	03FBH	02FBH
MODEM CONTROL REGISTER	03FCH	02FCH
LINE STATUS REGISTER	03FDH	02FDH
MODEM STATUS REGISTER	03FEH	02FEH

(Sumber: Dallas Semiconductor MAXIM MAX232 Data Sheet)

- Tx Buffer : berfungsi menampung dan menyimpan data yang akan dikirim keluar. Data ini dikirim oleh CPU ke Tx Buffer setelah memastikan diperolehkannya melakukan pengiriman.
- Rx Buffer : berfungsi menampung dan menyimpan data yang akan diterima. Data yang akan diterima lebih dahulu ditampung dalam Rx Buffer.

2.4. Sensor

2.4.1. Sensor Suhu

Tranduser suhu digunakan untuk mengubah besaran suhu menjadi sinyal listrik. Sensor suhu harus mempunyai kepekaan terhadap perubahan suhu yang akan diukur. Sinyal listrik ini kemudian diubah oleh converter analoh to digital (*Analog to Digital Converter*) sehingga bisa diolah oleh mikrikontroller AT89S8252.

Sensor suhu merupakan bagian dari elemen alat ukur dalam sistem kontrol dengan umpan balik. Karena sifat dinamik dan statik dari elemen ukur mempengaruhi penunjukan harga sebenarnya dari variabel kaluaran, maka elemen ukur memegang peranan penting dalam menentukan performasi keseluruhan sistem.

Sensor suhu yang digunakan adalah IC LM 35 produksi National Semiconduktor, IC tersebut mempunyai ketelitian dan ketepatan tinggi. Kaluaran IC ini mempunyai kelinieran yang tinggi dalam jangkauan yang memadai untuk kemampuan pengontrolan umum. Jangkauan atau kamampuan dari IC ini adalah –55°C sampai +150°C.

LM 35 memiliki impedansi keluaran rendah, keluaran linier dan memiliki kalibrasi yang tepat sehingga membuat pembacaan nilai keluaran menjadi mudah. Dengan sensitivitas 10 mV/°C, keluaran mengalami perubahan 10 mV setiap kenaikan suhu 1 °C.

Beberapa kelebihan yang dimiliki IC ini membuat mudah untuk antarmuka, pembacaan dan pengontrolan. Dapat digunakan untuk catu daya tunggal, juga dengan catu daya simertis plus dan minus. Dengan arus rendah yaitu 60μA dan mempunyai pemanasan sendiri yang rendah yaitu kurang dari 0,1 °C.

(Sumber: Sundoro W, 2006)

Spesifikasi dari Sensor Suhu LM35:

- Dikalibrasi secara langsung ke celcius
- Faktor skala linier +10 mV/°C
- Jaminan akurasinya 0,5 °C pada suhu +25 °C
- Rata-rata temperaturnya antara -55 °C sampai 150 °C.
- Dioperasikan pada 4 volt sampai 30 volt.
- Arus yang dibawa kurang dari 60 uA
- *Self-heating*-nya yaitu 0,08 °C pada udara tetap.
- Ketidak linieranya ± 0,25 °C.
- Impedansi outputnya rendah yaitu 0,1 Ω dari 1 mA muatan

(Sumber: Data Sheet Sensor LM35)

2.4.2. Sensor Kelembaban RHK1AN

Kelembaban Relatif/Relative Humidity (RH) adalah suatu perbandingan yang dinyatakan dalam prosentase, banyaknya persen uap air didalam atmosfer terhadap jumlah yang dibutuhkan untuk memenuhinya pada suhu yang sama. Kelembaban relative berubah-ubah menyesuaikan suhu. RH 50% "± 5%", symbol "± 5%" menjelaskan adanya batas toleransi 5%, yaitu lebih 2,5% atau kurang 2,5% dari standar 50%, yang berarti tidak boleh kurang dari 47,5% dan lebih dari 52,5%.

Kelembaban adalah salah satu faktor yang menentukan kondisi cuaca pada suatu daerah. Kelembaban dapat diukur dengan berbagai macam metode, salah satunya adalah dengan menggunakan sensor kelembaban RHK1AN yaitu sebuah sensor kelembaban yang resistansinya dapat berubah-ubah sesuai kondisi kelembaban udara yang terjadi saat itu.

Dalam melakukan pengukuran kelembaban pada suatu daerah sangat bergantung pada suhu udara sebagai faktor yang sangat berpengaruh terhadap kelembaban saat itu. Persen % RH (*Relative Humidity*) besarnya relative tergantung suhu udara saat itu, dalam arti bahwa persen kelembaban mempunyai nilai berbeda untuk suhu yang berbeda walaupun nilai resistansi sensor sama. Hal ini dapat dilihat pada table 2.10 berikut ini:

(Sumber: DT-51 Application Note AN27 - Temperature & Humidity)

Spesifikasi dari sensor kelembaban RHK1AN :

- Kapasitas temperarur pada -40 – +85°C
- Kapasitas kelembaban kurang dari 95% RH

- Diporerasikan pada temperature 0 – 60°C
- Dioperasikan pada kelembaban 20 – 90% RH
- Tegangan rata-rata AC 1 Volt (50 Hz – 1 KHz)
- Daya rata-rata 0,3 mWatt
- Standart karakteristik 60 kΩ (*at* 25°C, 60% RH)
- Ketelitian < +3% RH
- *Hysterisis Within* 3% RH

(Sumber: Data Sheet Sensor RHK1AN

Table 2-5
Karakteristik Kelembaban pada Temperatur

% RH	Resistansi (ohm)					
	pada 5°C	pada 15°C	pada 25°C	pada 35°C	pada 45°C	pada 55°C
20	16000	10000	6500	4200	2500	1500
25	10000	6500	4200	2500	1500	930
30	6500	4200	2500	1500	930	510
35	4200	2500	1500	930	510	275
40	2500	1500	930	510	275	130
45	1500	930	510	275	130	65
50	930	510	275	130	65	36
55	510	275	130	65	36	19,5
60	275	130	65	36	19,5	11
65	130	65	36	19,5	11	6,5
70	65	36	19,5	11	6,5	3,5
75	36	19,5	11	6,5	3,5	1,95
80	19,5	11	6,5	3,5	1,95	1,2
85	11	6,5	3,5	1,95	1,2	0,7
90	6,5	3,5	1,95	1,2	0,7	0,4

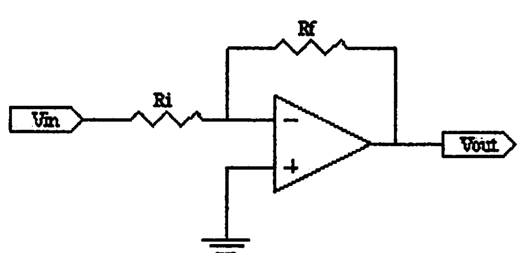
(Sumber : Data Sheet Sensor RHK1AN)

2.5. Penguat Instrumentasi

Operational amplifier atau disingkat Op-Amp merupakan salah satu komponen analog yang popular digunakan dalam berbagai aplikasi rangkaian elektronika. Pemakaian penguat instrumentasi adalah untuk memperkuat sinyal dari tranducer atau sensor dan lebih dikenal dengan rangkaian pengkondisi sinyal. Karena penguat instrumentasi adalah penguat dengan untaian tertutup, maka penguat instrumentasi ini dibuat dengan menggunakan penguat operasional amplifier.

2.5.1. Inverting Amplifier

Penguat inverting amplifier ini merupakan penguat yang membalik artinya pada penguat ini polaritas tegangan output merupakan kebalikan dari inputnya. Berikut ini merupakan gambar dari rangkaian penguat inverting amplifier.



Gambar 2.6
Penguat Inverting Amplifier

Untuk penguatan pada penguat inverting adalah sebagai berikut:

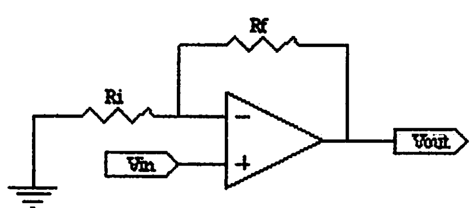
$$\text{Av} = -\frac{Rf}{Ri}$$

$$\text{Vout} = \text{Av x Vin}$$

$$= \text{Av}\left(-\frac{Rf}{Ri}\right)$$

2.5.2. Non-Inverting Amplifier

Penguat Non-Inverting adalah penguat operasional amplifier tak membalik, jadi tegangan output penguat ini polaritasnya tetap. Berikut ini merupakan gambar dari penguat non-inverting amplifer.



Gambar 2.7
Penguat Non Inverting Amplifier

Untuk penguatan pada penguatan non-inverting adalah sebagai berikut:

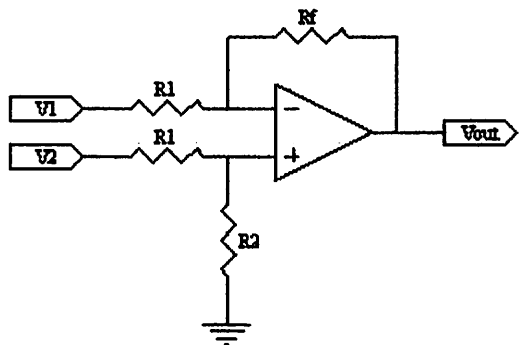
$$\text{Av} = 1 + \frac{Rf}{Ri}$$

$$\text{Vout} = \text{Av x Vin}$$

$$= \left(1 + \frac{Rf}{Ri}\right) x Vin$$

2.5.3. Differensial Amplifier

Penguat differensial merupakan penguat operasional amplifier yang mempunyai dua inputan yang kemudian selisih kedua input ini dikuatkan. Berikut ini merupakan gambar penguat dfferensial:



Gambar 2.8
Penguat Differensial Amplifier

Berikut merupakan persamaan penguatan pada penguat differensial amplifier:

$$Av = \frac{Rf}{Ri}$$

$$Vout = Av\ (V_2 - V_1)$$

$$= \frac{Rf}{Ri}(V_2 - V_1)$$

(Sumber: Panduan Praktikum Dasar Elektronika, 2005)

2.6. Dot Matrik LCD (*Liquid Crystal Display*)

Liquid Crystal Display adalah modul tampilan yang mempunyai konsumsi daya yang relatif rendah dan terdapat sebuah kontroller CMOS didalamnya. Kontroller tersebut sebagai pembangkit ROM/RAM dan display data RAM. Semua fungsi tampilan di kontrol oleh suatu instruksi modul LCD dapat dengan mudah diinterfacekan dengan MPU.

Spesifikasi dari LCD M1632:

- Terdiri dari 32 karakter yang dibagi menjadi 2 baris dengan display dot matrik 5 X 7 ditambah cursor
- Karakter generator ROM dengan 192 karakter
- Karakter generator RAM dengan 8 tipe karakter
- 80 X 8 bit display data RAM
- Dapat diinterfacekan dengan MPU 8 atau 4 bit
- Dilengkapi fungsi tambahan : Display clear, cursor home, display ON/OFF, cursor ON/ OFF, display character blink, cursor shift dan display shift
- Internal data
- Internal otomatis dan reset pada power ON
- +5 V power supply tunggal

(Sumber: LCD Module User Manual)

Berikut ini merupakan pin-pin LCD berserta konfigurasinya:

Tabel 2-6
Pin-Pin LCD Dan Konfigurasinya

Nama Pin	Jumlah	I/O	Tujuan	Fungsi
DB0-DB3	4	I/O	MPU	Tri state bidirectional lower data bus: data dibaca dari modul ke MPU atau dari MPU ditulis ke modul melalui bus
DB4-DB7	4	I/O	MPU	Tri state bidirectional upper fourdata bus: data dibaca dari modul ke MPU atau dari MPU ditulis ke modul melalui bus
E	1	Input	MPU	Sinyal operasi dimulai: sinyal aktif baca/tulis
R/W	1	Input	MPU	Sinyalpilih data dan tulis (0:tulis,1:baca)
RS	1	-	Power supply	Sinyal pilih register 0: Instruction register (write) Busy flag dan addess counter (read) 1:Data register (write dan read)
VLC	1	-	Power supply	Penyetelan kontras pada tampilan LCD
VDD	1	-	Power supply	+ 5V
VSS	1	-	Power supply	Ground 0V

(Sumber : LCD Module User Manual)

2.6.1. Register

Control LCD mempunyai 2 register 8 bit yaitu *Instruction register* (IR) dan *Data Register* (DR). Kedua register tersebut dipilih melalui *Register Select* (RS). IR menyimpan kode instruksi seperti Display clear dan cursor shift, dan alamat informasi dari Display Data RAM (DD RAM) dan character generator RAM (CG RAM)

DR menyimpan data sementara untuk ditulis ke DD RAM atau CG RAM, atau dibaca dari DD RAM atau CG RAM. Ketika data ditulis ke DD RAM atau CG RAM dari MPU, data di DR secara otomatis ditulis ke DD RAM atau CG RAM dengan operasi internal. Tetapi ketika data dibaca dari DD RAM atau CG RAM maka alamat data ditulis pada IR.Data tersebut akan dimasukkan ke DR dan MPU akan membaca data dari DR, Setelah operasi pembacaan, alamat berikutnya diset data dari DD RAM atau CG RAM pada alamat tersebut akan dimasukkan ke DR untuk operasi berikutnya.

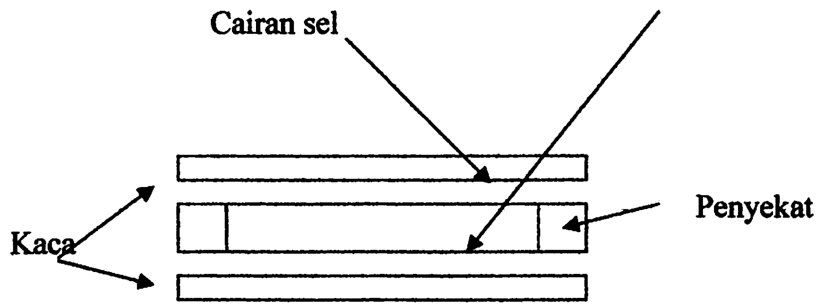
Display data RAM (DD RAM) mempunyai kapasitas area 80 X 8 bit. Beberapa area dari DDRAM yang tidak digunakan untuk display dapat digunakan sebagai General data RAM.

Pada LCD masing-masing pin mempunyai range alamat tersendiri, alamat itu diekspresikan dengan bilangan heksa. Untuk line 1 range alamat berkisar antara 00h-0Fh sedangkan untuk line 2 alamat berkisar antara 40h-4fh

Informasi atau data ada kalanya dikodekan dalam bentuk kode. Untuk mengkode data digital tersebut digunakan suatu encoder. Salah satu contoh dari encoder adalah encoder 16 to 4 line yang digunakan untuk mengkode 16 saluran data desimal menjadi 4 saluran data BCD. Keluaran encoder merupakan kode dari salah satu input yang diaktifkan. Encoder mempunyai 2^n masukan dan n buah jalur keluaran.

Penggunaan encoder pada umumnya digunakan untuk mengkodekan Elektroda tembus cahaya.

(Sumber:Andrew E. Y, 2006)



Gambar 2-9
Konstruksi dari cairan Sel Kristal
(Sumber : LCD Module User Manual)

2.7. Keypad 4X4

Keypad digunakan untuk memberikan masukkan data input ke mikrokontroler yang kemudian akan ditampilkan melalui LCD dengan cara menekan tombol yang ada pada *keypad*. *Keypad* yang ada umumnya jenis *keypad* 4 baris 4 kolom (keypad 4X4) dan jenis 4 baris 3 kolom (keypad 4X3). Dalam hal ini *keypad* yang akan digunakan adalah *keypad* 4X4 dengan sebuah *common.*

Jalur K1 sampai dengan K4 dan jalur B1 sampai dengan B4 dihubungkan ke port 2 mikrokontroler. Pada saat kondisi tidak terjadi penekanan tombol *keypad* maka kondisi logika pada port 2 adalah 1 pada setiap bitnya. Akan tetapi, apabila salah satu tombol ditekan baris dan kolom yang berhubungan akan terhubung ke *ground*, hal ini menyebabkan kondisi baris dan kolom akan berlogika 0.

(Sumber: Budhy Sutanto, 2002)

2.8. Kamera

Kamera disini yang digunakan adalah kamera web atau lebih dikenal WebCam (Web Camera). WebCam merupakan sebuah *hardware* (perangkat keras), lebih tepatnya WebCam adalah sebuah kamera yang dilengkapi dengan microphone. WebCam dapat digunakan memotret gambar, membuat video, *video chat*, tetapi WebCam umumnya digunakan sebagai media komunikasi lewat internet seperti melakukan *video chat, video conference*, atau wawancara secara *online*. Pengoperasian WebCam sangat mudah yaitu tinggal dihubungkan ke PC (*Personal Computer*) melalui port USB dan menginstal cd driver bawaan WebCam itu sendiri. Sekarang ini telah banyak dijual berbagai macam jenis atau merek dari WebCam. Begitu juga dengan harganya yang bervariasi mulai dari yang relatif murah sampai yang relatif mahal, tergantung dari fitur atau fasilitas yang dimiliki oleh WebCam itu sendiri, untuk kualitas sebuah WebCam tergantung juga dari merek dan tipenya.

(Sumber: Belajar Sendiri WebCam, 2005)

BAB III

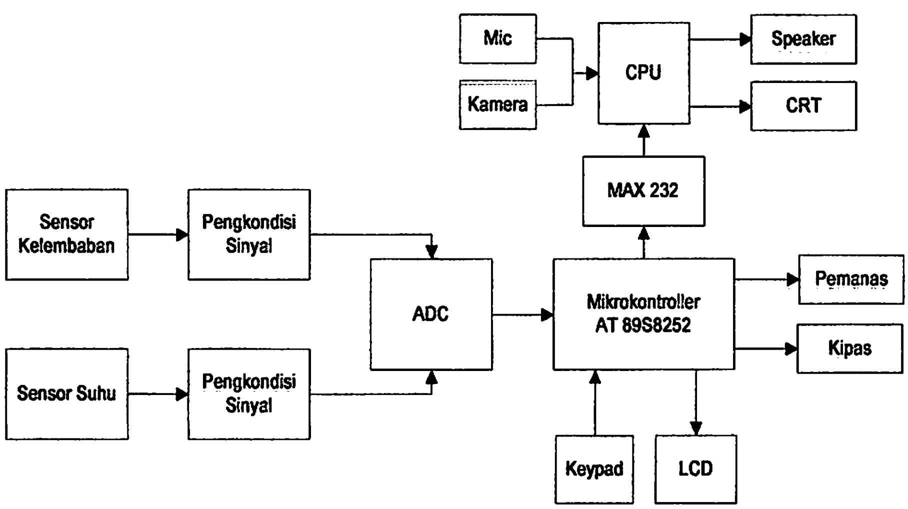
PERENCANAAN DAN PEMBUATAN ALAT

Bab ini akan membahas tentang perencanaan dan perancangan alat yang meliputi perencanaan perangkat keras (Hardware) dan perangkat lunak (Software) dari kontrol suhu inkubator bayi yang termonitor dengan PC ini. Perancangan secara keseluruhan dapat dibagi menjadi dua bagian, yaitu :

1. Perancangan Perangkat Keras (*Hardware*)
2. Perancangan Perangkat Lunak (*Software*)

3.1. Perancangan Perangkat Keras (*Hardware*)

digram blok sistem sebagai berikut:



Gambar 3-1
Digram Blok Sistem

Dari gambar blok diagram 3-1 dapat dijelaskan cara kerjanya sebagai berikut:

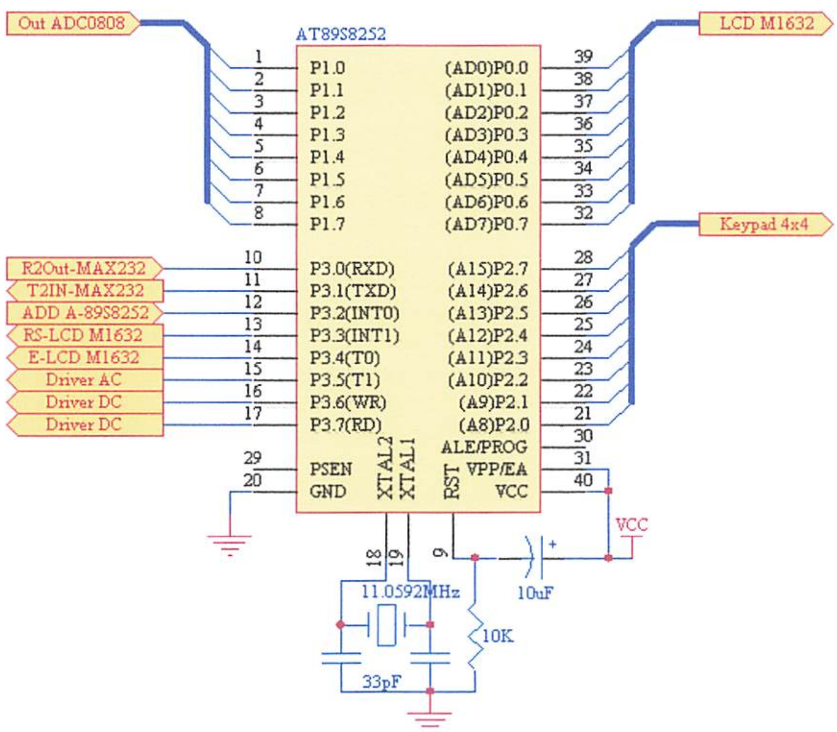
- Sensor Suhu dipergunakan untuk mendeteksi suhu inkubator.

- Sensor Kelembaban dipergunakan untuk mendeteksi kelembaban inkubator.
- Pengkondisi Sinyal disini berfungsi untuk menguatkan tegangan output dari sensor sebelum diinputkan ke ADC.
- ADC untuk mengubah data yang berbentuk analog menjadi data yang berbentuk digital.
- Mikrokontroller berfungsi sebagai pengontrol semua sistem, dalam IC ini terdapat 8Kbytes PEROM, 256bytes RAM internal, 32 *Programmable I/O lines*, 2Kbytes EEPROM dan 3 buah *timer / counter* 16 bit.
- *Keypad* sebagai inputan data 4 bit mikrokontroller yang digunakan untuk tombol pengoperasian alat dan penentuan suhu inkubator yang diinginkan.
- LCD sebagai display suhu dan kelembaban pada inkubator tersebut.
- MAX 232 sebagai *converter* level tegangan RS-232 menjadi level tegangan TTL.
- CPU sebagai pengolah data serial yang diterima dari Mikrokontroller untuk ditampilkan pada CRT.
- CRT sebagai tampilan / sistem informasi dari keadaan inkubator yang meliputi: suhu, kelembaban, tangisan bayi dan aktifitas / keadaan bayi dalam inkubator.
- *Microphone* berfungsi sebagai informasi suara bila bayi di inkubator menangis.
- Kamera untuk memonitor keadaan bayi dalam inkubator secara *real time*.
- *Speaker* sebagai display suara dari *microphone*.

3.1.1. Perencanaan Mikrokontroller AT 89S8252

Mikrokontroller AT89S8252 merupakan pengembangan dari mikrokontroller standart MCS-51, yang mana mikrokontroller AT89S8252 memiliki beberapa kelebihan dibandingkan dari mikrokontroller MCS-51.

Terlihat bahwa mikrokontroller AT89S8252 memiliki banyak fitur yang menguntungkan. Dipakainya *downloadable flash* memori memungkinkan mikrokontroller ini bekerja sendiri tanpa diperlukan tambahan chip lainya. Sementara *flash* memorinya mampu diprogram hingga seribu kali. Hal ini yang menguntungkan adalah sistem pemrograman jadi lebih sederhana dan tidak memerlukan rangkaian yang rumit.



Gambar 3-2
Rangkaian Mikrokontroller AT89S8252 dengan Komponen lain

Penjelasan dari pin-pin yang dipergunakan:

- Pin 1 sampai 8 dari outputan data 8 bit pada ADC 0808.
- Pin 9 sebagai reset.
- Pin 10 dan 11 dihubungkan dengan MAX 232.
- Pin 12 dihubungkan ke ADD-A pada ADC 0808.
- Pin 13 dan 14 dihubungkan dengan RS dan E pada LCD M1632.
- Pin 15 dihubungkan Driver AC untuk mengaktifkan *heater*.
- Pin 16 dan 17 dihubungkan Driver DC untuk mengaktifkan *fan*.
- Pin 18 dan 19 dihubungka dengan Kristal 11,0592 MHz.
- Pin 20 dihubungkan ke *Ground*.
- Pin 21 sampai 28 dihubungkan dengan keypad 4x4.
- Pin 31 dihubungkan dengan sumber tegangan 5 Volt.
- Pin 32 sampai 39 dihubungkan ke 8 bit data untuk LCD.
- Pin 40 dihubungkan dengan Vcc.

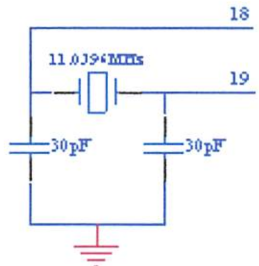
3.1.1.1.Rangkaian Clock

Mikrokontroller AT89S8252 ini memiliki rangkaian *internal clock* generator yang berfungsi sebagai sumber *clock*, tetapi masih diperlukan rangkaian tambahan untuk membangkitkan *clock* yang diperlukan.

Rangkaian ini terdiri dari dua buah kapasitor dan sebuah kristal, dengan ketentuan sebagai berikut:

- 6 – 14 MHz untuk besarnya nilai kristal.
- 27 – 33 pf untuk besarnya nilai kapasitor.

Gambar dari rangkaian clock adalah sebagai berikut:



Gambar 3-3
Rangkaian Clock AT89S8252

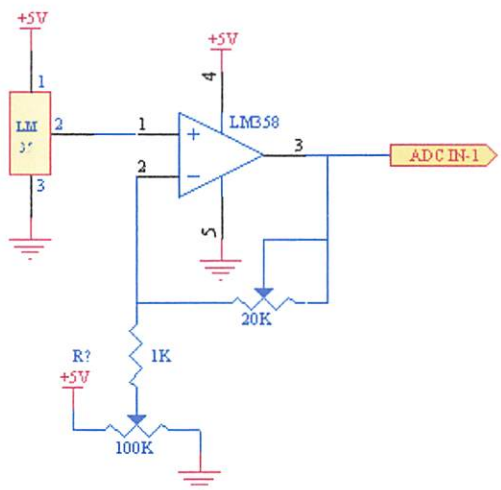
3.1.2. Sensor

3.1.2.1.Sensor Suhu

Sensor ini berfungsi sebagai pengindera suhu dalam inkubator dan mengubah informasi tersebut menjadi tegangan analog. Digunakan sensor LM 35 dengan pertimbangan antara lain sederhana rangkaiannya, keluarannya linier terhadap suhu, kepekaan cukup baik, terkalibrasi langsung dalam derajat celcius, serta murah dan mudah didapatkan.

Kepekaan sensor terhadap suhu adalah sebesar 0.01 Volt/°C dengan akurasi sebesar ± 2°C. Dengan menghubungkan pin Gnd ke tanah, maka batas bawah keluarannya adalah 0 Volt untuk 0°C sehingga keluarannya sebesar 1Volt pada 100°C. Karena suhu yang dibutuhkan antara 32°C sampai 35°C, maka suhu yang dibahas dibatasi antara 25°C sampai 40°C.

Rangkaian pengkondisi sinyal digunakan untuk menguatkan sinyal yang diterima dari sensor sehingga dapat diterima dan diproses oleh ADC. Rangkaian ini menggunakan IC penguat LM 358 yang didalamnya terdapat 2 op-amp sedangkan op-amp yang dipakai hanya 1, dapat menggunakan catu daya *non* simetris , hemat daya dan mempunyai penguatan yang cukup. Untuk outputan dari penguatan sensor ini terhubung langsung ke input ADC 0808 pada pin 27 (IN-1). Berikut ini pada gambar 3-4 adalah rangkaian penguat sinyal sensor suhu :



Gambar 3-4
Rangkaian Pengkondisi Sinyal Sensor Suhu

Untuk menghitung tegangan output dari sensor ini pada saat membaca temperature adalah :

Vout = Temp * 10mV/ ^{o}C

Dimana :

Vout : Tegangan output dari sensor LM35 (Volt)

Temp : Besarnya suhu yang dibaca sensor (^{o}C)

Sedangkan untuk mendapatkan tegangan keluaran ini maka output dari sensor diumpankan kesuatu rangkaian penguat *differensial amplifier* dengan menggunakan IC LM358, dapat dihitumg dengan menggunakan rumus:

$$Vout = Av * Vin$$

$$Av = \left(\frac{Rf}{Ri} \right)$$

$$Vout = \left(\frac{Rf}{Ri} \right) * Vin$$

Dengan:

Vin = V1 – Vref

V1 = tegangan output LM 35

Pada saat suhu 25 °C (Vout LM 35 = 0,25 Volt) tegangan output pengkondisi sinyal harus 0 Volt karena pada ADC 0808 menempati range ke 0 (range ADC antara 0 – 255), maka Vref di set pada tegangan:

$$Vout = Av * Vin$$

$$Vout = Av * (0,25 - Vref)$$

$$0\,Volt = Av * (0,25 - Vref)$$

$$Vref = 0,25\,Volt$$

Pada saat suhu 26 °C (Vout LM 35 = 0,26 Volt) dengan Vref sebesar +0,25 Volt dan pada ADC 0808 menempati range ke 10 (tegangan input ADC = 1,96 Volt), maka penguatannya dirancang sebesar:

$$Vout = Av * Vin$$

$$Av = \frac{Vout}{Vin}$$

$$Av = \frac{1,96\,V}{(0,26 - 0,25)V}$$

$$Av = \frac{1,96\,V}{0,1V}$$

$$Av = 19,6\,kali \approx 20\,kali$$

Dari perancangan diatas, maka:

$$Av = \left(\frac{Rf}{Ri}\right) * Vin$$

$$Av = \left(\frac{20\,K}{1K}\right) * (V1 - Vref)$$

$$Av = 20 * (V1 - Vref)$$

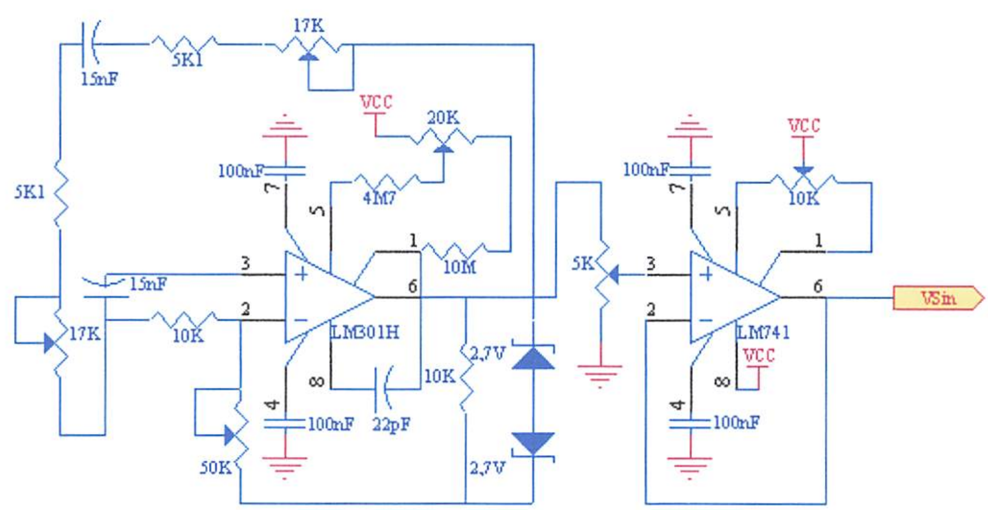
3.1.2.2.Sensor Kelembaban

Dalam melakukan pengukuran kelembaban pada suatu ruangan atau daerah maka kita harus memasukkan suhu sebagai faktor yang sangat berpengaruh terhadap kelembaban tersebut. Kelembaban Relatif / *Relative Humidity* (RH) adalah suatu perbandingan yang dinyatakan dalam prosentasi, banyaknya persen uap air di dalam atmosfer terhadap jumlah yang dibutuhkan untuk memenuhinya pada suhu yang sama. Kelembaban relatif berubah-ubah menyesuaikan suhu. RH 50% "± 5%", simbol "± 5%"menjelaskan adanya batas toleransi 5%, yaitu lebih 2,5% atau kurang 2,5% dari standar 50%, yang berarti tidak boleh kurang dari 47,5% dan lebih dari 52,5%. Suhu 20 °C "± 2 °C" ; simbol "± 2 °C " menjelaskan adanya batas toleransi 2 °C, yaitu lebih satu atau kurang satu dari standar 20°C, yang berarti tidak boleh kurang dari 19 °C dan lebih dari 21 °C.

Kelembaban dapat diukur dengan berbagai macam cara, maka pada perancangan alat ini digunakan sensor kelembaban RHK1AN. Untuk dapat mengambil sinyal hasil pengukuran dari sensor kelembaban, maka diperlikan rangkaian pengkondisi sinyal pada sensor tersebut.

Untuk menjaga kondisi sensor RHK1AN terhindar dari gangguan korosi akibat perubahan kondisi udara maka sebelumnya diberikan tegangan AC dengan suatu pembangkit tegangan AC. Generator sinus diatur untuk menghasilkan sinyal sinusoida antara 50 Hz sampai 1 KHz dengan amplitudo 1 V (Vrms= 1 V). Sinyal sinus diumpankan pada rangkaian jembatan dan outputnya dimasukkan pada penguat *inverting*.

Rancangan pengkondisi sinyal untuk sensor kelembaban udara ini terdiri dari beberapa bagian yaitu: pembangkit tegangan AC, pengkondisi sinyal, dan penyearah tegangan AC ke DC.



Gambar 3-5
Rangkaian Pembangkit Tegangan AC

Diketahui:

R1 = 5,1 KΩ

R2 = 17 KΩ

C = 15 nF

Sehingga:

$$f = \frac{1}{2\pi.R.C}$$

$$f = \frac{1}{2.3,14.(5,1.10^3 + 17.10^3).(15.10^{-9})}$$

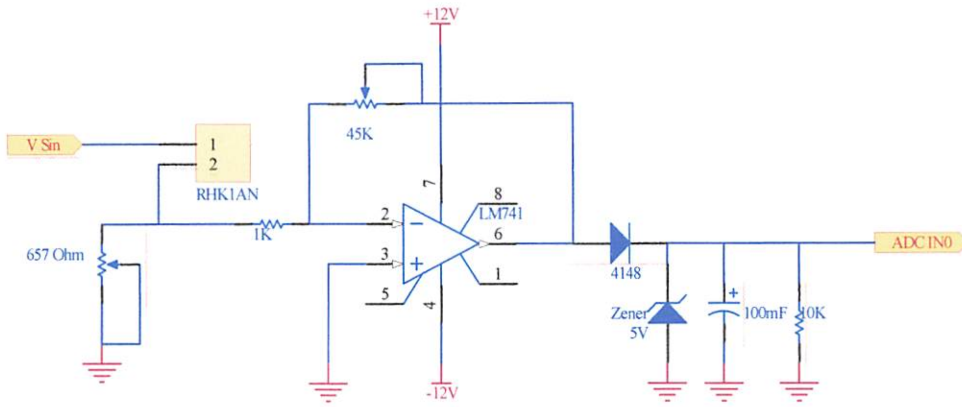
$$f = \frac{1}{6,28.(22,1.10^3).(15.10^{-9})}$$

$$f = \frac{1}{2,08.10^{-3}}$$

$$f = 480,77 Hz$$

Jika dilihat pada datasheet sensor RHK1AN, frekuensi yang dibutuhkan oleh sensor RHK1AN adalah antara 50 Hz sampai 1 KHz. Sehingga frekuensi yang dihasilkan oleh generator sinus ini sudah sesuai dan memenuhi syarat.

Setelah pembangkit tegangan AC diberikan pembatas tegangan berupa dua buah diode zener 2,7 Volt agar tegangan AC yang diberikan terhadap RHK1AN tidak melebihi dari 2,7 Volt.



Gambar 3-6
Rangkaian Pengkondisi Sinyal Sensor Kelembaban dan Penyearah Tegangan AC ke DC

Kemudian sinyal dari sensor dikuatkan lagi oleh penguat *inverting* yang penguatannya dapat dihitung:

Pada:

Rf = 45 KΩ

Ri = 1 KΩ

Sehingga:

$$Av = -\frac{Rf}{Ri}$$

$$Av = -\frac{45.10^3}{1.10^3}$$

$$Av = 45$$

Penguatannya 45 kali

Dan

$$Vout = Av * Vin$$

$$Vout = 45 * Vin$$

Selanjutnya Vout yang bertegangan AC tadi disearahkan oleh sebuah diode 1N4148 yang kemudian diinputkankan pada pin26 (IN-0) ADC untuk diproses selanjutnya.

3.1.3. ADC 0808 (Analog to Digital Convereter)

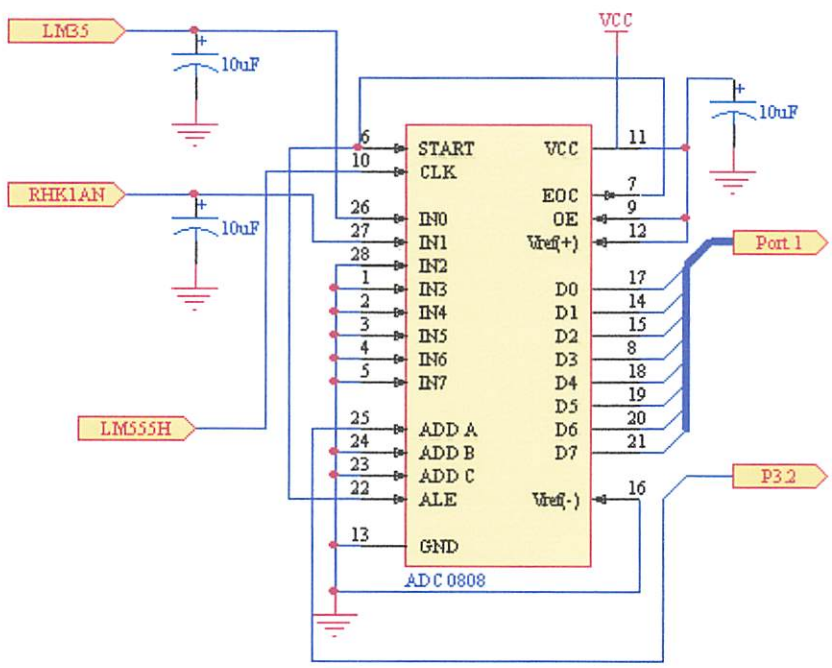
Dalam pembuatan alat ini juga dibutuhkan pengubah sinyal analog menjadi sinyal digital atau disebut *Analog to Digital Converter* (ADC), hal ini disebabkan karena sinyal-sinyal yang didapat dari sensor suhu dan sensor Kelembaban adalah berupa sinyal analog sedangkan rangkaian kontrolnya menggunakan sistem digital sehingga membutuhkan input berupa sinyal digital. Jenis ADC yang digunakan adalah ADC0808 yang memiliki kelebihan yaitu dapat menerima hingga 8 inputan. Pada alat ini hanya mengunakan 2 inputan saja yaitu ADD A (pin 25) sebagai inputan dari pengkondisi sinyal sensor suhu, sedangkan ADD B (pin 24) dan ADD C (pin 23) digroundkan karena input yang dipakai hanya 2 saja. Untuk lebih jelasnya dapat kita lihat pada tabel dibawah ini :

Tabel 3.1
Address Decoder ADC0808

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

(Sumber: Data Sheet ADC 0808)

Berikut adalah gambar dari rangkaian ADC0808 :



Gambar 3-7
Perencanaan Rangkaian ADC 0808

Penjelasan dari gambar diatas :

- IN0 (pin 26) merupakan inputan yang berupa sinyal analog dari pengkondisi sinyal sensor Kelembaban RHK1AN, IN1 (pin 27) merupakan inputan yang berupa sinyal analog yang berasal dari sensor Suhu LM35, sedangkan IN2 – IN7 digroundkan karena tidak digunakan.
- D0 – D7 digunakan untuk mengirim data digital ke mikrokontroller.
- ADD A digunakan untuk menerima sinyal dari mikrokontroller untuk memilih data antara sensor suhu atau sensor kelembaban.

Karena tegangan yang diukur cukup stabil, maka beda tegangan / bit dari ADC 0808 diharapkan kecil, sehingga diunakan $Vref^{(+)}$ = 5 Volt dan $Vref^{(-)}$ = 0 Volt. Dimana beda tegangan / bit dari ADC 0808 adalah:

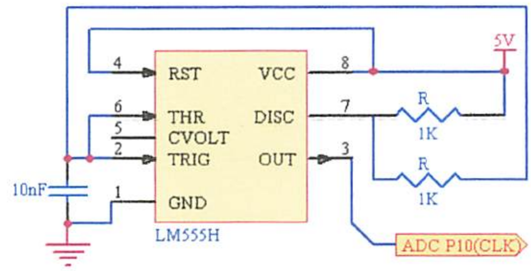
$$\text{Beda tegangan / bit} = \frac{Vref^{(+)} - Vref^{(-)}}{2^8 - 1}$$

$$= \frac{5-0}{256-1}$$

$$= \frac{5}{255}$$

$$= 0{,}0196 \text{ Volt}$$

Agar ADC 0808 dapat bekerja, maka diperlukan sebuah sumber pulsa (clock), karena pada ADC0808 tidak memiliki *clock internal* sehingga untuk mengaktifkanya diperlukan *clock eksternal*. Dalam hal ini menggunakan IC LM555. Berikut ini adalah gambar dari rangkaian clock eksternal ADC0808 :



Ganbar 3-8
Clock ADC 0808

Dari gambar rangkaian diatas dapat kita hitung besarnya frekuensi yang dihasilkan adalah sebagai berikut :

$$f = \frac{1{,}44}{(R_A + 2R_B) * R.C}$$

$$f = \frac{1{,}44}{(1.10^3 + 2.1.10^3).(10.10^{-9})}$$

$$f = \frac{1{,}44}{3.10^3.10.10^{-9}}$$

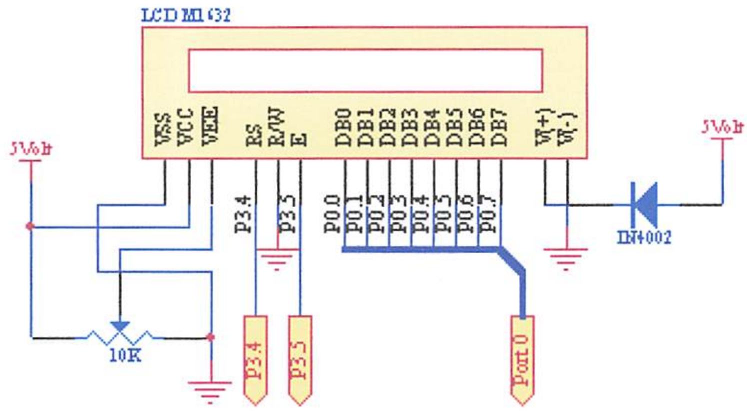
$$f = \frac{1{,}44}{3.10^{-5}}$$

$$f = 48KHz$$

Berdasarkan perhitugan diatas dapat diketahui frekuensi yang dihasilkan oleh rangkaian *clock eksternal* adalah 48 KHz. Jadi jika dilihat pada datasheet ADC0808, frekuensi clock yang dibutuhkan oleh ADC0808 adalah antara 10 – 280 KHz. Sehingga frekuensi yang dihasilkan oleh rangkaian clock eksternal ini sudah sesuai dan memenuhi syarat.

3.1.4. LCD (*Liquid Crystal Display*)

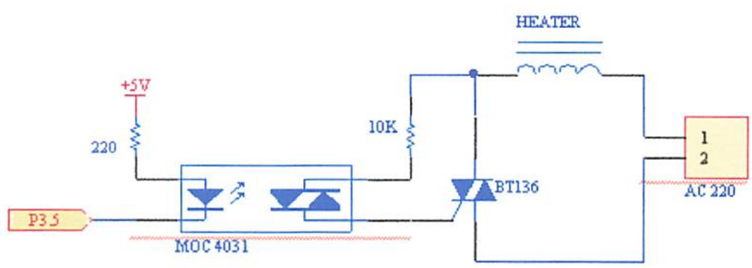
Bagian utama dari rangkaian ini adalah penampil karakter LCD 16 x 2 baris. Potensio berfungsi untuk mengatur kecerahan layar LCD. RS (*Register Select*) dan *Enable* pada pin 4 dan pin 6 yang merupakan kontrol dari LCD. Saluran data (*data bus*) dihubungkan ke port 0 mikrokontroler.



Gambar 3-9
Rangkaian LCD

3.1.5. Rangkaian Driver Pemanas

Untuk perancangan driver heater (pemanas) digunakan optotriac karena heater disini memakaisupply tegangan 220 VAC.



Gambar 3-10
Rangkaian Driver Pemanas

Tegangan output maksimal dari mikrokontroller adalah 5 Volt sedangkan untuk heater memerlukan supply 220VAC, maka diperlukan rangkaian driver untuk mengendalikannya. Rangkaian driver yang dipakai berupa optotriac MOC 3041 dan triac BT 139, untuk analisa data yang digunakan:

Vin = 5 Volt

Data Sheet untuk mengaktifkan MOC 3041:

V_F (tegangan forward dioda) = 1,5 Volt

I_{FT} (arus forward Trigger) = 15 mA

Maka untuk mengaktifkan optotriac, Resistor yang dipasang:

$$R = \frac{V_{in} - V_F}{I_{FT}}$$

$$R = \frac{5V - 1{,}5V}{15mA}$$

$$R = \frac{3{,}5V}{15mA}$$

$$R = 233\ \Omega$$

Karena nilai resistor 233 Ω tidak ada dipasaran, maka digunakan resistor yang mendekati yaitu 220 Ω.

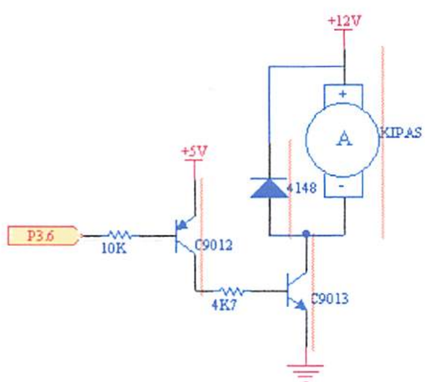
Karena tegangan jaringan yang digunakan adalah 220V dan arus gate maksimum (I_{GTM}) adalah 25 mA, maka total nilai R adalah :

$$R = \frac{V_{jaringan}}{I_{GTM}} = \frac{220}{25.10^{-3}} = 8{,}8K\Omega$$

Karena nilai resistor 8,8 KΩ tidak ada dipasaran, maka digunakan resistor yang mendekati yaitu 10 KΩ.

3.1.6. Rangkaian Driver Fan

Fan digunakan untuk membuang udara panas didalam ruangan keluar, selain itu fan berfungsi untuk sirkulasi udara. Untuk menggerakkan fan ini dengan cra memutar motor DC yang terdapat pada fan. Pada driver fan ini digunakan penguat transistor, dimana transistor ini difungsikan dalam kondisi cut off dan saturasi atau dapat dikatakan transistor ini berfungsi sebagai saklar.



Gambar 3-11
Rangkaian Driver Kipas

Dari transistor C9013 diketahui:

I_C = 100 mA

Hfe = 110

$V_{C(SAT)}$ = 0,16 Volt

V_{BE} = 0,7 Volt

Sehingga:

$$Ic = Hfe.I_B$$

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

$$I_B = \frac{100.10^{-3}}{110}$$

$$I_B = 0{,}909mA$$

R_B untuk Transistor 9013:

$$5 - V_{C(SAT)} - I_B.R_B - V_{BE} = 0$$

$$5 - 0{,}16 - 0{,}909.10^{-3}.R_B - 0{,}7 = 0$$

$$4{,}84 - 0{,}909.R_B - 0{,}7 = 0$$

$$R_B = \frac{4{,}84 - 0{,}7}{0{,}909.10^{-3}}$$

$$R_B = 4{,}55K\Omega$$

Karena nilai resistor 4,55 KΩ tidak ada dipasaran maka digunakan resistor yang mendekati yaitu 4,7 KΩ.

Dan dari transistor 9012 diketahui:

V_{EE} = 5 Volt

Hfe = 120

I_{E1} = 50 mA

V_{BE} = 0,7 Volt

Sehingga:

$$Ic = Hfe.I_B$$

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

$$I_B = \frac{50.10^{-3}}{120}$$

$$I_B = 0{,}416mA$$

R_B untuk Transistor 9013:

$$R_B = \frac{V_{BB} - V_{BE}}{I_B}$$

$$R_B = \frac{5-0,7}{0,416.10^{-3}}$$

$$R_B = 10,33 K\Omega$$

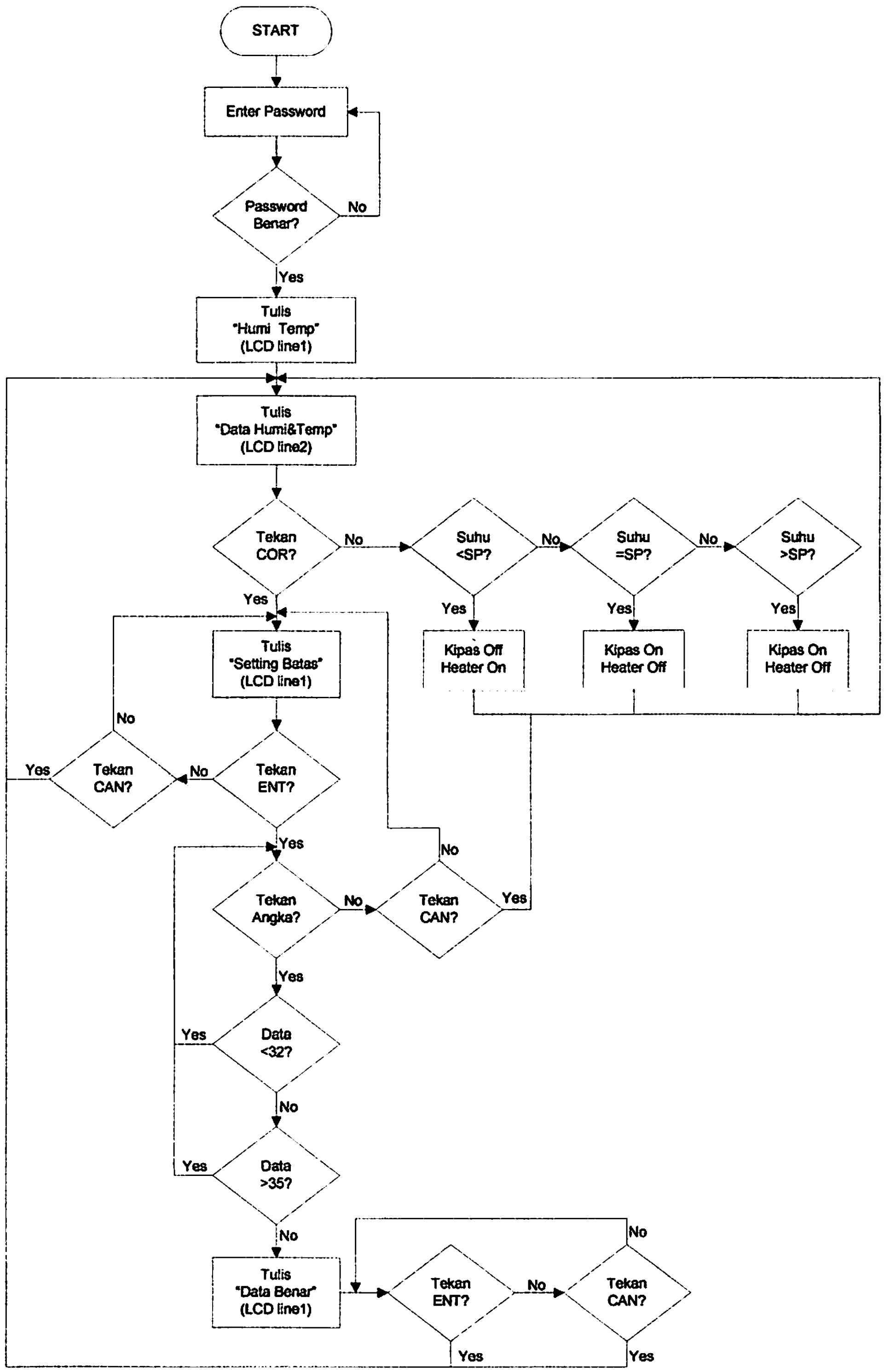
Karena nilai resistor 10,33 KΩ tidak ada dipasaran maka digunakan resistor yang mendekati yaitu 10 KΩ.

3.2. Perencanaan Perangkat Lunak (*Software*)

Untuk mendukung *hardware* yang sudah dibuat, maka dibutuhkan perangkat lunak (*software*) supaya perangkat keras tersebut bisa berjalan sesuai dengan tujuan. Mikrokontroler dapat mengendalikan seluruh sistem apabila ada urutan instruksi yang mendefinisikan secara jelas urutan kerja yang harus dilaksanakan. Dalam perancangan alat ini perangkat lunak yang digunakan adalah bahasa pemrograman *assembler* dan perangkat lunak bahasa pemrograman Delphi.

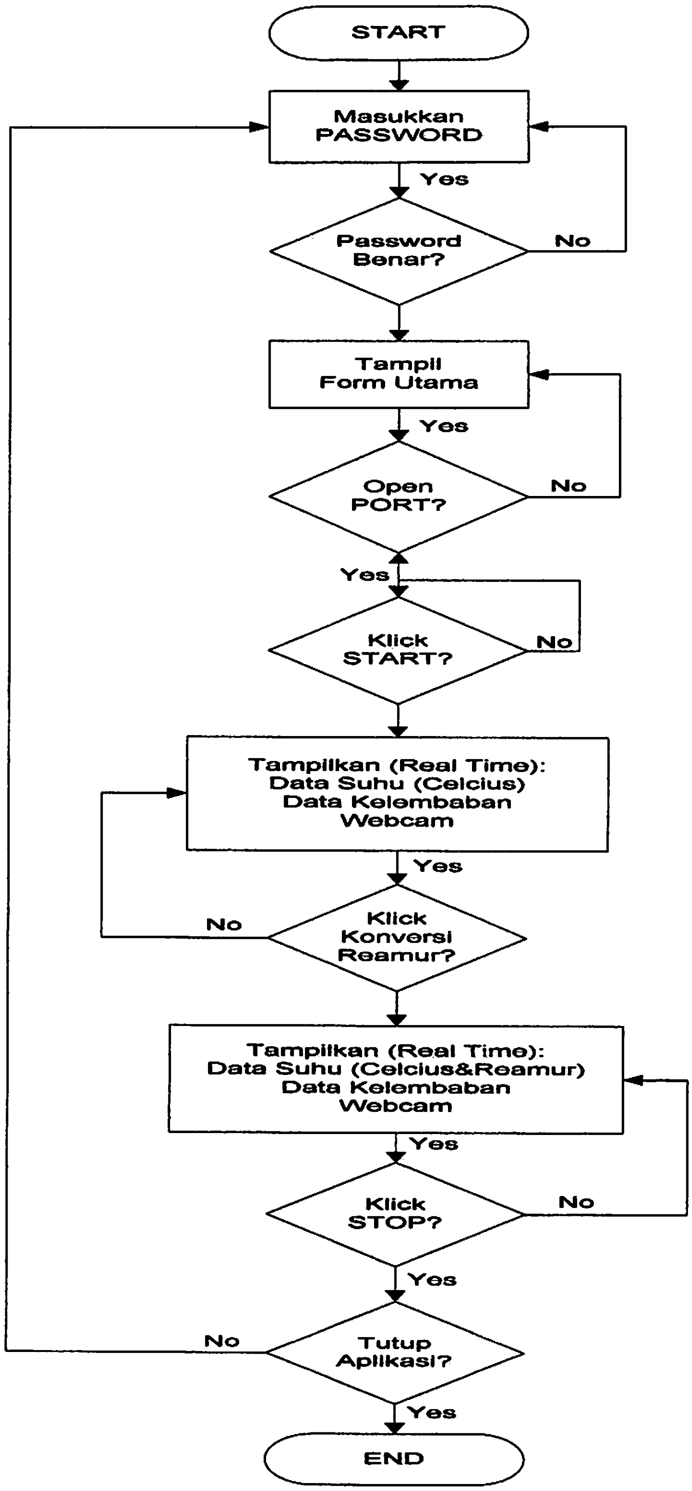
Sebelum membuat perangkat lunak, terlebih dahulu dibuat diagram alir (*flowchart*) dari proses yang akan dibuat supaya memudahkan dalam pembuatan perangkat lunak (*software*).

3.2.1. Flowchart Mikrokontroller



Gambar 3.12
Flowchart Mikrokontroller

3.2.2. Flowchart Pada PC



Gambar 3.13
Flowchart Pada PC

BAB IV

PENGUJIAN ALAT

Dalam bab ini membahas tentang pengujian dan pengukuran dari peralatan yang dibuat. Secara umum pengujian ini bertujuan untuk mengetahui apakah alat yang telah direalisasikan dapat bekerja sesuai dengan spesifikasi perencanaan yang telah ditetapkan.

4.1. Pengujian Rangkaian Sensor Suhu

4.1.1. Pengujian Rangkaian Sensor LM 35

a. Tujuan

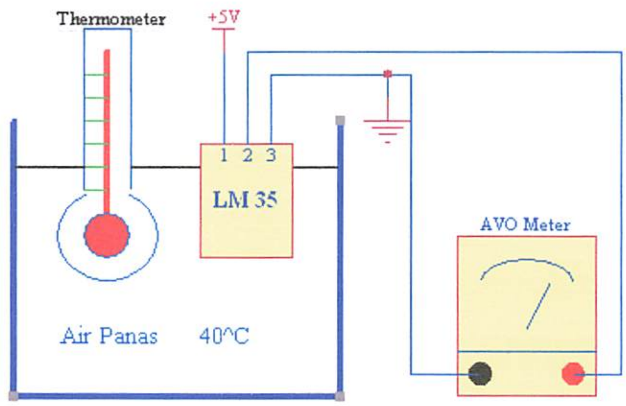
Untuk mengetahui besarnya tegangan output dari sensor *temperature* LM 35 berdasarkan perubahan temperature dari ruangan.

b. Peralatan yang digunakan

- Rangkaian yang akan diuji
- Voltmeter Digital (DT9205B)
- Sumber Tegangan +5 Volt
- Air Panas
- Termometer

c. Langkah-langkah pengujian

1. Merangkai rangkaian seperti pada gambar dibawah ini:



Gambar 4-1
Rangkaian Pengujian Sensor Suhu

2. Menghubungkan kaki IC LM 35 dengan tegangan DC +5 Volt pada kaki untuk Vcc, dengan Ground, dan kaki Vout ke Multimeter.
3. Meletakkan sensor LM 35, Air panas, dan Termometer pada satu tempat.
4. Melakukan pengukuran pada kaki output IC LM 35 dari suhu tinggi sampai suhu menurun sesuai berubahnya suhu air.

d. Analisa

Dari pengukuran dan pengamatan diuji apakah sensor suhu bekerja sesuai dengan input atau perubahan *temperature* ruangan.

Untuk hasil perhitungan dari sensor suhu dapat dihitung sebagai berikut:

Vout = 10mV * T

Dimana:

10mV = ketetapan tegangan setiap kenaikan 1°C

T = perubahan *temperature*

Contoh: Jika diketahui pada termometer menunjukkan *temperature* sebesar 25,1°C. Maka berapakah tegangan output yang dikeluarkan oleh LM 35?

Penyelesaian:

Vout = 10 * 25,1

= 251 mV

Berikut merupakan tabel perbandingan tegangan output antara hasil pengukuran dan hasil perhitungan dari sensor suhu LM 35:

Tabel 4-1
Perbandingan Tegangan Output Hasil
Perhitungan Suhu dari LM35 dengan Pengukuran Thermometer

Pengujian ke-	Pengukuran Suhu dengan Termometer (°C)	Tegangan Output (mV)	
		Hasil Perhitungan	Hasil Pengukuran
1	25,1	251	252
2	26,1	261	261
3	27,2	272	271
4	28,1	281	281
5	29,1	291	290
6	30,0	300	300
7	31,0	310	311
8	32,2	322	323
9	33,1	331	331
10	34,2	342	342
11	35,2	352	351
12	36,3	363	362
13	37,2	372	371
14	38,0	380	380
15	39,2	392	391
16	40,3	403	402

Setiap kenaikan tegangan 10 mV ≈ 1 °C, maka dari hasil pengukuran sensor suhu LM 35 dapat dihitung:

$$PengukuranSuhu(LM35) = \frac{Vout_{Pengukuran}}{10mV}$$

Contoh: Jika diketahui pengukuran suhu dengan Thermometer sebesar 25,1°C, $V_{out(pengukuran)}$= 252 mV. Berapakah pengukuran suhu dengan LM 35?

Penyelesaian:

$$PengukuranSuhu(LM35) = \frac{252mV}{10mV}$$

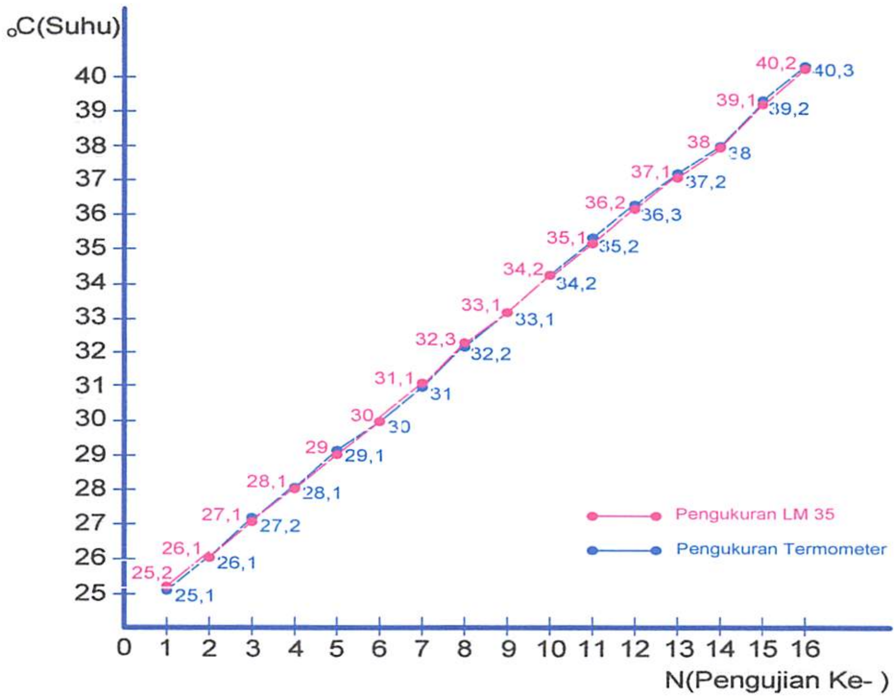
$$= 25{,}2\ ^{\circ}C$$

Berikut merupakan tabel perbandingan antara pengukuran suhu menggunakan termometer dibandingkan dengan pengukuran suhu menggunakan sensor LM 35:

Tabel 4-2
Perbandingan antara Pengukuran Suhu menggunakan Termometer Dibandingkan dengan Pengukuran Suhu Menggunakan Sensor LM 35

Pengujian ke-	Pengukuran Suhu (°C)	
	Thermometer	Sensor LM 35
1	25,1	25,2
2	26,1	26,1
3	27,2	27,1
4	28,1	28,1
5	29,1	29
6	30	30
7	31	31,1
8	32,2	32,3
9	33,1	33,1
10	34,2	34,2
11	35,2	35,1
12	36,3	36,2
13	37,2	37,1
14	38	38,0
15	39,2	39,1
16	40,3	40,2

Dari hasil pengujian sensor suhu menggunakan Termometer dan menggunakan LM 35 dengan 16 data pengujian, didapat grafik hubungan antara N(jumlah pengujian) dan suhu (°C) sebagai berikut:



Grafik 4-1
Karakteristik Perbedaan Pengukuran Suhu Thermometer dan Suhu LM 35

Dan dari tabel 4-1 diatas dapat dicari persentase kesalahan (% Error) antara perhitungan dari sensor suhu dengan pengukuran termometer. Kesalahan dapat dicari dengan rumus sebagai berikut:

$$E = \left| \frac{Pengukuran - Perhitungan}{Perhitungan} \right| x100\%$$

Contoh: Jika diketahui hasil tegangan output perhitungan sebesar 252 mV dan tegangan output pengukuran 251 mV, maka persentase error/kesalahnnya adalah:

Penyelesaian:

$$E = \left|\frac{(251-252)}{251}\right| x100\%$$

$$= \frac{1}{251} x100\%$$

$$= 0{,}4\ \%$$

Dengan rumus diatas dapat diketahui persentase kesalahan (error) dari alat yang dibuat seperti yang ditunjukkan pada tabel berikut:

Tabel 4-3
Persen Kesalahan (% Error) Tegangan Output Lm 35 antara Hasil Pengukuran dengan Hasil Perhitungan

Pengujian ke-	Tegangan Output Perhitungan (mV)	Tegangan Output LM 35 (mV)	Kesalahan (Error) (%)
1	251	252	0,4
2	261	261	0
3	272	271	0,37
4	281	281	0
5	291	290	0,34
6	300	300	0
7	310	311	0,32
8	322	323	0,3
9	331	331	0
10	342	342	0
11	352	351	0,28
12	363	362	0,28
13	372	371	0,27
14	380	380	0
15	392	391	0,26
16	403	402	0,25
% Kesalahan (Error) rata-rata			**0,19**

Dari tabel 4-3 tesebut didapatkan bahwa kesalahan (Error) rata-rata dalam persen adalah 0,19%. Dari pengamatan pengujian alat, kesalahan terjadi karena faktor keakuratan dan kepresisian komponen yang digunakan serta alat ukur yang digunakan.

4.1.2. Pengujian Rangkaian Pengkondisi Sinyal Sensor Suhu

a. Tujuan

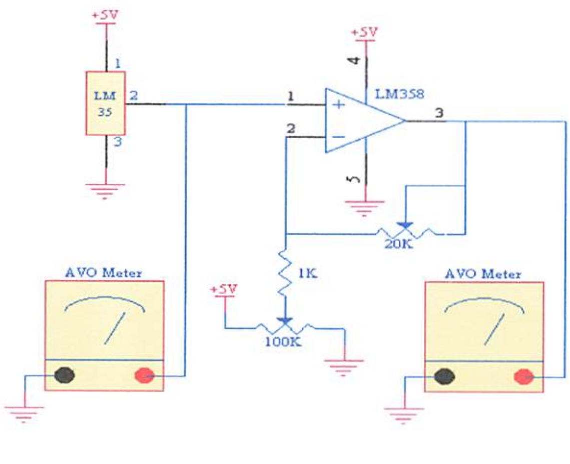
Untuk mengetahui apakah rangkaian pengkondisi sinyal bekerja sesuai dengan yang diharapkan.

b. Peralatan yang digunakan

- Rangkaian yang akan diuji
- 2 buah Multimeter digital (DT9205B, DT9202)
- Sumber tegangan +5 Volt
- Air panas
- Termometer

c. Langkah-langkah Pengujian

1. Merangkai rangkaian seperti pada gambar dibawah ini:



Gambar 4-2
Rangkaian Pengujian Pengkondisi Sinyal

2. Menghubungkan sumber tegangan +5 Volt untuk catu daya IC LM358 dan LM 35.
3. Menghubungkan kaki Vout LM 35 ke Voltmeter dan menghubungkan Vout dari pengkondisi sinyal ke Voltmeter.
4. Meletakkan sensor LM 35, Air panas, dan Termometer pada satu tempat.
5. Melakukan pengukuran pada kaki output IC LM 35 dan pengukuran output rangkaian pengkondisi sinyal dari suhu tinggi sampai suhu menurun sesuai berubahnya suhu air.

d. Analisa

Untuk perhitungan tegangan output dari rangkaian pengkondisi sinyal dapat dicari dengan menggunakan rumus berikut:

Vout = Av * Vin

$$Av = \frac{Rf}{Ri}$$

$$= \frac{20K}{1K}$$

= 20 kali

Dimana:

Vin = selisih antara Vout sensor LM 35 dengan Vref sebesar +0,25 Volt (V1 - V2)

Av = penguatan dari *differensial amplifier* (20 kali)

Contoh: Jika diketahui tegangan input sebesar 0,25 Volt, maka berapakah tegangan output dari penguat pada rangkaian pengkondisi sinyal?

Penyelesaian:

Vout = 20 * (0,25 – 0,25)

= 0 Volt

Dari pengukuran dan perhitungan tegangan output rangkaian pengkondisi sinyal dapat ditunjukkan dalam tabel 4-4 sebagai berikut:

Tabel 4-4
Hasil Pengujian Rangkaian
Pengkondisi Sinyal Sensor Suhu

Pengujian ke-	Pada Suhu	Tegangan Input (Volt)	Tegangan Output (Volt)	
			Perhitungan	Pengukuran
1	25	0,00	0,0	0,00
2	26	0,01	0,2	0,19
3	27	0,02	0,4	0,38
4	28	0,03	0,6	0,59
5	29	0,04	0,8	0,78
6	30	0,05	1	0,96
7	31	0,06	1,2	1,16
8	32	0,07	1,4	1,39
9	33	0,08	1,6	1,58
10	34	0,09	1,8	1,77
11	35	0,10	2	1,98
12	36	0,11	2,2	2,17
13	37	0,12	2,4	2,39
14	38	0,13	2,6	2,57
15	39	0,14	2,8	2,76
16	40	0,15	3	2,94

Dari hasil pengujian Rangkaian pengkondisi sinyal sensor suhu diatas diperoleh:

$\Sigma V_{out(pengukuran)}$ = 23,61 Volt

ΣV_{in} = 1,2 Volt

Dan penguatan rata-rata pada alat sebenarnya bisa dihitung dengan menggunakan rumus:

$$Av = \frac{\Sigma V_{out(pengukuran)}}{\Sigma V_{in}}$$

$$Av = \frac{23,61}{1,2}$$

$$= 19,675 \approx 20 \text{ kali (Av perencanaan= 20 kali)}$$

Dari tabel 4-4 diatas dapat dicari persentase kesalahan (%error) dari rangkaian pengkondisi sinyal. Untuk persentase kesalahan dapat dicari dengan menggunakan persamaan sebagai berikut:

$$E = \left| \frac{Pengukuran - Perhitungan}{Perhitungan} \right| x100\%$$

Contoh: Jika diketahui hasil tegangan output perhitungan sebesar 0,4 Volt dan tegangan hasil pengukuran sebesar 0,39 Volt, maka persentase error atau kesalahan adalah?

Penyelesaian:

$$E = \left| \frac{Pengukuran - Perhitungan}{Perhitungan} \right| x100\%$$

$$E = \left| \frac{0,4 - 0,39}{0,4} \right| x100\%$$

$$E = 2,5\%$$

Dengan rumus diatas dapat diketahui persentase kesalahan (error) dari alat yang dibuat seperti yang ditunjukkan pada tabel 4-5 berikut:

Tabel 4-5
Presentase Kesalahan (Error) Pengujian
Rangkaian Pengkondisi Sinyal Sensor Suhu

Pengujian ke-	**Tegangan Output (Volt)**		**% Kesalahan (Error)**
	Perhitungan	**Pengukuran**	
1	0,0	0,00	0,00
2	0,2	0,2	0,00
3	0,4	0,39	2,50
4	0,6	0,59	1,67
5	0,8	0,78	2,50
6	1	0,99	1,00
7	1,2	1,16	3,33
8	1,4	1,39	1,39
9	1,6	1,58	1,25
10	1,8	1,77	1,67
11	2	1,98	1,00
12	2,2	2,17	1,36
13	2,4	2,39	0,42
14	2,6	2,57	1,15
15	2,8	2,76	1,43
16	3	2,94	2,00
Persentase (%) kesalahan rata-rata			**1,41**

Dari hasil pengujian suhu menggunakan Termometer (sebagai alat ukur suhu sebenarnya) dan menggunakan sensor LM 35 (tampilan LCD) dengan 16 data pengujian, dapat dibuat tabel:

Tabel 4-6
Perbandingan Tampilan Suhu pada LCD dan Termometer

Pengujian ke-	Tampilan Suhu (°C)		% Kesalahan (Error)
	Termometer	LCD	
1	40	40	0
2	39	39	0
3	38	38	0
4	37	37	0
5	36	36,2	0,55
6	35	35,3	0,86
7	34	34,4	1,17
8	33	33,5	1,5
9	32	32,3	0,94
10	31	31,4	1,29
11	30	30,5	1,67
12	29	29,6	2,07
13	28	28,5	1,78
14	27	27,4	1,48
15	26	26,4	1,54
16	25	25,3	1,2
Persentase (%) kesalahan rata-rata			**1,003**

4.2. Pengujian Rangkaian Sensor Kelembaban

4.2.1. Pengujian Rangkaian Generator Sinus

a. Tujuan

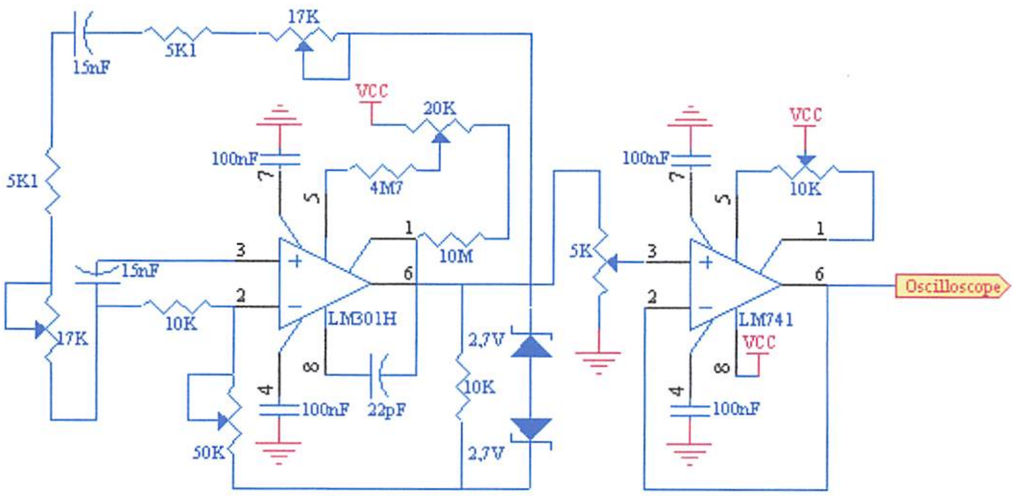
Untuk mengetahui besar frekuensi dan tegangan yang dibangkitkan oleh rangkaian generator sinus telah sesuai dengan yang dibutuhkan oleh sensor kelembaban (RHK1AN) yaitu dengan frekuensi berkisar antara 50 Hz sampai 1 KHz dengan V rms sebesar 1 V.

b. Peralatan yang digunakan

- Rangkaian pengujian Generator Sinus
- Oscilloscope (HEWLETT PACKARD 54601A)

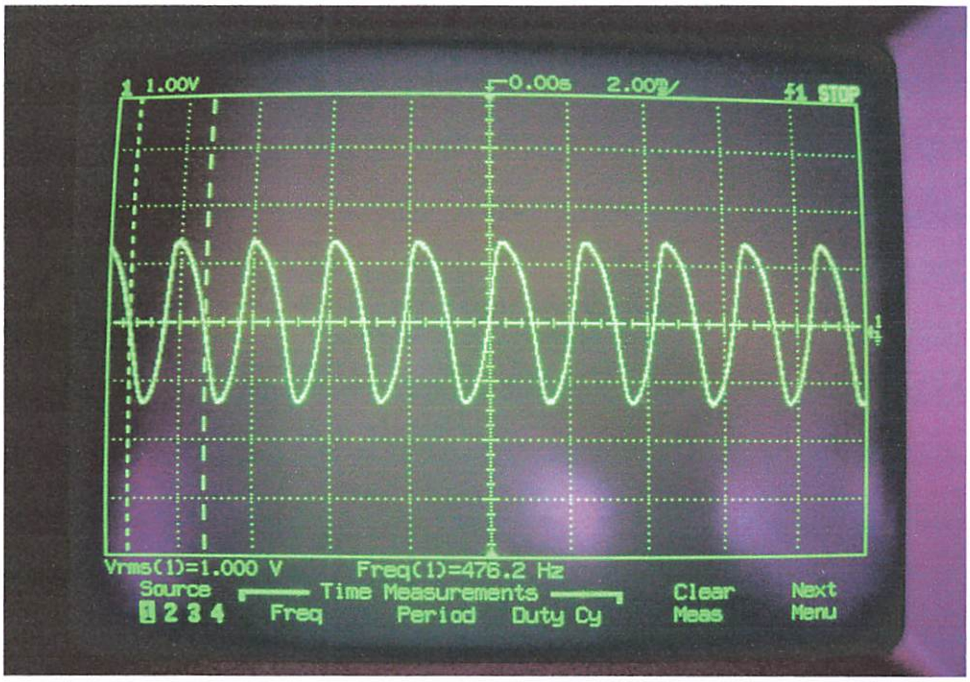
c. Langkah pengujian

Pengujian dilakukan dengan cara melihat sinyal output *Osilator*, yaitu pada pin output LM 741 (Pin 6), *Osiloscope* diset pada 500 V / div dan 1.00 ms /div, Probe merah pada *Osiloscope* dipasang pada pin 6 pada LM 741 dan probe hitam *Osiloscope* dipasang pada *ground.*



Gambar 4-3
Rangkaian Pengujian Generator Sinus

Sinyal yang dihasilkan oleh Generator Sinus tersebut terlihat seperti pada gambar 4-5 dengan frekuensi yang dihasilkan sebesar 476,2 Hz dengan V_{rms} sebesar 1 Volt pada Volt / div sebesar 1V dan Time / div sebesar 2 ms.



Gambar 4-4
Sinyal Output Generator Sinus

d. Analisa

Hasil pengujian yang terlihat pada osciloscope memastikan bahwa bentuk sinyal yang dihasilkan yaitu berupa sinyal sinusoida. Pada oscilloscope pembacaan frekuensi yang dihasilkan 476,2 Hz. Sedangkan sinyal yang direncanakan 480,77 Hz. maka terdapat persentase kesalahan/error sebesar:

$$Error = \left| \frac{pengukuran - perencanaan}{nilaiperencanaan} \right| x100\%$$

$$= \left| \frac{476{,}2Hz - 480{,}77Hz}{476{,}2Hz} \right| x100\%$$

$$= \frac{4{,}57Hz}{480{,}77Hz} x100\%$$

$= 0{,}95$ %

4.2.2. Pengujian Rangkaian Sensor Kelembaban RHK1AN

a. Tujuan

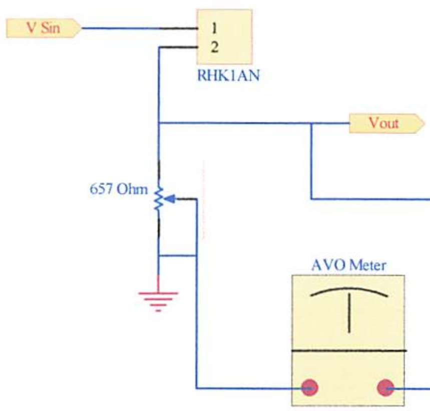
Untuk mengetahui besarnya tegangan output dari rangkaian sensor kelembaban RHK1AN berdasarkan perubahan kelembaban di ruangan.

b. Peralatan yang digunakan

- Rangkaian Pengujian Pengkondisi Sinyal Sensor Kelembaban
- Voltmeter Digital (DT9205B)
- Handuk Basah
- Hygrometer Digital (DEKKO 303C)

c. Langkah-langkah Pengujian

1. Merangkai rangkaian seperti pada gambar dibawah ini:



Gambar 4-5
Rangkaian Sensor Kelembaban RHK1AN

2. Memberikan sinyal sinusoida pada Vsin (Vin rangkaian sensor RHK1AN).
3. Mengukur Tegangan Output rangkaian sensor terhadap Ground dengan menghubungkan probe merah Multimeter pada Vout (seperti pada gambar 4-5 diatas).

d. Analisa

Gambar di atas adalah rangkaian sensor yang terbentuk dari komponen RHK1AN sebagai sensor kelembaban dan sebuah Potensio yang diset pada 657 Ω konstan dengan :

$$\text{Vout} = \frac{R_1}{R1 + R_{RHK1AN}} xVin$$

Berdasarkan karakteristik RHK1AN bahwa untuk setiap kelembaban yang berbeda, RHK1AN memiliki nilai resistansi yang berbeda, yang akan mempengaruhi Vout yang masuk ke pengkondisi sinyal. Pada saat:

- Kelembaban 60 %.

  $R_{RHK1AN} = 65000\ \Omega$

  $$\text{Maka : Vout} = \frac{657}{657 + 65000} x1$$

  $$= 0{,}01 \text{ Volt}$$

- Kelembaban 70 %

  $R_{RHK1AN} = 19500\ \Omega$

  $$\text{Maka : Vout} = \frac{657}{657 + 19500} x1$$

  $$= 0{,}032 \text{ Volt}$$

- Kelembaban 74 %

  $R_{RHK1AN} = 12400\ \Omega$

  $$\text{Maka : Vout} = \frac{657}{657 + 12400} x1$$

  $$= 0{,}05 \text{ Volt}$$

- Kelembaban 77 %

$R_{RHK1AN} = 9000\ \Omega$

$$\text{Maka : Vout} = \frac{657}{657 + 9000} x1$$

$= 0{,}068$ Volt

- Kelembaban 80 %

$R_{RHK1AN} = 6500\ \Omega$

$$\text{Maka : Vout} = \frac{657}{657 + 6500} x1$$

$= 0{,}091$ Volt

- Kelembaban 82 %

$R_{RHK1AN} = 5100\ \Omega$

$$\text{Maka : Vout} = \frac{657}{657 + 5100} x1$$

$= 0{,}114$ Volt

Dari hasil perhitungan diatas dan dari hasil pengukuran dapat dibuat tabel perbandingan:

Tabel 4-7
Perbandingan Tegangan Output Perhitungan dengan Pengukuran Sensor Kelembaban RHK1AN

Kelembaban (%)	Resistansi KΩ	V_{OUTPUT}		Error (%)
		Perhitungan	Pengukuran	
60	65	0,01	0,01	0
70	19,5	0,032	0,03	6,25
74	12,4	0,05	0,05	0
77	9	0,068	0,07	2,94
80	6,5	0,091	0,09	1,09
82	5,1	0,114	0,11	3,5
Persentase (%) kesalahan rata-rata				**2,29**

4.2.3. Pengujian Rangkaian Pengkondisi Sinyal Sensor Kelembaban

a. Tujuan

Untuk mengetahui tegangan maksimum dan tegangan minimum yang

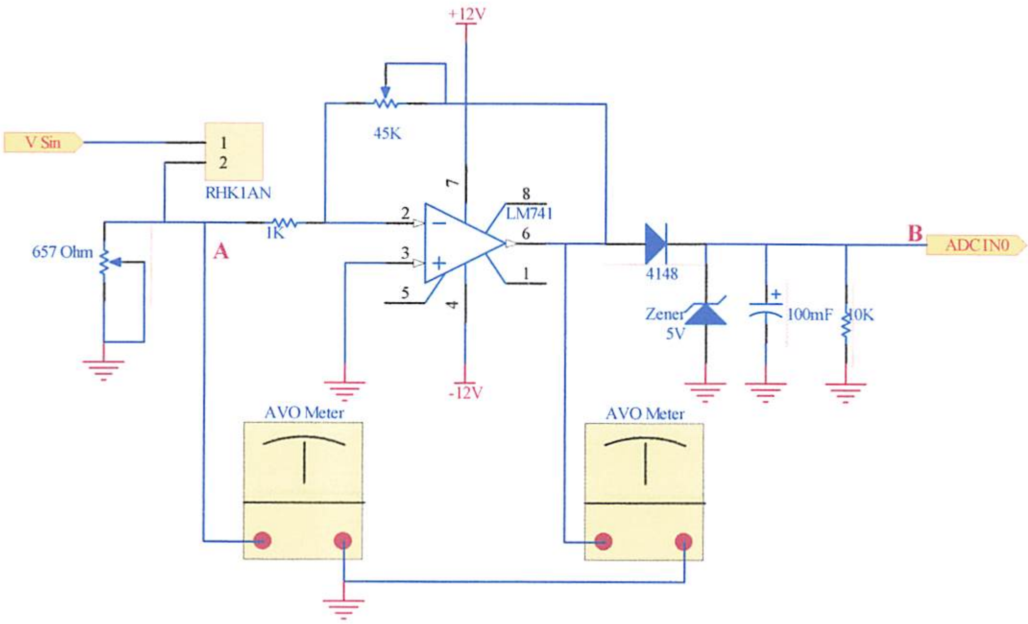
(*Relative Humidity*)

b. Peralatan yang digunakan

- Rangkaian Pengujian Pengkondisi Sinyal Sensor Kelembaban
- Voltmeter Digital (DT9205B, DT9202)
- Sumber Tegangan +12 dan -12 Volt
- Handuk Basah
- Hygrometer Digital (DEKKO 303C)

c. Langkah-langkah Pengujian

1. Merangkai rangkaian seperti pada gambar dibawah ini:



Gambar 4-5
Rangkaian Pengujian Sensor Kelembaban

2. Menghubungkan sumber tegangan simetris +12 Volt dan -12 Volt untuk catu daya IC LM741.
3. Seting Multimeter pada V_{AC} 20 mV, dan menghubungkan salah satu probe Multimeter di titik A dan lainnya di Ground. Hasil yang terlihat pada Multimeter merupakan output RHK1AN.
4. Setting Multimeter yang lain pada V_{DC} 20 mV, dan menghubungkan probe merah Multimeter di titik B dan probe hitam di Ground. Hasil yang terlihat pada Multimeter merupakan output dari pengkondisi sinyal yang sudah disearahkan.

d. Analisa

Dari hasil perancangan pada Bab III, didapatkan nilai R_f dan R_I sebagai berikut :

$Rf = 45\ K\Omega$

$Ri = 1\ K\Omega$

Sehingga:

$$Av = -\frac{Rf}{Ri}$$

$$Av = -\frac{45.10^3}{1.10^3}$$

$$Av = 45$$

Penguatannya 45 kali

Dan:

$$Vout = AvxVin$$

$$Vout = 45 * Vin$$

Dari hasil pengukuran diperoleh :

Tabel 4-8
Perbandingan Tegangan Output Hasil
Perhitungan Pengukuran Pengkondisi Sinyal Sensor Kelembaban

Vin	Vout (V_{rms})	
V_{rms}	Perhitungan	Pengukuran
0,01	0,45	0,43
0,03	1,35	1,31
0,05	2,25	2,23
0,07	3,15	3,11
0,09	4,05	4,02
0,11	4,95	4,91

Dari tabel diatas dapat dicari persentase kesalahan (%error) dari rangkaian pengkondisi sinyal. Untuk persentase kesalahan dapat dicari dengan menggunakan persamaan sebagai berikut:

$$E = \left| \frac{Pengukuran - Perhitungan}{Perhitungan} \right| x100\%$$

Dengan rumus diatas dapat diketahui persentase kesalahan (error) dari alat yang dibuat seperti yang ditunjukkan pada tabel berikut:

Tabel 4-9
Presentase Kesalahan (Error) Pengujian
Rangkaian Pengkondisi Sinyal Sensor Kelembaban

Vout (V_{rms})		Error
Perhitungan	Pengukuran	(%)
0,45	0,43	4,44
1,35	1,31	2,22
2,25	2,23	0,88
3,15	3,11	0,63
4,05	4,02	0,74
4,95	4,91	0,8
Persentase (%) kesalahan rata-rata		1,62

4.3. Pengujian Rangkaian ADC 0808

a. Tujuan

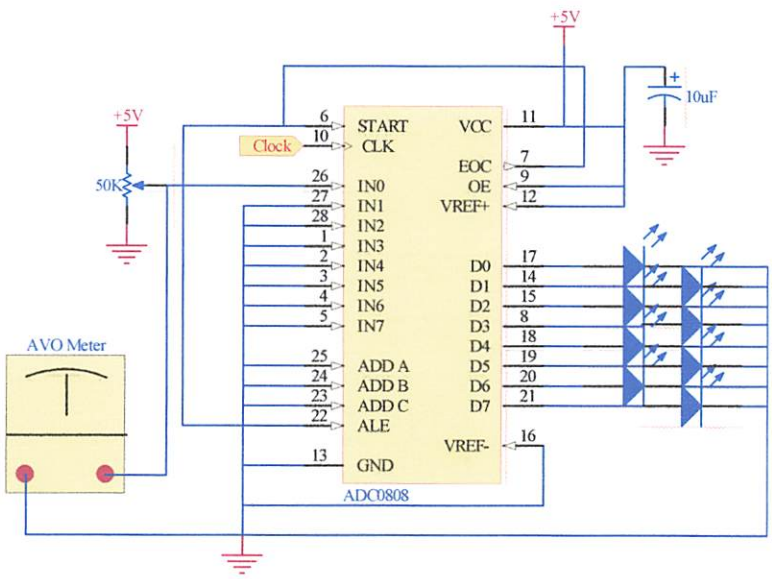
Untuk mengetahui hasil konversi tegangan *analog* menjadi bentuk tegangan *digital* (high '1' dan low '0') dari tiap volt *input* tegangan *analog.*

b. Peralatan yang digunakan

- Rangkaian pengujian ADC 0808
- Voltmeter digital (DT9205B)
- Sumber tegangan +5 Volt

c. Langkah Pengujian

1. Merangkai rangkaian seperti pada gambar dibawah ini:



Gambar 4-6
Rangkaian Pengujian ADC 0808

2. Menghubungkan pin – pin keluaran dari ADC 0808 dengan rangkaian LED.

3. Menghubungkan V_R = 50K ke pin 26 pada ADC 0808 (Vin-0).
4. Menghubungkan rangkaian pengujian ADC 0808 dengan sumber tegangan 5 Volt.
5. Menghubungkan kutub positif dan negatif multimeter digital (multimeter diset pada skala 20 Volt DC) pada V_R sebagai Vin-0, kemudian memutar V_R (tentukan nilai Vin-0 yang diinginkan) dan mencatatnya pada tabel 4-6.
6. Mengamati LED yang menyala dan mati sebagai indikator keluaran 8 bit dari ADC 0808. Mencatat hasilnya pada tabel 4-6.

d. Analisa

Untuk perhitungan Beda tegangan/bit dari output ADC 0808 dapat dicari dengan menggunakan rumus berikut:

$$\text{Beda tegangan / bit} = \frac{Vref^{(+)} - Vref^{(-)}}{2^8 - 1}$$

Dimana: $Vref^{(+)}$ = 5 Volt

$Vref^{(-)}$ = 0 Volt

Sehingga:

$$\text{Beda tegangan / bit} = \frac{Vref^{(+)} - Vref^{(-)}}{2^8 - 1}$$

$$= \frac{5-0}{256-1}$$

$$= \frac{5}{255}$$

$$= 0{,}0196 \text{ Volt}$$

Dan untuk keluaran ADC 0808 dapat dicari dengan menggunakan rumus berikut:

$$Out_{ADC(desimal)} = \frac{Vin}{BedaTegangan/Bit}$$

Dimana:

Vin = tegangan input ADC 0808 (V_R = 50 K ke pin 26)

Beda Tagangan/Bit = 0,0196 Volt

Contoh: Jika diketahui Vin 0,25 Volt. Maka berapakah keluaran ADC 0808 ?

Penyelesaian:

$$Out_{ADC(desimal)} = \frac{Vin}{BedaTegangan/Bit}$$

$$Out_{ADC(desimal)} = \frac{0,25}{0,0196}$$

$$= 12,75 \approx 13_{(10)}$$

$$Out_{ADC(biner)} = 00001101_{(2)}$$

$$Out_{ADC(hexa)} = 0D_{(16)}$$

Berikut merupakan tabel perbandingan tegangan output antara hasil pengukuran dan hasil perhitungan dari keluaran ADC 0808:

Tabel 4-10
Data Hasil Pengukuran Rangkaian Konversi ADC 0808

Vin (Volt)	Keluaran ADC 0808					
	Perhitungan			Pengukuran		
	D7-D0	Desimal	Hexadesimal	D7-D0	Desimal	Hexadesimal
0	00000000	0	00h	00000000	0	00h
0,25	00001101	13	0Dh	00001100	12	0Ch
0,5	00011010	26	1Ah	00011010	26	1Ah
0,75	00100110	38	26h	00100111	39	27h
1,01	00110100	52	34h	00110100	52	34h
1,26	01000000	64	40h	01000000	64	40h
1,5	01001101	77	4Dh	01001100	76	4Ch
1,75	01011001	89	59h	01011000	88	58h
2,02	01100111	103	67h	01101000	104	68h
2,25	01110011	115	73h	01110100	116	74h
2,5	10000000	128	80h	10000000	128	80h
2,75	10001100	140	8Ch	10001110	142	8Eh
3	10011001	153	99h	10011000	152	98h
3,25	10100110	166	A6h	10101000	168	A8h
3,5	10110011	179	B3h	10110100	180	B4h
3,75	10111111	191	BFh	11000010	194	C2h
4	11001100	204	CCh	11001110	206	Ceh
4,25	11011001	217	D9h	11011000	216	D8h
4,5	11100110	230	E6h	11101000	232	E8h
4,75	11110010	242	F2h	11110101	245	F5h
4,99	11111111	255	FFh	11111111	255	FFh

Dari tabel tersebut dapat dicari selisih antara hasil perhitungan dengan hasil pengukuran keluaran ADC 0808. Selisih dapat dicari dengan rumus sebagai berikut:

Selisih = |Pengukuran-Perhitungan|

Contoh: Jika diketahui hasil keluaran ADC 0808 perhitungan sebesar $13_{(10)}$ dan pengukuran sebesar $12_{(10)}$, maka selisihnya adalah:

Penyelesaian:

Selisih = |Pengukuran-Perhitungan|

= |12-13|

= $1_{(10)} = 01_{(16)}$

Dengan rumus diatas dapat diketahui selisih antara hasil perhitungan dengan hasil pengukuran keluaran ADC 0808 ditunjukkan pada tebel berikut:

Tabel 4-11
Data Hasil Pengukuran Rangkaian Konversi ADC 0808

Keluaran ADC 0808						Selisih (Hexa)
Perhitungan			Pengukuran			
D7-D0	Desimal	Hexadesimal	D7-D0	Desimal	Hexadesimal	
00000000	0	00h	00000000	0	00h	00h
00001101	13	0Dh	00001100	12	0Ch	01h
00011010	26	1Ah	00011010	26	1Ah	00h
00100110	38	26h	00100111	39	27h	01h
00110100	52	34h	00110100	52	34h	00h
01000000	64	40h	01000000	64	40h	00h
01001101	77	4Dh	01001100	76	4Ch	01h
01011001	89	59h	01011000	88	58h	01h
01100111	103	67h	01101000	104	68h	01h
01110011	115	73h	01110100	116	74h	01h
10000000	128	80h	10000000	128	80h	00h
10001100	140	8Ch	10001110	142	8Eh	02h
10011001	153	99h	10011000	152	98h	01h
10100110	166	A6h	10101000	168	A8h	02h
10110011	179	B3h	10110100	180	B4h	01h
10111111	191	BFh	11000010	194	C2h	03h
11001100	204	CCh	11001110	206	Ceh	02h
11011001	217	D9h	11011000	216	D8h	01h
11100110	230	E6h	11101000	232	E8h	02h
11110010	242	F2h	11110101	245	F5h	03h
11111111	255	FFh	11111111	255	FFh	00h

Dari tabel diatas dapat dicari persentase kesalahan (%error) dari rangkaian pengkondisi sinyal. Untuk persentase kesalahan dapat dicari dengan menggunakan persamaan sebagai berikut:

$$\text{Error rata-rata} = \frac{JumlahError}{JumlahPerhitungan} x100\%$$

Jika dari tabel diketahui:

$\sum$ Perhitungan (desimal) = 2682

$\sum$ Error = $17_{(16)}$ = $23_{(10)}$

Sehingga kesalahan rata-ratanya:

$$\text{Error rata-rata} = \frac{JumlahError}{JumlahPerhitungan} x100\%$$

$$= \frac{23}{2682} x100\%$$

$$= 0{,}856\ \%$$

4.4. Pengujian Driver Motor AC

a. Tujuan

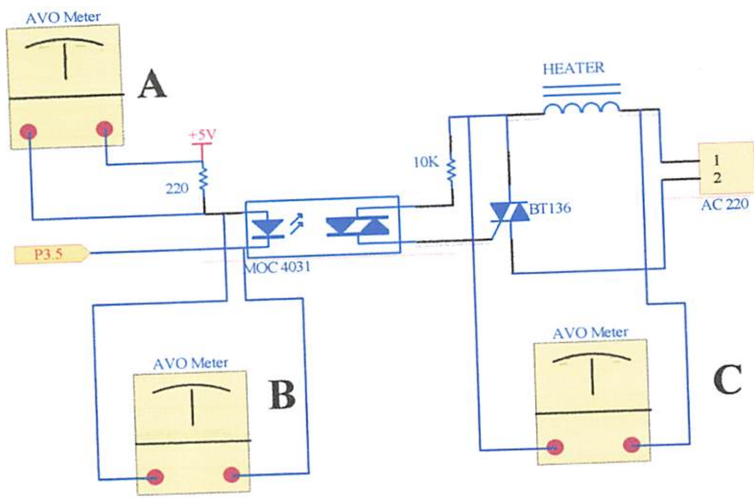
Untuk mengetahui apakah driver ini dapat menggerakkan atau mengaktifkan motor AC dalam hal ini Heater / Pemanas.

b. Peralatan yang digunakan

- Rangkaian pengujian
- Voltmeter digital (DT9205B)
- Sumber tegangan AC 220 Volt
- Sumber tegangan +5 Volt
- Pemanas / Heater

c. Langkah-langkah Pengujian

1. Merangkai rangkaian driver seperti pada gambar dibawah ini:



Gambar 4-7
Rangkaian Pengujian Driver AC

2. Melakukan pengukuran dan pengamatan.

d. Analisa

Hasil pengujian rangkaian *driver* motor AC adalah sebagai berikut :

Tabel 4-12
Hasil Pengujian Driver Motor AC

Kondisi Heater	Pengukuran		
	Multi Meter A V (DC)	Multi Meter B V (DC)	Multi Meter C V (AC)
Aktif	3,11	1,2	188
Tidak Aktif	0	0	0

Dari tabel diatas dapat dicari persentase kesalahan (%error) dari rangkaian pengkondisi sinyal. Untuk persentase kesalahan dapat dicari dengan menggunakan persamaan sebagai berikut:

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$$= \frac{23}{2682} x100\%$$

$$= 0{,}856\ \%$$

4.4. Pengujian Driver Motor AC

a. Tujuan

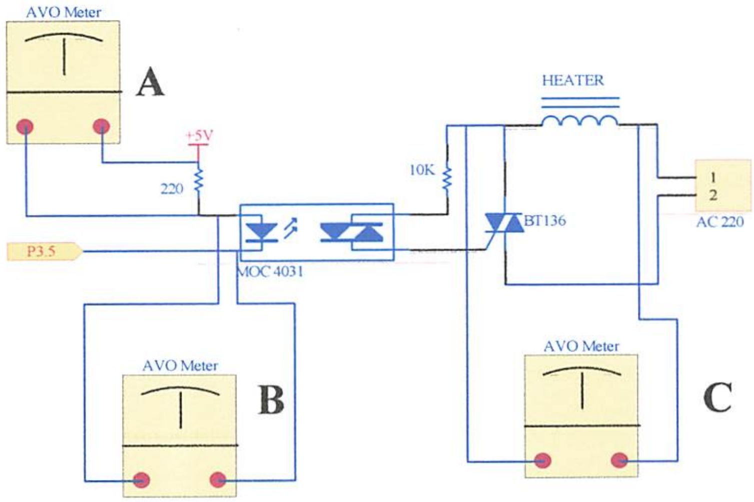
Untuk mengetahui apakah driver ini dapat menggerakkan atau mengaktifkan motor AC dalam hal ini Heater / Pemanas.

b. Peralatan yang digunakan

- Rangkaian pengujian
- Voltmeter digital (DT9205B)
- Sumber tegangan AC 220 Volt
- Sumber tegangan +5 Volt
- Pemanas / Heater

c. Langkah-langkah Pengujian

1. Merangkai rangkaian driver seperti pada gambar dibawah ini:



Gambar 4-7
Rangkaian Pengujian Driver AC

2. Melakukan pengukuran dan pengamatan.

d. Analisa

Hasil pengujian rangkaian *driver* motor AC adalah sebagai berikut :

Tabel 4-12
Hasil Pengujian Driver Motor AC

Kondisi Heater	Pengukuran		
	Multi Meter A V (DC)	Multi Meter B V (DC)	Multi Meter C V (AC)
Aktif	3,11	1,2	188
Tidak Aktif	0	0	0

Dari tabel 4-11 di atas didapat :

Tegangan pada Resistor 220 (V_{R220}) = 3,11 Volt

Tegangan pada Photodioda Optocoupler V_D = 1,2 Volt

Tegangan Output Low Controller (V_{OH}) = 0.56 Volt

Dan diketahui V_{CC} = 5 Volt

Maka :

$$V_{CC} = V_{R220} + V_D + V_{OH}$$

$$= 3{,}11 + 1{,}2 + 0{,}56$$

$$= 4{,}87 \text{ Volt} \approx 5 \text{ Volt}$$

4.5. Pengujian Driver Kipas

a. Tujuan

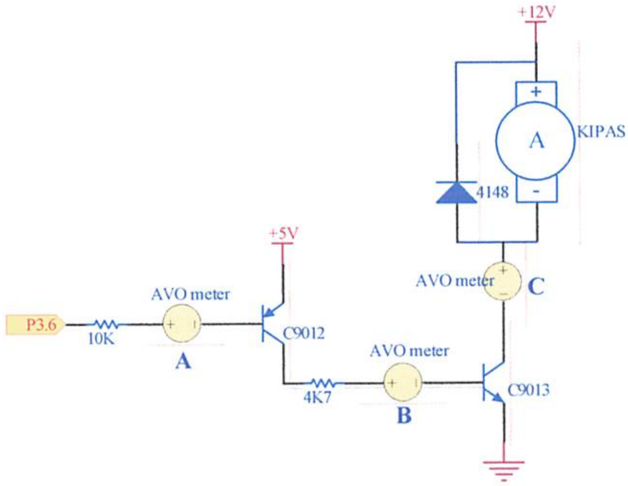
Untuk mengetahui apakah driver ini dapat menggerakkan atau mengaktifkan motor DC dalam hal ini Fan / kipas.

b. Peralatan yang digunakan

- Rangkaian pengujian (Driver Kipas)
- Sumber tegangan +5 dan +12 Volt
- Kipas DC.
- 3 buah Multimeter (DT9205B, DT9202)

c. Langkah-langkah Pengujian

1. Merangkai rangkaian driver seperti pada gambar dibawah ini:



Gambar 4-8
Rangkaian Pengujian Driver DC

2. Melakukan pengukuran dan pengamatan.

d. Analisa

Pada saat kipas aktif (motor berputar), nilai yang didapatkan dari hasil pengukuran pada setiap multimeter di atas adalah sebagai berikut :

i. I_B pada 9012 (AVO meter A) = 0,36 mA.

ii. I_B pada 9013 (AVO meter B) = 0,85 mA.

iii. I_C pada 9013 (AVO meter C) = 1,2 mA.

Dan diketahui :

R_{KIPAS} = 10 Kohm.

R_B9013 = 4,7 Kohm

R_B9012 = 10 Kohm

V_{CE}9013 = 0,6 Volt

V_{CE}9012 = 0,6 Volt

V_{OL} = 0,5 Volt

Maka, untuk menentukan nilai Arus Kolektor pada 9013 adalah:

$$V_{CC} - I_C.R_C - V_{CE} = 0$$

$$I_C = \frac{Vcc - V_{CE}}{R_C}$$

$$= \frac{12 - 0,6}{10K}$$

$$= 1,14 \text{ mA}$$

dan Arus Basis pada 9013 adalah :

$$I_B = \frac{V_{EE} - V_{CE(sat)} - 0,7}{R_B}$$

$$= \frac{5 - 0,6 - 0,7}{4700}$$

$$= 0,78 \text{ mA}$$

Arus Basis pada 9012 adalah :

$$I_B = \frac{V_{EE} - 0,7 - V_{OL}}{R_B}$$

$$= \frac{5 - 0,7 - 0,5}{10000}$$

$$= 0,38 \text{ mA}$$

Tabel 4-13
Tabel Hasil Pengukuran dan Perhitungan Driver Motor AC

Parameter	Perhitungan	Pengukuran
I_C 9013	1,14 mA	1,2 mA
I_B 9013	0,78 mA	0,85 mA
I_B 9012	0,38mA	0,36 mA

4.6. Pengujian Serial Interface

a. Tujuan

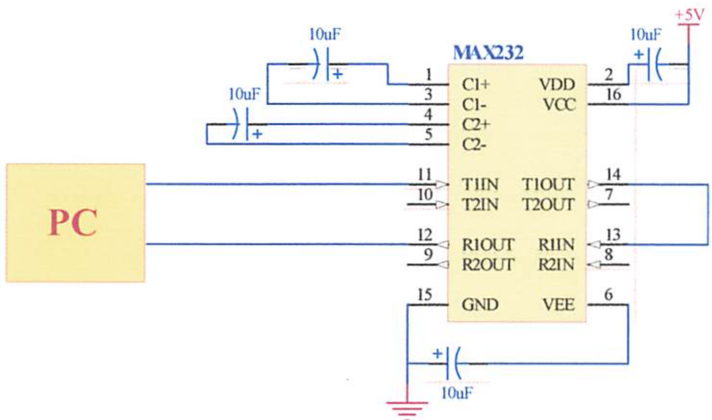
Untuk mengetahui fungsi pin Tx (pengiriman data) dan Rx(penerimaan data) pada MAX232 sudah berfungsi dengan baik. Dengan cara mengirimkan data dari PC ke Mikrokontroller melalui rangkaian MAX232 dan pada pin10 dan 11 (Rx dan Tx) dijumper, sehingga data yang akan dikirimkan oleh PC ke Mikrokontroller akan dibalikkan lagi ke PC.

b. Peralatan yang digunakan

- Rangkaian MAX232
- Kabel Serial (DB 9)
- Power Supply +5 volt
- Jumper

c. Langkah-langkah Pengujian

1. Merangkai rangkaian driver seperti pada gambar dibawah ini:

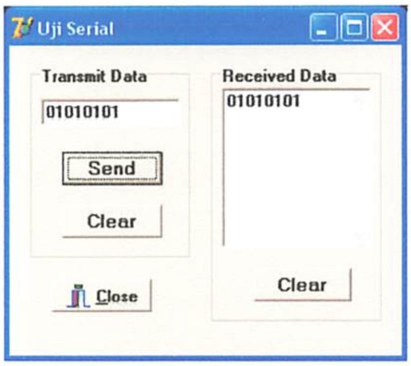


Gambar 4-9
Rangkaian Pengujian Serial Interface

2. Pada gambar di atas, output MAX232 (Pin T_X) dihubungkan dengan input (Pin R_X), dengan demikian semua data yang dikirim melalui PC akan diumpan-balikkan ke PC lagi.

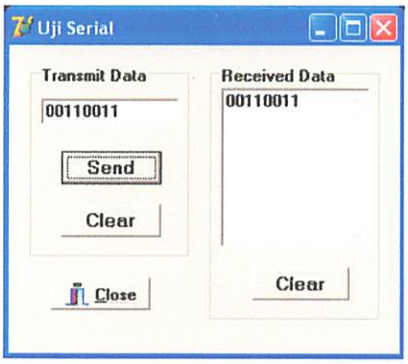
d. Hasil Pengujian

Data yang dikirim PC 01010101 maka data yang diterima oleh PC pun sama 01010101.



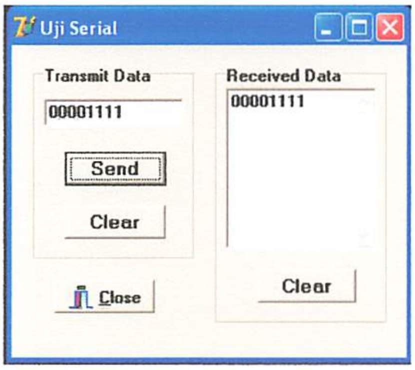
4-10
Hasil pengujian Serial Interface (pengujian 1)

Data yang dikirim PC 00110011 maka data yang diterima oleh PC pun sama 00110011.



4-11
Hasil pengujian Serial Interface (pengujian 2)

Data yang dikirim PC 00001111 maka data yang diterima oleh PC pun sama 00001111.



4-12
Hasil pengujian Serial Interface (pengujian 3)

4.7. Pengujian Sistem dengan Interface Software

a. Tujuan

Untuk mengetahui data yang dikirimkan mikrokontroller sama dengan data yang diterima oleh PC (*Personal Computer*). Dengan cara melihat data setting point suhu, data suhu dan kelembaban pada LCD sama dengan data pada interface di PC. Dan pengujian tampilan Webcam yang diletakkan didalam inkubator untuk mengetahui/memonitor keadaan bayi yang nantinya akan ditampilkan pada monitor PC.

b. Peralatan Yang Digunakan

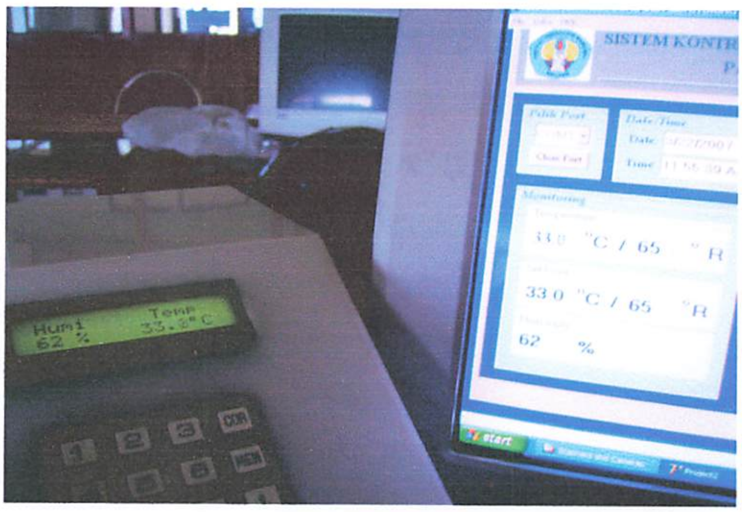
- Rangkaian Keseluruhan Sistem
- Sumber Tegangan AC 220 Volt
- 1 buah PC (*Personal Computer*)

c. Hasil Pengujian

Setting point suhu pada LCD 33 °C sama dengan tampilan pada sofware delphi pada PC juga 33 °C. Terlihat pada gambar 4-13.

4-13
Hasil Pengujian Sistem dengan Interface Software (pengujian 1)

Data pada LCD untuk suhu 33 °C dan kelembaban 62% sama dengan data pada tampilan software delphi pada PC juga 33 °C utuk suhu dan 62% untuk kelembaban. Terlihat pada gambar 4-14.



4-14
Hasil Pengujian Sistem dengan Interface Software (pengujian 2)

Pada gambar 4-15 merupakan simulasi inkubator bayi yang didalamnya diletakkan benda seukuran bayi untuk melihat hasil monitor yang ditampilkan pada software delphi. Yang mana hasil monitor dapat dilihat pada gambar 4-16.

4-15
Simulasi Inkubator Bayi

4-16
Hasil Monitor Software Delphi secara Keseluruhan

BAB V

PENUTUP

Pada bab ini penulis akan menyampaikan kesimpulan dan saran setelah melakukan pengujian pada alat kontrol suhu dan monitoring kelembaban pada inkubator bayi.

5.1. Kesimpulan

Setelah melakukan perencanaan, pembuatan dan pengujian pada alat kontrol suhu dan monitoring kelembaban pada inkubator bayi, dapat diambil kesimpulan :

1. Berdasarkan pengujian rangkaian sensor suhu LM 35 pada bab sebelumnya, dapat dikatakan bahwa alat ini dapat berfungsi dengan baik, hal ini terbukti dengan didapatkannya error rata-rata yang relatif kecil, yaitu :
   a. Pada pembacaan suhu oleh LM 35, error yang didapat adalah 0,19 %.
   b. Pada Perbandingan Display pada LCD dengan alat yang yang telah ada dipasaran didapat error rata-rata 1,003 %.
2. Berdasarkan pengujian rangkaian sensor kelembaban RHK1AN, dapat dikatakan bahwa alat ini dapat berfungsi dengan baik, terbukti dengan didapatkannya error:
   a. Hasil pengujian rangkaian sensor kelembaban, tegangan output antara pengukuran dan perhitungan diperoleh error 2,29 %.

b. Hasil pengujian rangkaian pengkondisi sinyal antara perhitungan dan pengukuran diperoleh error 1,62 %.

3. Dari pengujian rangkaian ADC 0808 dapat dikatakan rangkaian ini berfungsi dengan baik, terbukti dengan didapatkan error antara perhitungan dan pengukuran 0,856 %.
4. Dalam sistem ini, sebagai acuan dalam proses *set-point* adalah suhu, sedangkan pada kelembaban hanya pengukuran (*monitoring*).

5.2. Saran

1. Dalam proses kalibrasi, sebaiknya dilakukan minimal dengan dua alat ukur yang memiliki kualitas baik, untuk mendapatkan hasil yang baik.
2. Untuk pengembangan selanjutnya sebaiknya inkubator yang dimonitor lebih dari 1.
3. Untuk software pada PC sebaiknya dilengkapi database pasien.

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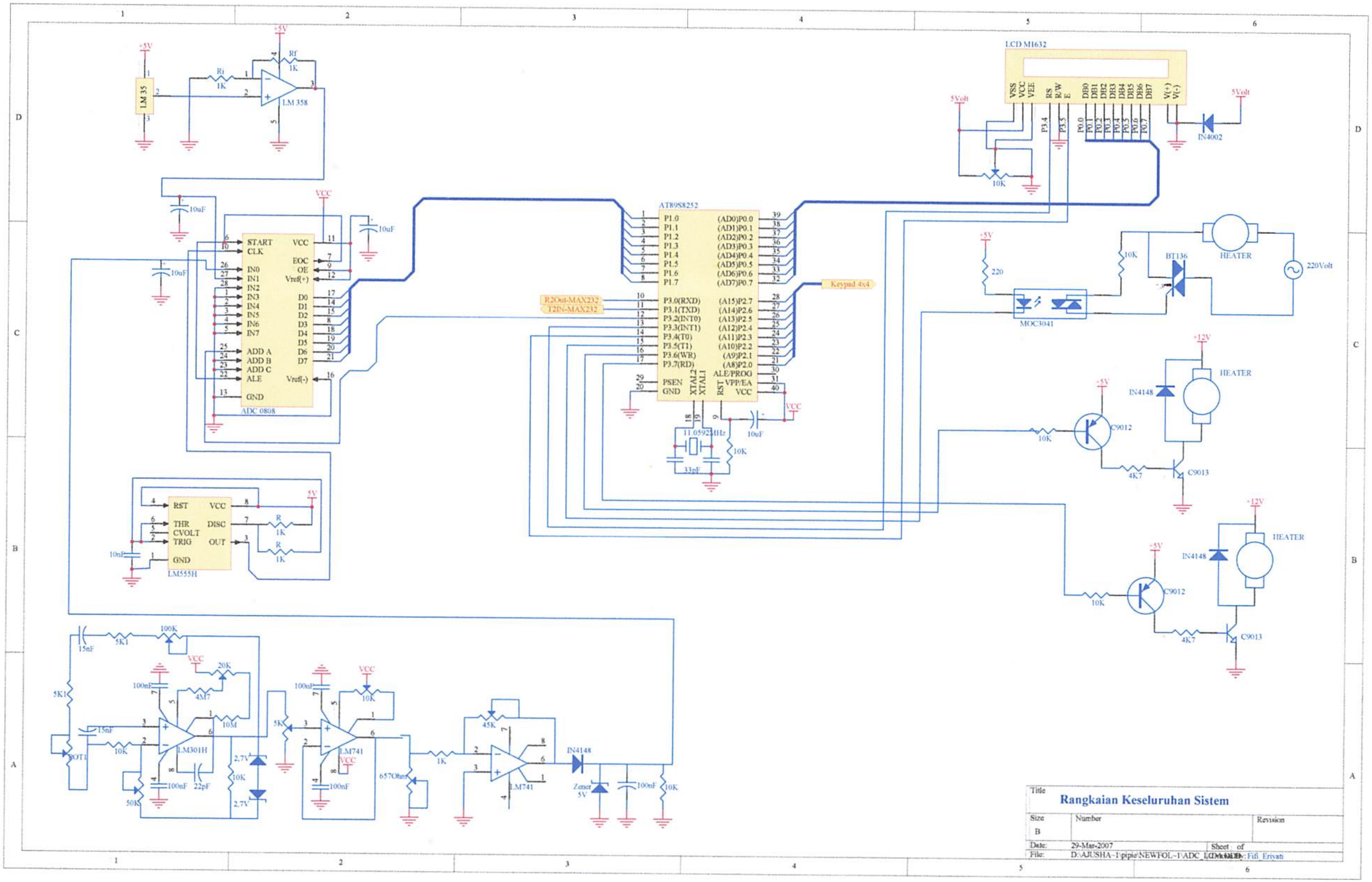
LAMPIRAN



LCD M1632
VSS VCC VEE RS R/W E DB0 DB1 DB2 DB3 DB4 DB5 DB6 DB7 V(+) V(-)
5Volt
IN4002
10K
LM 35
Ri 1K
Rf 1K
LM 358
+5V
10uF
VCC
START
CLK
IN0 IN1 IN2 IN3 IN4 IN5 IN6 IN7
ADD A ADD B ADD C ALE
GND
EOC OE Vref(+)
D0 D1 D2 D3 D4 D5 D6 D7
Vref(-)
ADC 0808
AT89S8252
P1.0 P1.1 P1.2 P1.3 P1.4 P1.5 P1.6 P1.7
P3.0(RXD) P3.1(TXD) P3.2(INT0) P3.3(INT1) P3.4(T0) P3.5(T1) P3.6(WR) P3.7(RD)
PSEN GND XTAL2 XTAL1 RST
(AD0)P0.0 (AD1)P0.1 (AD2)P0.2 (AD3)P0.3 (AD4)P0.4 (AD5)P0.5 (AD6)P0.6 (AD7)P0.7
(A15)P2.7 (A14)P2.6 (A13)P2.5 (A12)P2.4 (A11)P2.3 (A10)P2.2 (A9)P2.1 (A8)P2.0
ALE/PROG VPP/EA VCC
R2Out-MAX232
T2IN-MAX232
Keypad 4x4
11.0592MHz
33pF
10uF
10K
HEATER
BT136
220Volt
220
MOC3041
+12V
IN4148
C9012
C9013
4K7
RST VCC THR DISC CVOLT TRIG OUT GND
LM555H
R 1K
10nF
15nF 5K1 100K
20K 4M7 10M
LM301H
POT1
50K
100nF 22pF
2,7V
5K
LM741
45K
657Ohm
1K
IN4148
Zener 5V
100nF
10K
Title
Rangkaian Keseluruhan Sistem
Size B
Number
Revision
Date: 29-Mar-2007
Sheet of
File: D:\AJUSHA~1\pipie\NEWFOL~1\ADC_LCD.DDB
Drawn By: Fifi Eriyati

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FAKULTAS TEKNOLOGI INDUSTRI
JURUSAN TEKNIK ELEKTRO

FORMULIR BIMBINGAN SKRIPSI

Nama : FIFI ERIYATI
NIM : 02 17 127
Masa Bimbingan : 3 Juni 2006 – 3 Desember 2006
Judul Skripsi : PERENCANAAN DAN PEMBUATAN ALAT KONTROL SUHU PADA INKUBATOR BAYI DENGAN MENGGUNAKAN AT89S8252 YANG TERMONITOR DENGAN PC.

No	Tanggal	Uraian	Paraf Pembimbing
1.	15/12 06.	Bab I :	
2.		– Rumusan masalah	[signature]
3.		– Batasan "	
4.		Bab II :	[signature]
5.		– Referensi dicantumkan	
6.		– Rencana Daftar isi	[signature]
7.		Bab I s/d Bab V	
8.		– Lengkapi bab III dst.	[signature]
9.	12/02 07	Block Diagram diperbaiki	[signature]
10.	Bab IV	– Gambar sinyal dicek	[signature]

– Error kelembaban diuji ulang.

Malang,
Dosen Pembimbing I

[signature]

Ir. Poerwanto, MT
NIP.P. 131574847

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JURUSAN TEKNIK ELEKTRO

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Nama : FIFI ERIYATI
NIM : 02 17 127
Masa Bimbingan : 3 Juni -3 Desember 2006
Judul Skripsi : PERANCANGAN DAN PEMBUATAN ALAT KONTROL SUHU PADA INKUBATOR BAYI DENGAN MENGGUNAKAN AT89S8252 YANG TERMONITOR DENGAN PC.

No	Tanggal	Uraian	Paraf Pembimbing
1	14/02 07.	Bab V :	[signature]
2	–	Kesimpulan di lengkapi	
3	–	Saran diperbaiki.	
4	–	Acc Seminar hasil.	
5			
6			
7			
8			
9			
10			

Malang,

Dosen Pembimbing I

[signature]

Ir. Poerwanto, MT
NIP.P. 131574847

Form. S – 4b

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JURUSAN TEKNIK ELEKTRO

FORMULIR BIMBINGAN SKRIPSI

Nama	:	FIFI ERIYATI
NIM	:	02 17 127
Masa Bimbingan	:	3 Juni 2006 – 3 Desember 2006
Judul Skripsi	:	PERENCANAAN DAN PEMBUATAN ALAT KONTROL SUHU PADA INKUBATOR BAYI DENGAN MENGGUNAKAN AT89S8252 YANG TERMONITOR DENGAN PC.

No	Tanggal	Uraian	Paraf Pembimbing
1.	14/2 '07	Konsultasi bab I s/d III	
2.	19/2 '07	Konsultasi bab IV & V	
3.	19/2 '07	Konsultasi Makalah Seminar	
4.	1/3 '07	Demo Alat + Op.. Amp	
5.			
6.			
7.			
8.			
9.			
10.			

Malang,

Dosen Pembimbing II

Sotyohadi, ST, MT

NIP.

INSTITUT TEKNOLOGI NASIONAL
FAKULTAS TEKNOLOGI INDUSTRI
JURUSAN TEKNIK ELEKTRO

Formulir Perbaikan Ujian Skripsi

Dalam pelaksanaan Ujian Skripsi Janjang Strata 1 Jurusan Teknik Elektro Konsentasi T. Energi Listrik / T. Elektronika, maka perlu adanya perbaikan skripsi untuk mahasiswa :

NAMA : FIFI ERIYATI
N I M : 0217127
Perbaikan meliputi :

1. Gambar 2.1, 2.2
2. Flowchart.
3. Borland delphi →
4. Pengujian system dan Interface Software.

Malang,

( )

M. Ashar

INSTITUT TEKNOLOGI NASIONAL
FAKULTAS TEKNOLOGI INDUSTRI
JURUSAN TEKNIK ELEKTRO S-1
Jl. Karanglo KM. 2 Malang

FORMULIR PERBAIKAN SKRIPSI

Dalam pelaksanaan Ujian Skripsi Jenjang Strata Satu (S-1) Jurusan Teknik Elektro Konsentrasi Teknik Elektronika, maka perlu adanya perbaikan skripsi untuk mahasiswa :

Nama	: Fifi Eriyati
Nim	: 02 17 127
Jurusan	: Teknik Elektro S-1
Konsentrasi	: Teknik Elektronika
Masa Bimbingan	: 3 Desember 2006 s/d 3 Juni 2007
Judul Skripsi	: Perencanaan Dan Pembuatan Alat Kontrol Suhu Pada Inkubator Bayi Dengan Menggunakan AT89S8252 Yang Termonitor Dengan PC

Tanggal	Uraian	Paraf
16 Maret 2007	❖ Gambar 2-1, 2-2. ❖ Landasan Teori untuk Borland Delphi dihilangkan ❖ Flowchart ❖ Pengujian Sistem dengan Interface.	

Mengetahui,

Dosen Pembimbing I

(Ir. Poerwanto, MT)
NIP.P. 131574847

Dosen Pembimbing II

27/3 '07

(Sotyohadi, ST.MSc.)

Dosen Penguji,

Penguji Kedua

(M. Ashar, ST, MT)

```
        org     00h
        sjmp    init
;
        org     23h
        clr     ES
        jnb     RI,$
        clr     RI
        mov     R2,SBUF
        setb    ES
        reti
;
        KpsH    Bit P3.7
        Slct    Bit P3.2
        Rest    Bit P3.3
        Enbl    Bit P3.4
        Heat    Bit P3.5
        Kips    Bit P3.6
        Wmcn    Data 96h                ; eeprom control
        Eemn    Equ 08h                 ; 00001000b -> eeprom data read
        Eemw    Equ 10h                 ; 00010000b -> eeprom data write
        Wtdg    Equ 02h                 ; 00000010b -> watchdog wait write
        Psw0    Equ 30h
        Psw1    Equ 31h
        Psw2    Equ 32h
        Psw3    Equ 33h
        Psw4    Equ 34h
        Psw5    Equ 35h
        Psw6    Equ 36h
        Psd0    Equ 37h
        Psd1    Equ 38h
        Psd2    Equ 39h
        Psd3    Equ 3Ah
        Psd4    Equ 3Bh
        Psd5    Equ 3Ch
        Psd6    Equ 3Dh
        Dsh0    Equ 40h
        Dsh1    Equ 41h
        Dhum    Equ 42h
        Dta0    Equ 43h
        Dta1    Equ 44h
        Dta2    Equ 45h
        Dta3    Equ 46h
        Dbt0    Equ 47h
        Dbt1    Equ 48h
        Dbt2    Equ 49h
        Dbts    Equ 4Ah
        Stts    Equ 4Bh
        Hurf    Equ 4Ch
        Cslh    Equ 4Dh
        Dly0    Equ 50h
        Dly1    Equ 51h
        Dly2    Equ 52h
;
init:   acall   jeda
        acall   ser_in
        acall   lcd_op
        clr     Slct                    ; reset ADC address
        setb    Heat
        setb    KpsH                    ; reset Heater
        setb    Kips                    ; reset Kipas
        acall   rdmemb                  ; baca memory batas suhu
        mov     R2,#00h                 ; reset data serial
        mov     Cslh,#3
;
mulai:  mov     DPTR,#logo
        acall   line1
        mov     Hurf,#16
        acall   tulis
```

```
        acall   line2
        mov     Hurf,#16
        acall   tulis
        acall   delay1
        acall   line1
        mov     Hurf,#16
        acall   tulis
        acall   line2
        mov     Hurf,#16
        acall   tulis
        acall   delay1
        acall   line1
        mov     Hurf,#16
        acall   tulis
        acall   line2
        mov     Hurf,#16
        acall   tulis
        acall   delay1
        mov     DPTR,#kosng
        acall   line2
        mov     Hurf,#16
        acall   tulis
;
;
        mov     DPTR,#enpsw
        acall   line1
        mov     Hurf,#16
        acall   tulis
;
        mov     DPTR,#kosng
        acall   line2
        mov     Hurf,#4
        acall   tulis
        mov     Stts,#0                 ; status layer 0
        mov     DPTR,#angka
        acall   tg_tkn
        mov     Psw0,R1
        mov     A,#13
        acall   wr_chr
        acall   tg_lps
        acall   tg_tkn
        mov     Psw1,R1
        mov     A,#13
        acall   wr_chr
        acall   tg_lps
        acall   tg_tkn
        mov     Psw2,R1
        mov     A,#13
        acall   wr_chr
        acall   tg_lps
        acall   tg_tkn
        mov     Psw3,R1
        mov     A,#13
        acall   wr_chr
        acall   tg_lps
        acall   tg_tkn
        mov     Psw4,R1
        mov     A,#13
        acall   wr_chr
        acall   tg_lps
        acall   tg_tkn
        mov     Psw5,R1
        mov     A,#13
        acall   wr_chr
        acall   tg_lps
        acall   tg_tkn
        mov     Psw6,R1
        mov     A,#13
```

```
        acall   wr_chr
        acall   tg_lps
;
        acall   rdmemp
        clr     C
        mov     A,Psw0
        mov     B,Psd0
        subb    A,B
        cjne    A,#0,pswslh
        mov     A,Psw1
        mov     B,Psd1
        subb    A,B
        cjne    A,#0,pswslh
        mov     A,Psw2
        mov     B,Psd2
        subb    A,B
        cjne    A,#0,pswslh
        mov     A,Psw3
        mov     B,Psd3
        subb    A,B
        cjne    A,#0,pswslh
        mov     A,Psw4
        mov     B,Psd4
        subb    A,B
        cjne    A,#0,pswslh
        mov     A,Psw5
        mov     B,Psd5
        subb    A,B
        cjne    A,#0,pswslh
        mov     A,Psw6
        mov     B,Psd6
        subb    A,B
        cjne    A,#0,pswslh
        sjmp    pswbnr
;
pswslh: djnz    Cslh,pwdslh
        sjmp    tpswsb
pwdslh: mov     DPTR,#psslh
        acall   line1
        mov     Hurf,#16
        acall   tulis
        acall   delayt
        mov     DPTR,#kosng
        acall   line2
        mov     Hurf,#16
        acall   tulis
        ljmp    mulai
;
tpswsb: mov     DPTR,#kosng
        acall   line2
        mov     Hurf,#4
        acall   tulis
        mov     DPTR,#angka
        mov     A,Psd0
        acall   wr_chr
        mov     A,Psd1
        acall   wr_chr
        mov     A,Psd2
        acall   wr_chr
        mov     A,Psd3
        acall   wr_chr
        mov     A,Psd4
        acall   wr_chr
        mov     A,Psd5
        acall   wr_chr
        mov     A,Psd6
        acall   wr_chr
        mov     DPTR,#kosng
```

```
        mov     Hurf,#5
        acall   tulis
        acall   delayt
        acall   delayt
        mov     DPTR,#kosng
        acall   line2
        mov     Hurf,#16
        acall   tulis
        mov     Cslh,#3
        ljmp    mulai
;
pswbnr: mov     DPTR,#psbnr
        acall   line1
        mov     Hurf,#16
        acall   tulis
        acall   delayt
;
get:    mov     DPTR,#tphum
        acall   line1
        mov     Hurf,#16
        acall   tulis
loop:   mov     DPTR,#angka
        acall   line2
        acall   bc_hm
        mov     A,Dta0
        acall   wr_chr
        mov     A,Dta1
        acall   wr_chr
        mov     A,Dta2
        acall   wr_chr
        mov     A,#10
        acall   wr_chr
        mov     R0,#025h
        acall   w_chr
        mov     A,#10
        acall   wr_chr
        mov     A,#10
        acall   wr_chr
        mov     A,#10
        acall   wr_chr
        acall   bc_sh
        mov     A,Dta0
        acall   wr_chr
        mov     A,Dta1
        acall   wr_chr
        mov     A,Dta2
        acall   wr_chr
        mov     A,#11
        acall   wr_chr
        mov     A,Dta3
        acall   wr_chr
        mov     R0,#0DFh
        lcall   w_chr
        mov     A,#12
        acall   wr_chr
        mov     A,#10
        acall   wr_chr
        acall   ckbts                   ; cek batas suhu
        acall   delays
        cjne    R2,#01h,ckdsrl
        mov     R2,#00h
        acall   krmdta
ckdsrl: sjmp    loop
;
bc_hm:
        ;clr    Slct                    ;\  pilih ADC address humi
        ;acall  jeda
        ;mov    A,P1
```

```
        ;mov     B,#10
        ;div     AB
        ;mov     Dhum,B
        ;mov     A,Dhum
        ;mov     B,#60
        ;add     A,B
        ;acall   cacah
        ;ret
        ;clr     Slct                        ;\  pilih ADC address humi
        ;acall   jeda                        ; | tunggu konversi
        ;mov     A,P1                        ; | ambil data port
        ;mov     Dhum,A                      ; | simpan data humi
        ;acall   cacah                       ; | cacah data
        ;ret
        clr     Slct                         ;\ pilih ADC address suhu
        acall   jeda                         ;/ tunggu konversi
        mov     A,P1                         ;\
        mov     B,#10                        ; |
        div     AB                           ; | suhu 25-40 -> ADC 27-177
        mov     Dta3,B                       ; | data ADC dibagi dg 10
        mov     B,#60                        ; | sisa = angka dibelakang koma
        add     A,B                          ; | hasil ditambah 25
        mov     Dhum,A                       ; | simpan data suhu puluhan-satuan
;        mov     Dsh1,Dta3                   ; | simpan data dibelakang koma
        acall   cacah                        ; |
        ret
        ;clr     Slct                        ;\ pilih ADC address suhu
        ;acall   jeda
        ;mov     A,P1
        ;mov     B,#155
        ;subb    A,B
        ;acall   cacah
        ;ret                                         ;/
;
bc_sh:  setb    Slct                         ;\ pilih ADC address suhu
        acall   jeda                         ;/ tunggu konversi
        mov     A,P1                         ;\
        mov     B,#10                        ; |
        div     AB                           ; | suhu 25-40 -> ADC 27-177
        mov     Dta3,B                       ; | data ADC dibagi dg 10
        mov     B,#25                        ; | sisa = angka dibelakang koma
        add     A,B                          ; | hasil ditambah 25
        mov     Dsh0,A                       ; | simpan data suhu puluhan-satuan
        mov     Dsh1,Dta3                    ; | simpan data dibelakang koma
        acall   cacah                        ; |
        ret                                  ;/
;
cacah:  mov      B,#100
        div      AB
        mov      Dta0,A
        mov      A,B
        mov      B,#10
        div      AB
        mov      Dta1,A
        mov      Dta2,B
hps0:   mov      A,Dta0
        cjne     A,#0,hps1
        mov      Dta0,#10
hps1:   mov      A,Dta1
        cjne     A,#0,hps2
        mov      A,Dta0
        cjne     A,#10,hps2
        mov      Dta1,#10
hps2:   ret
;
setbts: mov      DPTR,#stbts
        acall    line1
        mov      Hurf,#16
```

```
        acall   tulis
        mov     DPTR,#lstst
        acall   line2
        mov     Hurf,#10
        acall   tulis
        acall   rdmemb
        mov     DPTR,#angka
        mov     A,Dbt0
        acall   wr_chr
        mov     A,Dbt1
        acall   wr_chr
        mov     A,#11
        acall   wr_chr
        mov     A,Dbt2
        acall   wr_chr
        mov     R0,#0DFh
        lcall   w_chr
        mov     A,#12
        acall   wr_chr
        acall   tg_lps
;
bole0:  acall   scnkpd
        cjne    R1,#11,bole1
        ljmp    get
bole1:  cjne    R1,#12,bole0
warn:   mov     DPTR,#warng
        acall   line1
        mov     Hurf,#13
        acall   tulis
        mov     DPTR,#angka
        mov     R0,#0DFh
        lcall   w_chr
        mov     A,#12
        acall   wr_chr
        mov     A,#10
        acall   wr_chr
        acall   delayt
ulang:  mov     Stts,#1                         ; status layer 1
        mov     DPTR,#btshu
        acall   line1
        mov     Hurf,#16
        acall   tulis
        mov     DPTR,#kosng
        acall   line2
        mov     Hurf,#16
        acall   tulis
        mov     DPTR,#mashu
        acall   line2
        mov     Hurf,#13
        acall   tulis
        mov     DPTR,#angka
        mov     R0,#0DFh
        lcall   w_chr
        mov     A,#12
        acall   wr_chr
        mov     A,#10
        acall   wr_chr
;
        mov     DPTR,#mashu
        acall   line2
        mov     Hurf,#8
        acall   tulis
        acall   tg_lps
        mov     DPTR,#angka
        acall   tg_tkn
        mov     Dbt0,R1
        mov     A,R1
        acall   wr_chr
```

```
        acall   tg_lps
        mov     Stts,#2                 ; status layer 2
        acall   tg_tkn
        mov     Dbt1,R1
        mov     A,R1
        acall   wr_chr
        acall   tg_lps
        mov     A,#11                   ;\ char titik
        acall   wr_chr                  ;/
        acall   tg_tkn
        mov     Dbt2,R1
        mov     A,R1
        acall   wr_chr
        acall   tg_lps
;
ckn10:  mov     A,Dbt0
        mov     B,#10
        mul     AB
        mov     B,Dbt1
        add     A,B
        mov     B,#32
        div     AB
ckn11:  cjne    A,#0,ckn13
ckn12:  ljmp    warn
ckn13:  mov     A,Dbt0
        mov     B,#10
        mul     AB
        mov     B,Dbt1
        add     A,B
        mov     B,#36
        div     AB
        cjne    A,#0,ckn12
ckn14:  mov     A,Dbt0                  ; angka puluhan dikali 10
        mov     B,#10                   ; ditambah angka satuan
        mul     AB                      ;
        mov     B,Dbt1                  ; kurangi dengan 35
        add     A,B                     ; jika = 0 ? maka **
        mov     B,#35                   ; jika >< 0 maka warning
        subb    A,B                     ;
        cjne    A,#0,ckn15              ;
        mov     A,Dbt2                  ; ** cek angka dibelakan koma = 0 ?
        cjne    A,#0,ckn12              ; ya -> lanjut, tidak -> warning
;
ckn15:  mov     DPTR,#dtbnr
        acall   line1
        mov     Hurf,#16
        acall   tulis
bole2:  acall   scnkpd
        cjne    R1,#11,bole3
        ljmp    ulang
bole3:  cjne    R1,#12,bole2
        acall   wrmemb
        ljmp    get
;
ckbts:  mov     A,Dbt0
        mov     B,#10
        mul     AB
        mov     B,Dbt1
        add     A,B
        mov     Dbts,A                  ; simpan (dbt0x10+bdt1) -> dbts
;
        mov     A,Dsh0
        mov     B,Dbts
        div     AB
ckbt0:  cjne    A,#0,ckbt2
ckbt1:  clr     Heat
        clr     KpsH
        setb    Kips
```

```
        sjmp    ckbt4
ckbt2:  mov     A,Dsh0
        mov     B,Dbts
        subb    A,B
        cjne    A,#0,ckbt3
        mov     A,Dsh1                  ; suhu dibelakang koma
        mov     B,Dbt2                  ; batas suhu dibelakang koma
        div     AB
        cjne    A,#0,ckbt3
        sjmp    ckbt1
ckbt3:  setb    Heat
        setb    KpsH
        clr     Kips
ckbt4:  ret
;
gntpsw: mov     DPTR,#gntps
        acall   line1
        mov     Hurf,#16
        acall   tulis
gntpwd: mov     Stts,#1                 ; status layer 1
        mov     DPTR,#kosng
        acall   line2
        mov     Hurf,#16
        acall   tulis
        mov     DPTR,#kosng
        acall   line2
        mov     Hurf,#4
        acall   tulis
        acall   tg_lps
        mov     DPTR,#angka
        acall   tg_tkn
        mov     Psw0,R1
        mov     A,R1
        acall   wr_chr
        acall   tg_lps
        mov     Stts,#3                 ; status layer 3
        acall   tg_tkn
        mov     Psw1,R1
        mov     A,R1
        acall   wr_chr
        acall   tg_lps
        acall   tg_tkn
        mov     Psw2,R1
        mov     A,R1
        acall   wr_chr
        acall   tg_lps
        acall   tg_tkn
        mov     Psw3,R1
        mov     A,R1
        acall   wr_chr
        acall   tg_lps
        acall   tg_tkn
        mov     Psw4,R1
        mov     A,R1
        acall   wr_chr
        acall   tg_lps
        acall   tg_tkn
        mov     Psw5,R1
        mov     A,R1
        acall   wr_chr
        acall   tg_lps
        acall   tg_tkn
        mov     Psw6,R1
        mov     A,R1
        acall   wr_chr
        acall   tg_lps
        mov     DPTR,#kosng
        mov     Hurf,#5
```

```
        acall   tulis
        mov     DPTR,#psbnr
        acall   line1
        mov     Hurf,#16
        acall   tulis
bole4:  acall   scnkpd
        cjne    R1,#11,bole5
        acall   tg_lps
        ljmp    gntpwd
bole5:  cjne    R1,#12,bole4
        acall   tg_lps
        acall   wrmemp
        ljmp    get
;
krmdta: acall   bc_hm
        mov     A,#"$"
        acall   kr_srl
        mov     A,Dta0
        acall   kr_srl
        mov     A,Dta1
        acall   kr_srl
        mov     A,Dta2
        acall   kr_srl
        acall   bc_sh
        mov     A,Dta0
        acall   kr_srl
        mov     A,Dta1
        acall   kr_srl
        mov     A,Dta2
        acall   kr_srl
        mov     A,#"&"
        acall   kr_srl
;
        mov     A,#"@"
        acall   kr_srl
        mov     A,Dta3
        acall   kr_srl
        acall   rdmemb
        mov     A,Dbt0
        acall   kr_srl
        mov     A,Dbt1
        acall   kr_srl
        mov     A,Dbt2
        acall   kr_srl
        mov     A,#"%"
        acall   kr_srl
        mov     A,#"%"
        acall   kr_srl
        mov     A,#"%"
        acall   kr_srl
        ret
;
line1:  mov     R0,#80h
        acall   w_ins
        ret
;
line2:  mov     R0,#0C0h
        acall   w_ins
        ret
;
tulis:  clr     A
        movc    A,@A+DPTR
        mov     R0,A
        inc     DPTR
        acall   w_chr
        djnz    hurf,tulis
        ret
;
```

```
wr_chr: movc    A,@A+DPTR
        mov     R0,A
        acall   w_chr
        ret
;
w_ins:  clr     Enbl
        clr     Rest
        mov     P0,R0
        setb    Enbl
        clr     Enbl
        acall   jeda
        ret
;
w_chr:  clr     Enbl
        setb    Rest
        mov     P0,R0
        setb    Enbl
        clr     Enbl
        acall   jeda
        ret
;
lcd_op: acall   delays
        mov     R0,#03Fh
        acall   w_ins
        acall   w_ins
        mov     R0,#0Dh
        acall   w_ins
        mov     R0,#06h
        acall   w_ins
        mov     R0,#01h
        acall   w_ins
        mov     R0,#0Ch
        acall   w_ins
        acall   delays
        ret
;
ser_in: setb    EA
        mov     TMOD,#20h
        mov     TH1,#0FDH
        setb    TR1
        mov     SCON,#50h
        setb    ES
        ret
;
kr_srl: clr     ES
        mov     SBUF,A
        jnb     TI,$
        clr     TI
        setb    ES
        ret
;
scnkpd: mov     R1,#10
        acall   jeda
col1:   mov     P2,#11111110b
        mov     A,P2
c1b1:   cjne    A,#11101110b,c1b2
        mov     R1,#1
c1b2:   cjne    A,#11011110b,c1b3
        mov     R1,#2
c1b3:   cjne    A,#10111110b,c1b4
        mov     R1,#3
c1b4:   cjne    A,#01111110b,col2
        mov     R1,#13
;
col2:   mov     P2,#11111101b
        mov     A,P2
c2b1:   cjne    A,#11101101b,c2b2
        mov     R1,#4
```

```
c2b2:   cjne    A,#11011101b,c2b3
        mov     R1,#5
c2b3:   cjne    A,#10111101b,c2b4
        mov     R1,#6
c2b4:   cjne    A,#01111101b,col3
        mov     R1,#14
;
col3:   mov     P2,#11111011b
        mov     A,P2
c3b1:   cjne    A,#11101011b,c3b2
        mov     R1,#7
c3b2:   cjne    A,#11011011b,c3b3
        mov     R1,#8
c3b3:   cjne    A,#10111011b,c3b4
        mov     R1,#9
c3b4:   cjne    A,#01111011b,col4
        mov     R1,#15
;
col4:   mov     P2,#11110111b
        mov     A,P2
c4b1:   cjne    A,#11100111b,c4b2
        mov     R1,#11
c4b2:   cjne    A,#11010111b,c4b3
        mov     R1,#0
c4b3:   cjne    A,#10110111b,c4b4
        mov     R1,#12
c4b4:   cjne    A,#01110111b,back
        mov     R1,#16
back:   ret
;
tg_tkn: acall   scnkpd
tg_tk0: cjne    R1,#16,tg_tk1
        sjmp    tg_tkn
tg_tk1: cjne    R1,#15,tg_tk2
        sjmp    tg_tkn
tg_tk2: cjne    R1,#14,tg_tk3
        sjmp    tg_tkn
tg_tk3: cjne    R1,#13,tg_tk4
        sjmp    tg_tkn
tg_tk4: cjne    R1,#12,tg_tk5
        sjmp    tg_tkn
tg_tk5: cjne    R1,#11,tg_tkA
        mov     A,Stts
tg_tk6: cjne    A,#0,tg_tk7
        sjmp    tg_tkn
tg_tk7: cjne    A,#1,tg_tk8
        ljmp    get
tg_tk8: cjne    A,#2,tg_tk9
        ljmp    ulang
tg_tk9: cjne    A,#3,tg_tkA
        ljmp    gntpwd
tg_tkA: cjne    R1,#10,tg_tkB
        sjmp    tg_tkn
tg_tkB: ret
;
tg_lps: acall   scnkpd
        cjne    R1,#10,tg_lps
        ret
;
wt_wr:  mov     A,Wmcn
        anl     A,#Wtdg
        jz      wt_wr
        ret
;
stwrmm: orl     Wmcn,#Eemn
        orl     Wmcn,#Eemw
        ret
;
```

```
enwrmm: xrl     Wmcn,#Eemw
        xrl     Wmcn,#Eemn
        ret
;
strdmm: orl     Wmcn,#Eemn
        ret
;
enrdmm: xrl     Wmcn,#Eemn
        ret
;
rdmemp: acall   strdmm              ; read memory password
        mov     DPTR,#00h
        movx    A,@DPTR
        acall   cknlff
        mov     Psd0,A
        inc     DPTR
        movx    A,@DPTR
        acall   cknlff
        mov     Psd1,A
        inc     DPTR
        movx    A,@DPTR
        acall   cknlff
        mov     Psd2,A
        inc     DPTR
        movx    A,@DPTR
        acall   cknlff
        mov     Psd3,A
        inc     DPTR
        movx    A,@DPTR
        acall   cknlff
        mov     Psd4,A
        inc     DPTR
        movx    A,@DPTR
        acall   cknlff
        mov     Psd5,A
        inc     DPTR
        movx    A,@DPTR
        acall   cknlff
        mov     Psd6,A
        acall   enrdmm
        ret
;
rdmemb: acall   strdmm              ; read memory batas suhu
        mov     DPTR,#10h
        movx    A,@DPTR
        acall   cknlff
        mov     Dbt0,A
        inc     DPTR
        movx    A,@DPTR
        acall   cknlff
        mov     Dbt1,A
        inc     DPTR
        movx    A,@DPTR
        acall   cknlff
        mov     Dbt2,A
        acall   enrdmm
        ret
;
wrmemp: acall   stwrmm              ; write memory password
        mov     DPTR,#00h
        mov     A,Psw0
        movx    @DPTR,A
        lcall   wt_wr
        inc     DPTR
        mov     A,Psw1
        movx    @DPTR,A
        lcall   wt_wr
        inc     DPTR
```

```
        mov     A,Psw2
        movx    @DPTR,A
        lcall   wt_wr
        inc     DPTR
        mov     A,Psw3
        movx    @DPTR,A
        lcall   wt_wr
        inc     DPTR
        mov     A,Psw4
        movx    @DPTR,A
        lcall   wt_wr
        inc     DPTR
        mov     A,Psw5
        movx    @DPTR,A
        lcall   wt_wr
        inc     DPTR
        mov     A,Psw6
        movx    @DPTR,A
        lcall   wt_wr
        acall   enwrmm
        ret
;
wrmemb: acall   stwrmm                  ; write memory batas suhu
        mov     DPTR,#10h
        mov     A,Dbt0
        movx    @DPTR,A
        lcall   wt_wr
        inc     DPTR
        mov     A,Dbt1
        movx    @DPTR,A
        lcall   wt_wr
        inc     DPTR
        mov     A,Dbt2
        movx    @DPTR,A
        lcall   wt_wr
        acall   enwrmm
        ret
;
cknlff: cjne    A,#0FFh,cknlf
        mov     A,#00h
cknlf:  ret
;
jeda:   djnz    Dly0,$
        ret
;
delays: mov     Dly1,#255
dlys0:  acall   scnkpd
        cjne    R1,#13,dlys1
        ljmp    setbts
dlys1:  cjne    R1,#14,dlys2
        ljmp    gntpsw
dlys2:  djnz    Dly1,dlys0
        ret
;
delayt: mov     Dly2,#5
dlyt:   acall   delays
        djnz    Dly2,dlyt
        ret
;
delayl: mov     Dly2,#20
dlyl:   acall   delays
        djnz    Dly2,dlyl
        ret
;
logo:   DB      '  Fifi Eriyati  '
        DB      '   02 17 127    '
        DB      ' Teknik Elektro '
        DB      '   ITN Malang   '
```

```
        DB      '  Control Suhu  '
        DB      '    Humidity    '
enpsw:  DB      ' Enter Password '
psbnr:  DB      ' Password Benar '
psslh:  DB      ' Password Salah '
gntps:  DB      ' Ganti Password '
tphum:  DB      ' Humi      Temp '
stbts:  DB      ' Setting Batas? '
lstst:  DB      'Last Set:       '
warng:  DB      ' Range: 32-35   '
btshu:  DB      '   Batas Suhu   '
mashu:  DB      '  Suhu: 00.0    '
dtbnr:  DB      '  Data Benar ?  '
angka:  DB      '0123456789 .C*  '
kosng:  DB      '                '
;
        end
```

```
unit Unit1;

interface

uses
  Windows, Messages, SysUtils, Variants, Classes, Graphics, Controls, Forms,
  Dialogs, ComCtrls, StdCtrls, ExtCtrls;

type
  TForm1 = class(TForm)
    GroupBox1: TGroupBox;
    Edpas: TEdit;
    Label3: TLabel;
    StatusBar1: TStatusBar;
    Panel1: TPanel;
    Label4: TLabel;
    Label5: TLabel;
    Panel2: TPanel;
    Button2: TButton;
    Button3: TButton;
    Button1: TButton;
    Panel3: TPanel;
    GroupBox2: TGroupBox;
    Panel4: TPanel;
    Panel5: TPanel;
    Panel6: TPanel;
    procedure FormCreate(Sender: TObject);
    procedure EdpasKeyPress(Sender: TObject; var Key: Char);
    procedure Button2Click(Sender: TObject);
    procedure Button3Click(Sender: TObject);
    procedure Button1Click(Sender: TObject);
    //procedure Button1Click(Sender: TObject);
    //procedure Label2Click(Sender: TObject);
  private
    { Private declarations }
  public
    { Public declarations }
  end;

var
  Form1: TForm1;

implementation

uses Unit2;

{$R *.dfm}

procedure TForm1.FormCreate(Sender: TObject);
begin
  Edpas.Text:='';
end;

procedure TForm1.EdpasKeyPress(Sender: TObject; var Key: Char);
begin
  if Key=#13 then
  begin
    if Edpas.Text='0217127' then
    Form2.showmodal();
    if Edpas.Text<>'0217127' then
    ShowMessage('Maaf Password salah');
  end;
end;
```

```
cedure TForm1.Button2Click(Sender: TObject);
in
dpas.Clear;
;

cedure TForm1.Button3Click(Sender: TObject);
in
pplication.Terminate;
;

cedure TForm1.Button1Click(Sender: TObject);
in
f Key=#13 then
/begin
 if Edpas.Text='0217127' then
 Form2.showmodal();
 if Edpas.Text<>'0217127' then
 ShowMessage('Maaf Password salah');
/end;
;


.
```

```
it Unit2;

.terface

ıes
 Windows, Messages, SysUtils, Variants, Classes, Graphics, Controls, Forms,
 Dialogs, StdCtrls, ExtCtrls, VaClasses, VaComm, Menus, VidGrab, ComCtrls;

ype
 TForm2 = class(TForm)
   GroupBox1: TGroupBox;
   VideoGrabber1: TVideoGrabber;
   MainMenu1: TMainMenu;
   File1: TMenuItem;
   Open1: TMenuItem;
   Close1: TMenuItem;
   CloseAll1: TMenuItem;
   Data1: TMenuItem;
   Kontrol1: TMenuItem;
   Boidata1: TMenuItem;
   Help1: TMenuItem;
   About1: TMenuItem;
   VaComm1: TVaComm;
   Button1: TButton;
   Label7: TLabel;
   Edit4: TEdit;
   Timer1: TTimer;
   Label12: TLabel;
   Edit5: TEdit;
   Label13: TLabel;
   Label14: TLabel;
   Panel1: TPanel;
   Panel2: TPanel;
   GroupBox3: TGroupBox;
   ComboBox1: TComboBox;
   Button3: TButton;
   GroupBox2: TGroupBox;
   GroupBox4: TGroupBox;
   GroupBox5: TGroupBox;
   Label1: TLabel;
   Label4: TLabel;
   Label8: TLabel;
   Label9: TLabel;
   Label10: TLabel;
   Label15: TLabel;
   Label16: TLabel;
   GroupBox6: TGroupBox;
   Label17: TLabel;
   GroupBox7: TGroupBox;
   Label2: TLabel;
   Label3: TLabel;
   Label5: TLabel;
   Label6: TLabel;
   Label11: TLabel;
   Label18: TLabel;
   Label19: TLabel;
   Label20: TLabel;
   Editc: TEdit;
   Timer2: TTimer;
   Button5: TButton;
   Image1: TImage;
   Panel3: TPanel;
   Panel4: TPanel;
```

```
 procedure Button1Click(Sender: TObject);
 procedure Close1Click(Sender: TObject);
 procedure VaComm1RxChar(Sender: TObject; Count: Integer);
 procedure CloseAll1Click(Sender: TObject);
 procedure Timer1Timer(Sender: TObject);
 procedure Button2Click(Sender: TObject);
 procedure About1Click(Sender: TObject);
 procedure Boidata1Click(Sender: TObject);
 procedure Button3Click(Sender: TObject);
// procedure Button4Click(Sender: TObject);
 procedure Timer2Timer(Sender: TObject);
 procedure Button5Click(Sender: TObject);
'   procedure FormCreate(Sender: TObject);
    procedure Button2Click(Sender: TObject);
rivate
  { Private declarations }
ublic
  { Public declarations }
nd;

orm2: TForm2;
umidity,setpoint:String;
temp:array[0..1] of string;
lementation

es Unit4, Unit3;

 *.dfm}

nction StrToChar(Str: string): Char;
r
A: Integer;
gin
if Length(Str) > 0 then
begin
  if (Str[1] = '#') and (Length(Str) > 1) then
  begin
    try
      A := StrToInt(Copy(Str, 2, Length(Str) - 1));
    except
      A := 0;
    end;
    Result := Chr(Byte(A));
  end
  else
    Result := Str[1];
end
else
  Result := #0;
d;

nction ambil_hex(str:String):String;
gin
ambil_hex := copy(str,2,1);
d;

ocedure TForm2.Button1Click(Sender: TObject);
gin
if Timer1.Enabled=False then
  begin
    VaComm1.WriteText(#1);
    VideoGrabber1.StartPreview;
```

```
    Button1.Caption:='STOP';
    Timer1.Enabled:=True;
    Label1.Visible:=true;
    Label10.Visible:=true;
    Label15.Visible:=true;
    Label16.Visible:=true;
    Label4.Visible:=true;
    Label8.Visible:=true;
/     Label9.Visible:=true;
//    aa.Text:=floattostr(round(StrToFloat(editc.Text)+32));
    Label11.Visible:=true;
    Label17.Visible:=true;
    Label18.Visible:=true;
    Label19.Visible:=true;
    Label3.Visible:=true;
    Label5.Visible:=true;
    Label6.Visible:=true;


  end
lse
  begin
    VaComm1.PurgeReadWrite;
    VideoGrabber1.StopPreview;
    Timer1.Enabled:=False;
    Label1.Visible:=false;
    Label10.Visible:=false;
    Label15.Visible:=false;
    Label16.Visible:=false;
    Label4.Visible:=false;
    Label8.Visible:=false;
//    Label9.Visible:=false;
    Label11.Visible:=false;
    Label17.Visible:=false;
    Label18.Visible:=false;
    Label19.Visible:=false;
    Label3.Visible:=false;
    Label5.Visible:=false;
    Label6.Visible:=false;
    Timer2.Enabled:=false;
    Edit4.Clear;
    Edit5.Clear;
    Button1.Caption:='START';
    Button3.Caption:='Open Port';
    Label1.Caption:='';
  end
d;

ocedure TForm2.VaComm1RxChar(Sender: TObject; Count: Integer);
  packet_1 : array [0..5] of String;
  packet_2 : array [0..3] of String;
  start_bit, stop_bit : array [0..1] of String;
  seri_masuk, data_bit : String;
  i : Integer;
gin
seri_masuk := VaComm1.ReadText;

start_bit[0] := copy(seri_masuk,pos('$',seri_masuk),1);
stop_bit[0] := copy(seri_masuk,pos('&',seri_masuk),1);

start_bit[1] := copy(seri_masuk,pos('@',seri_masuk),1);
stop_bit[1] := copy(seri_masuk,pos('%',seri_masuk),1);
```

```
f (start_bit[0] = '$') and (stop_bit[0] = '&') then
egin
 data_bit := copy(seri_masuk,pos('$',seri_masuk)+1,pos('&',seri_masuk));
 for i := 0 to 5 do
 begin
   packet_1[i]:=copy(data_bit ,i+1,2);
   packet_1[i]:=IntToHex(ord(StrToChar((packet_1[i]))),2);
   packet_1[i]:=ambil_hex(packet_1[i]);

   humidity :=packet_1[1]+packet_1[2];
   temp[0]:= packet_1[4]+packet_1[5];
 end;
nd;

 (start_bit[1] = '@') and (stop_bit[1] = '%') then
egin
 data_bit := copy(seri_masuk,pos('@',seri_masuk)+1,pos('%',seri_masuk));
 for i := 0 to 3 do
 begin
   packet_2[i]:=copy(data_bit ,i+1,2);
   packet_2[i]:=IntToHex(ord(StrToChar((packet_2[i]))),2);
   packet_2[i]:=ambil_hex(packet_2[i]);

   temp[1] := packet_2[0];
   setpoint := packet_2[1]+packet_2[2]+'.'+packet_2[3]+' ';
 end;
end;
Label1.Caption := temp[0]+ '.' + temp[1];
Editc.Text := temp[0]+ '.' + temp[1];
Label17.Caption:= setpoint;
Label2.Caption := humidity;
d;

ocedure TForm2.Close1Click(Sender: TObject);
gin
Form2.Close;
d;

ocedure TForm2.CloseAll1Click(Sender: TObject);
gin
Application.Terminate;
d;

ocedure TForm2.Timer1Timer(Sender: TObject);
gin
VaComm1.WriteText(#1);
Edit4.Text:=TimeToStr(now);
Edit5.Text:=DateToStr(now);
d;

ocedure TForm2.Button2Click(Sender: TObject);
gin
VaComm1.PurgeReadWrite;
vacomm1.Close;
VideoGrabber1.StopPreview;
Timer1.Enabled:=False;
Label1.Caption:='';
Label17.CleanupInstance;
//Label2.Clear;
Edit4.Clear;
Edit5.Clear;
d;}
```

```
:edure TForm2.About1Click(Sender: TObject);
n
›rm4.showmodal();
;

:edure TForm2.Boidata1Click(Sender: TObject);
in
›rm3.showmodal();
;

:edure TForm2.Button3Click(Sender: TObject);
in
F VaComm1.Active = false then
 begin
   VaComm1.DeviceName := ComboBox1.Text;
   VaComm1.Open;
   Button3.Caption := 'Close Port';
 end
lse
 begin
   VaComm1.PurgeReadWrite;
   VaComm1.Close;
   Button3.Caption := 'Open Port'
 end
;

ocedure TForm2.Button4Click(Sender: TObject);
in
bel9.Caption:=floattostr((StrTofloat(editc.Text))+32);
; }

cedure TForm2.Timer2Timer(Sender: TObject);
in
bel9.Caption:=floattostr((StrTofloat(editc.Text))+32);
;

cedure TForm2.Button5Click(Sender: TObject);
in
imer2.Enabled:=true;
/Label9.Visible:=true;
f Timer2.Enabled=False then
 begin
 Button5.Caption := 'Hide Rheamur';
 Label9.Visible:=false;
nd
lse
 begin
  Button5.Caption := 'Get Rheamur';
  Label9.Visible:=true;
 end
l;

imer2.Enabled:=true;
nd;

l.
```

atures

- ompatible with MCS-51™ Products
- K Bytes of In-System Reprogrammable Downloadable Flash Memory
  - SPI Serial Interface for Program Downloading
  - Endurance: 1,000 Write/Erase Cycles
- :K Bytes EEPROM
  - Endurance: 100,000 Write/Erase Cycles
- ɪV to 6V Operating Range
- Fully Static Operation: 0 Hz to 24 MHz
- Three-level Program Memory Lock
- 256 x 8-bit Internal RAM
- 32 Programmable I/O Lines
- Three 16-bit Timer/Counters
- Nine Interrupt Sources
- Programmable UART Serial Channel
- SPI Serial Interface
- Low-power Idle and Power-down Modes
- Interrupt Recovery From Power-down
- Programmable Watchdog Timer
- Dual Data Pointer
- Power-off Flag

escription

ie AT89S8252 is a low-power, high-performance CMOS 8-bit microcomputer with
(bytes of downloadable Flash programmable and erasable read only memory and
(bytes of EEPROM. The device is manufactured using Atmel's high-density nonvol-
ile memory technology and is compatible with the industry-standard 80C51
struction set and pinout. The on-chip downloadable Flash allows the program mem-
y to be reprogrammed in-system through an SPI serial interface or by a
nventional nonvolatile memory programmer. By combining a versatile 8-bit CPU
th downloadable Flash on a monolithic chip, the Atmel AT89S8252 is a powerful
icrocomputer which provides a highly-flexible and cost-effective solution to many
nbedded control applications.

ie AT89S8252 provides the following standard features: 8K bytes of downloadable
ash, 2K bytes of EEPROM, 256 bytes of RAM, 32 I/O lines, programmable watch-
g timer, two data pointers, three 16-bit timer/counters, a six-vector two-level
errupt architecture, a full duplex serial port, on-chip oscillator, and clock circuitry. In
ldition, the AT89S8252 is designed with static logic for operation down to zero fre-
iency and supports two software selectable power saving modes. The Idle Mode
ɔps the CPU while allowing the RAM, timer/counters, serial port, and interrupt sys-
m to continue functioning. The Power-down mode saves the RAM contents but
eezes the oscillator, disabling all other chip functions until the next interrupt or hard-
are reset.

ie downloadable Flash can be changed a single byte at a time and is accessible
rough the SPI serial interface. Holding RESET active forces the SPI bus into a serial
ogramming interface and allows the program memory to be written to or read from
lless Lock Bit 2 has been activated.

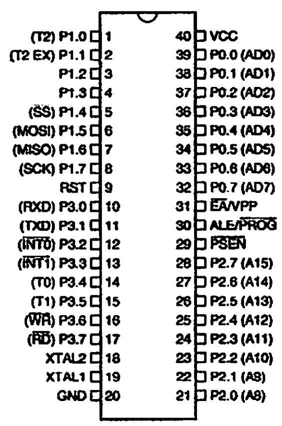
8-bit Microcontroller with 8K Bytes Flash

AT89S8252

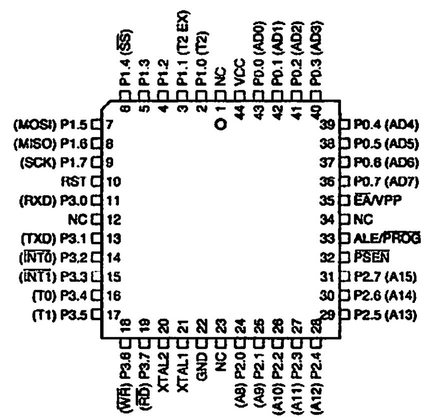
Rev. 0401E–02/00

n Configurations

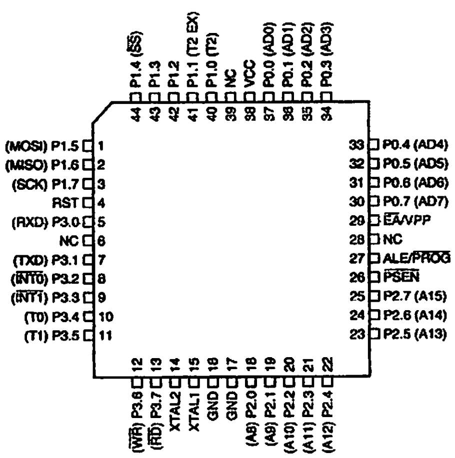
PDIP



PLCC



PQFP/TQFP



n Description

:C

pply voltage.

ID

ound.

rt 0

rt 0 is an 8-bit open drain bbi-didirectional I/O port. As an tput port, each pin can sink eight TTL inputs. When 1s ꞩ written to port 0 pins, the pins can be used as high-pedance inputs.

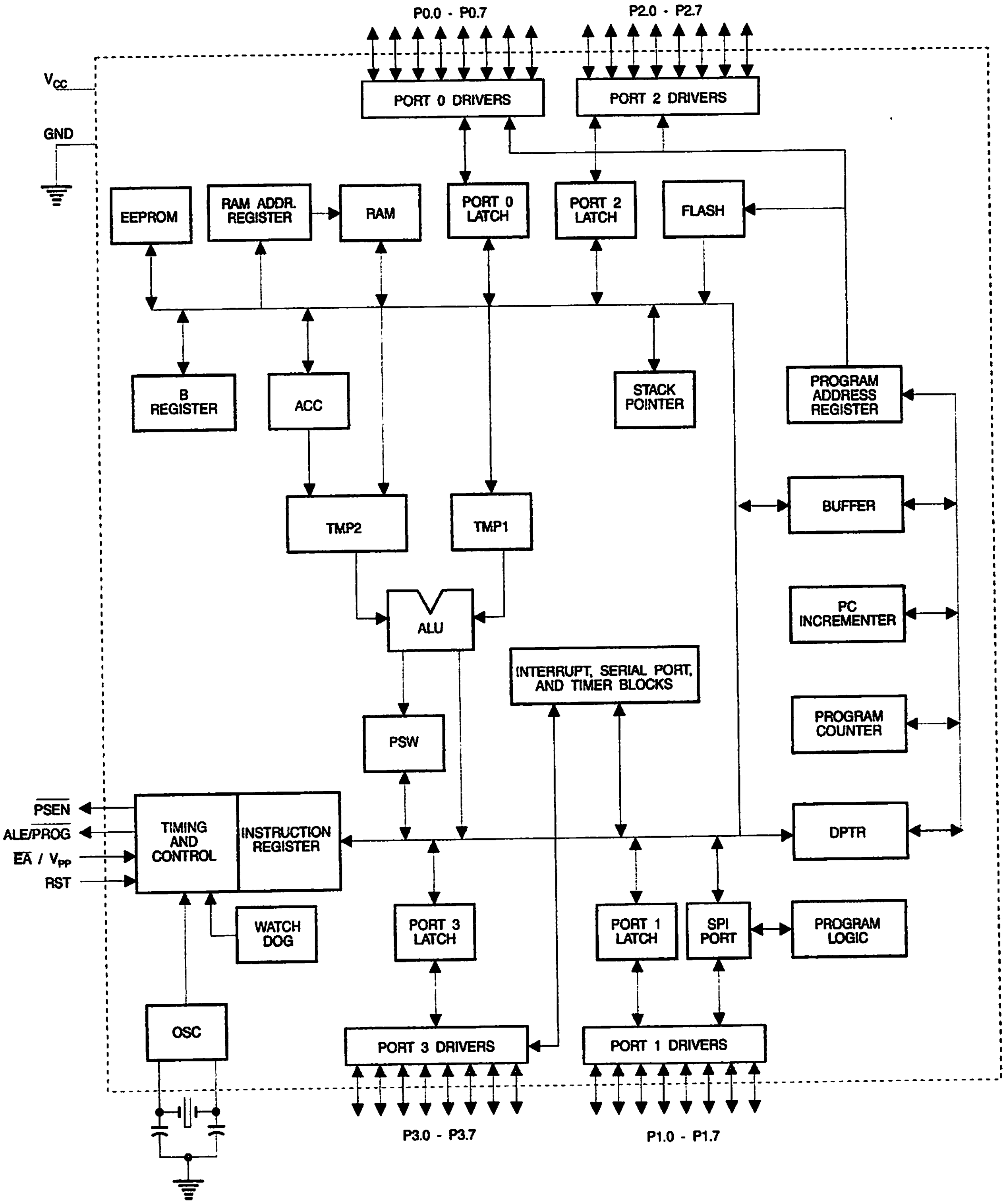
ırt 0 can also be configured to be the multiplexed low-ꞩder address/data bus during accesses to external program and data memory. In this mode, P0 has internal pullups.

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

Port 1

Port 1 is an 8-bit bi-directional I/O port with internal pullups. 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 pullups 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 pullups.

ck Diagram


P0.0 - P0.7
P2.0 - P2.7
VCC
GND
PORT 0 DRIVERS
PORT 2 DRIVERS
EEPROM
RAM ADDR. REGISTER
RAM
PORT 0 LATCH
PORT 2 LATCH
FLASH
B REGISTER
ACC
STACK POINTER
PROGRAM ADDRESS REGISTER
TMP2
TMP1
BUFFER
ALU
PC INCREMENTER
INTERRUPT, SERIAL PORT, AND TIMER BLOCKS
PSW
PROGRAM COUNTER
PSEN
ALE/PROG
EA / VPP
RST
TIMING AND CONTROL
INSTRUCTION REGISTER
DPTR
WATCH DOG
PORT 3 LATCH
PORT 1 LATCH
SPI PORT
PROGRAM LOGIC
OSC
PORT 3 DRIVERS
PORT 1 DRIVERS
P3.0 - P3.7
P1.0 - P1.7

ıe Port 1 pins provide additional functions. P1.0 and can be configured to be the timer/counter 2 external ıt input (P1.0/T2) and the timer/counter 2 trigger input 1/T2EX), respectively.

ı Description

hermore, P1.4, P1.5, P1.6, and P1.7 can be configured he SPI slave port select, data input/output and shift k input/output pins as shown in the following table.

rt Pin	Alternate Functions
.0	T2 (external count input to Timer/Counter 2), clock-out
.1	T2EX (Timer/Counter 2 capture/reload trigger and direction control)
.4	$\overline{\text{SS}}$ (Slave port select input)
.5	MOSI (Master data output, slave data input pin for SPI channel)
.6	MISO (Master data input, slave data output pin for SPI channel)
.7	SCK (Master clock output, slave clock input pin for SPI channel)

t 1 also receives the low-order address bytes during ɪh programming and verification.

t 2

t 2 is an 8-bit bi-directional I/O port with internal pullups. ı Port 2 output buffers can sink/source four TTL inputs. en 1s are written to Port 2 pins, they are pulled high by internal pullups and can be used as inputs. As inputs, t 2 pins that are externally being pulled low will source ·ent (I_{IL}) because of the internal pullups.

t 2 emits the high-order address byte during fetches n external program memory and during accesses to ɜrnal data memory that use 16-bit addresses (MOVX @ TR). In this application, Port 2 uses strong internal pul- s when emitting 1s. During accesses to external data mory that use 8-bit addresses (MOVX @ RI), Port 2 its the contents of the P2 Special Function Register.

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

·t 3

t 3 is an 8 bit bi-directional I/O port with internal pullups. ɜ Port 3 output buffers can sink/source four TTL inputs. ıen 1s are written to Port 3 pins, they are pulled high by internal pullups 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 pullups.

Port 3 also serves the functions of various special features of the AT89S8252, 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	$\overline{\text{INT0}}$ (external interrupt 0)
P3.3	$\overline{\text{INT1}}$ (external interrupt 1)
P3.4	T0 (timer 0 external input)
P3.5	T1 (timer 1 external input)
P3.6	$\overline{\text{WR}}$ (external data memory write strobe)
P3.7	$\overline{\text{RD}}$ (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.

ALE/$\overline{\text{PROG}}$

Address Latch Enable is an output pulse for latching the low byte of the address during accesses to external memory. This pin is also the program pulse input ($\overline{\text{PROG}}$) during Flash programming.

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

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

$\overline{\text{PSEN}}$

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

When the AT89S8252 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.

$\overline{\text{EA}}$/VPP

External Access Enable. $\overline{\text{EA}}$ must be strapped to GND in order to enable the device to fetch code from external prom memory locations starting at 0000H up to FFFFH. :e, however, that if lock bit 1 is programmed, $\overline{EA}$ will be ernally latched on reset.

should be strapped to V_{CC} for internal program execu- ns. This pin also receives the 12-volt programming able voltage (V_{PP}) during Flash programming when 12- t programming is selected.

XTAL1

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

XTAL2

Output from the inverting oscillator amplifier.

ble 1. AT89S8252 SFR Map and Reset Values

0F8H									0FFH
0F0H	B 00000000								0F7H
0E8H									0EFH
0E0H	ACC 00000000								0E7H
0D8H									0DFH
0D0H	PSW 00000000					SPCR 000001XX			0D7H
0C8H	T2CON 00000000	T2MOD XXXXXX00	RCAP2L 00000000	RCAP2H 00000000	TL2 00000000	TH2 00000000			0CFH
0C0H									0C7H
0B8H	IP XX000000								0BFH
0B0H	P3 11111111								0B7H
0A8H	IE 0X000000		SPSR 00XXXXXX						0AFH
0A0H	P2 11111111								0A7H
98H	SCON 00000000	SBUF XXXXXXXX							9FH
90H	P1 11111111						WMCON 00000010		97H
88H	TCON 00000000	TMOD 00000000	TL0 00000000	TL1 00000000	TH0 00000000	TH1 00000000			8FH
80H	P0 11111111	SP 00000111	DP0L 00000000	DP0H 00000000	DP1L 00000000	DP1H 00000000	SPDR XXXXXXXX	PCON 0XXX0000	87H

›ecial Function Registers

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

te that not all of the addresses are occupied, and unoc- ɔied addresses may not be implemented on the chip. ad accesses to these addresses will in general return ıdom data, and write accesses will have an indeterminate ect.

ıer 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 9) 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.

ble 2. T2CON—Timer/Counter 2 Control Register

2CON Address = 0C8H　　　　Reset Value = 0000 0000B

it Addressable

	TF2	EXF2	RCLK	TCLK	EXEN2	TR2	$C/\overline{T2}$	$CP/\overline{RL2}$
it	7	6	5	4	3	2	1	0

ymbol	Function
F2	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.
XF2	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).
ICLK	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 overflows to be used for the receive clock.
CLK	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.
XEN2	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.
R2	Start/Stop control for Timer 2. TR2 = 1 starts the timer.
$:/\overline{T2}$	Timer or counter select for Timer 2. $C/\overline{T2}$ = 0 for timer function. $C/\overline{T2}$ = 1 for external event counter (falling edge triggered).
$:P/\overline{RL2}$	Capture/Reload select. $CP/\overline{RL2}$ = 1 causes captures to occur on negative transitions at T2EX if EXEN2 = 1. $CP/\overline{RL2}$ = 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.

tchdog and Memory Control Register The WMCON ister contains control bits for the Watchdog Timer own in Table 3). The EEMEN and EEMWE bits are used to select the 2K bytes on-chip EEPROM, and to enable byte-write. The DPS bit selects one of two DPTR registers available.

ɔle 3. WMCON—Watchdog and Memory Control Register

/MCON Address = 96H   Reset Value = 0000 0010B

	PS2	PS1	PS0	EEMWE	EEMEN	DPS	WDTRST	WDTEN
it	7	6	5	4	3	2	1	0

ymbol	Function
'S2 'S1 'S0	Prescaler Bits for the Watchdog Timer. When all three bits are set to "0", the watchdog timer has a nominal period of 16 ms. When all three bits are set to "1", the nominal period is 2048 ms.
EMWE	EEPROM Data Memory Write Enable Bit. Set this bit to "1" before initiating byte write to on-chip EEPROM with the MOVX instruction. User software should set this bit to "0" after EEPROM write is completed.
EMEN	Internal EEPROM Access Enable. When EEMEN = 1, the MOVX instruction with DPTR will access on-chip EEPROM instead of external data memory. When EEMEN = 0, MOVX with DPTR accesses external data memory.
PS	Data Pointer Register Select. DPS = 0 selects the first bank of Data Pointer Register, DP0, and DPS = 1 selects the second bank, DP1
/DTRST DY/$\overline{BSY}$	Watchdog Timer Reset and EEPROM Ready/$\overline{Busy}$ Flag. Each time this bit is set to "1" by user software, a pulse is generated to reset the watchdog timer. The WDTRST bit is then automatically reset to "0" in the next instruction cycle. The WDTRST bit is Write-Only. This bit also serves as the RDY/$\overline{BSY}$ flag in a Read-Only mode during EEPROM write. RDY/$\overline{BSY}$ = 1 means that the EEPROM is ready to be programmed. While programming operations are being executed, the RDY/$\overline{BSY}$ bit equals "0" and is automatically reset to "1" when programming is completed.
/DTEN	Watchdog Timer Enable Bit. WDTEN = 1 enables the watchdog timer and WDTEN = 0 disables the watchdog timer.

'I Registers Control and status bits for the Serial Periph- al Interface are contained in registers SPCR (shown in ble 4) and SPSR (shown in Table 5). The SPI data bits ɘ contained in the SPDR register. Writing the SPI data jister during serial data transfer sets the Write Collision , WCOL, in the SPSR register. The SPDR is double buff- ɘd for writing and the values in SPDR are not changed by ıset.

:errupt Registers The global interrupt enable bit and the lividual interrupt enable bits are in the IE register. In dition, the individual interrupt enable bit for the SPI is in ɘ SPCR register. Two priorities can be set for each of the : interrupt sources in the IP register.

Dual Data Pointer Registers To facilitate accessing both internal EEPROM and external data memory, two banks of 16 bit Data Pointer Registers are provided: DP0 at SFR address locations 82H-83H and DP1 at 84H-85H. Bit DPS = 0 in SFR WMCON 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.

ble 4. SPCR—SPI Control Register

CR Address = D5H Reset Value = 0000 01XXB

	SPIE	SPE	DORD	MSTR	CPOL	CPHA	SPR1	SPR0
Bit	7	6	5	4	3	2	1	0

ymbol	Function
PIE	SPI Interrupt Enable. This bit, in conjunction with the ES bit in the IE register, enables SPI interrupts: SPIE = 1 and ES = 1 enable SPI interrupts. SPIE = 0 disables SPI interrupts.
PE	SPI Enable. SPI = 1 enables the SPI channel and connects $\overline{SS}$, MOSI, MISO and SCK to pins P1.4, P1.5, P1.6, and P1.7. SPI = 0 disables the SPI channel.
ORD	Data Order. DORD = 1 selects LSB first data transmission. DORD = 0 selects MSB first data transmission.
ISTR	Master/Slave Select. MSTR = 1 selects Master SPI mode. MSTR = 0 selects Slave SPI mode.
POL	Clock Polarity. When CPOL = 1, SCK is high when idle. When CPOL = 0, SCK of the master device is low when not transmitting. Please refer to figure on SPI Clock Phase and Polarity Control.
PHA	Clock Phase. The CPHA bit together with the CPOL bit controls the clock and data relationship between master and slave. Please refer to figure on SPI Clock Phase and Polarity Control.
PR0 PR1	SPI Clock Rate Select. These two bits control the SCK rate of the device configured as master. SPR1 and SPR0 have no effect on the slave. The relationship between SCK and the oscillator frequency, $F_{OSC.}$, is as follows: SPR1 SPR0 SCK = $F_{OSC.}$ divided by 0 0 4 0 1 16 1 0 64 1 1 128

ble 5. SPSR – SPI Status Register

PSR Address = AAH Reset Value = 00XX XXXXB

	SPIF	WCOL	–	–	–	–	–	–
Bit	7	6	5	4	3	2	1	0

ymbol	Function
PIF	SPI Interrupt Flag. When a serial transfer is complete, the SPIF bit is set and an interrupt is generated if SPIE = 1 and ES = 1. The SPIF bit is cleared by reading the SPI status register with SPIF and WCOL bits set, and then accessing the SPI data register.
/COL	Write Collision Flag. The WCOL bit is set if the SPI data register is written during a data transfer. During data transfer, the result of reading the SPDR register may be incorrect, and writing to it has no effect. The WCOL bit (and the SPIF bit) are cleared by reading the SPI status register with SPIF and WCOL set, and then accessing the SPI data register.

ble 6. SPDR – SPI Data Register

PDR Address = 86H Reset Value = unchanged

	SPD7	SPD6	SPD5	SPD4	SPD3	SPD2	SPD1	SPD0
Bit	7	6	5	4	3	2	1	0

ıta Memory – EEPROM and RAM

ı AT89S8252 implements 2K bytes of on-chip EEPROM data storage and 256 bytes of RAM. The upper 128 es of RAM occupy a parallel space to the Special Func- ı Registers. That means the upper 128 bytes have the ne addresses as the SFR space but are physically sepa- e from SFR space.

ıen an instruction accesses an internal location above dress 7FH, the address mode used in the instruction ecifies whether the CPU accesses the upper 128 bytes RAM or the SFR space. Instructions that use direct dressing access SFR space.

r example, the following direct addressing instruction cesses the SFR at location 0A0H (which is P2).

```
MOV 0A0H, #data
```

ıtructions that use indirect addressing access the upper 8 bytes of RAM. For example, the following indirect dressing instruction, where R0 contains 0A0H, accesses ı data byte at address 0A0H, rather than P2 (whose dress is 0A0H).

```
MOV @R0, #data
```

ıte that stack operations are examples of indirect dressing, so the upper 128 bytes of data RAM are avail- le as stack space.

e on-chip EEPROM data memory is selected by setting ı EEMEN bit in the WMCON register at SFR address ation 96H. The EEPROM address range is from 000H to FH. The MOVX instructions are used to access the PROM. To access off-chip data memory with the MOVX tructions, the EEMEN bit needs to be set to "0".

e EEMWE bit in the WMCON register needs to be set to before any byte location in the EEPROM can be written. er software should reset EEMWE bit to "0" if no further PROM write is required. EEPROM write cycles in the ial programming mode are self-timed and typically take ms. The progress of EEPROM write can be monitored reading the RDY/$\overline{BSY}$ bit (read-only) in SFR WMCON. Y/$\overline{BSY}$ = 0 means programming is still in progress and Y/$\overline{BSY}$ = 1 means EEPROM write cycle is completed d another write cycle can be initiated.

addition, during EEPROM programming, an attempted ıd from the EEPROM will fetch the byte being written h the MSB complemented. Once the write cycle is com- ted, true data are valid at all bit locations.

ogrammable Watchdog Timer

e programmable Watchdog Timer (WDT) operates from independent oscillator. The prescaler bits, PS0, PS1 d PS2 in SFR WMCON are used to set the period of the ıtchdog Timer from 16 ms to 2048 ms. The available ıer periods are shown in the following table and the actual timer periods (at V_{CC} = 5V) are within ±30% of the nominal.

The WDT is disabled by Power-on Reset and during Power-down. It is enabled by setting the WDTEN bit in SFR WMCON (address = 96H). The WDT is reset by setting the WDTRST bit in WMCON. When the WDT times out without being reset or disabled, an internal RST pulse is generated to reset the CPU.

Table 7. Watchdog Timer Period Selection

WDT Prescaler Bits			
PS2	PS1	PS0	Period (nominal)
0	0	0	16 ms
0	0	1	32 ms
0	1	0	64 ms
0	1	1	128 ms
1	0	0	256 ms
1	0	1	512 ms
1	1	0	1024 ms
1	1	1	2048 ms

Timer 0 and 1

Timer 0 and Timer 1 in the AT89S8252 operate the same way as Timer 0 and Timer 1 in the AT89C51, AT89C52 and AT89C55. For further information, see the October 1995 Microcontroller Data Book, page 2-45, section titled, "Timer/Counters."

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/$\overline{T2}$ 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 8.

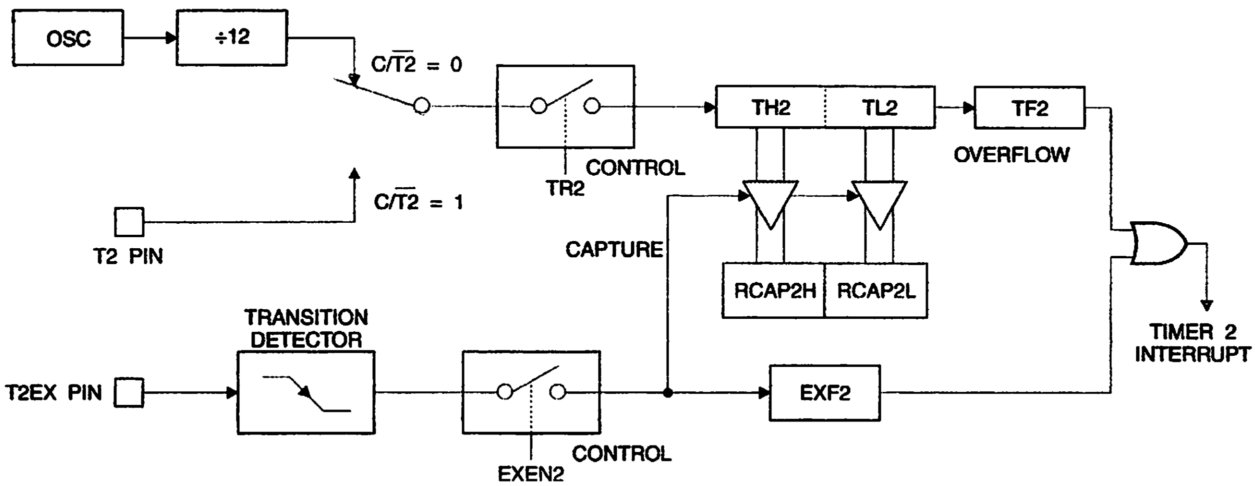
Timer 2 consists of two 8-bit registers, TH2 and TL2. In the Timer function, the TL2 register is incremented every machine cycle. Since a machine cycle consists of 12 oscillator periods, the count rate is 1/12 of the oscillator frequency.

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 S3P1 of the cycle following the one in which transition was detected. Since two machine cycles (24 ıillator periods) are required to recognize a 1-to-0 transiı, the maximum count rate is 1/24 of the oscillator ןuency. To ensure that a given level is sampled at least ɔe before it changes, the level should be held for at least ɘ full machine cycle.

ble 8. Timer 2 Operating Modes

RCLK + TCLK	CP/$\overline{RL2}$	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)

ıgure 1. Timer 2 in Capture Mode



Capture Mode

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

ıto-reload (Up or Down Counter)

ıer 2 can be programmed to count up or down when ıfigured in its 16 bit auto-reload mode. This feature is oked by the DCEN (Down Counter Enable) bit located in SFR T2MOD (see Table 9). Upon reset, the DCEN bit set to 0 so that timer 2 will default to count up. When ;EN is set, Timer 2 can count up or down, depending on value of the T2EX pin.

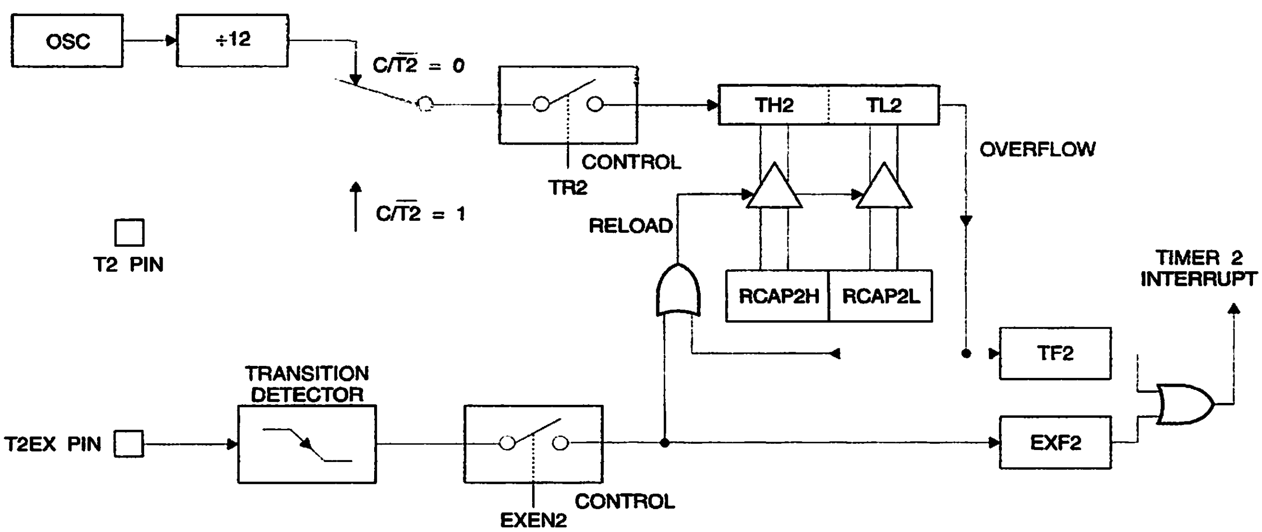
jure 2 shows Timer 2 automatically counting up when ;EN = 0. In this mode, two options are selected by bit (EN2 in T2CON. If EXEN2 = 0, Timer 2 counts up to FFFH and then sets the TF2 bit upon overflow. The erflow also causes the timer registers to be reloaded with 16 bit value in RCAP2H and RCAP2L. The values in ;AP2H and RCAP2L are preset by software. If EXEN2 = a 16 bit reload can be triggered either by an overflow or by a 1-to-0 transition at external input T2EX. This transition also sets the EXF2 bit. Both the TF2 and EXF2 bits can generate an interrupt if enabled.

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

jure 2. Timer 2 in Auto Reload Mode (DCEN = 0)



ble 9. T2MOD – Timer 2 Mode Control Register

2MOD Address = 0C9H — Reset Value = XXXX XX00B

lot Bit Addressable

	–	–	–	–	–	–	T2OE	DCEN
Bit	7	6	5	4	3	2	1	0

ymbol	Function
	Not implemented, reserved for future use.
2OE	Timer 2 Output Enable bit.
CEN	When set, this bit allows Timer 2 to be configured as an up/down counter.

Figure 3. Timer 2 Auto Reload Mode (DCEN = 1)

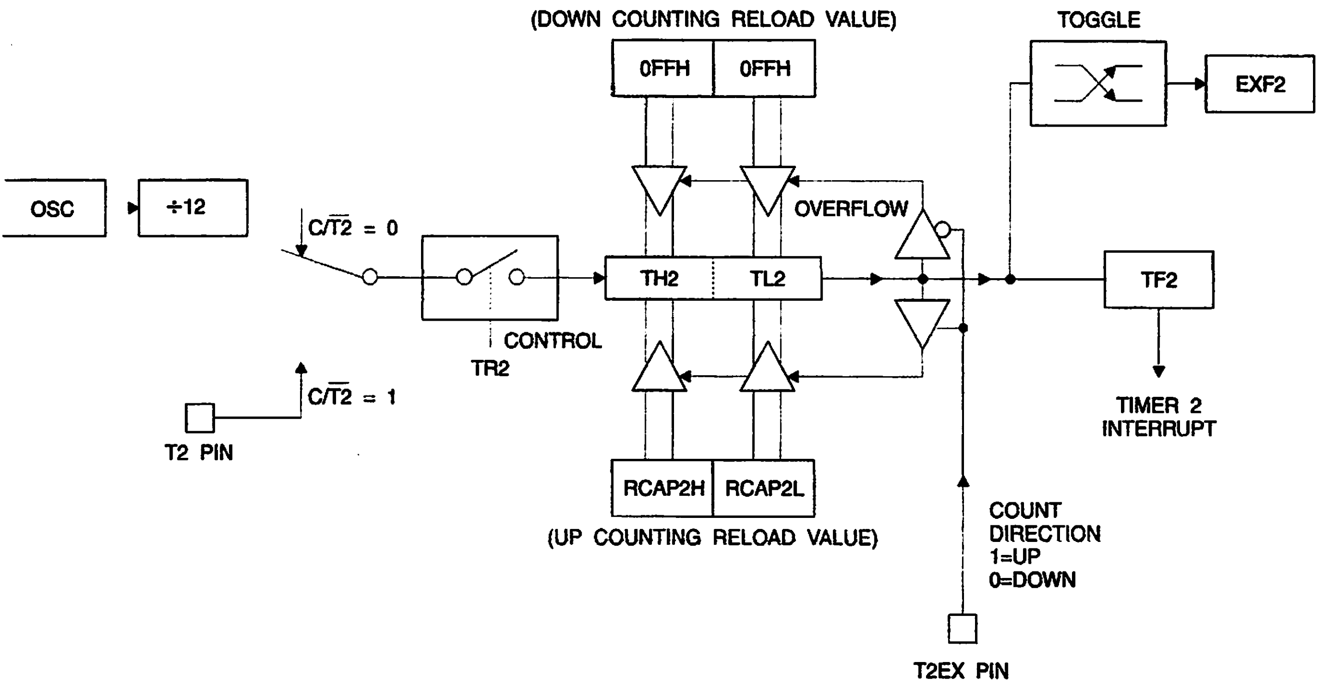
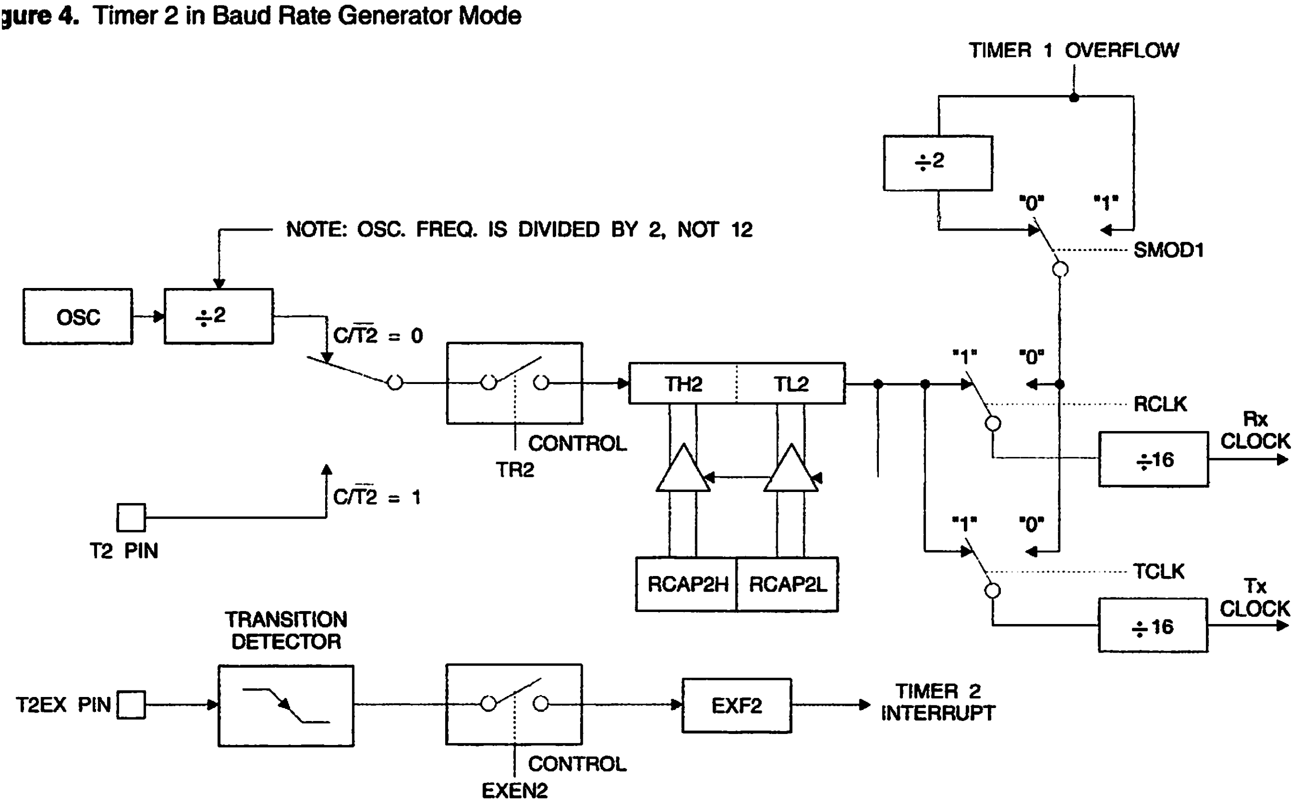


Figure 4. Timer 2 in Baud Rate Generator Mode



aud Rate Generator

ner 2 is selected as the baud rate generator by setting LK and/or RCLK in T2CON (Table 2). Note that the ıd rates for transmit and receive can be different if Timer ; used for the receiver or transmitter and Timer 1 is used the other function. Setting RCLK and/or TCLK puts ner 2 into its baud rate generator mode, as shown in Fig- ; 4.

e baud rate generator mode is similar to the auto-reload ›de, in that a rollover in TH2 causes the Timer 2 registers be reloaded with the 16 bit value in registers RCAP2H d RCAP2L, which are preset by software.

e baud rates in Modes 1 and 3 are determined by Timer ; overflow rate according to the following equation.

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

e Timer can be configured for either timer or counter eration. In most applications, it is configured for timer eration ($CP/\overline{T2}$ = 0). The timer operation is different for ner 2 when it is used as a baud rate generator. Normally, a timer, it increments every machine cycle (at 1/12 the cillator frequency). As a baud rate generator, however, it :rements every state time (at 1/2 the oscillator fre- ency). The baud rate formula is given below.

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

ere (RCAP2H, RCAP2L) is the content of RCAP2H and :AP2L taken as a 16 bit unsigned integer.

ner 2 as a baud rate generator is shown in Figure 4. This ure is valid only if RCLK or TCLK = 1 in T2CON. Note ıt a rollover in TH2 does not set TF2 and will not gener- ; an interrupt. Note too, that if EXEN2 is set, a 1-to-0 nsition in T2EX will set EXF2 but will not cause a reload m (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.

Programmable Clock Out

A 50% duty cycle clock can be programmed to come out on P1.0, as shown in Figure 5. This pin, besides being a regular I/O pin, has two alternate functions. It can be programmed to input the external clock for Timer/Counter 2 or to output a 50% duty cycle clock ranging from 61 Hz to 4 MHz at a 16 MHz operating frequency.

To configure the Timer/Counter 2 as a clock generator, bit $C/\overline{T2}$ (T2CON.1) must be cleared and bit T2OE (T2MOD.1) must be set. Bit TR2 (T2CON.2) starts and stops the timer.

The clock-out frequency depends on the oscillator frequency and the reload value of Timer 2 capture registers (RCAP2H, RCAP2L), as shown in the following equation.

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

In the clock-out mode, Timer 2 rollovers 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.

Figure 5. Timer 2 in Clock-out Mode

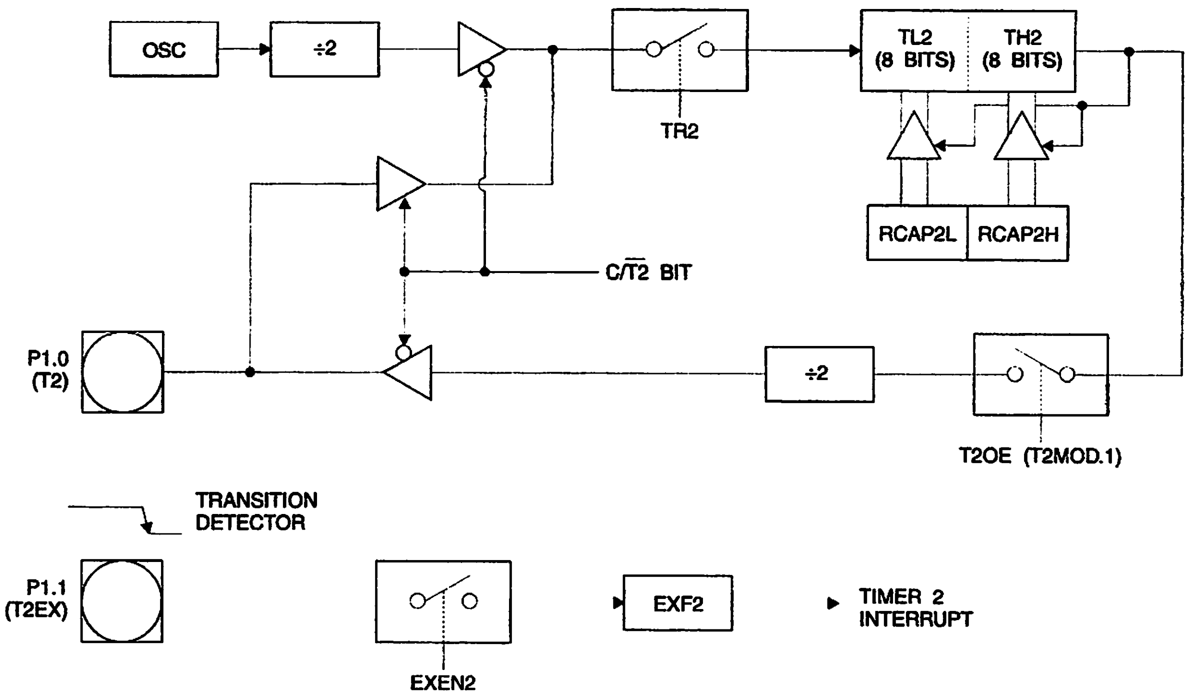
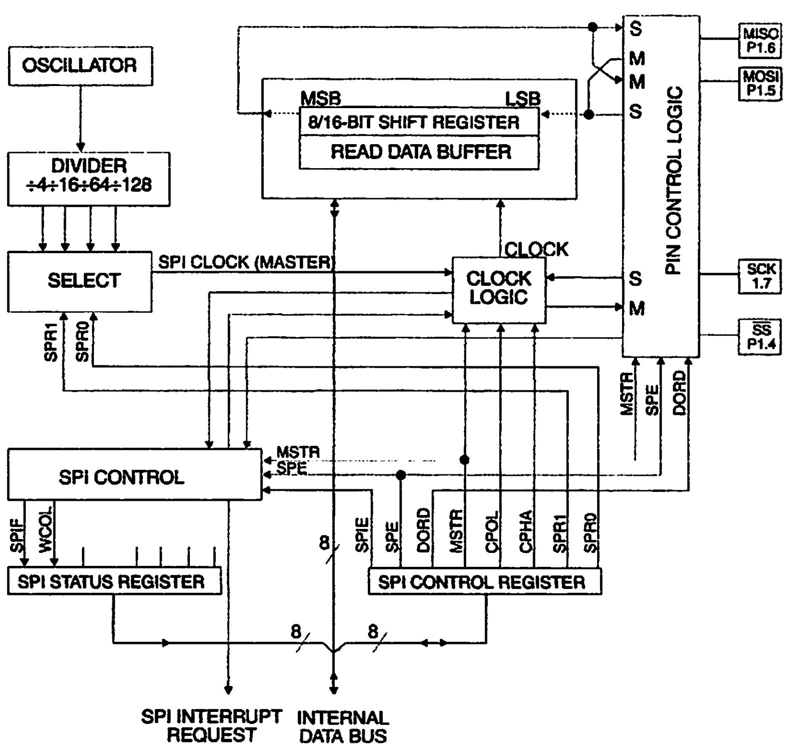


Figure 6. SPI Block Diagram



ART

e UART in the AT89S8252 operates the same way as ı UART in the AT89C51, AT89C52 and AT89C55. For ther information, see the October 1995 Microcontroller ta Book, page 2-49, section titled, "Serial Interface."

ərial Peripheral Interface

e serial peripheral interface (SPI) allows high-speed synronous data transfer between the AT89S8252 and ıripheral devices or between several AT89S8252 ıvices. The AT89S8252 SPI features include the lowing:

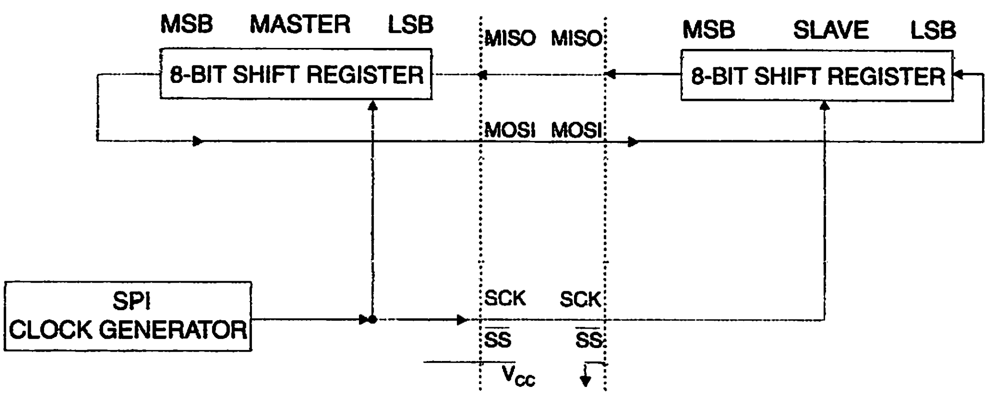
- Full-Duplex, 3-Wire Synchronous Data Transfer
- Master or Slave Operation
- 1.5 MHz Bit Frequency (max.)
- LSB First or MSB First Data Transfer
- Four Programmable Bit Rates
- End of Transmission Interrupt Flag
- Write Collision Flag Protection
- Wakeup from Idle Mode (Slave Mode Only)

The interconnection between master and slave CPUs with SPI is shown in the following figure. The SCK pin is the clock output in the master mode but is the clock input in the slave mode. Writing to the SPI data register of the master CPU starts the SPI clock generator, and the data written shifts out of the MOSI pin and into the MOSI pin of the slave CPU. After shifting one byte, the SPI clock generator stops, setting the end of transmission flag (SPIF). If both the SPI interrupt enable bit (SPIE) and the serial port interrupt enable bit (ES) are set, an interrupt is requested.

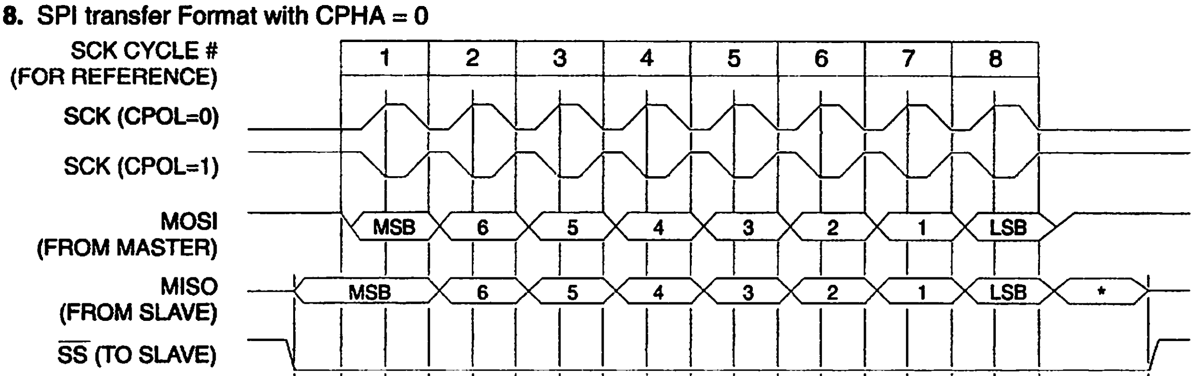
The Slave Select input, $\overline{SS}$/P1.4, is set low to select an individual SPI device as a slave. When $\overline{SS}$/P1.4 is set high, the SPI port is deactivated and the MOSI/P1.5 pin can be used as an input.

There are four combinations of SCK phase and polarity with respect to serial data, which are determined by control bits CPHA and CPOL. The SPI data transfer formats are shown in Figure 8 and Figure 9.

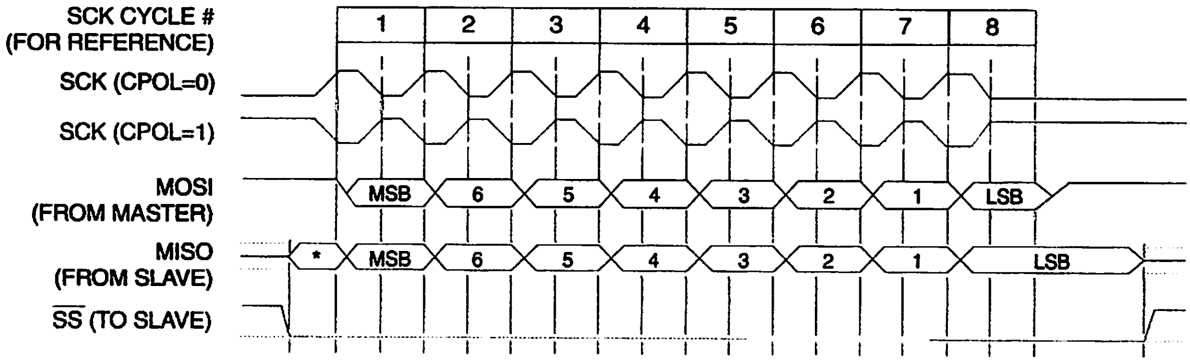
ɟure 7. SPI Master-slave Interconnection



ɟure 8. SPI transfer Format with CPHA = 0



ot defined but normally MSB of character just received jure 9. SPI Transfer Format with CPHA = 1



ot defined but normally LSB of previously transmitted character

ıterrupts

ıe AT89S8252 has a total of six interrupt vectors: two ternal interrupts ($\overline{INT0}$ and $\overline{INT1}$), three timer interrupts ımers 0, 1, and 2), and the serial port interrupt. These errupts are all shown in Figure 10.

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

ıte that Table 10 shows that bit position IE.6 is unimple-ented. In the AT89C51, bit position IE.5 is also implemented. User software should not write 1s to these : positions, since they may be used in future AT89 ɔducts.

ner 2 interrupt is generated by the logical OR of bits TF2 d EXF2 in register T2CON. Neither of these flags is ıared by hardware when the service routine is vectored In fact, the service routine may have to determine ıether it was TF2 or EXF2 that generated the interrupt, d that bit will have to be cleared in software.

e Timer 0 and Timer 1 flags, TF0 and TF1, are set at P2 of the cycle in which the timers overflow. The values ɜ then polled by the circuitry in the next cycle. However, ɜ Timer 2 flag, TF2, is set at S2P2 and is polled in the me cycle in which the timer overflows.

Table 10. 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	SPI and UART 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.

gure 10. Interrupt Sources

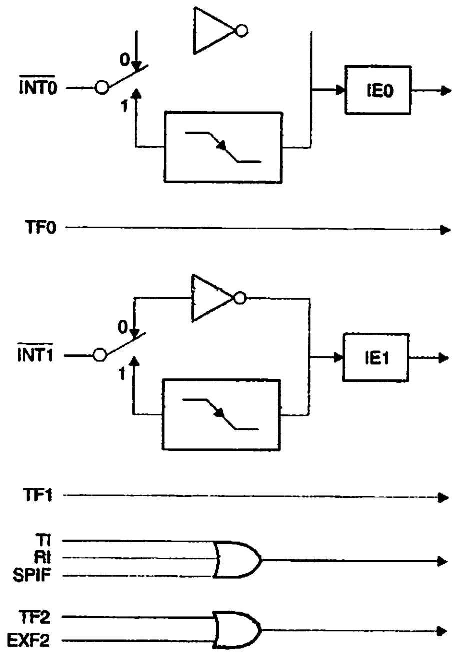
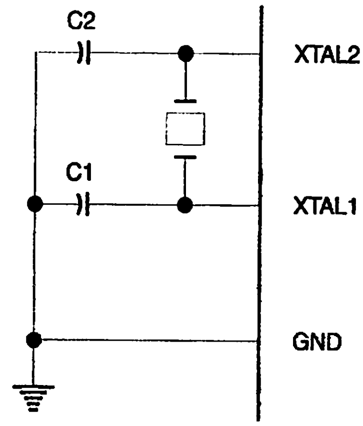
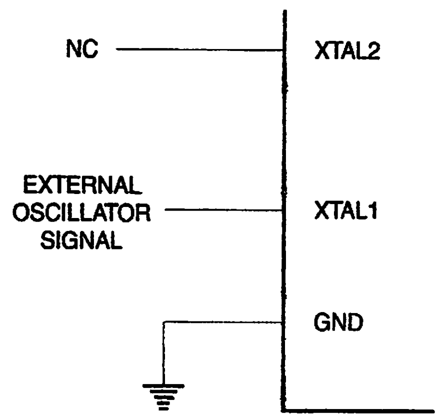


Figure 11. Oscillator Connections



Note: Note: C1, C2 = 30 pF ± 10 pF for Crystals
= 40 pF ± 10 pF for Ceramic Resonators

Figure 12. External Clock Drive Configuration



scillator Characteristics

'AL1 and XTAL2 are the input and output, respectively, an inverting amplifier that can be configured for use as on-chip oscillator, as shown in Figure 11. Either a quartz /stal or ceramic resonator may be used. To drive the vice from an external clock source, XTAL2 should be left connected while XTAL1 is driven, as shown in Figure 12. ere are no requirements on the duty cycle of the external ›ck signal, since the input to the internal clocking circuitry through a divide-by-two flip-flop, but minimum and maxi- ım voltage high and low time specifications must be served.

le Mode

idle mode, the CPU puts itself to sleep while all the on-ip peripherals remain active. The mode is invoked by ftware. The content of the on-chip RAM and all the spe-ıl functions registers remain unchanged during this ıde. The idle mode can be terminated by any enabled errupt or by a hardware reset.

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

atus of External Pins During Idle and Power-down Modes

ode	Program Memory	ALE	$\overline{\text{PSEN}}$	PORT0	PORT1	PORT2	PORT3
le	Internal	1	1	Data	Data	Data	Data
le	External	1	1	Float	Data	Address	Data
ɔwer-down	Internal	0	0	Data	Data	Data	Data
ɔwer-down	External	0	0	Float	Data	Data	Data

ɔwer-down Mode

he power-down mode, the oscillator is stopped and the truction that invokes power-down is the last instruction ecuted. The on-chip RAM and Special Function Regis-s retain their values until the power-down mode is minated. Exit from power-down can be initiated either by ardware reset or by an enabled external interrupt. Reset lefines the SFRs but does not change the on-chip RAM. e reset should not be activated before V_{CC} is restored to normal operating level and must be held active long ough to allow the oscillator to restart and stabilize.

exit power-down via an interrupt, the external interrupt st be enabled as level sensitive before entering power-wn. The interrupt service routine starts at 16 ms (nomi-) after the enabled interrupt pin is activated.

Program Memory Lock Bits

The AT89S8252 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.

When lock bit 1 is programmed, the logic level at the $\overline{\text{EA}}$ pin is sampled and latched during reset. If the device is powered up without a reset, the latch initializes to a random value and holds that value until reset is activated. The latched value of $\overline{\text{EA}}$ must agree with the current logic level at that pin in order for the device to function properly.

Once programmed, the lock bits can only be unprogrammed with the Chip Erase operations in either the parallel or serial modes.

ɔck Bit Protection Modes[(1)(2)]

Program Lock Bits				
	LB1	LB2	LB3	Protection Type
1	U	U	U	No internal memory lock feature.
2	P	U	U	MOVC instructions executed from external program memory are disabled from fetching code bytes from internal memory. $\overline{\text{EA}}$ is sampled and latched on reset and further programming of the Flash memory (parallel or serial mode) is disabled.
3	P	P	U	Same as Mode 2, but parallel or serial verify are also disabled.
4	P	P	P	Same as Mode 3, but external execution is also disabled.

es: 1. U = Unprogrammed
2. P = Programmed

rogramming the Flash and EEPROM

nel's AT89S8252 Flash Microcontroller offers 8K bytes in-system reprogrammable Flash Code memory and 2K :es of EEPROM Data memory.

e AT89S8252 is normally shipped with the on-chip Flash de and EEPROM Data memory arrays in the erased ite (i.e. contents = FFH) and ready to be programmed. is device supports a High-voltage (12V) Parallel pro- amming mode and a Low-voltage (5V) Serial ogramming mode. The serial programming mode pro- es a convenient way to download the AT89S8252 inside user's system. The parallel programming mode is com- tible with conventional third party Flash or EPROM grammers.

e Code and Data memory arrays are mapped via sepa- e address spaces in the serial programming mode. In parallel programming mode, the two arrays occupy one ntiguous address space: 0000H to 1FFFH for the Code ay and 2000H to 27FFH for the Data array.

e Code and Data memory arrays on the AT89S8252 are grammed byte-by-byte in either programming mode. An o-erase cycle is provided with the self-timed program- ng operation in the serial programming mode. There is need to perform the Chip Erase operation to reprogram / memory location in the serial programming mode ess any of the lock bits have been programmed.

he parallel programming mode, there is no auto-erase le. To reprogram any non-blank byte, the user needs to the Chip Erase operation first to erase both arrays.

rallel Programming Algorithm: To program and verify AT89S8252 in the parallel programming mode, the fol- ing sequence is recommended:

Power-up sequence:

Apply power between V_{CC} and GND pins.

Set RST pin to "H".

Apply a 3 MHz to 24 MHz clock to XTAL1 pin and wait for at least 10 milliseconds.

Set $\overline{PSEN}$ pin to "L"

ALE pin to "H"

$\overline{EA}$ pin to "H" and all other pins to "H".

Apply the appropriate combination of "H" or "L" logic levels to pins P2.6, P2.7, P3.6, P3.7 to select one of the programming operations shown in the Flash Programming Modes table.

Apply the desired byte address to pins P1.0 to P1.7 and P2.0 to P2.5.

Apply data to pins P0.0 to P0.7 for Write Code operation.

5. Raise $\overline{EA}/V_{PP}$ to 12V to enable Flash programming, erase or verification.
6. Pulse ALE/$\overline{PROG}$ once to program a byte in the Code memory array, the Data memory array or the lock bits. The byte-write cycle is self-timed and typically takes 1.5 ms.
7. To verify the byte just programmed, bring pin P2.7 to "L" and read the programmed data at pins P0.0 to P0.7.
8. Repeat steps 3 through 7 changing the address and data for the entire 2K or 8K bytes array or until the end of the object file is reached.
9. Power-off sequence:

   Set XTAL1 to "L".

   Set RST and $\overline{EA}$ pins to "L".

   Turn V_{CC} power off.

In the parallel programming mode, there is no auto-erase cycle and to reprogram any non-blank byte, the user needs to use the Chip Erase operation first to erase both arrays.

$\overline{DATA}$ Polling: The AT89S8252 features $\overline{DATA}$ Polling to indicate the end of a write cycle. During a write cycle in the parallel or serial programming mode, an attempted read of the last byte written will result in the complement of the written datum on P0.7 (parallel mode), and on the MSB of the serial output byte on MISO (serial mode). Once the write cycle has been completed, true data are valid on all outputs, and the next cycle may begin. $\overline{DATA}$ Polling may begin any time after a write cycle has been initiated.

Ready/$\overline{Busy}$: The progress of byte programming in the parallel programming mode can also be monitored by the RDY/$\overline{BSY}$ output signal. Pin P3.4 is pulled Low after ALE goes High during programming to indicate $\overline{BUSY}$. P3.4 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 or Data byte can be read back via the address and data lines for verification. The state of the lock bits can also be verified directly in the parallel programming mode. In the serial programming mode, the state of the lock bits can only be verified indirectly by observing that the lock bit features are enabled.

Chip Erase: Both Flash and EEPROM arrays are erased electrically at the same time. In the parallel programming mode, chip erase is initiated by using the proper combination of control signals and by holding ALE/$\overline{PROG}$ low for 10 ms. The Code and Data arrays are written with all "1"s in the Chip Erase operation.

the serial programming mode, a chip erase operation is tiated by issuing the Chip Erase instruction. In this mode, ip erase is self-timed and takes about 16 ms.

uring chip erase, a serial read from any address location l return 00H at the data outputs.

erial Programming Fuse: A programmable fuse is available to disable Serial Programming if the user needs aximum system security. The Serial Programming Fuse n only be programmed or erased in the Parallel Programng Mode.

e AT89S8252 is shipped with the Serial Programming ode enabled.

eading the Signature Bytes: The signature bytes are ad by the same procedure as a normal verification of ations 030H and 031H, except that P3.6 and P3.7 must pulled to a logic low. The values returned are as follows:

(030H) = 1EH indicates manufactured by Atmel
(031H) = 72H indicates 89S8252

ogramming Interface

ery code byte in the Flash and EEPROM arrays can be itten, and the entire array can be erased, by using the propriate combination of control signals. The write operon cycle is self-timed and once initiated, will omatically time itself to completion.

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

erial Downloading

th the Code and Data memory arrays can be proammed using the serial SPI bus while RST is pulled to . The serial interface consists of pins SCK, MOSI (input) d MISO (output). After RST is set high, the Programming able instruction needs to be executed first before prom/erase operations can be executed.

auto-erase cycle is built into the self-timed programming eration (in the serial mode ONLY) and there is no need first execute the Chip Erase instruction unless any of the k bits have been programmed. The Chip Erase operan turns the content of every memory location in both the de and Data arrays into FFH.

e Code and Data memory arrays have separate address aces:

0000H to 1FFFH for Code memory and 000H to 7FFH for Data memory.

Either an external system clock is supplied at pin XTAL1 or a crystal needs to be connected across pins XTAL1 and XTAL2. The maximum serial clock (SCK) frequency should be less than 1/40 of the crystal frequency. With a 24 MHz oscillator clock, the maximum SCK frequency is 600 kHz.

Serial Programming Algorithm

To program and verify the AT89S8252 in the serial programming mode, the following sequence is recommended:

1. Power-up sequence:

   Apply power between VCC and GND pins.

   Set RST pin to "H".

   If a crystal is not connected across pins XTAL1 and XTAL2, apply a 3 MHz to 24 MHz clock to XTAL1 pin and wait for at least 10 milliseconds.

2. Enable serial programming by sending the Programming Enable serial instruction to pin MOSI/P1.5. The frequency of the shift clock supplied at pin SCK/P1.7 needs to be less than the CPU clock at XTAL1 divided by 40.

3. The Code or Data array is programmed one byte at a time by supplying the address and data together with the appropriate Write instruction. The selected memory location is first automatically erased before new data is written. The write cycle is self-timed and typically takes less than 2.5 ms at 5V.

4. Any memory location can be verified by using the Read instruction which returns the content at the selected address at serial output MISO/P1.6.

5. At the end of a programming session, RST can be set low to commence normal operation.

Power-off sequence (if needed):

   Set XTAL1 to "L" (if a crystal is not used).

   Set RST to "L".

   Turn V_{CC} power off.

Serial Programming Instruction

The Instruction Set for Serial Programming follows a 3-byte protocol and is shown in the following table:

ıstruction Set

ıstruction	Input Format: Byte 1	Byte 2	Byte 3	Operation
'rogramming Enable	1010 1100	0101 0011	xxxx xxxx	Enable serial programming interface after RST goes high.
:hip Erase	1010 1100	xxxx x100	xxxx xxxx	Chip erase both 8K & 2K memory arrays.
lead Code Memory	aaaa a001	low addr	xxxx xxxx	Read data from Code memory array at the selected address. The 5 MSBs of the first byte are the high order address bits. The low order address bits are in the second byte. Data are available at pin MISO during the third byte.
Vrite Code Memory	aaaa a010	low addr	data in	Write data to Code memory location at selected address. The address bits are the 5 MSBs of the first byte together with the second byte.
lead Data Memory	00aa a101	low addr	xxxx xxxx	Read data from Data memory array at selected address. Data are available at pin MISO during the third byte.
/rite Data Memory	00aa a110	low addr	data in	Write data to Data memory location at selected address.
/rite Lock Bits	1010 1100	x x111	xxxx xxxx	Write lock bits. Set LB1, LB2 or LB3 = "0" to program lock bits.

te: 1. DATA polling is used to indicate the end of a write cycle which typically takes less than 2.5 ms at 5V.
2. "aaaaa" – high order address.
3. "x" = don't care.

lash and EEPROM Parallel Programming Modes

Mode	RST	PSEN	ALE/PROG	EA/V_{PP}	P2.6	P2.7	P3.6	P3.7	Data I/O P0.7:0	Address P2.5:0 P1.7:0
Serial Prog. Modes	H	h(1)	h(1)	x						
Chip Erase	H	L	⎺_/⎺ (2)	12V	H	L	L	L	X	X
Write (10K bytes) Memory	H	L	⎺_/⎺	12V	L	H	H	H	DIN	ADDR
Read (10K bytes) Memory	H	L	H	12V	L	L	H	H	DOUT	ADDR
Write Lock Bits:	H	L	⎺_/⎺	12V	H	L	H	L	DIN	X
Bit - 1									P0.7 = 0	X
Bit - 2									P0.6 = 0	X
Bit - 3									P0.5 = 0	X
Read Lock Bits:	H	L	H	12V	H	H	L	L	DOUT	X
Bit - 1									@P0.2	X
Bit - 2									@P0.1	X
Bit - 3									@P0.0	X
Read Atmel Code	H	L	H	12V	L	L	L	L	DOUT	30H
Read Device Code	H	L	H	12V	L	L	L	L	DOUT	31H
Serial Prog. Enable	H	L	⎺_/⎺ (2)	12V	L	H	L	H	P0.0 = 0	X
Serial Prog. Disable	H	L	⎺_/⎺ (2)	12V	L	H	L	H	P0.0 = 1	X
Read Serial Prog. Fuse	H	L	H	12V	H	H	L	H	@P0.0	X

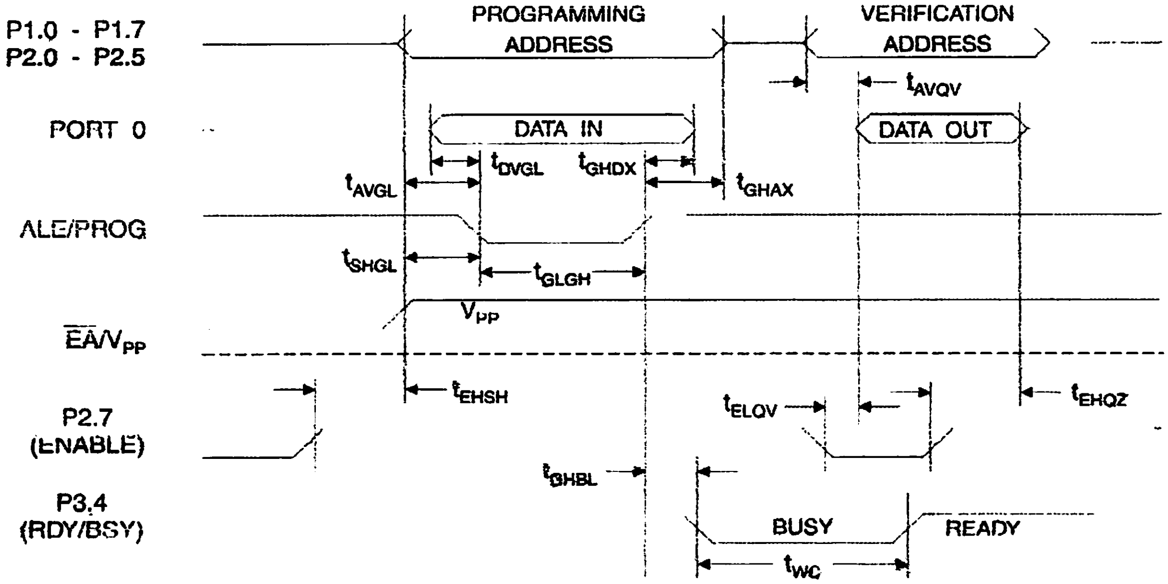
otes:
1. "h" = weakly pulled "High" internally.
2. Chip Erase and Serial Programming Fuse require a 10 ms PROG pulse. Chip Erase needs to be performed first before reprogramming any byte with a content other than FFH.
3. P3.4 is pulled Low during programming to indicate RDY/BSY.
4. "X" = don't care

lash Programming and Verification Characteristics – Parallel Mode

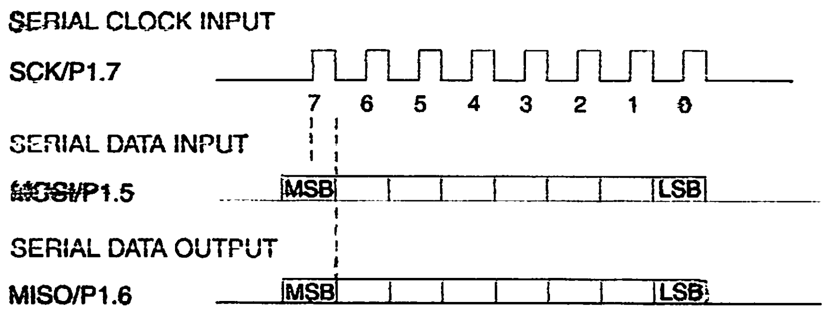
= 0°C to 70°C, V_{CC} – 5.0V ± 10%

Symbol	Parameter	Min	Max	Units
V_{PP}	Programming Enable Voltage	11.5	12.5	V
I_{PP}	Programming Enable Current		1.0	mA
$1/t_{CLCL}$	Oscillator Frequency	3	24	MHz
t_{AVGL}	Address Setup to $\overline{PROG}$ Low	$48t_{CLCL}$		
t_{GHAX}	Address Hold after $\overline{PROG}$	$48t_{CLCL}$		
t_{DVGL}	Data Setup to $\overline{PROG}$ Low	$48t_{CLCL}$		
t_{GHDX}	Data Hold after $\overline{PROG}$	$48t_{CLCL}$		
t_{EHSH}	P2.7 ($\overline{ENABLE}$) High to V_{PP}	$48t_{CLCL}$		
t_{SHGL}	V_{PP} Setup to $\overline{PROG}$ Low	10		µs
t_{GLGH}	$\overline{PROG}$ Width	1	110	µs
t_{AVQV}	Address to Data Valid		$48t_{CLCL}$	
t_{ELQV}	$\overline{ENABLE}$ Low to Data Valid		$48t_{CLCL}$	
t_{EHQZ}	Data Float after $\overline{ENABLE}$	0	$48t_{CLCL}$	
t_{GHBL}	$\overline{PROG}$ High to $\overline{BUSY}$ Low		1.0	µs
t_{WC}	Byte Write Cycle Time		2.0	ms

lash/EEPROM Programming and Verification Waveforms – Parallel Mode



;erial Downloading Waveforms



bsolute Maximum Ratings*

Operating Temperature	-55°C to +125°C
Storage Temperature	-65°C to +150°C
Voltage on Any Pin with Respect to Ground	-1.0V to +7.0V
Maximum Operating Voltage	6.6V
DC 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.

C Characteristics

he values shown in this table are valid for T_A = -40°C to 85°C and V_{CC} = 5.0V ± 20%, unless otherwise noted.

Symbol	Parameter	Condition	Min	Max	Units
V_{IL}	Input Low-voltage	(Except $\overline{EA}$)	-0.5	0.2 V_{CC} - 0.1	V
V_{IL1}	Input Low-voltage ($\overline{EA}$)		-0.5	0.2 V_{CC} - 0.3	V
V_{IH}	Input Hifh-voltage	(Except XTAL1, RST)	0.2 V_{CC} + 0.9	V_{CC} + 0.5	V
V_{IH1}	Input Hifh-voltage	(XTAL1, RST)	0.7 V_{CC}	V_{CC} + 0.5	V
V_{OL}	Output Low-voltage (1) (Ports 1,2,3)	I_{OL} = 1.6 mA		0.5	V
V_{OL1}	Output Low-voltage (1) (Port 0, ALE, $\overline{PSEN}$)	I_{OL} = 3.2 mA		0.5	V
V_{OH}	Output Hifh-voltage (Ports 1,2,3, ALE, $\overline{PSEN}$)	I_{OH} = -60 µA, V_{CC} = 5V ± 10%	2.4		V
		I_{OH} = -25 µA	0.75 V_{CC}		V
		I_{OH} = -10 µA	0.9 V_{CC}		V
V_{OH1}	Output Hifh-voltage (Port 0 in External Bus Mode)	I_{OH} = -800 µA, V_{CC} = 5V ± 10%	2.4		V
		I_{OH} = -300 µA	0.75 V_{CC}		V
		I_{OH} = -80 µA	0.9 V_{CC}		V
I_{IL}	Logical 0 Input Current (Ports 1,2,3)	V_{IN} = 0.45V		-50	µA
I_{TL}	Logical 1 to 0 Transition Current (Ports 1,2,3)	V_{IN} = 2V, V_{CC} = 5V ± 10%		-650	µA
I_{LI}	Input Leakage Current (Port 0, $\overline{EA}$)	0.45 < V_{IN} < V_{CC}		±10	µA
RRST	Reset Pull-down Resistor		50	300	KΩ
C_{IO}	Pin Capacitance	Test Freq. = 1 MHz, T_A = 25°C		10	pF
I_{CC}	Power Supply Current	Active Mode, 12 MHz		25	mA
		Idle Mode, 12 MHz		6.5	mA
	Power-down Mode (2)	V_{CC} = 6V		100	µA
		V_{CC} = 3V		40	µA

otes: 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

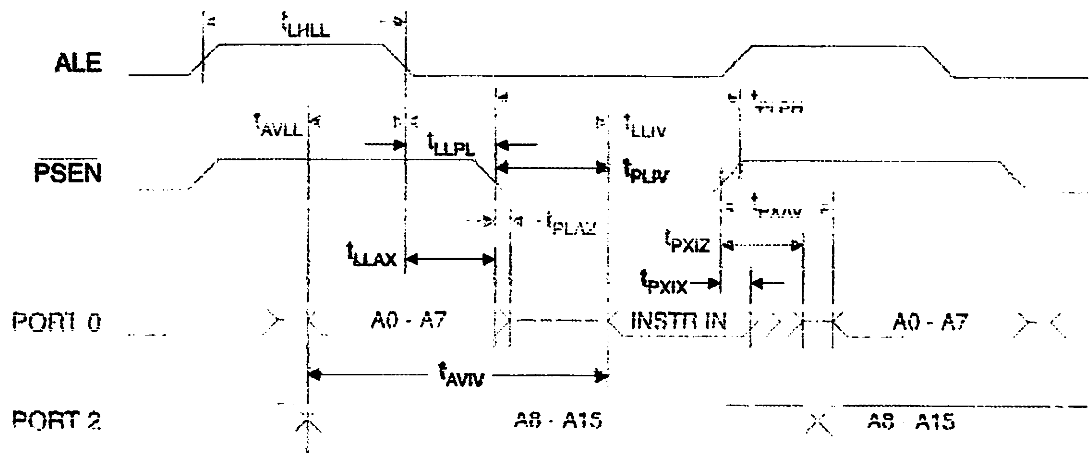
.C Characteristics

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

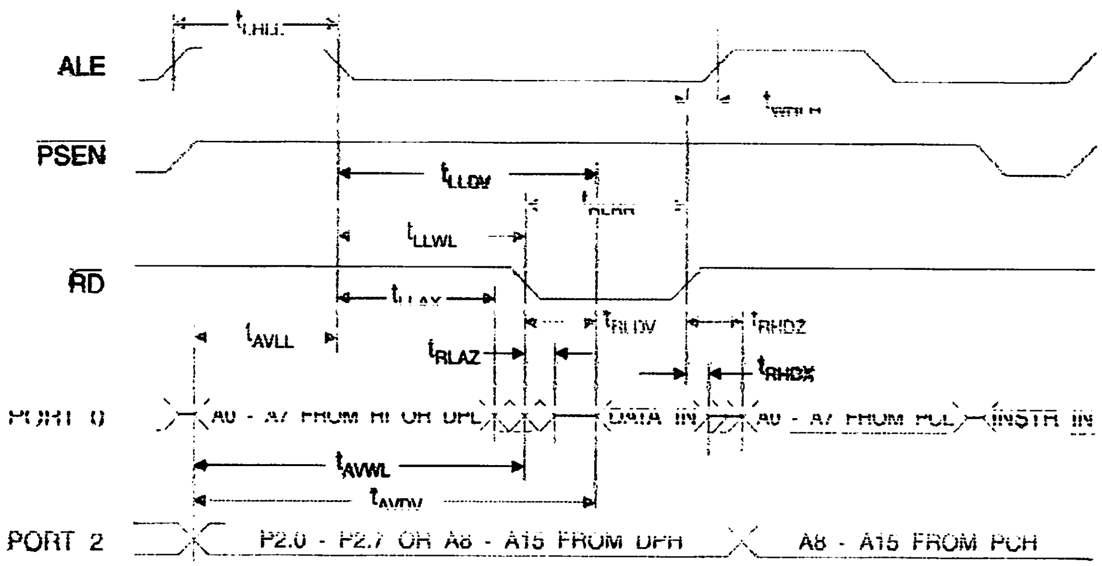
xternal Program and Data Memory Characteristics

Symbol	Parameter	Variable Oscillator		Units
		Min	Max	
$1/t_{CLCL}$	Oscillator Frequency	0	24	MHz
t_{LHLL}	ALE Pulse Width	$2t_{CLCL} - 40$		ns
t_{AVLL}	Address Valid to ALE Low	$t_{CLCL} - 13$		ns
t_{LLAX}	Address Hold after ALE Low	$t_{CLCL} - 20$		ns
t_{LLIV}	ALE Low to Valid Instruction In		$4t_{CLCL} - 65$	ns
t_{LLPL}	ALE Low to PSEN Low	$t_{CLCL} - 13$		ns
t_{PLPH}	PSEN Pulse Width	$3t_{CLCL} - 20$		ns
t_{PLIV}	PSEN Low to Valid Instruction In		$3t_{CLCL} - 45$	ns
t_{PXIX}	Input Instruction Hold after PSEN	0		ns
t_{PXIZ}	Input Instruction Float after PSEN		$t_{CLCL} - 10$	ns
t_{PXAV}	PSEN to Address Valid	$t_{CLCL} - 8$		ns
t_{AVIV}	Address to Valid Instruction In		$5t_{CLCL} - 55$	ns
t_{PLAZ}	PSEN Low to Address Float		10	ns
t_{RLRH}	RD Pulse Width	$6t_{CLCL} - 100$		ns
t_{WLWH}	WR Pulse Width	$6t_{CLCL} - 100$		ns
t_{RLDV}	RD Low to Valid Data In		$5t_{CLCL} - 90$	ns
t_{RHDX}	Data Hold after RD	0		ns
t_{RHDZ}	Data Float after RD		$2t_{CLCL} - 28$	ns
t_{LLDV}	ALE Low to Valid Data In		$8t_{CLCL} - 150$	ns
t_{AVDV}	Address to Valid Data In		$9t_{CLCL} - 165$	ns
t_{LLWL}	ALE Low to RD or WR Low	$3t_{CLCL} - 50$	$3t_{CLCL} + 50$	ns
t_{AVWL}	Address to RD or WR Low	$4t_{CLCL} - 75$		ns
t_{QVWX}	Data Valid to WR Transition	$t_{CLCL} - 20$		ns
t_{QVWH}	Data Valid to WR High	$7t_{CLCL} - 120$		ns
t_{WHQX}	Data Hold after WR	$t_{CLCL} - 20$		ns
t_{RLAZ}	RD Low to Address Float		0	ns
t_{WHLH}	RD or WR High to ALE High	$t_{CLCL} - 20$	$t_{CLCL} + 25$	ns

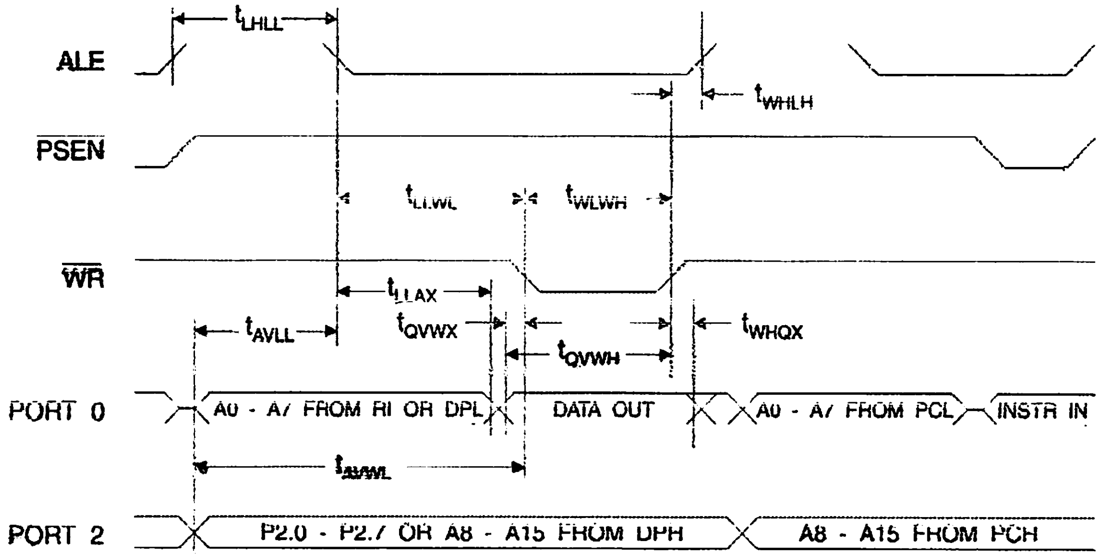
External Program Memory Read Cycle



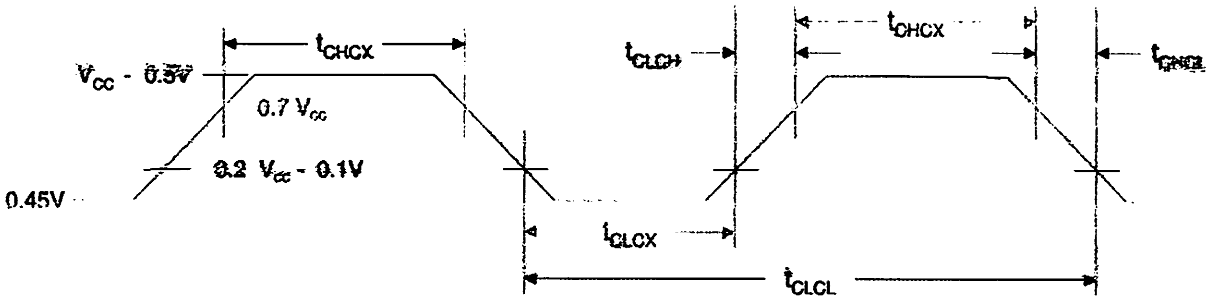
External Data Memory Read Cycle



External Data Memory Write Cycle



External Clock Drive Waveforms



External Clock Drive

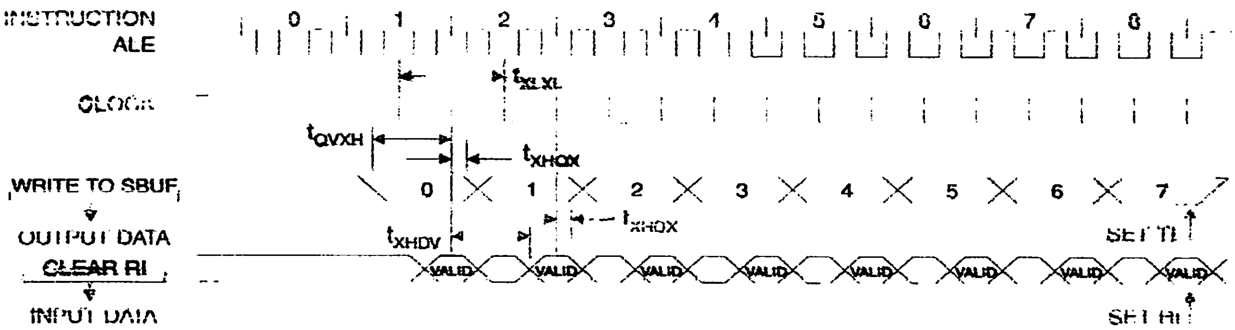
Symbol	Parameter	V_{CC} = 4.0V to 6.0V		Units
		Min	Max	
$1/t_{CLCL}$	Oscillator Frequency	0	24	MHz
t_{CLCL}	Clock Period	41.6		ns
t_{CHCX}	High Time	15		ns
t_{CLCX}	Low Time	15		ns
t_{CLCH}	Rise Time		20	ns
t_{CHCL}	Fall Time		20	ns

Serial Port Timing: Shift Register Mode Test Conditions

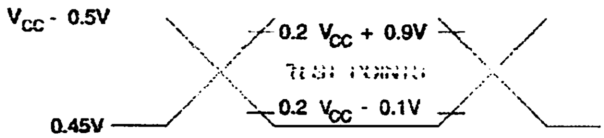
The values in this table are valid for V_{CC} = 4.0V to 6V and Load Capacitance = 80 pF.

Symbol	Parameter	Variable Oscillator		Units
		Min	Max	
t_{XLXL}	Serial Port Clock Cycle Time	$12t_{CLCL}$		µs
t_{QVXH}	Output Data Setup to Clock Rising Edge	$10t_{CLCL}$ - 133		ns
t_{XHQX}	Output Data Hold after Clock Rising Edge	$2t_{CLCL}$ - 117		ns
t_{XHDX}	Input Data Hold after Clock Rising Edge	0		ns
t_{XHDV}	Clock Rising Edge to Input Data Valid		$10t_{CLCL}$ - 133	ns

Shift Register Mode Timing Waveforms

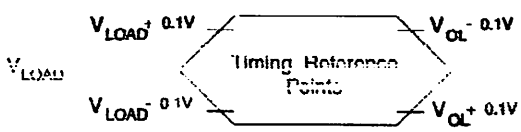


AC Testing Input/Output Waveforms(1)



Notes: 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.

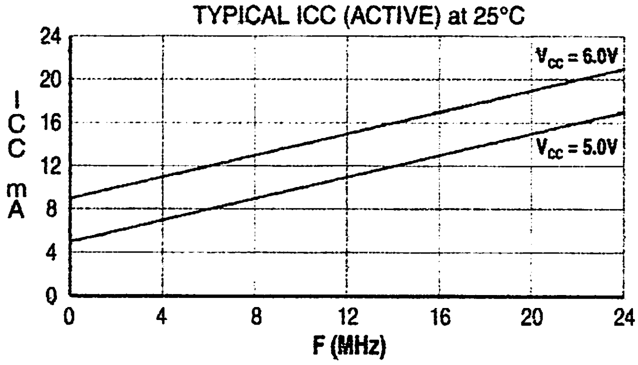
Float Waveforms(1)



Notes: 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.

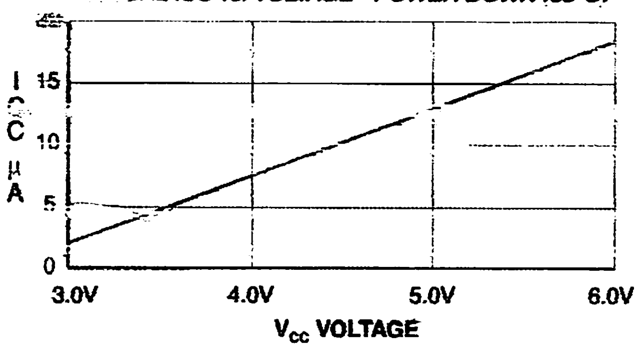
AT89S8252

TYPICAL ICC (ACTIVE) at 25°C



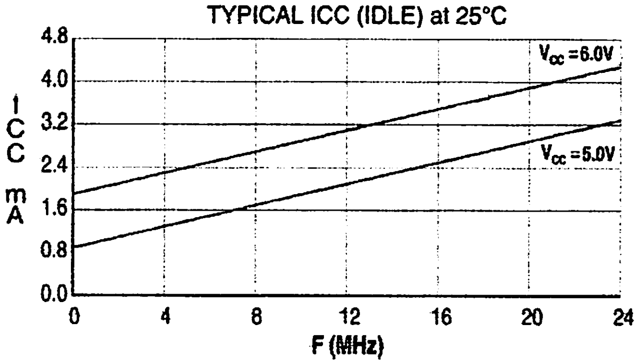
AT89S8252

TYPICAL ICC vs. VOLTAGE - POWER DOWN (85°C)



AT89S8252

TYPICAL ICC (IDLE) at 25°C



Notes: 1. XTAL1 tied to GND for Icc (power-down)
2. Lock bits programmed

Ordering Information

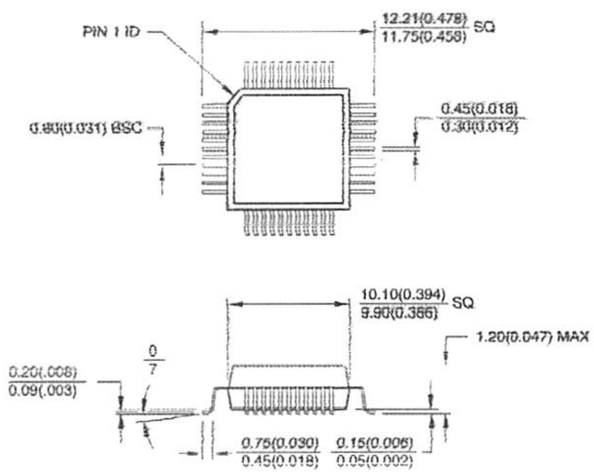
Speed (MHz)	Power Supply	Ordering Code	Package	Operation Range
24	4.0V to 6.0V	AT89S8252-24AC	44A	Commercial
		AT89S8252-24JC	44J	(0°C to 70°C)
		AT89S8252-24PC	40P6	
		AT89S8252-24QC	44Q	
	4.0V to 6.0V	AT89S8252-24AI	44A	Industrial
		AT89S8252-24JI	44J	(-40°C to 85°C)
		AT89S8252-24PI	40P6	
		AT89S8252-24QI	44Q	
33	4.5V to 5.5V	AT89S8252-33AC	44A	Commercial
		AT89S8252-33JC	44J	(0°C to 70°C)
		AT89S8252-33PC	40P6	
		AT89S8252-33QC	44Q	

= Preliminary Information

Package Type	
44A	44-lead, Thin Plastic Gull Wing Quad Flatpack (TQFP)
44J	44-lead, Plastic J-leaded Chip Carrier (PLCC)
40P6	40-lead, 0.600" Wide, Plastic Dual Inline Package (PDIP)
44Q	44-lead, Plastic Gull Wing Quad Flatpack (PQFP)

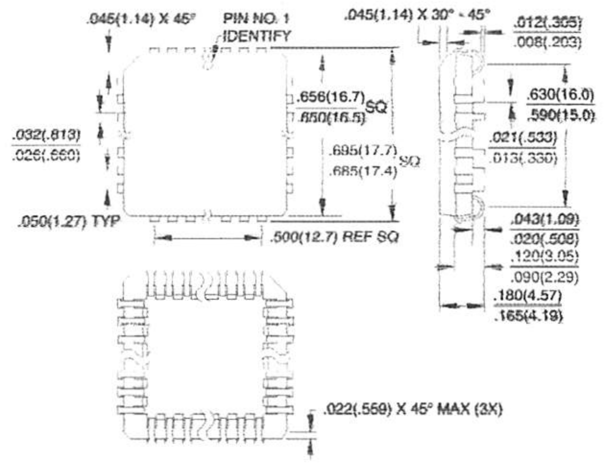
Packaging Information

44A, 44-lead, Thin (1.0 mm) Plastic Gull Wing Quad Flatpack (TQFP)
*Dimensions in Millimeters and (Inches)**
JEDEC STANDARD MS-026 ACB



Controlling dimension: millimeters

44J, 44-lead, Plastic J-leaded Chip Carrier (PLCC)
Dimensions in Inches and (Millimeters)
JEDEC STANDARD MS-018 AC



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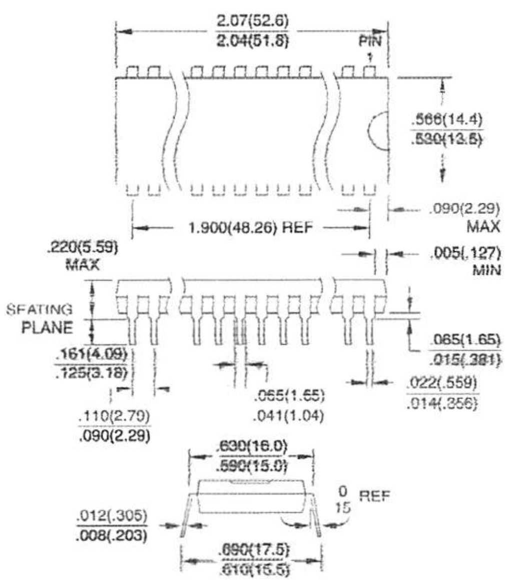

44Q, 44-lead, Plastic Quad Flat Package (PQFP)
Dimensions in Millimeters and (Inches)*
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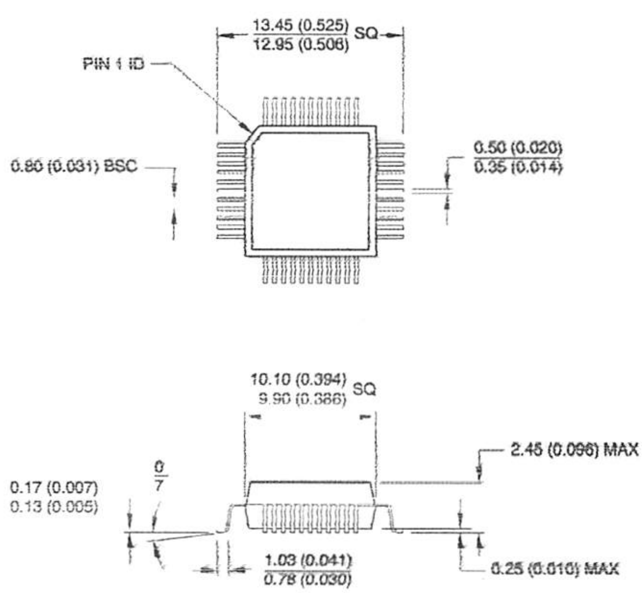

Controlling dimension: millimeters

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Using the ADC0808/ADC0809 8-Bit μP Compatible A/D Converters with 8-Channel Analog Multiplexer

National Semiconductor
Application Note 247
Larry Wakeman
September 1980

INTRODUCTION

The ADC0808/ADC0809 Data Acquisition Devices (DAD) implement on a single chip most the elements of the standard data acquisition system. They contain an 8-bit A/D converter, 8-channel multiplexer with an address input latch, and associated control logic. These devices provide most of the logic to interface to a variety of microprocessors with the addition of a minimum number of parts.

These circuits are implemented using a standard metal-gate CMOS process. This process is particularly suitable to applications where both analog and digital functions must be implemented on the same chip.

These two converters, the ADC0808 and ADC0809, are functionally identical except that the ADC0808 has a total unadjusted error of $\pm\frac{1}{2}$ LSB and the ADC0809 has an unadjusted error of ± 1 LSB. They are also related to their big brothers, the ADC0816 and ADC0817 expandable 16 channel converters. All four converters will typically do a conversion in ~100 μs when using a 640 kHz clock, but can convert a single input in as little as ~50 μs.

1.0 FUNCTIONAL DESCRIPTION

The ADC0808/ADC0809, shown in *Figure 1*, can be functionally divided into 2 basic subcircuits. These two subcircuits are an analog multiplexer and an A/D converter. The multiplexer uses 8 standard CMOS analog switches to provide for up to 8 analog inputs. The switches are selectively turned on, depending on the data latched into a 3-bit multiplexer address register.

The second function block, the successive approximation A/D converter, transforms the analog output of the multiplexer to an 8-bit digital word. The output of the multiplexer goes to one of two comparator inputs. The other input is derived from a 256R resistor ladder, which is tapped by a MOSFET transistor switch tree. The converter control logic controls the switch tree, funneling a particular tap voltage to the comparator. Based on the result of this comparison, the control logic and the successive approximation register (SAR) will decide whether the next tap to be selected should be higher or lower than the present tap on the resistor ladder. This algorithm is executed 8 times per conversion, once every 8 clock periods, yielding a total conversion time of 64 clock periods.

When the conversion cycle is complete the resulting data is loaded into the TRI-STATE® output latch. The data in the output latch can then be read by the host system any time before the end of the next conversion. The TRI-STATE capability of the latch allows easy interface to bus oriented systems.

The operation of these converters by a microprocessor or some control logic is very simple. The controlling device first selects the desired input channel. To do this, a 3 bit channel address is placed on the A, B, C input pins; and the ALE input is pulsed positively, clocking the address into the multiplexer address register. To begin the conversion, the START pin is pulsed. On the rising edge of this pulse the internal registers are cleared and on the falling edge the start conversion is initiated.

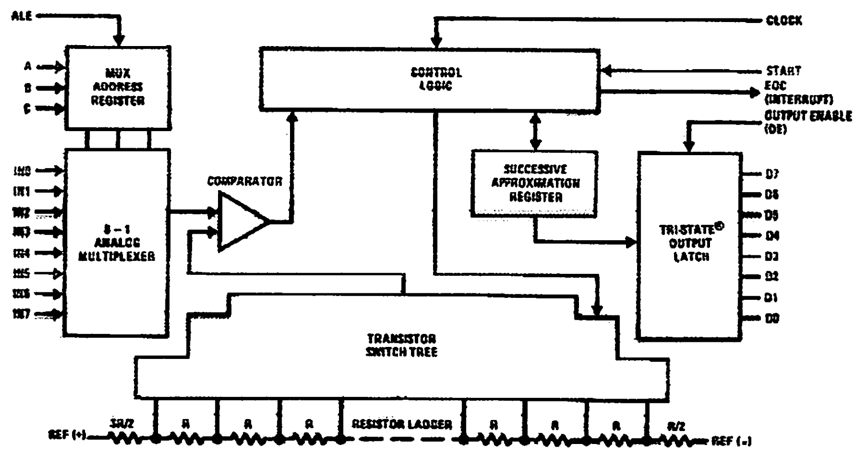

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FIGURE 1. ADC0808/ADC0809 Functional Block Diagram

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As mentioned earlier, there are 8 clock periods per approximation. Even though there is no conversion in progress the ADC0808/ADC0809 is still internally cycling through these 8 clock periods. A start pulse can occur any time during this cycle but the conversion will not actually begin until the converter internally cycles to the beginning of the next 8 clock period sequence. As long as the start pin is held high no conversion begins, but when the start pin is taken low the conversion will start within 8 clock periods.

The EOC output is triggered on the rising edge of the start pulse. It, too, is controlled by the 8 clock period cycle, so it will go low within 8 clock periods of the rising edge of the start pulse. One can see that it is entirely possible for EOC to go low before the conversion starts internally, but this is not important, since the positive transition of EOC, which occurs at the end of a conversion, is what the control logic is looking for.

Once EOC does go high this signals the interface logic that the data resulting from the conversion is ready to be read. The output enable (OE) is then raised high. This enables the TRI-STATE outputs, allowing the data to be read. *Figure 2* shows the timing diagram.

2.0 ANALOG INPUTS

2.1 Ratiometric Inputs

The arrangement of the REF(+) and REF(−) inputs is intended to enable easy design of ratiometric converter systems. The REF inputs are located at either end of the 256R resistor ladder and by proper choice of the input voltages several applications can be easily implemented.

Figure 3 shows a typical input connection for ratiometric transducers. A ratiometric transducer is a conversion device whose output is proportional to some arbitrary full-scale value. In other words, the transducer's absolute output value is of no particular concern but the ratio of the output to the full-scale is of great importance. For example, the potentiometric displacement transducers of *Figure 3* have this feature. When the wiper is at midscale, the output voltage is $V_O = V_F \times$ (Wiper Displacement) $= V_F \times 0.5$. This enables the use of much less accurate and less expensive references. The important consideration for this reference is noise. The reference must be "glitch free" because a voltage spike during a conversion cycle could cause conversion inaccuracies.

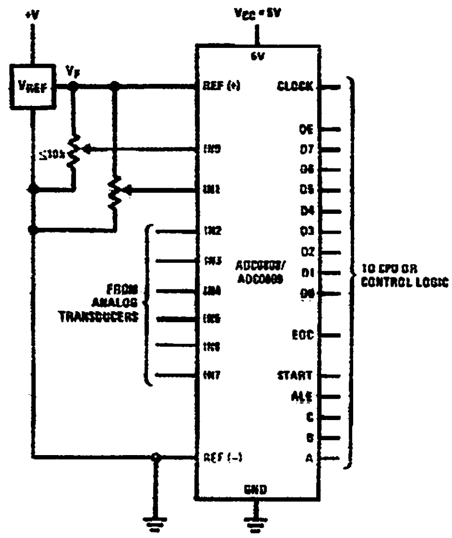

FIGURE 3. Ratiometric Converter with Separate Reference

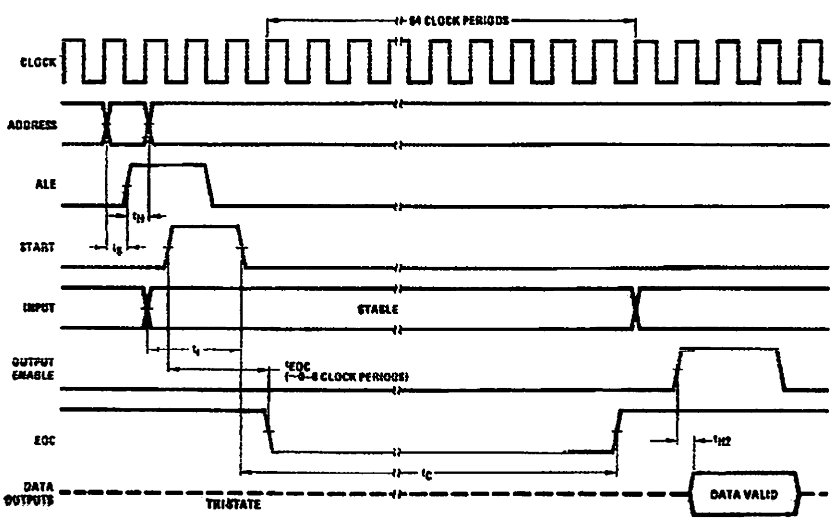

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FIGURE 2. ADC0808/ADC0809 Timing Diagram

Since highly accurate references aren't required it is possible to use the system power supply as a reference, as shown in *Figure 4*. If the power supply is to be used in this manner supply noise must be kept to a minimum to preserve conversion accuracy. If possible the supply should be well bypassed and separate reference and supply PC board traces, originating as close as possible to the power supply or regulator, should be used. This is illustrated in *Figure 4*. External accessibility of both ends of the resistor ladder enables several variations on these basic connections, and are shown in *Figures 5* and *6*. The magnitude of the reference voltage, V_{REF} = REF(+) − REF(−), can be varied from about ~0.5V to V_{CC}, but the center voltage must be maintained within ±0.1V of $V_{CC}/2$. This constraint is due to the design of the transistor switch tree, which could malfunction if the offset from center scale becomes excessive. Variation of the reference voltage can sometimes eliminate the need for external gain blocks to scale the input voltage to a full-scale range of 5V.

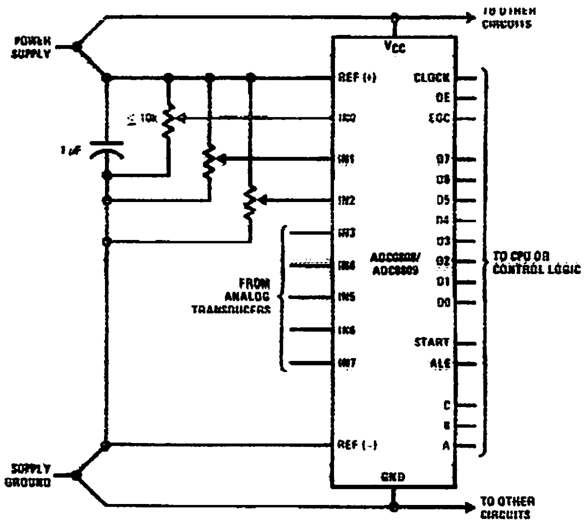

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FIGURE 4. Ratiometric Converter with Power Supply Reference

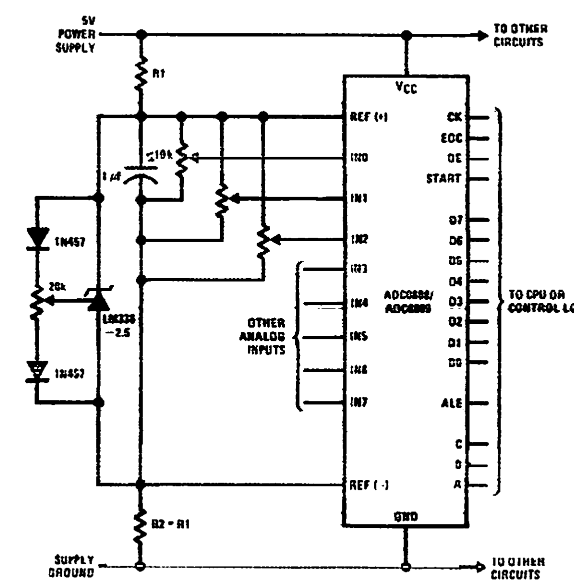

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FIGURE 5. Mid-Supply Centered Reference Using LM336 2.5V Reference

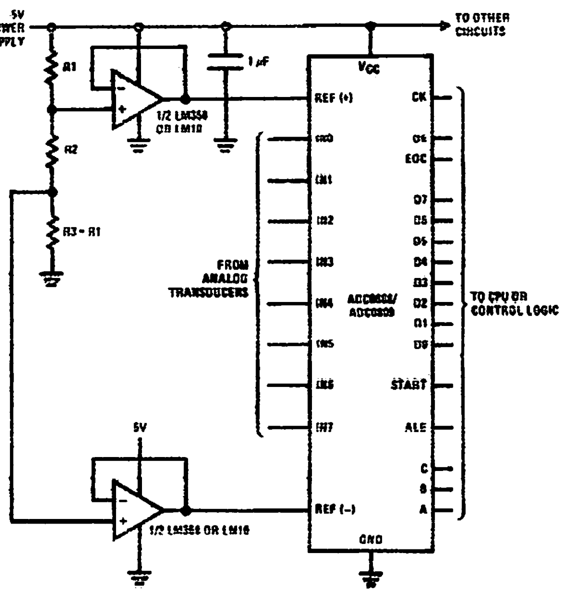

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FIGURE 6. Mid-Supply Centered Reference Using Buffered Resistors

Figure 5 shows a center referencing technique, using two equal resistors to symmetrically offset an LM336 2.5V reference, from both supplies. The offset from either supply is:

$$V_{OFF} = \frac{V_{CC} - V_{REF}}{2} = 1.25V$$

These resistors should be chosen so that they limit current through the LM336 to a reasonable value, say 5 mA. The total resistor current is:

$$I_R = I_{REF} + I_{LADDER} + I_{TRAN}$$

where I_{LADDER} is the 256R ladder current, I_{TRAN} is the current through all the transducers, and I_{REF} is the current through the reference. R1 and R2 should be well matched and track each other over temperature.

For odd values of reference voltage, the reference could be replaced by a resistor, but due to loading and temperature problems, these resistors should be buffered to the REF(+) and REF(−) inputs, *Figure 6*. The power supply must be well bypassed as supply glitches would otherwise be passed to the reference inputs. The reference voltage magnitude is:

$$V_{REF} = V_{DD}\left(\frac{R2}{2R1 + R2}\right) \text{ For } R3 = R1$$

There are several op amps that can be used for buffering this ladder. Without adding another supply, an LM358 could be used if the REF(+) input is not to be set above 3.5V. The LM10 can swing closer to the positive supply and can be used if a higher $V_{REF(+)}$ voltage is needed.

As the REF(+) to REF(−) voltage decreases the incremental voltage step size decreases. At 5V one LSB represents ~20 mV, but at 1V, one LSB represents ~4 mV.

As the reference voltage decreases, system noise will become more significant so greater precaution should be enforced at lower voltages to compensate for system noise; i.e., adequate supply and reference bypassing, and physical as well as electrical isolation of the inputs.

2.2 Absolute Analog Inputs

The ADC0808/ADC0809 may have been designed to easily utilize ratiometric transducers, but this does not preclude the use of non-ratiometric inputs. A second type of input is the absolute input. This is one which is independent of the reference. This implies that its *absolute* numerical voltage value is very critical, and to accurately measure this voltage the accuracy of the reference voltage becomes equally critical. The previous designs can be modified to accommodate absolute input signals by using a more accurate reference. In *Figure 4* the power supply reference could be replaced by LM336-5.0 reference. R1 and R2 of *Figure 6*, and R1 and R3 of *Figure 7* may have to be made more accurately equal.

In some small systems it is possible to use the precision reference as the power supply as shown in *Figure 7*. An unregulated supply voltage >5V is required, but the LM336-5.0 functions as both a regulator and reference. The dropping resistor R must be chosen so that, for the whole range of supply currents needed by the system, the LM336-5.0 will stay in regulation. As in *Figure 4* separate supply and reference traces should be used to maintain a noiseless supply.

If the system requires more power, an op amp can be used as shown in *Figure 8* to isolate the reference and boost the supply current capabilities. Here again, a single unregulated supply is required.

2.3 Differential Inputs

Differential measurements can be obtained by playing a little software trick. This simply involves sequentially converting two channels then subtracting the two results. For example, if the difference voltage between channel 1 and 2 is required, merely convert channel 1 and read the result. Then convert channel 2, input the result, and subtract it from the first result. (See *Figure 9.*) When using this procedure, both input signals must be stable throughout both conversion times or the end result will be incorrect. One way to get around this is to use two sample/holds which are sampled at the same time.

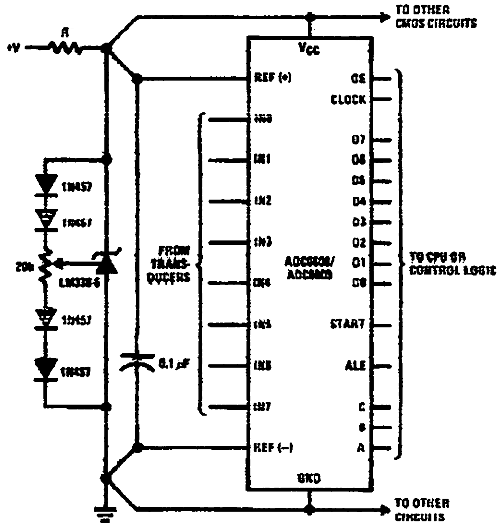

FIGURE 7. Precision Reference used as a Power Supply

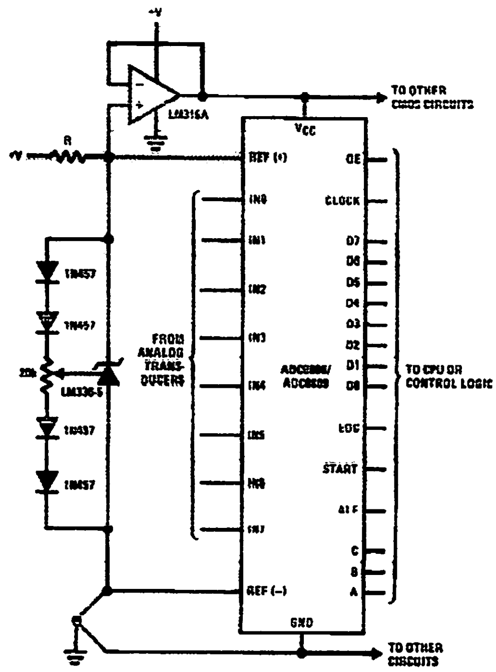

FIGURE 8. Precision Reference Buffered for Power Supply

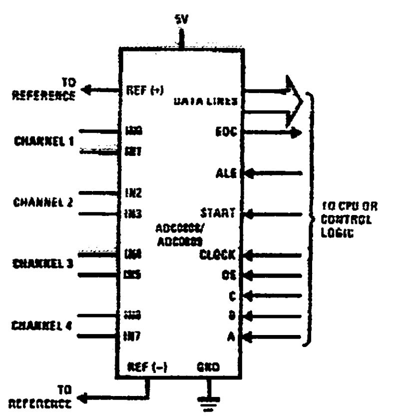

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FIGURE 9. Software Controlled Differential Converter

A second method is to use two chips to convert a differential channel, *Figure 10*. Typically each channel 1 would be connected to opposite sides of the differential input. Both converters are started simultaneously. When both converters' EOC outputs go high the output of the AND gate will go high indicating that the data is ready to be read.

The circuit in *Figure 10* can be slightly modified to provide increased data throughput by using two converters in a parallel data acquisition scheme. *Figure 11* shows this circuit in which all the input channels are connected in pairs through LF398 monolithic sample/holds. Under normal operation a sample/hold is accessed through an MM74C42 which will pulse an MM74C221, generating a sample pulse. After a sample/hold is done sampling the signal, the appropriate channel is started. If this process is alternated between two converters the sample rate can be doubled.

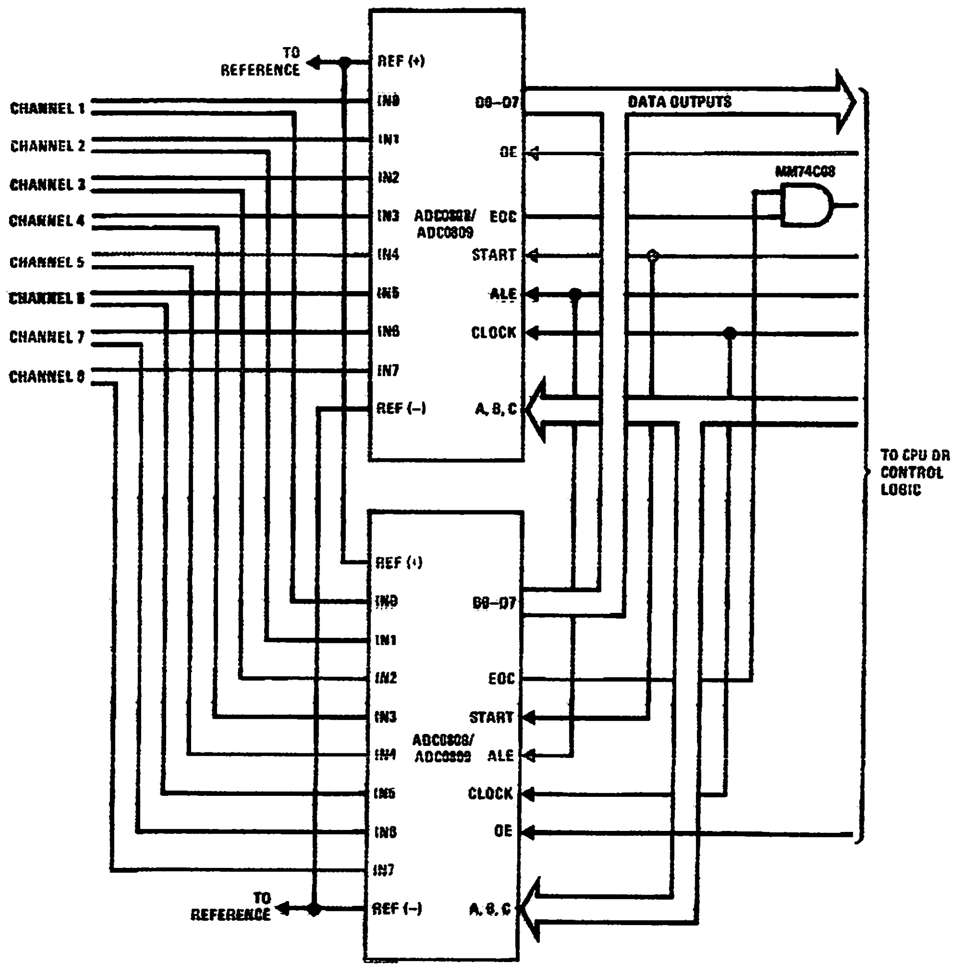

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FIGURE 10. Dual Converter Differential Circuit

2.4 Analog Input Considerations

Analog inputs into the ADC0808/ADC0809 can handle any input signal that is maintained within the supply limits, but some careful consideration must be given to the output impedance of the transducer or buffer. Using transducers with large source impedances can cause errors due to comparator input currents.

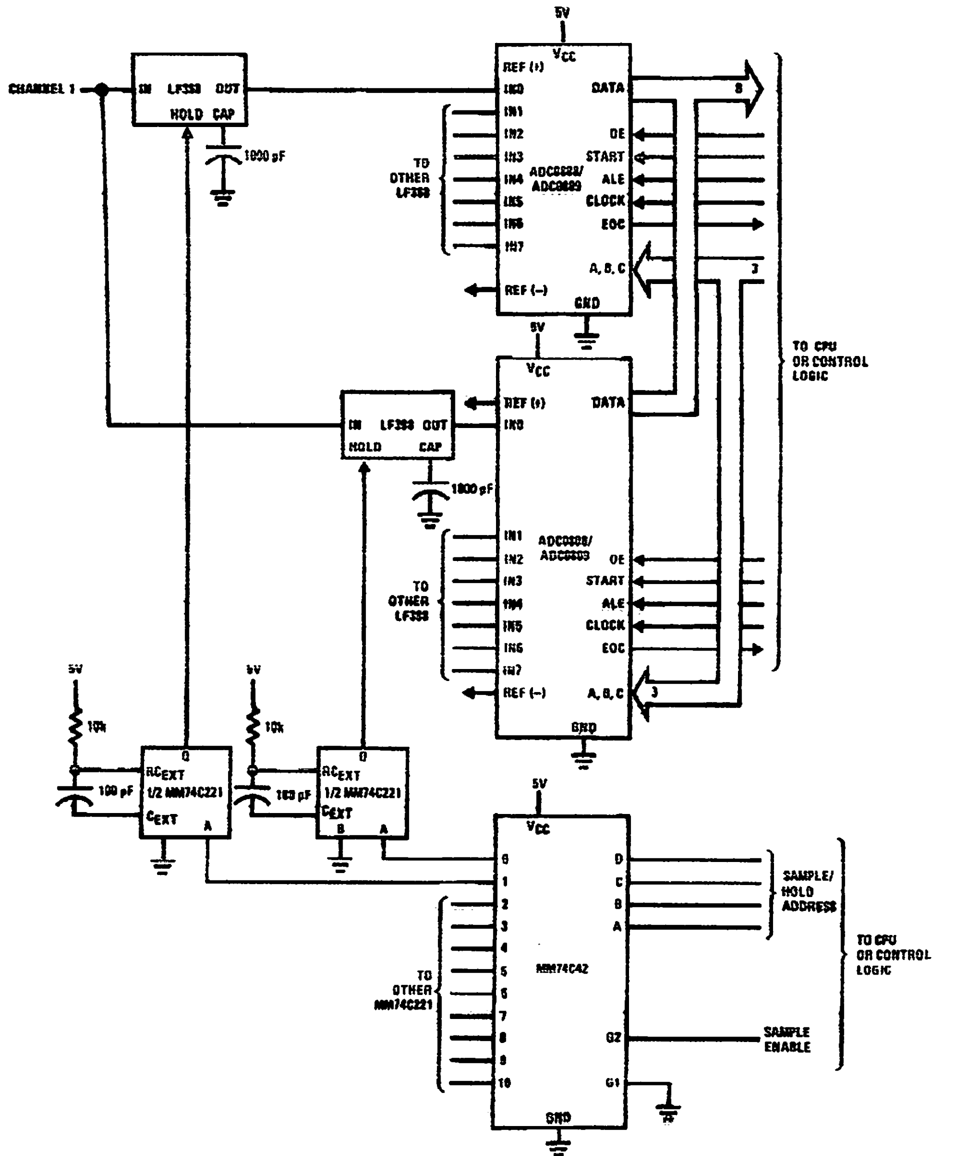

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FIGURE 11. Parallel Data Acquisition with Sample/Holds

To understand the nature of these currents a short discussion of comparator operation is required. *Figure 12* shows a simplified model of the comparator and multiplexer. This comparator alternately samples the input voltage and the ladder voltage. As it samples the input, C_C and C_P are charged up to the input voltage. It then samples the ladder and discharges the capacitor. The net charge difference is determined by a modified inverter chain and results in a 1 or 0 state at the output.

Eight samples are made per conversion, resulting in eight spikes of varying magnitude on the input.

If the source resistance is large, it adds to the RC time constant of the switched capacitor which will inhibit the input from settling properly, causing errors. As one might expect, the maximum source resistance allowable for accurate conversions is inversely proportional to clock frequency. This resistance should be ≤1 kΩ at 1.2 MHz and ≤2 kΩ at 640 kHz. If a potentiometer-type ratiometric transducer is used it should be ≤5 kΩ at 1.2 MHz and ≤10 kΩ at 640 kHz.

If large source impedances are unavoidable (≥2 kΩ at 640 kHz), the transient errors can be reduced by placing a bypass capacitor ≥0.1 μF from the analog inputs to ground. This will reduce the spikes to a small average current which will cause some error as well, but this can be much less than the error otherwise incurred. The maximum voltage error for a potentiometer input with a bypass capacitor added is:

$$V_{ERR} \approx \left[\frac{R_{POT}}{5}(I_{IN})\frac{Ck}{640\ kHz}\right] V$$

where R_{POT} = total potentiometer resistance; I_{IN} = maximum input current at 640 kHz, 2 μA; and Ck = clock frequency.

For standard buffer source impedance the maximum error is:

$$V_{ERR} = \left[I_{IN}R_S\left(\frac{Ck}{640\ kHz}\right)\right] V$$

where R_S = buffer source resistance; I_{IN} = the maximum input current at 640 kHz, 2 μA; and Ck = clock frequency.

3.0 MICROPROCESSOR INTERFACING

The ADC0808/ADC0809 converters were designed to interface to most standard microprocessors with very little external logic, but there are a few general requirements which must be considered to ensure proper converter operation. Most microprocessors are designed to be TTL compatible and, due to speed and drive requirements, incorporate many TTL circuits. The data outputs of the ADC0808/ADC0809 are capable of driving one standard TTL load which is adequate for most small systems, but for larger systems extra buffering may be necessary. The EOC output is not quite as powerful as the data outputs, but normally it is not bussed like the data outputs.

The converter inputs are standard CMOS compatible inputs. When TTL outputs are connected to any of the digital inputs a pull-up resistor should be tied from the TTL output to V_{CC}, ~ 5 kΩ. This will ensure that the TTL will pull-up above 3.5V.

Usually the converter clock will be derived from the microprocessor system clock. Some slower microprocessor clocks can be used directly, but at worst a few divider stages may be necessary to divide microprocessor clock frequencies above 1.2 MHz to a usable value.

The timing of the START and ALE pulses relative to channel selection and signal stability can be critical. The simplest approach to microprocessor interfaces usually ties START and ALE together. When these lines are strobed the address is strobed into the address register and the conversion is started. The propagation delay from ALE to comparator input of the selected input signal is about ~3.0 μs (input source resistance <<1 kΩ). If the start pulse is very short the comparator can sample the analog input before it is stable. When using a slow clock ≤500 kHz the sample period of the comparator input is long enough to allow this delay to settle out.

If the ADC0808/ADC0809 clock is >500 kHz, a delay between the START and ALE pulses is required. There are three basic methods to accomplish this. The first possibility is to design the microprocessor interface so that the START and ALE inputs are separately accessible. This is simple if some extra address decoding is available. Separate accessibility of the START and ALE pins allows the microprocessor, via software, to set the delay time between the START and ALE pulses.

If extra decoding is not available, then START and ALE could be tied together. To obtain the proper delay, the microprocessor would cause START/ALE to be strobed twice by executing the load and start instruction twice. The first time this instruction is executed, the new channel address is loaded and the conversion is started. The second execution of this instruction will reload the same channel address and restart the conversion. But since the multiplexer address register contents are unchanged the selected analog input will have already settled by the time the second instruction is issued. Actual implementations of these ideas are shown in following sections.

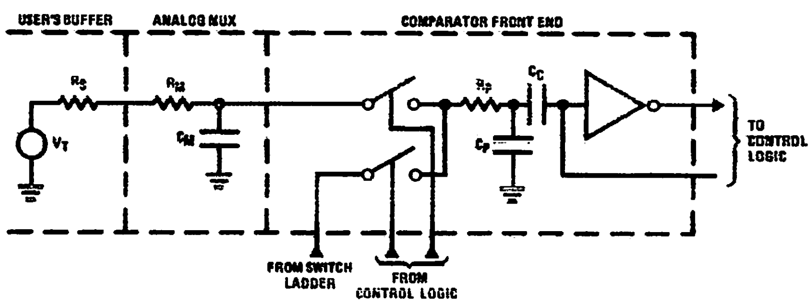

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FIGURE 12. Analog Multiplexer and Comparator Input Model

A third possibility when ALE and START are tied together is to stretch the microprocessor derived ALE/START pulse by inserting a one-shot at these inputs and creating a positive pulse >3 µs. Since ALE loads the multiplexer register on the positive going edge of the pulse and START begins the conversion on the falling edge, the width of the pulse sets the ALE to START delay time.

Most microprocessor interfaces would be designed such that a START pulse is issued by a memory or I/O write instruction, although a memory or I/O read can be used. The ALE strobe on the other hand, requires a write by the CPU when A, B, and C are connected to the data bus, and could use a read instruction if A, B, and C are connected to the address bus, but the software could get confusing. The logic to derive the OE strobe must be connected to the microprocessor so that a memory or I/O read instruction will cause OE to be pulsed. A read is required since the ADC0808/ADC0809 data must be read.

3.1 Interfacing to the 8080

The simplest interface would contain no address decoding, which may seem unreasonable; but if the system ports are I/O mapped, up to 8 of them can be connected to the CPU with no decoding. Each of the 8 I/O address lines would serve as a simple port enable line which would be gated with read and write strobes to select a particular port. This scheme is shown in *Figure 13*. A7 is the address line used and, whenever it is zero and an I/O read or write is low, the port is accessed. This implementation shows A, B, C connected to D0, D1, D2 causing the information on the data bus to select the channel, but A, B, and C could be connected to the address bus, with a loss of only 3 ports. Both decoding schemes are tabulated in *Figure 14*. (Remember A, B, C inputs are only valid when selecting a channel to convert, and are not used to read data.)

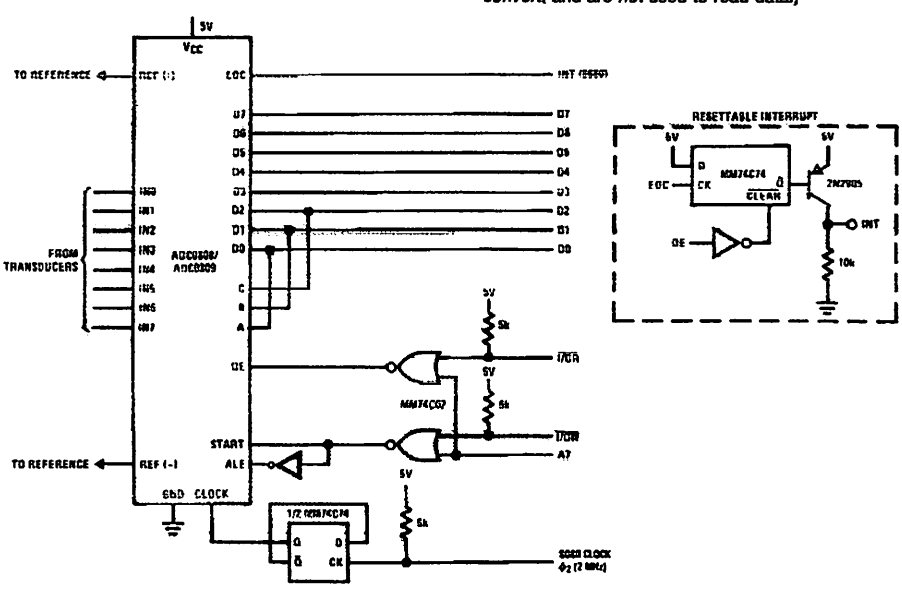


FIGURE 13. Minimum 8080/8224/8228 Interface

TL/H/5823-9

A7	A6	A5	A4	A3	A2	A1	A0	D2	D1	D0	Output Port Description
1	1	1	1	1	1	1	0	X	X	X	Spare Port
1	1	1	1	1	1	0	1	X	X	X	Spare Port
1	1	1	1	1	0	1	1	X	X	X	Spare Port
1	1	1	1	0	1	1	1	X	X	X	Spare Port
1	1	1	0	1	1	1	1	X	X	X	Spare Port
1	1	0	1	1	1	1	1	X	X	X	Spare Port
1	0	1	1	1	1	1	1	X	X	X	Spare Port
0	1	1	1	1	1	1	1	0	0	0	Channel 0 Port
0	1	1	1	1	1	1	1	0	0	1	Channel 1 Port
0	1	1	1	1	1	1	1	0	1	0	Channel 2 Port
0	1	1	1	1	1	1	1	0	1	1	Channel 3 Port
0	1	1	1	1	1	1	1	1	0	0	Channel 4 Port
0	1	1	1	1	1	1	1	1	0	1	Channel 5 Port
0	1	1	1	1	1	1	1	1	1	0	Channel 6 Port
0	1	1	1	1	1	1	1	1	1	1	Channel 7 Port

FIGURE 14a. Write Address Decoding for 8080 Output Ports (A, B, C Connected to D0, D1, D2)

A7	A6	A5	A4	A3	A2	A1	A0	Output Port Description
0	1	1	1	1	0	0	0	Channel 0 Port
0	1	1	1	1	0	0	1	Channel 1 Port
0	1	1	1	1	0	1	0	Channel 2 Port
0	1	1	1	1	0	1	1	Channel 3 Port
0	1	1	1	1	1	0	0	Channel 4 Port
0	1	1	1	1	1	0	1	Channel 5 Port
0	1	1	1	1	1	1	0	Channel 6 Port
0	1	1	1	1	1	1	1	Channel 7 Port
1	1	1	1	0	X	X	X	Spare Port
1	1	1	0	1	X	X	X	Spare Port
1	1	0	1	1	X	X	X	Spare Port
1	0	1	1	1	X	X	X	Spare Port

X − don't care

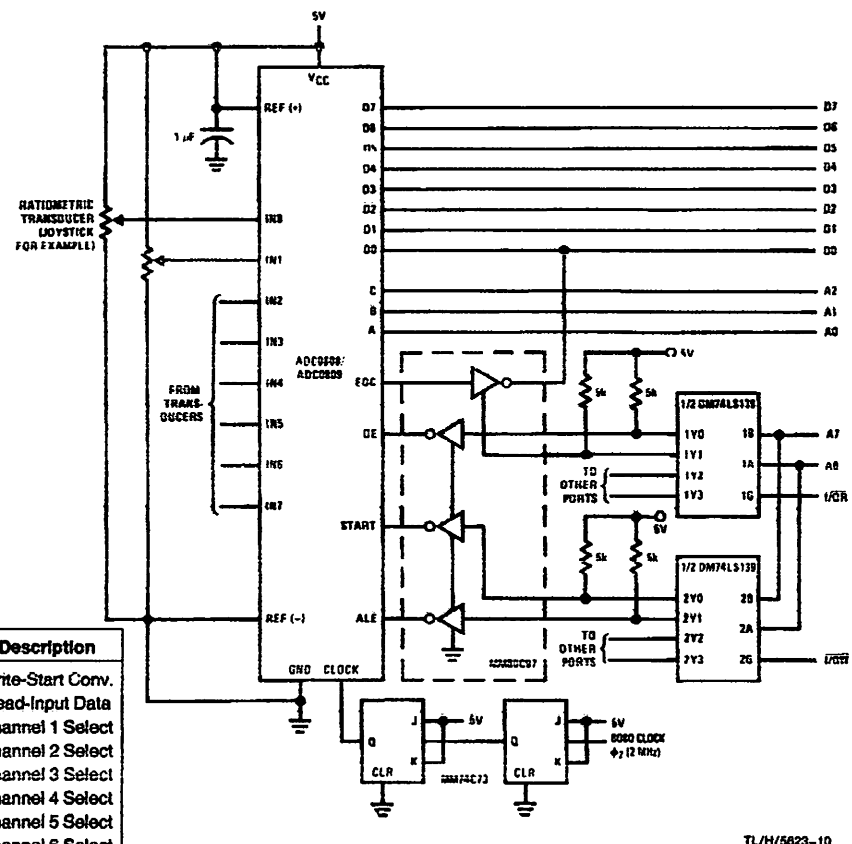
FIGURE 14b. Modified Write Address Decoding for 8080 Output Ports (A, B, C Connected to A0, A1, A2)

Two LSTTL NOR gates are used to generate the ADC0808/ ADC0809 read/write strobes. When the 8080 writes to the ADC0808/ADC0809 the ALE and START inputs are strobed, loading and starting the conversion. When the CPU reads the ADC0808/ADC0809 the OE input is taken high, and the data outputs are enabled.

Figure 13 implements a simple interrupt concept where EOC is tied directly to the 8080 interrupt input. When the INS8228 is used and the INTA pin is tied high through a 1 kΩ resistor, the interrupt will cause a restart, RST, instruction to be executed, which will then cause a jump to a restart vector and execution of the interrupt routine. If a very simple multi-interrupt system is desired, a wire OR'ed configuration employing resettable latches as shown in *Figure 13's* inset can be used. In this simple design the MM74C74 is reset when the ADC0808/ADC0809 data is read. If more complicated interrupt structures are required, then an interrupt controller is usually the best solution.

The I/O port address structure for *Figure 13's* implementation is shown in *Figure 14a*. If the A, B, C inputs are tied to A0, A1, A2 inputs the port structure is as shown in *Figure 14b*. The later method makes each channel look like a separate port address, whereas if A, B, C are tied to the data bus the ADC0808/ADC0809 looks like one start conversion port address whose channel is selected by the 3-bit status word written to it on the data bus.

Figure 15 shows a slightly more complex interface, where the address is partially decoded by a DM74LS139, dual 2-4 line decoder which creates the read and write strobes to operate the converter. This design interfaces to the processor in a polled type of interface. An MM80C97 TRI-STATE buffer is used to buffer the EOC line to the data bus, as well as provide the correct level for the START, ALE, and OE pulses. The converter clock is a divided 8080 system clock.



Address A7–A0	Description
0 0 X X X X X X	Write-Start Conv.
0 0 X X X X X X	Read-Input Data
0 1 X X X 0 0 0	Channel 1 Select
0 1 X X X 0 0 1	Channel 2 Select
0 1 X X X 0 1 0	Channel 3 Select
0 1 X X X 0 1 1	Channel 4 Select
0 1 X X X 1 0 0	Channel 5 Select
0 1 X X X 1 0 1	Channel 6 Select
0 1 X X X 1 1 0	Channel 7 Select
0 1 X X X 1 1 1	Channel 8 Select
0 1 X X X X X X	Read-Input EOC

FIGURE 15. 8080/8224/8228 Interface Using Partial Decoding

Typically, the software to use *Figure 15* would first select the desired channel by writing the channel address to the ALE port address, 01XXXCBA, where X=don't care, and CBA is the channel address. Next the conversion is started by writing to the START address, 00XXXXXX. Now the processor must wait a few instruction cycles to allow EOC to fall. Once EOC falls, its status can be checked by reading the EOC line, address 01XXXXXX. When the EOC line is detected high again (a low on DO), the data can be read by accessing the OE port, address 00XXXXXX. As in the previous example the A, B, C inputs can be tied to D0, D1, D2 rather than A0, A1, A2, so that the information on the data bus selects the channel to be converted. *Figure 15* can be connected in an interrupt mode by incorporating the interrupt flip-flop of *Figure 13*.

A few typical utility routines to operate the ADC0808/ADC0809 application in *Figure 13* are shown in *Figure 16a*. These routines assume that the resettable interrupt flip-flop is used. *Figure 16b* illustrates some typical polled I/O routines for *Figure 15*. Notice that in *Figure 16a* the OUT START1 instruction is executed twice to allow the analog input signal to settle as discussed earlier.

```
;
;
; START CONVERSION (A, B, C CONNECTED TO D0, D1, D2)
;
CHANN1          EQU     7
START1          EQU     7FH
DATA            EQU     7FH
;
START:          LDA     CHANN1      ; LOAD CHANNEL ADDRESS INTO ACE
                OUT     START1      ; STORE IT TO ADC0808/ADC0809 AND START
                OUT     START1      ; RESTART ADC0808/ADC0809 TO ACCOUNT FOR
;                                   ; MULTIPLEXER DELAY
                EI                  ; ENABLE INTERRUPTS IF NOT ALREADY
                —       —           ; PROCESS PROGRAM
;
; INTERRUPT HANDLER ROUTINE
;
INTRP:          IN      DATA        ; READ DATA AND RESET INTERRUPT
                —       —           ; PROCESS DATA
                EI                  ; ENABLE INTERRUPTS IF DESIRED
                RET                 ; RETURN TO MAIN PROGRAM
```

FIGURE 16a. Typical 8080 Resettable Interrupt I/O Routines

```
;
; START CONVERSION (A, B, C CONNECTED TO A0, A2, A3) AND POLL EOC
; (FIGURE 15)
SELECT          EQU     40H         ; SELECT CHANNEL 0
START           EQU     00H         ; START CONVERTER
EOCIN           EQU     40H         ; READ EOC
DATA            EQU     00H         ; READ DATA
START:          OUT     SELECT      ; SELECT CHANNEL
                OUT     START       ; START CONVERSION
                NOP                 ; INSERT INSTRUCTIONS TO WAIT 0-8
                NOP                 ; CLOCK PERIODS OF ADC0808/ADC0809 CLOCK
                NOP                 ; FOR EOC TO DROP (8NOPs MINIMUM)
                NOP
                NOP
;
; READ AND TEST EOC
;
STATUS:         IN      EOCIN       ; INPUT EOC BIT
                ANI     01H         ; MASK OUT OTHER BITS
                JZ      READY       ; IF INPUT BIT IS ZERO JUMP READY
                —       —           ; ELSE CONTINUE EXECUTING PROGRAM
; OR
; CONTINUOUS POLLING ROUTINE
;
STAT 2:         IN      EOCIN       ; INPUT EOC STATUS BIT
                ANI     01H         ; MASK OUT ALL BITS BUT D0
                JNZ     STAT 2      ; JUMP TO TRY AGAIN IF NOT READY
READY:          IN      DATA        ; IF READY INPUT DATA
                —       —           ; CONTINUE EXECUTING PROGRAM
```

FIGURE 16b. Typical Polled I/O Routines for ADC0808/ADC0809

The application in *Figure 17* uses a 6-bit bus comparator and a few gates to decode a read and write strobe. Viewed from the CPU this interface looks like a bidirectional data port whose address is set by the logic levels on the T_n inputs of the DM8131 comparator. When data is written to the ADC0808/ADC0809 the 3 least significant bits on the address bus define the channel to be converted. The rest of the bits are decoded to provide the START and ALE strobes. When the conversion is completed EOC sets the interrupt flip-flop, and when the data is read the interrupt is reset.

Both the decoder and the bus comparator methods of address decoding have their own advantages. Bus comparators will more completely decode addresses but are capable of only a limited number of port strobes. Decoders, on the other hand, provide less decoding but more port strobes. There is a trade off for minimum parts systems as far as which route to go, and it will depend on the CPU and type of system.

3.2 Interfacing to the 6800

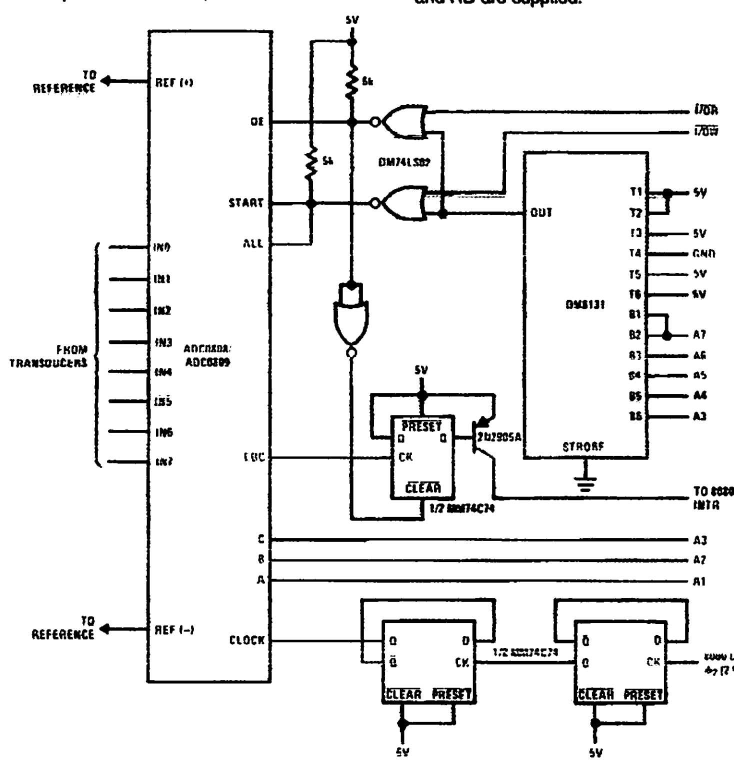
The ADC0808/ADC0809 easily interface to more than one microprocessor. The 6800 can also be used to control the converter. The 6800 has no separate I/O address space so all I/O transfers must be memory mapped. In general more address decoding logic is required to ensure that the I/O ports don't overlap existing memory. For small systems a partial address decoding scheme is shown in *Figure 18*. Generally, if several ports are desired, a small block of memory would be set aside, as is accomplished by the DM8131. *Figure 18* also illustrates a typical 6800 interrupt scheme using a flip-flop and open collector transistor. The interrupt is reset when the data is read. If more ports are needed, a decoder could be added as shown in *Figure 19*. *Figure 19* also illustrates a polled I/O mode using TRI-STATE buffer to gate EOC onto the data bus. As with the INS8080 the A, B, C inputs of the ADC0808/ADC0809 can be connected to the address bus or the data bus.

The 6800 differs from the INS8080 in that the 6800 has a single read/write ($R/\overline{W}$) strobe and a valid memory address (VMA), whereas the INS8080 has separate read and write strobes ($\overline{I/OR}$ and $\overline{I/OW}$). Normally, to obtain a read pulse, VMA, $R/\overline{W}$ and ϕ_2 are gated together and, for a write $R/\overline{W}$ is inverted. ϕ_2 is the 6800 phase 2 system clock. Also notice that the 6800 $\overline{INT}$ interrupt input is active low. This enables a standard wired-OR open collector design to be implemented.

Figure 20 illustrates some typical 6800 software utility routines for either polled or interrupt interfaces. Again notice double start instructions.

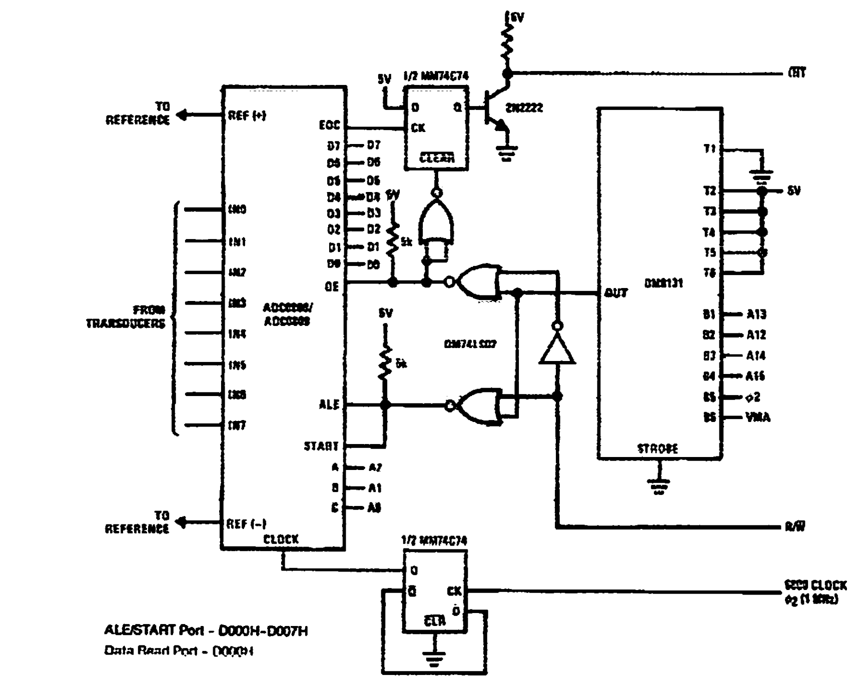
3.3 Z80 Interface

Interfacing the Z80 to the ADC0808 is much the same as interfacing to an 8080/8224/8228 CPU group. CPU instruction timing is very similar, except the read/write control signals are slightly different. Instead of the $\overline{I/OW}$ write strobe there is the $\overline{IOREQ}$ and $\overline{WR}$ and instead of $\overline{I/OR}$, $\overline{IOREQ}$ and $\overline{RD}$ are supplied.



TL/H/5623–11

FIGURE 17. Interrupt-Type 8080/8224/8228 Interface Using 6-Bit Bus Comparator



ALE/START Port - D000H-D007H
Data Read Port - D00XH

FIGURE 18. Typical 6800 Interface with Partial Address Decoding

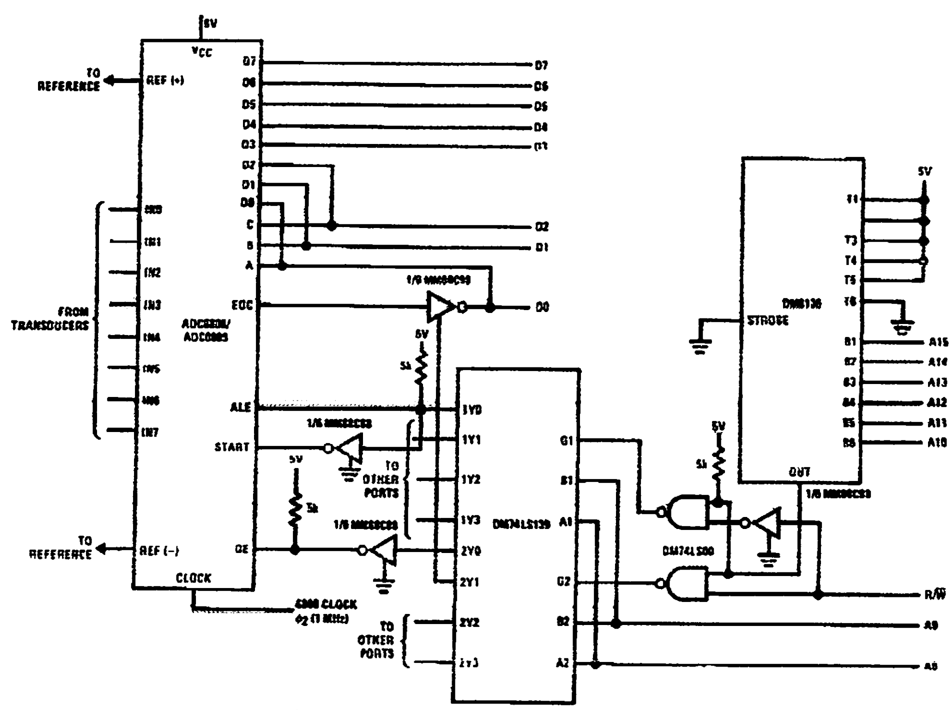


FIGURE 19. Full Decoded 6800 Interface Address

TL/H/5623-12

```
*
*UTILITY ROUTINES FOR ADC0808/ADC0809 INTERFACE
*
*
*LOAD AND START CONVERSION (FIGURE 18)
*
    STATUS      EQU     $D800       START ADDRESS FOR CHANNEL 0
    DATA        EQU     $D800       CONVERTER DATA ADDRESS
*
*
*
    START       STA     STATUS      SELECT CHANNEL 0 AND START
                STA     STATUS      DO AGAIN TO LET INPUTS SETTLE
                LDX     #VECTOR     LOAD INTERRUPT VECTOR ADDRESS
                STX     $FFF8       STORE IT
                ——                  EXECUTE MISC PROGRAM
                ——
                ——
                CLI                 ENABLE INTERRUPT IF NOT ALREADY
                ——                  EXECUTE MISC PROGRAM
                WAI                 WAIT FOR INTERRUPT
*
*INTERRUPT HANDLER (FIGURE 18)
*
    VECTOR      LDAA    DATA        LOAD DATA RESET INTERRUPT
                CLI                 ENABLE INTERRUPTS (OPTION)
                ——                  EXECUTE PROGRAM
                RTI                 RETURN TO MAIN PROGRAM
*
*START AND TEST CONVERSION POLLED MODE (FIGURE 19)
*
    DATA2       EQU     $F800       CONVERTER DATA ADDRESS
    CHANN2      EQU     02          CHANNEL 2 ADDRESS
    EOCIN       EQU     $F900       EOC INPUT PORT
    START2      LDAA    CHANN2      LOAD A ACCUMULATOR
                STAA    STATUS      LOAD ADDRESS AND START
                NOP                 WAIT
                STAA    STATUS      RESTART TO LET MUX SETTLE
                NOP                 8 NOPS TO WAIT FOR EOC
                ——                  TO GO LOW
                LDAA    EOCIN       LOAD EOC STATUS BIT
                ANDA    01          MASK BITS 1-7
                BEQ     READY       IF A = 0 THEN CONVERTER DONE
*
*
                ——                  EXECUTE MISC PROGRAM
*
*CONTINUOUS POLLING OF EOC (FIGURE 19)
*
*
    POLLIT      LDAA    EOCIN       LOAD EOC STATUS
                ANDA    CHANN2      MASK MSBs
                BNE     POLL IT     IT ACC≠0 NOT READY, LOOP
    READY LDAA          DATA        ELSE READ DATA
                ——                  CONTINUE PROGRAM
                ——
```

FIGURE 20. Typical I/O Routines for ADC0808/ADC0809 and 6800 Interface

Figure 21 shows a very simple Z80 interface, which is similar to the INS8080 interface of *Figure 13*, except that the interrupt flip-flop design is closer to the 6800 designs. This is because the Z80 $\overline{\text{INT}}$ is active low as is the 6800, but the INS8080 INT is active high.

Figure 22 shows a fully decoded bus comparator design where the DM8131 decodes 5 address bits and the $\overline{\text{IOREQ}}$ I/O request strobe. Two NOR gates gate the $\overline{\text{RD}}$ and $\overline{\text{WR}}$ strobes for ALE, START and OE inputs.

4.0 CONCLUSION

Both the ADC0808 and the ADC0809 can be easily used in microprocessor controlled environments. Many sophisticated medium throughput applications can be handled with a minimum of extra hardware, but additional hardware can increase flexibility and simplify software. Putting both the multiplexer and A/D on the same chip frees the designer from matching multiplexers and A/Ds to implement a 7 or 8-bit accurate system. Design time and overall system cost can be reduced by using these low cost converters.

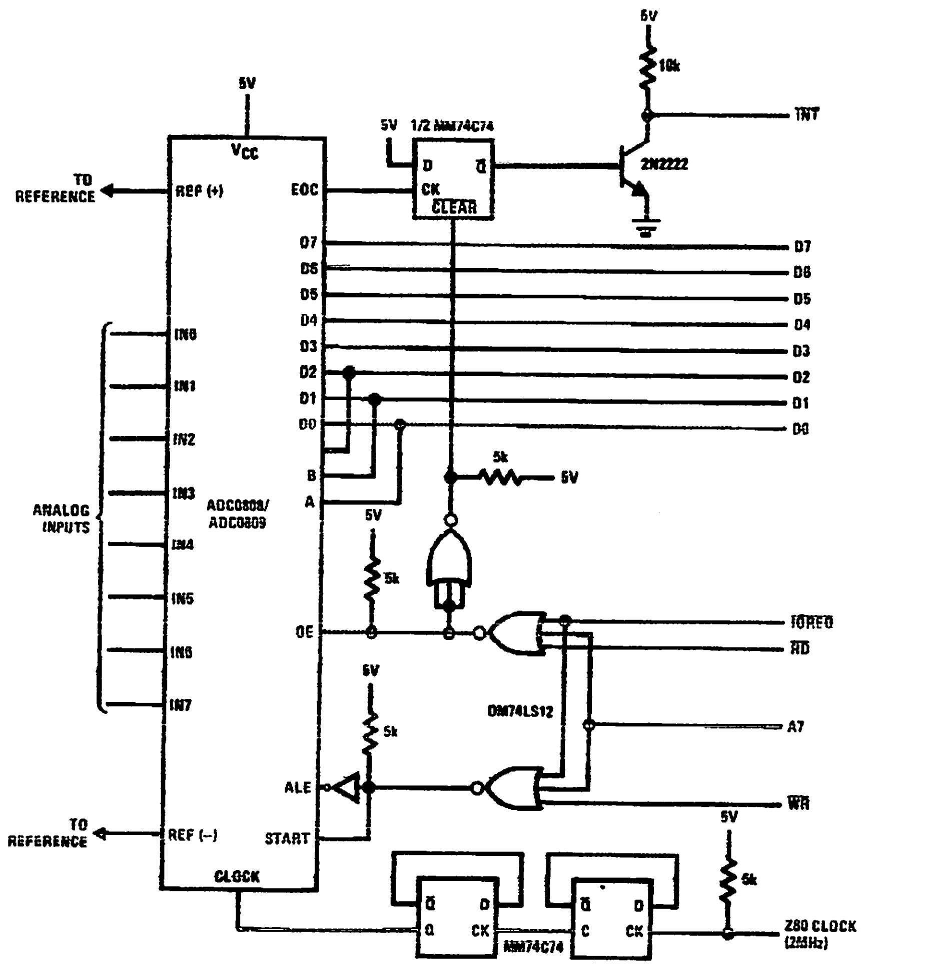


FIGURE 21. Simple Z80 Interface

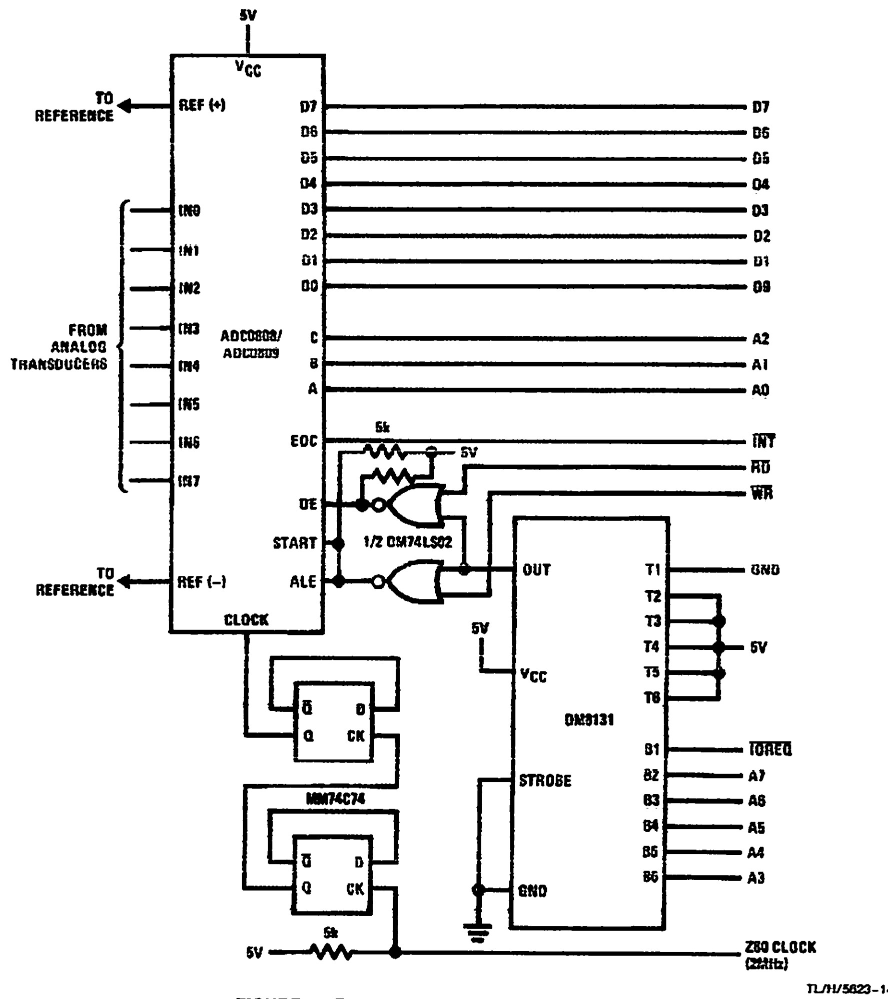


FIGURE 22. Z80 Partial Decoding Interface

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November 2000

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 ±¼˚C at room temperature and ±¾˚C over a full −55 to +150˚C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 µA from its supply, it has very low self-heating, less than 0.1˚C in still air. The LM35 is rated to operate over a −55˚ to +150˚C temperature range, while the LM35C is rated for a −40˚ to +110˚C range (−10˚ with improved accuracy). The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-220 package.

Features

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

Typical Applications

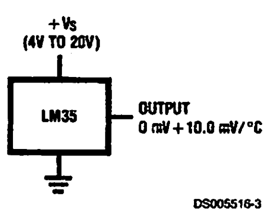
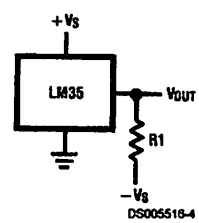


FIGURE 1. Basic Centigrade Temperature Sensor (+2˚C to +150˚C)



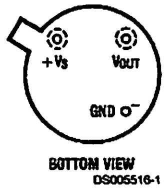
Choose $R_1 = -V_S/50\ \mu A$
V_{OUT} = +1,500 mV at +150˚C
= +250 mV at +25˚C
= −550 mV at −55˚C

FIGURE 2. Full-Range Centigrade Temperature Sensor

 DS005516

Connection Diagrams

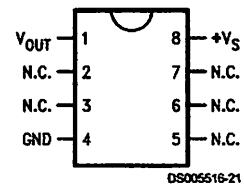
TO-46
Metal Can Package*



*Case is connected to negative pin (GND)

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

SO-8
Small Outline Molded Package



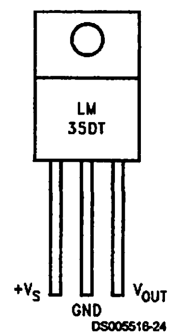
N.C. = No Connection

Top View
Order Number LM35DM
See NS Package Number M08A

TO-92
Plastic Package

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

TO-220
Plastic Package*



*Tab is connected to the negative pin (GND).

Note: The LM35DT pinout is different than the discontinued LM35DP.

Order Number LM35DT
See NS Package Number TA03F

Absolute Maximum Ratings (Note 10)

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

Supply Voltage	+35V to −0.2V
Output Voltage	+6V to −1.0V
Output Current	10 mA
Storage Temp.;	
TO-46 Package,	−60°C to +180°C
TO-92 Package,	−60°C to +150°C
SO-8 Package,	−65°C to +150°C
TO-220 Package,	−65°C to +150°C
Lead Temp.:	
TO-46 Package, (Soldering, 10 seconds)	300°C
TO-92 and TO-220 Package, (Soldering, 10 seconds)	260°C
SO Package (Note 12)	
Vapor Phase (60 seconds)	215°C
Infrared (15 seconds)	220°C
ESD Susceptibility (Note 11)	2500V
Specified Operating Temperature Range: T_{MIN} to T_{MAX} (Note 2)	
LM35, LM35A	−55°C to +150°C
LM35C, LM35CA	−40°C to +110°C
LM35D	0°C to +100°C

Electrical Characteristics

(Notes 1, 6)

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

Electrical Characteristics

(Notes 1, 6)

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

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

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

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

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

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

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

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

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

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

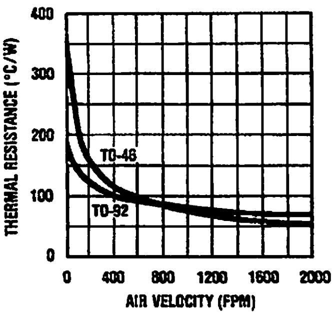
Note 10: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions. See Note 1.

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

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

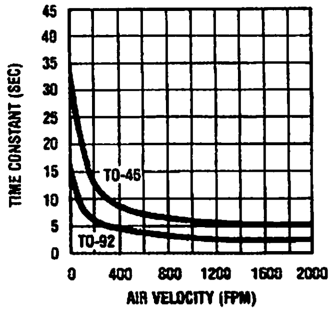
Typical Performance Characteristics

Thermal Resistance Junction to Air



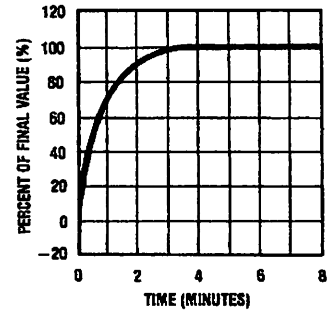
DS005516-25

Thermal Time Constant



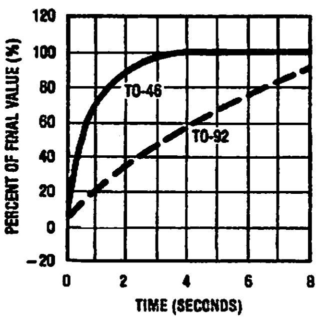
DS005516-26

Thermal Response in Still Air



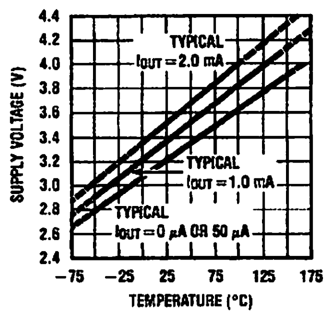
DS005516-27

Thermal Response in Stirred Oil Bath



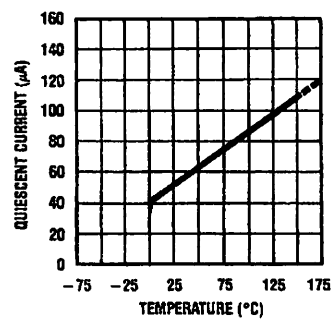
DS005516-28

Minimum Supply Voltage vs. Temperature



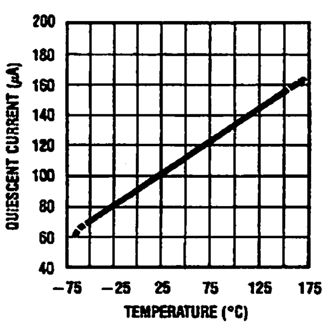
DS005516-29

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



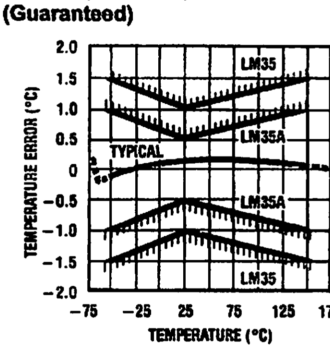
DS005516-30

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



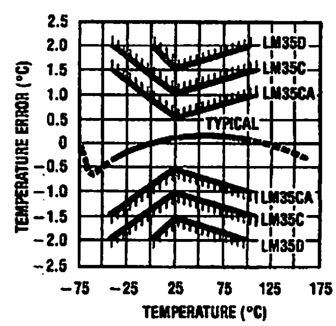
DS005516-31

Accuracy vs. Temperature (Guaranteed)



DS005516-32

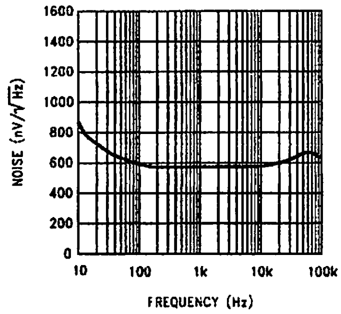
Accuracy vs. Temperature (Guaranteed)



DS005516-33

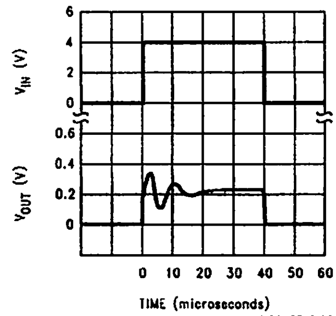
Typical Performance Characteristics (Continued)

Noise Voltage



DS005516-34

Start-Up Response



DS005516-35

Applications

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

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

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

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

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

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

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

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

Typical Applications

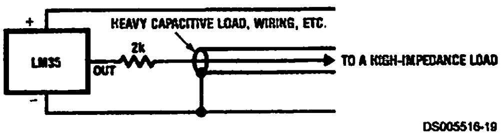


FIGURE 3. LM35 with Decoupling from Capacitive Load

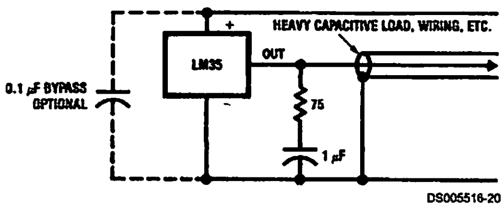


FIGURE 4. LM35 with R-C Damper

CAPACITIVE LOADS

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

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

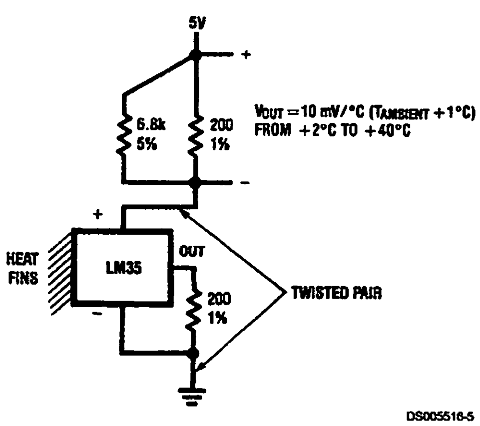


FIGURE 5. Two-Wire Remote Temperature Sensor (Grounded Sensor)

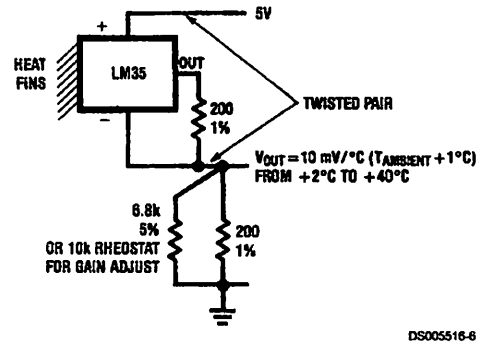


FIGURE 6. Two-Wire Remote Temperature Sensor (Output Referred to Ground)

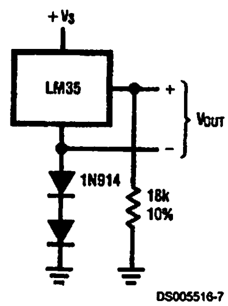


FIGURE 7. Temperature Sensor, Single Supply, −55˚ to +150˚C

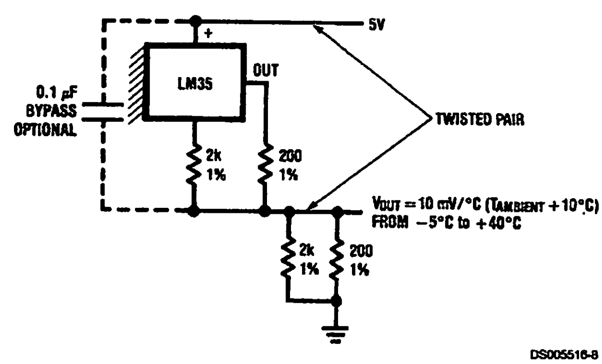


FIGURE 8. Two-Wire Remote Temperature Sensor (Output Referred to Ground)

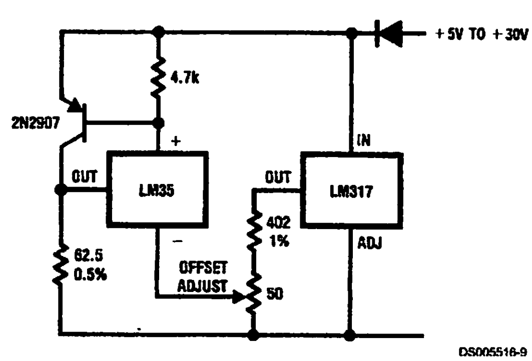


FIGURE 9. 4-To-20 mA Current Source (0˚C to +100˚C)

Typical Applications (Continued)

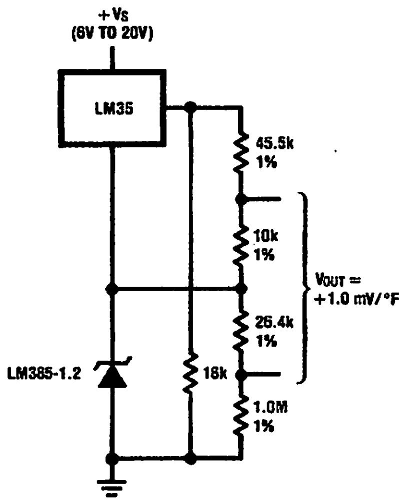


FIGURE 10. Fahrenheit Thermometer

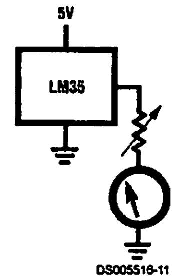


FIGURE 11. Centigrade Thermometer (Analog Meter)

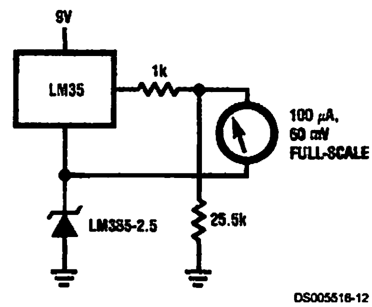


FIGURE 12. Fahrenheit ThermometerExpanded Scale Thermometer
(50° to 80° Fahrenheit, for Example Shown)

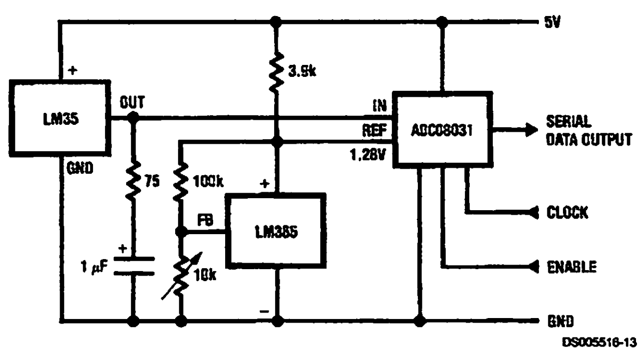


FIGURE 13. Temperature To Digital Converter (Serial Output) (+128°C Full Scale)

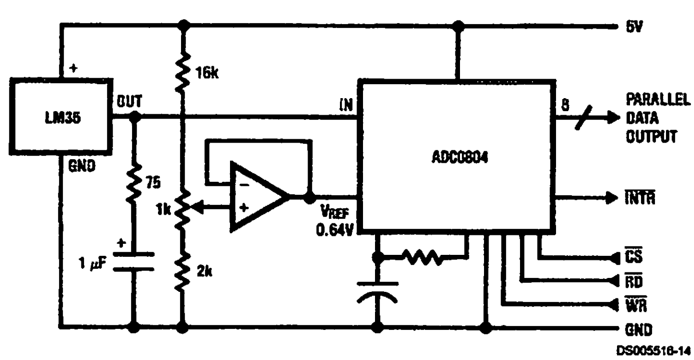
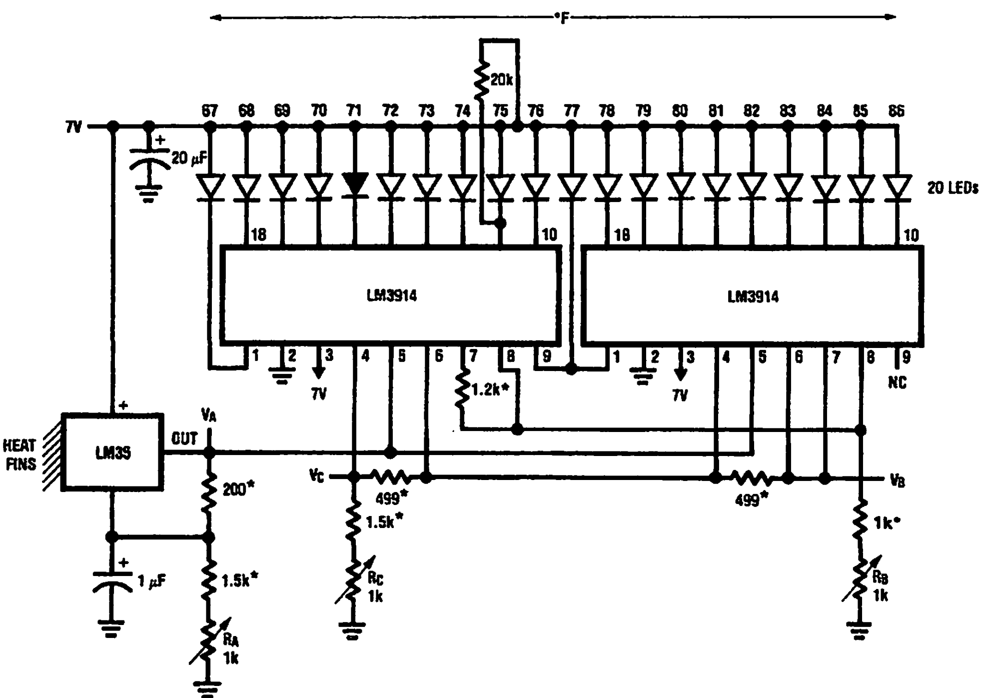


FIGURE 14. Temperature To Digital Converter (Parallel TRI-STATE™ Outputs for Standard Data Bus to µP Interface) (128°C Full Scale)

Typical Applications (Continued)



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

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

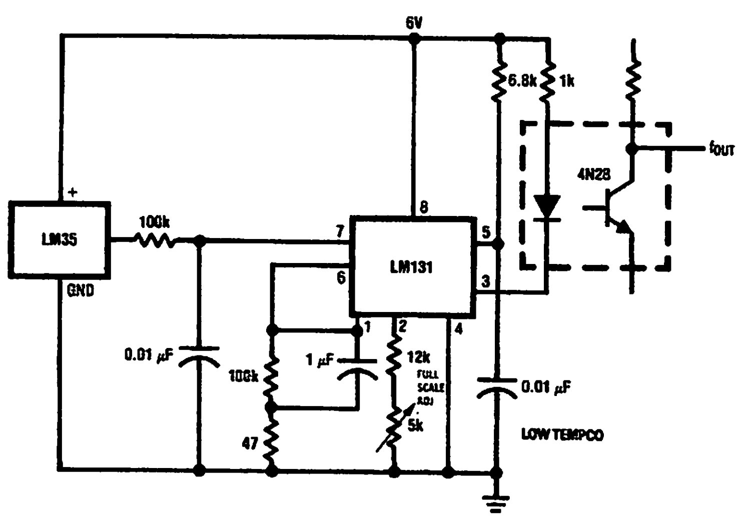
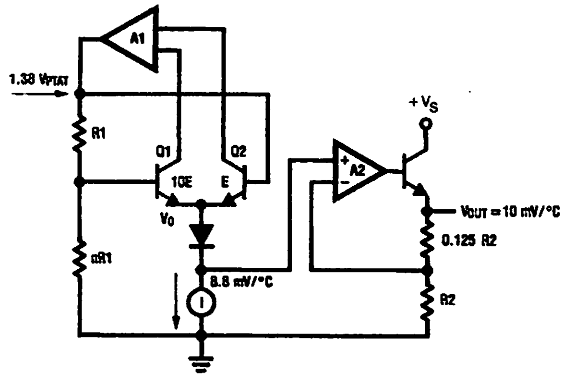


FIGURE 16. LM35 With Voltage-To-Frequency Converter And Isolated Output (2°C to +150°C; 20 Hz to 1500 Hz)

Block Diagram



DS005516-23

RHKIAN

General Specifications

1. Part name	: Humidity Sensor
2. Type	: RHKIAN
3. Storage temperature range	: -40 ~ 85℃
4. Storage humidity range	Less than 95%RH
5. Operating temperature range	: 0 ~ 60℃
6. Operating humidity range	: 20 ~ 90%RH
7. Rated voltage	: AC 1V (50Hz ~ 1Hz)
8. Rated power	: 0.3 mW
9. Standard characteristic	: 60 kΩ (at 25℃, 60%RH)
10. Accuracy	: < ± 3%RH
11. Hysteresis	: Within 3%RH
12. Typical humidity response characteristic	: Show in Fig. 1
13. Typical humidity response characteristic	: Show in Fig. 2
14. Dimension	: Show in Fig. 3

RHK1AN

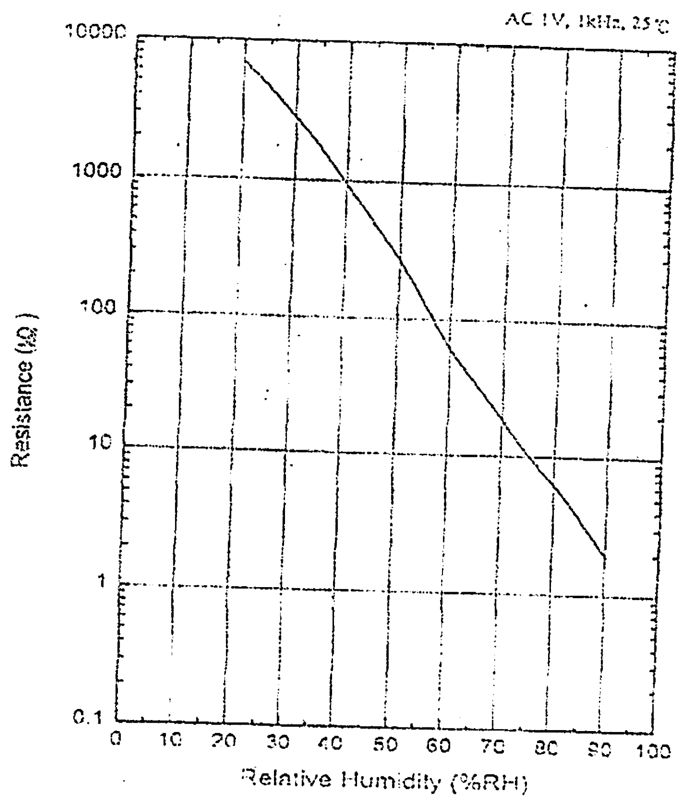


Fig. 1 Typical Characteristics

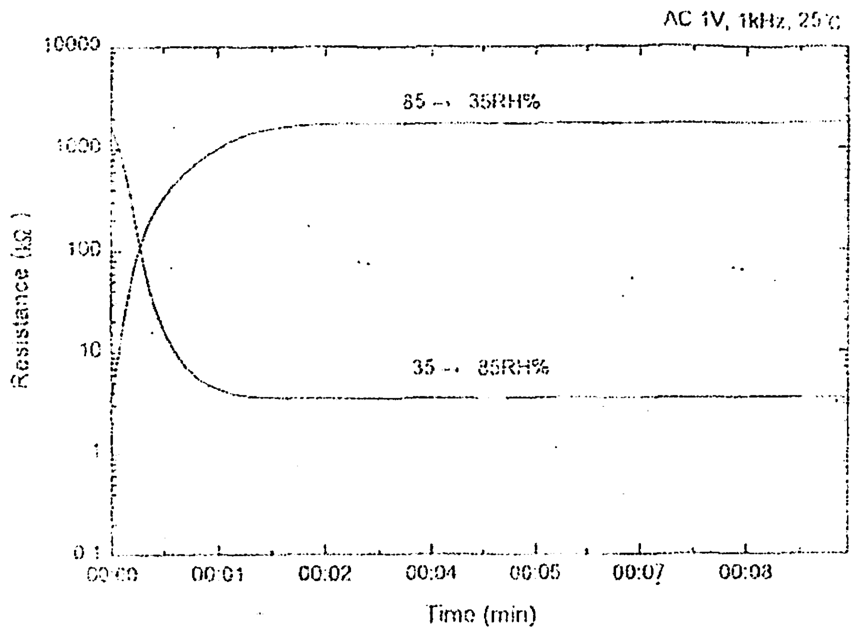


Fig. 2 Typical humidity response characteristic

hs4 (1700x2340x256 jpeg)

RHK1AN

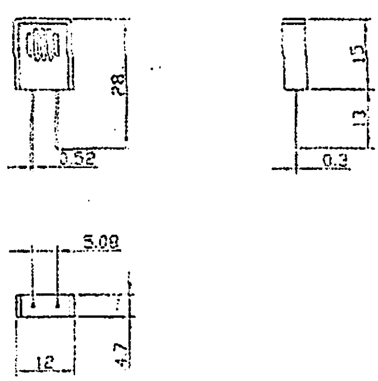


Fig.3 Dimension of Humidity Sensor

RHKIAN

Mechanical characteristics

1. Soldering heat resistance

The Humidity Sensor should be kept the original appearance and electrical characteristics after soldering the lead for 3 seconds at 270 +/-5℃ temperature condition.

2. Termination strength

Lead terminal should be safe after pulling with it by 500g force for 10 seconds.

3. Shock resistance

The Humidity Sensor should be kept the original appearance and electrical characteristics after falling down 5 times on the hard place from 70cm height.

4. Vibration resistance

The Humidity Sensor should be kept the original appearance and eletrical characteristics after testing the vibration for 2 hours in each direction(X,Y,Z) 10-55Hz frequency in the box(10x 60x 10).

Reliability

1. Humidity resistance

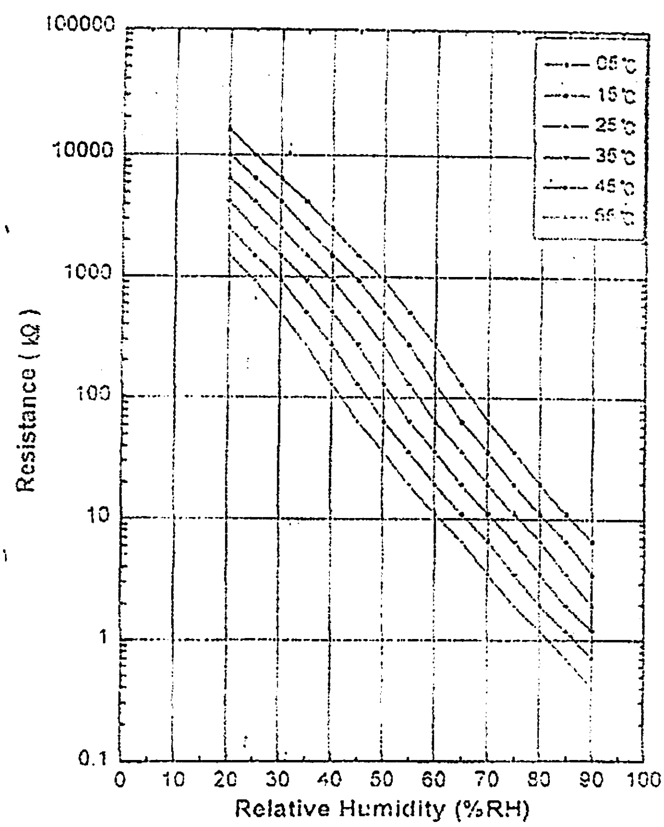
Put it for 1000 hours at 40℃ and 90%RH, put it more for 1hour in usual humidity and temperature conditions. After that, the value is changed within +/-3%RH from the initial value.

2. Humidity cycle

One cycle should be to put for 30 minutes at 25℃ and 30%RH continue to put it for 30 minutes while raising to 90%RH, put it for 30 minutes at 90%RH and put it more for 30 minutes while lowering to 30%RH. Repeat 500 these cycles, then put it for 1 hour in the usual humidity and temperature conditions. After that, the value is changed within +/-5%RH from the initial value.

RHK1AN

Temperature Characteristic



RHK1AN

RHK1AN (25℃) %RH / kΩ

20%RH	6500
21%RH	6000
22%RH	5500
23%RH	5000
24%RH	4600
25%RH	4200
26%RH	3800
27%RH	3500
28%RH	3100
29%RH	2800
30%RH	2500
31%RH	2200
32%RH	2000
33%RH	1800
34%RH	1650
35%RH	1500
36%RH	1350
37%RH	1270
38%RH	1140
39%RH	1050
40%RH	930
41%RH	820
42%RH	740
43%RH	650
44%RH	580
45%RH	510
46%RH	450
47%RH	400
48%RH	350
49%RH	310
50%RH	275
51%RH	230
52%RH	200
53%RH	175
54%RH	150
55%RH	130
56%RH	115
57%RH	130
58%RH	85
59%RH	74
60%RH	65
61%RH	57
62%RH	51
63%RH	45
64%RH	40
65%RH	36
66%RH	32
67%RH	28
68%RH	25
69%RH	22
70%RH	19.5
71%RH	17.7
72%RH	15.8
73%RH	14
74%RH	12.4
75%RH	11
76%RH	10
77%RH	9
78%RH	8.1
79%RH	7.2
80%RH	6.5
81%RH	5.8
82%RH	5.1
83%RH	4.5
84%RH	3.9
85%RH	3.5
86%RH	3.05
87%RH	2.7
88%RH	2.4
89%RH	2.15
90%RH	1.95

RHK1AN

Temperature characteristics at each temperature

Unit : Ω

%RH	Resistance at 5℃	Resistance at 15℃	Resistance at 25℃	Resistance at 35℃	Resistance at 45℃	Resistance at 55℃
20	16,000	10,000	6,500	4,200	2,500	1,500
25	10,000	6,500	4,200	2,500	1,500	930
30	6,500	4,200	2,500	1,500	930	510
35	4,200	2,500	1,500	930	510	275
40	2,500	1,500	930	510	275	130
45	1,500	930	510	275	130	65
50	930	510	275	130	65	36
55	510	275	130	65	36	19.5
60	275	130	65	36	19.5	11
65	130	65	36	19.5	11	6.5
70	65	36	19.5	11	6.5	3.5
75	36	19.5	11	6.5	3.5	1.95
80	19.5	11	6.5	3.5	1.95	1.2
85	11	6.5	3.5	1.95	1.2	0.7
90	6.5	3.5	1.95	1.2	0.7	0.4

National Semiconductor

March 1998

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 ±15V power supplies.

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

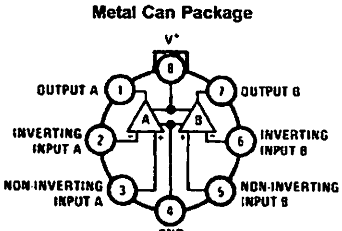
- Two internally compensated op amps in a single package
- Eliminates need for dual supplies
- Allows directly sensing near GND and V_{OUT} also goes to GND
- Compatible with all forms of logic
- Power drain suitable for battery operation
- Pin-out same as LM1558/LM1458 dual operational amplifier

Features

- 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: ±1.5V to ±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 (Top Views)

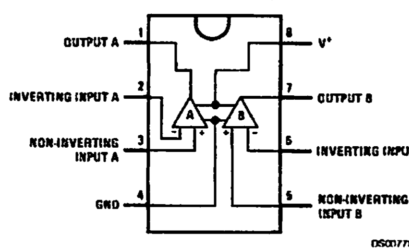
Metal Can Package



DS007787-1

Order Number LM158AH, LM158AH/883 (Note 1), LM158H, LM158H/883 (Note 1), LM258H or LM358H
See NS Package Number H08C

DIP/SO Package



DS007787-2

Order Number LM158J, LM158J/883 (Note 1), LM158AJ or LM158AJ/883 (Note 1)
See NS Package Number J08A
Order Number LM358M, LM358AM or LM2904M
See NS Package Number M08A
Order Number LM358AN, LM358N or LM2904N
See NS Package Number N08E

Note 1: LM158 is available per SMD #5962-8771001
LM158A is available per SMD #5962-8771002

Absolute Maximum Ratings (Note 10)

If 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 2)		
Molded DIP	830 mW	830 mW
Metal Can	550 mW	
Small Outline Package (M)	530 mW	530 mW
Output Short-Circuit to GND		
(One Amplifier) (Note 3)		
$V^+ \leq 15V$ and $T_A = 25°C$	Continuous	Continuous
Input Current ($V_{IN} < -0.3V$) (Note 4)	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.

ESD Tolerance (Note 11)	250V	250V

Electrical Characteristics

$V^+ = +5.0V$, unless otherwise stated

Parameter	Conditions	LM158A			LM358A			LM158/LM258			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	(Note 6), $T_A = 25°C$		1	2		2	3		2	5	mV
Input Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$, $T_A = 25°C$, $V_{CM} = 0V$, (Note 7)		20	50		45	100		45	150	nA
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$, $V_{CM} = 0V$, $T_A = 25°C$		2	10		5	30		3	30	nA
Input Common-Mode Voltage Range	$V^+ = 30V$, (Note 8) (LM2904, $V^+ = 26V$), $T_A = 25°C$	0		$V^+-1.5$	0		$V^+-1.5$	0		$V^+-1.5$	V
Supply Current	Over Full Temperature Range $R_L = \infty$ on All Op Amps										
	$V^+ = 30V$ (LM2904 $V^+ = 26V$)		1	2		1	2		1	2	mA
	$V^+ = 5V$		0.5	1.2		0.5	1.2		0.5	1.2	mA

Electrical Characteristics

$V^+ = +5.0V$, unless otherwise stated

Parameter	Conditions	LM358			LM2904			Units
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	(Note 6) , $T_A = 25°C$		2	7		2	7	mV
Input Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$, $T_A = 25°C$, $V_{CM} = 0V$, (Note 7)		45	250		45	250	nA
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$, $V_{CM} = 0V$, $T_A = 25°C$		5	50		5	50	nA
Input Common-Mode Voltage Range	$V^+ = 30V$, (Note 8) (LM2904, $V^+ = 26V$), $T_A = 25°C$	0		$V^+-1.5$	0		$V^+-1.5$	V
Supply Current	Over Full Temperature Range $R_L = \infty$ on All Op Amps							
	$V^+ = 30V$ (LM2904 $V^+ = 26V$)		1	2		1	2	mA
	$V^+ = 5V$		0.5	1.2		0.5	1.2	mA

Electrical Characteristics

$V^+ = +5.0V$, (Note 5), unless otherwise stated

Parameter		Conditions	LM158A			LM358A			LM158/LM258			Units
			Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Large Signal Voltage Gain		$V^+ = 15V$, $T_A = 25°C$, $R_L \geq 2\ k\Omega$, (For $V_O = 1V$ to 11V)	50	100		25	100		50	100		V/mV
Common-Mode Rejection Ratio		$T_A = 25°C$, $V_{CM} = 0V$ to $V^+-1.5V$	70	85		65	85		70	85		dB
Power Supply Rejection Ratio		$V^+ = 5V$ to 30V (LM2904, $V^+ = 5V$ to 26V), $T_A = 25°C$	65	100		65	100		65	100		dB
Amplifier-to-Amplifier Coupling		f = 1 kHz to 20 kHz, $T_A = 25°C$ (Input Referred), (Note 9)		−120			−120			−120		dB
Output Current	Source	$V_{IN}^+ = 1V$, $V_{IN}^- = 0V$, $V^+ = 15V$, $V_O = 2V$, $T_A = 25°C$	20	40		20	40		20	40		mA
	Sink	$V_{IN}^- = 1V$, $V_{IN}^+ = 0V$ $V^+ = 15V$, $T_A = 25°C$, $V_O = 2V$	10	20		10	20		10	20		mA
		$V_{IN}^- = 1V$, $V_{IN}^+ = 0V$ $T_A = 25°C$, $V_O = 200\ mV$, $V^+ = 15V$	12	50		12	50		12	50		μA
Short Circuit to Ground		$T_A = 25°C$, (Note 3), $V^+ = 15V$		40	60		40	60		40	60	mA
Input Offset Voltage		(Note 6)			4			5			7	mV
Input Offset Voltage Drift		$R_S = 0\Omega$		7	15		7	20		7		μV/°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		pA/°C
Input Bias Current		$I_{IN(+)}$ or $I_{IN(-)}$		40	100		40	200		40	300	nA
Input Common-Mode Voltage Range		$V^+ = 30\ V$, (Note 8) (LM2904, $V^+ = 26V$)	0		V^+-2	0		V^+-2	0		V^+-2	V

Electrical Characteristics (Continued)

$V^+ = +5.0V$, (Note 5), unless otherwise stated

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

Electrical Characteristics

$V^+ = +5.0V$, (Note 5), unless otherwise stated

Parameter		Conditions	LM358			LM2904			Units
			Min	Typ	Max	Min	Typ	Max	
Large Signal Voltage Gain		$V^+ = 15V$, $T_A = 25°C$, $R_L \geq 2\ k\Omega$, (For V_O = 1V to 11V)	25	100		25	100		V/mV
Common-Mode Rejection Ratio		$T_A = 25°C$, 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), $T_A = 25°C$	65	100		50	100		dB
Amplifier-to-Amplifier Coupling		f = 1 kHz to 20 kHz, $T_A = 25°C$ (Input Referred), (Note 9)		−120			−120		dB
Output Current	Source	$V_{IN}^+ = 1V$, $V_{IN}^- = 0V$, $V^+ = 15V$, $V_O = 2V$, $T_A = 25°C$	20	40		20	40		mA
	Sink	$V_{IN}^- = 1V$, $V_{IN}^+ = 0V$ $V^+ = 15V$, $T_A = 25°C$, $V_O = 2V$	10	20		10	20		mA
		$V_{IN}^- = 1V$, $V_{IN}^+ = 0V$ $T_A = 25°C$, $V_O = 200\ mV$, $V^+ = 15V$	12	50		12	50		µA
Short Circuit to Ground		$T_A = 25°C$, (Note 3), $V^+ = 15V$		40	60		40	60	mA
Input Offset Voltage		(Note 6)			9			10	mV
Input Offset Voltage Drift		$R_S = 0\Omega$		7			7		µV/°C
Input Offset Current		$I_{IN(+)} - I_{IN(-)}$			150		45	200	nA
Input Offset Current Drift		$R_S = 0\Omega$		10			10		pA/°C
Input Bias Current		$I_{IN(+)}$ or $I_{IN(-)}$		40	500		40	500	nA
Input Common-Mode Voltage Range		V^+ = 30 V, (Note 8) (LM2904, V^+ = 26V)	0		V^+−2	0		V^+ −2	V

Electrical Characteristics (Continued)

V^+ = +5.0V, (Note 5), 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) $R_L \geq 2$ kΩ		15			15			V/mV
Output Voltage Swing	V_{OH}	V^+ = +30V	R_L = 2 kΩ	26			22			V
		(LM2904, V^+ = 26V)	R_L = 10 kΩ	27	28		23	24		V
	V_{OL}	V^+ = 5V, R_L = 10 kΩ			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 2: For operating at high temperatures, the LM358/LM358A, LM2904 must be derated based on a +125°C maximum junction temperature and a thermal resistance of 120°C/W 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°C maximum junction temperature. The dissipation is the total of both amplifiers — use external resistors, where possible, to allow the amplifier to saturate or to reduce the power which is dissipated in the integrated circuit.

Note 3: 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 4: 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°C).

Note 5: These specifications are limited to −55°C ≤ T_A ≤ +125°C for the LM158/LM158A. With the LM258/LM258A, all temperature specifications are limited to −25°C ≤ T_A ≤ +85°C, the LM358/LM358A temperature specifications are limited to 0°C ≤ T_A ≤ +70°C, and the LM2904 specifications are limited to −40°C ≤ T_A ≤ +85°C.

Note 6: V_O ≅ 1.4V, R_S = 0Ω with V^+ from 5V to 30V; and over the full input common-mode range (0V to V^+ −1.5V) at 25°C. For LM2904, V^+ from 5V to 26V.

Note 7: 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 8: The input common-mode voltage of either input signal voltage should not be allowed to go negative by more than 0.3V (at 25°C). The upper end of the common-mode voltage range is V^+ −1.5V (at 25°C), but either or both inputs can go to +32V without damage (+26V for LM2904), independent of the magnitude of V^+.

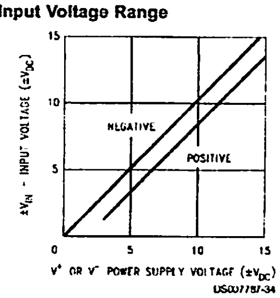
Note 9: Due to proximity of external components, insure that coupling is not originating via stray capacitance between these external parts. This typically can be detected as this type of capacitance increases at higher frequencies.

Note 10: Refer to RETS158AX for LM158A military specifications and to RETS158X for LM158 military specifications.

Note 11: Human body model, 1.5 kΩ in series with 100 pF.

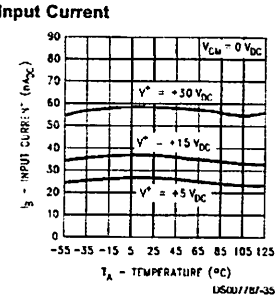
Typical Performance Characteristics

Input Voltage Range



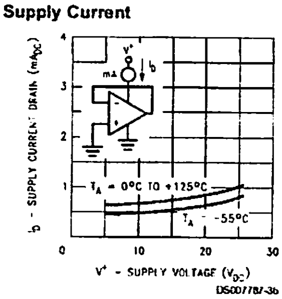
DS007787-34

Input Current



DS007787-35

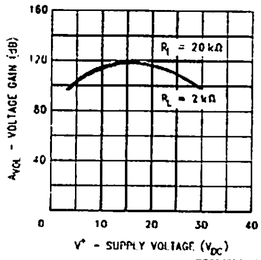
Supply Current



DS007787-36

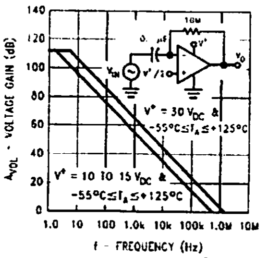
Typical Performance Characteristics (Continued)

Voltage Gain



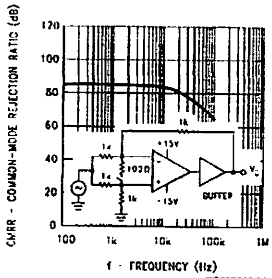
DS007787-37

Open Loop Frequency Response



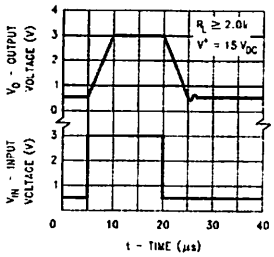
DS007787-38

Common-Mode Rejection Ratio



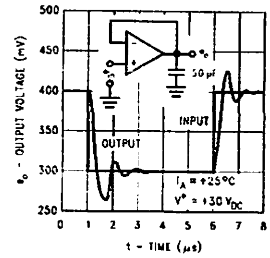
DS007787-39

Voltage Follower Pulse Response



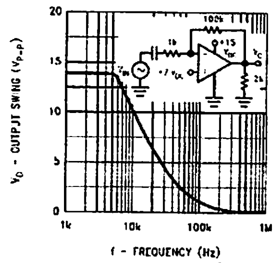
DS007787-40

Voltage Follower Pulse Response (Small Signal)



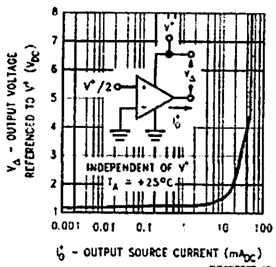
DS007787-41

Large Signal Frequency Response



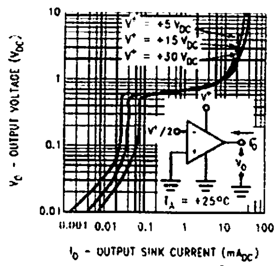
DS007787-42

Output Characteristics Current Sourcing



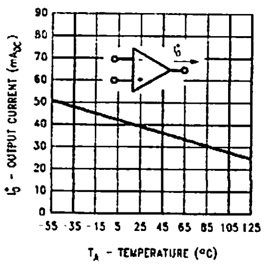
DS007787-43

Output Characteristics Current Sinking



DS007787-44

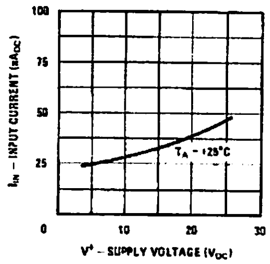
Current Limiting



DS007787-45

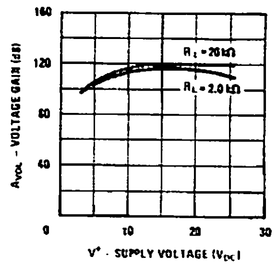
Typical Performance Characteristics (Continued)

Input Current (LM2902 only)



DS007787-46

Voltage Gain (LM2902 only)



DS007787-47

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°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 accomodated 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°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 accomodated 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.

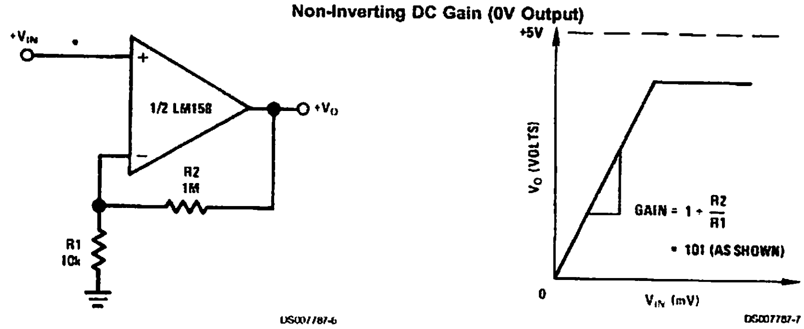
The bias network of the LM158 establishes a drain current which is independent of the magnitude of the power supply voltage over the range of 3 V_{DC} to 30 V_{DC}.

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 function 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°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.

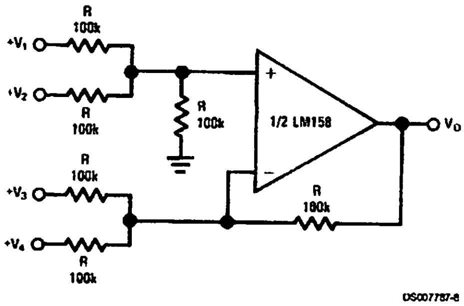
Typical Single-Supply Applications ($V^+ = 5.0\ V_{DC}$)

Non-Inverting DC Gain (0V Output)



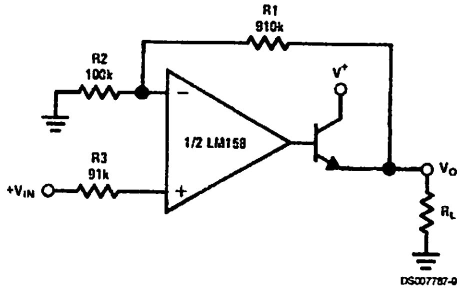
*R not needed due to temperature independent I_{IN}

DC Summing Amplifier
(V_{IN}'s ≥ 0 V_{DC} and V_O ≥ 0 V_{DC})



Where: $V_O = V_1 + V_2 - V_3 - V_4$
$(V_1 + V_2) \geq (V_3 + V_4)$ to keep $V_O > 0\ V_{DC}$

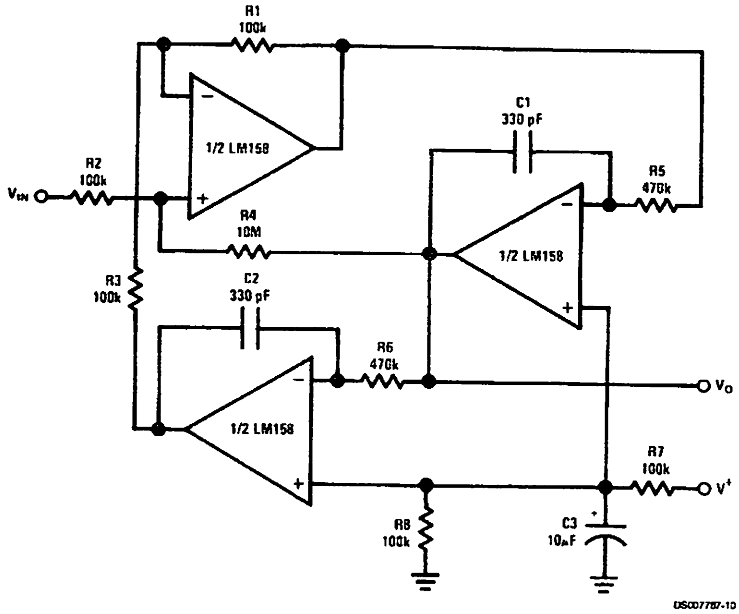
Power Amplifier



$V_O = 0\ V_{DC}$ for $V_{IN} = 0\ V_{DC}$
$A_V = 10$

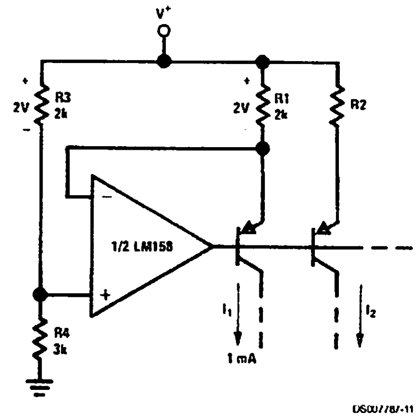
Typical Single-Supply Applications ($V^+ = 5.0\ V_{DC}$) (Continued)

"BI-QUAD" RC Active Bandpass Filter



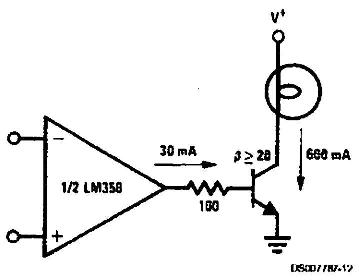
$f_o = 1$ kHz
Q = 50
$A_v = 100$ (40 dB)

Fixed Current Sources



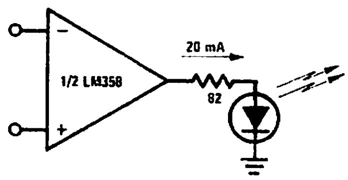
$I_2 = \left(\frac{R1}{R2}\right) I_1$

Lamp Driver

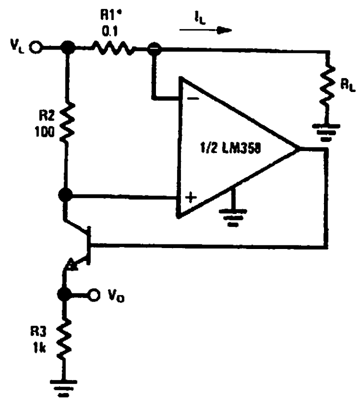


Typical Single-Supply Applications ($V^+ = 5.0\ V_{DC}$) (Continued)

LED Driver



Current Monitor

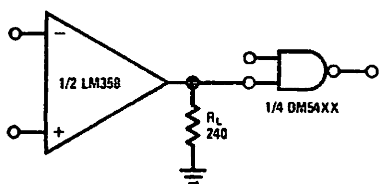


$$V_O = \frac{1V\,(I_L)}{1A}$$

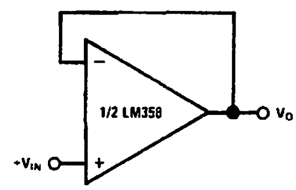
*(Increase R1 for I_L small)

$V_L \le V^+ - 2V$

Driving TTL

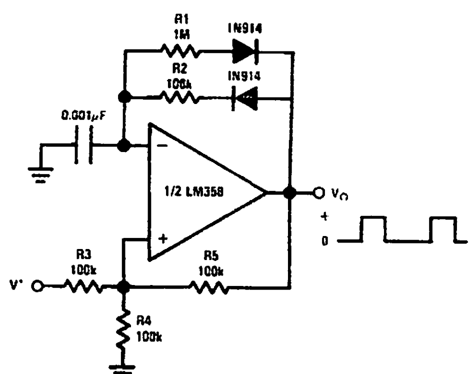


Voltage Follower



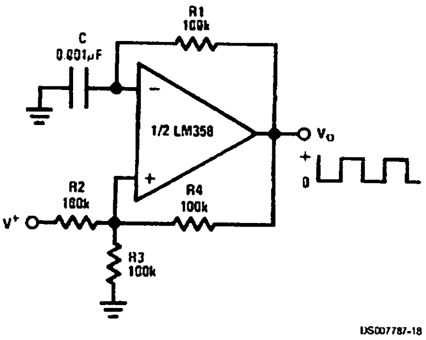
$V_O = V_{IN}$

Pulse Generator

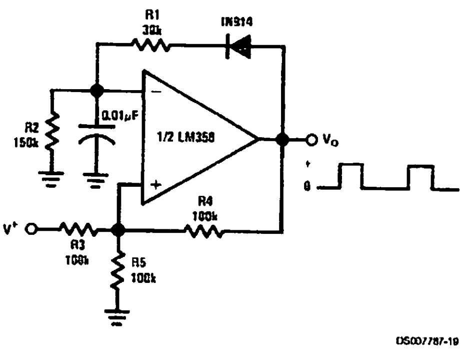


Typical Single-Supply Applications $(V^+ = 5.0\ V_{DC})$ (Continued)

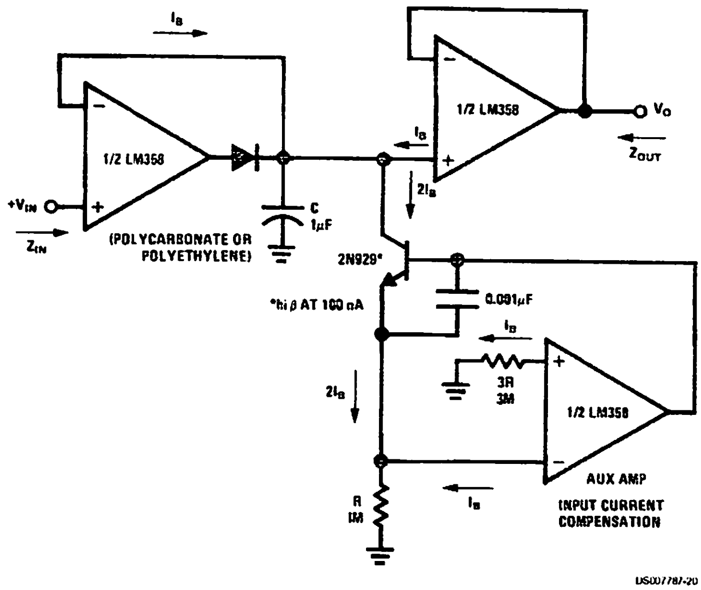
Squarewave Oscillator



Pulse Generator



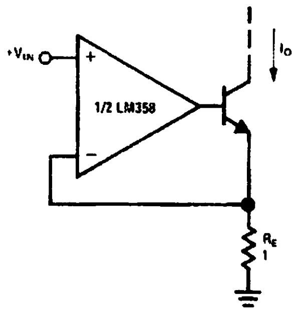
Low Drift Peak Detector



HIGH Z_{IN}
LOW Z_{OUT}

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

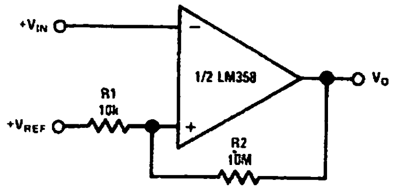
High Compliance Current Sink



DS007787-21

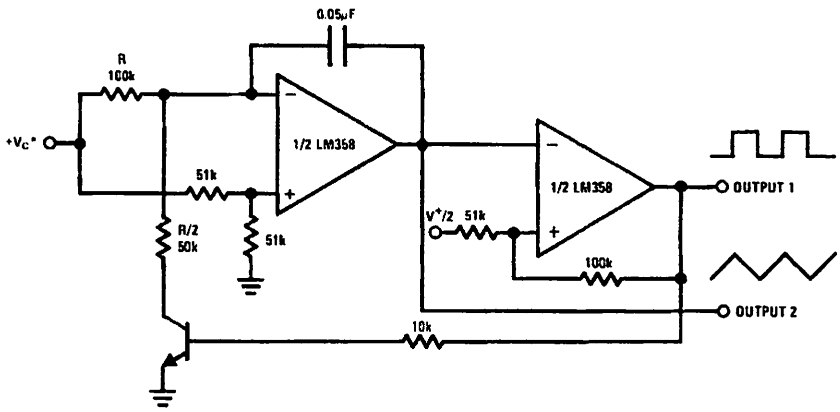
I_O = 1 amp/volt V_{IN}
(Increase R_E for I_O small)

Comparator with Hysteresis



DS007787-22

Voltage Controlled Oscillator (VCO)

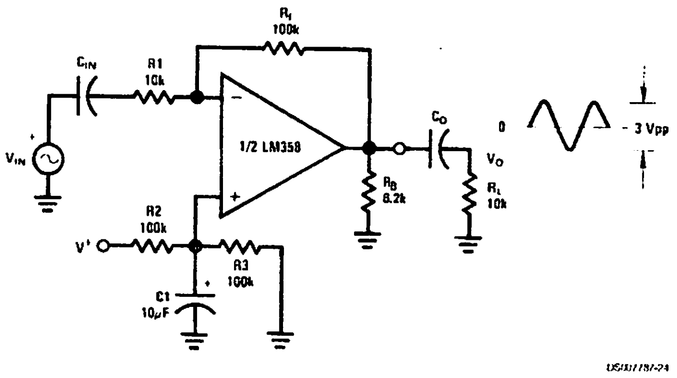


DS007787-23

*WIDE CONTROL VOLTAGE RANGE: $0\ V_{DC} \leq V_C \leq 2\ (V^+ - 1.5V_{DC})$

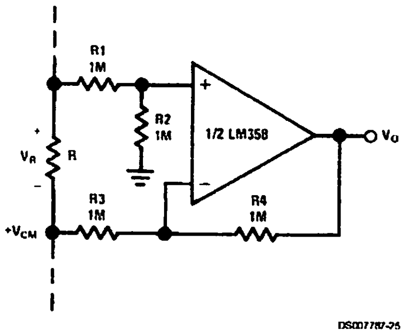
Typical Single-Supply Applications ($V^+ = 5.0\ V_{DC}$) (Continued)

AC Coupled Inverting Amplifier



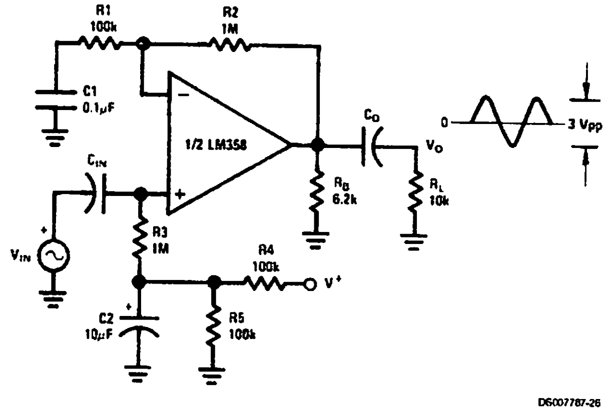
$A_V = \frac{R_f}{R1}$ (As shown, $A_V = 10$)

Ground Referencing a Differential Input Signal



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

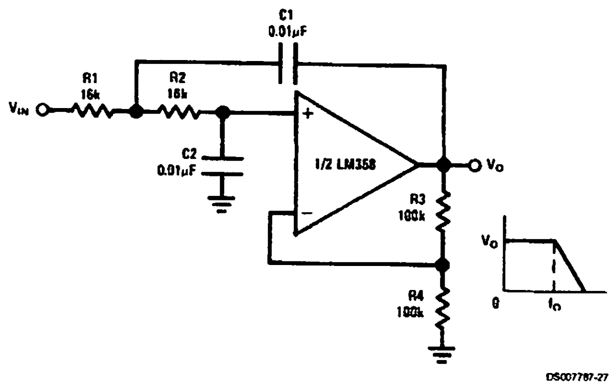
AC Coupled Non-Inverting Amplifier



$$A_V = 1 + \frac{R2}{R1}$$

A_V = 11 (As Shown)

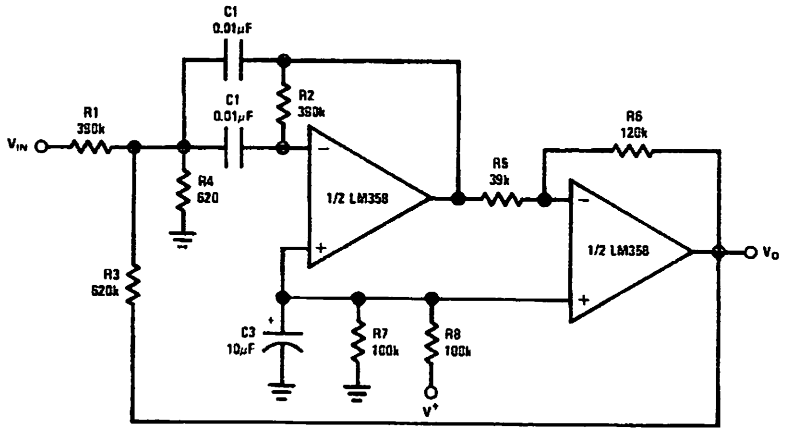
DC Coupled Low-Pass RC Active Filter



f_O = 1 kHz
Q = 1
A_V = 2

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

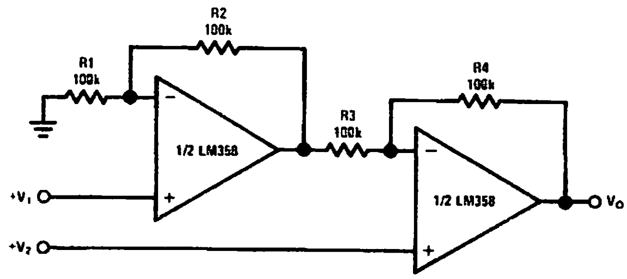
Bandpass Active Filter



DS007787-28

$f_o = 1$ kHz
$Q = 25$

High Input Z, DC Differential Amplifier



DS007787-29

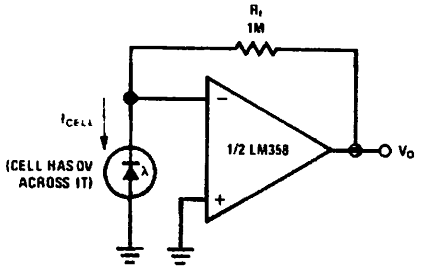
For $\frac{R1}{R2} = \frac{R4}{R3}$ (CMRR depends on this resistor ratio match)

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

As Shown: $V_O = 2 (V_2 - V_1)$

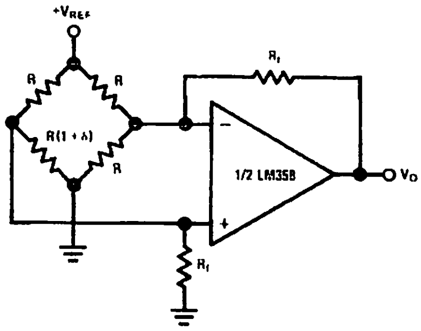
Typical Single-Supply Applications ($V^+ = 5.0\ V_{DC}$) (Continued)

Photo Voltaic-Cell Amplifier



DS007787-30

Bridge Current Amplifier

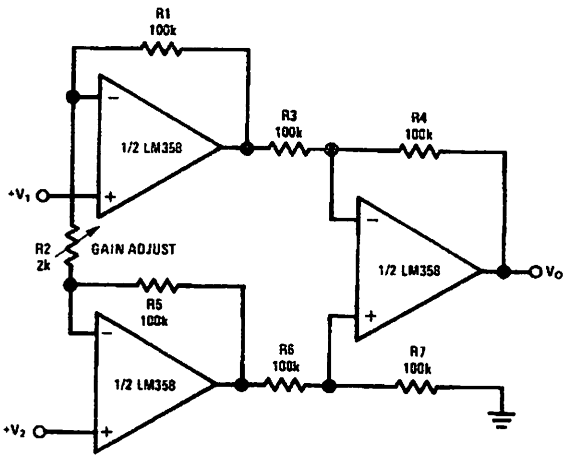


DS007787-33

For $\delta << 1$ and $R_f >> R$

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

High Input Z Adjustable-Gain DC Instrumentation Amplifier



DS007787-31

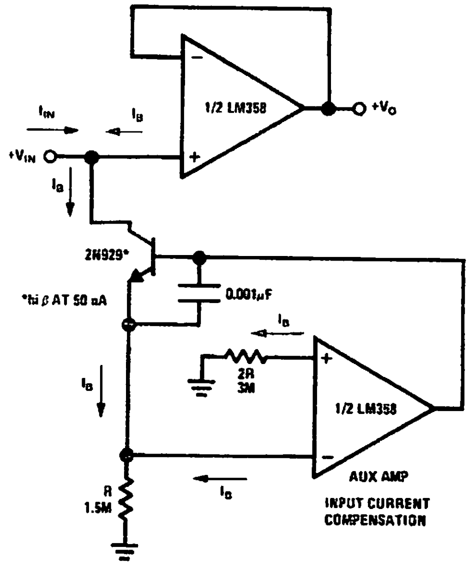
If R1 = R5 & R3 = R4 = R6 = R7 (CMRR depends on match)

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

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

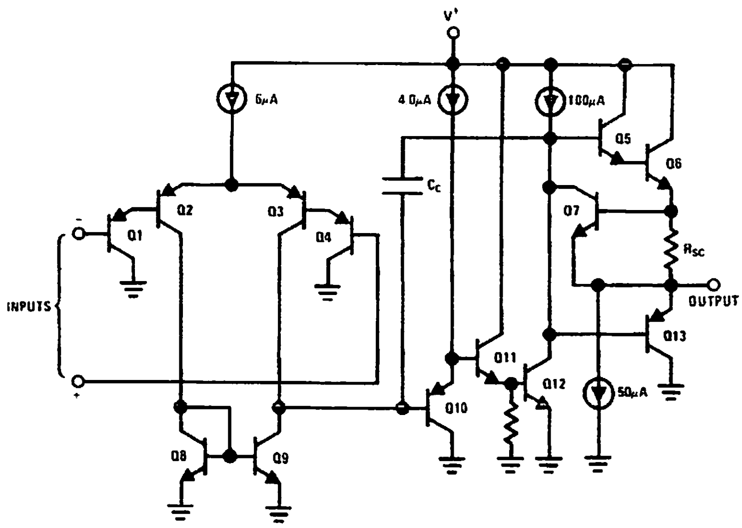
Typical Single-Supply Applications (V+ = 5.0 V_{DC}) (Continued)

Using Symmetrical Amplifiers to Reduce Input Current (General Concept)



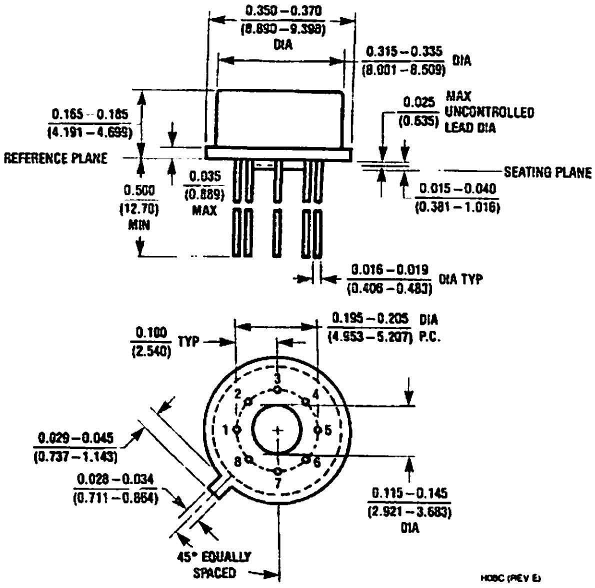
DS007787-32

Schematic Diagram (Each Amplifier)

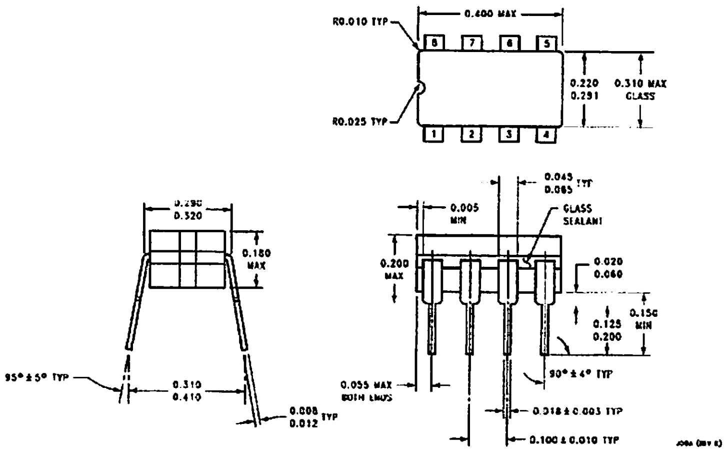


DS007787-3

Physical Dimensions inches (millimeters) unless otherwise noted

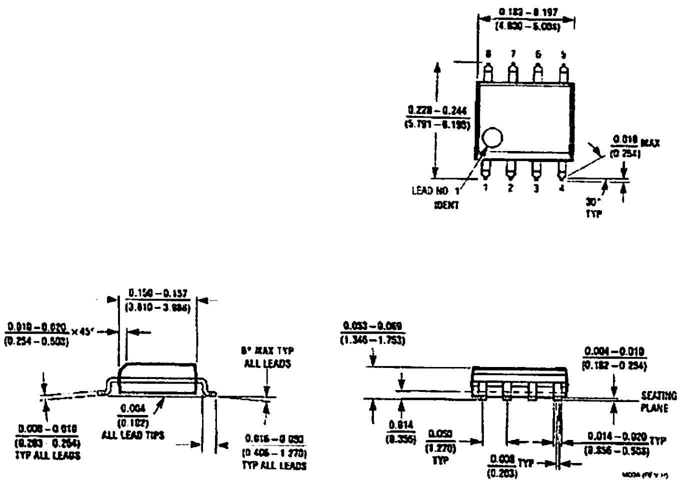


Metal Can Package (H)
Order Number LM158AH, LM158AH/883, LM158H, LM158H/883, LM258H or LM358H
NS Package Number H08C

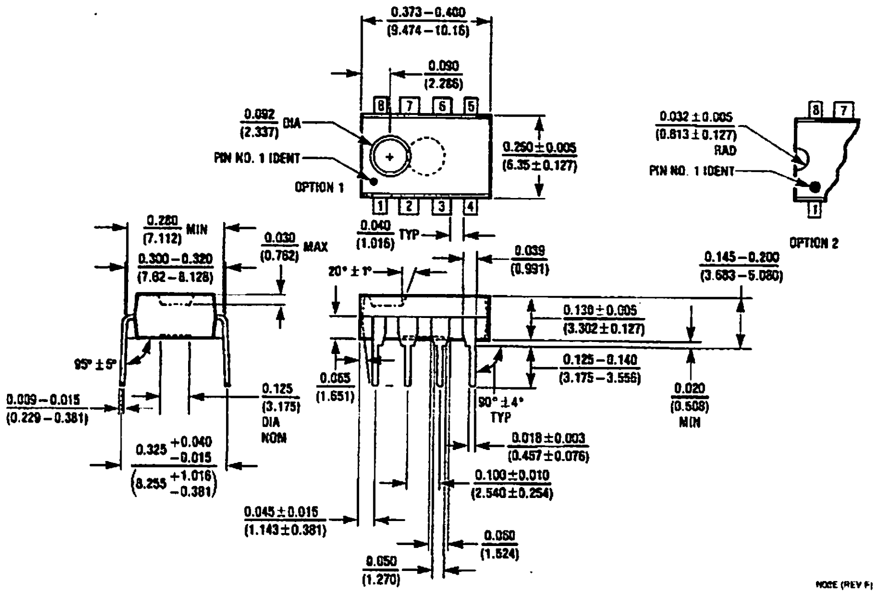


Cerdip Package (J)
Order Number LM158J, LM158J/883, LM158AJ or LM158AJ/883
NS Package Number J08A

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



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



Molded Dip Package (N)
Order Number LM358AN, LM358N or LM2904N
NS Package Number N08E

FAIRCHILD
SEMICONDUCTOR®

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LM741

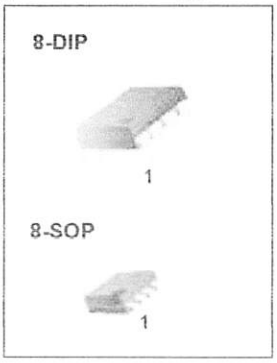
Single Operational Amplifier

Features

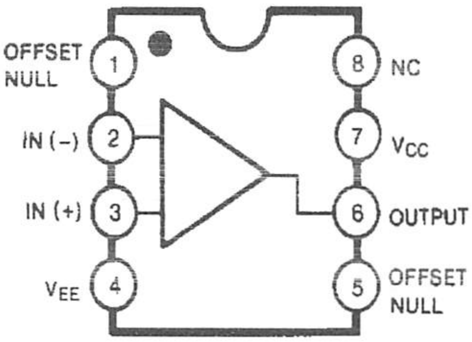
- Short circuit protection
- Excellent temperature stability
- Internal frequency compensation
- High Input voltage range
- Null of offset

Description

The LM741 series are general purpose operational amplifiers. It is intended for a wide range of analog applications. The high gain and wide range of operating voltage provide superior performance in intergrator, summing amplifier, and general feedback applications.

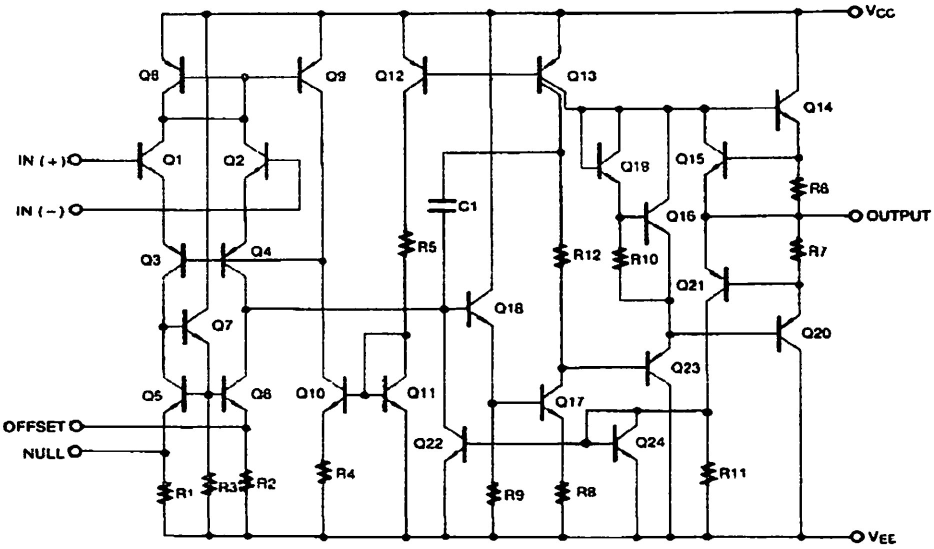


Internal Block Diagram



Rev. 1.0.1

Schematic Diagram



Absolute Maximum Ratings (T_A = 25°C)

Parameter	Symbol	Value	Unit
Supply Voltage	V_{CC}	±18	V
Differential Input Voltage	$V_{I(DIFF)}$	30	V
Input Voltage	V_I	±15	V
Output Short Circuit Duration	-	Indefinite	-
Power Dissipation	P_D	500	mW
Operating Temperature Range LM741C LM741I	T_{OPR}	0 ~ + 70 -40 ~ +85	°C
Storage Temperature Range	T_{STG}	-65 ~ + 150	°C

Electrical Characteristics

(V_{CC} = 15V, V_{EE} = - 15V. T_A = 25 °C, unless otherwise specified)

Parameter		Symbol	Conditions		LM741C/LM741I			Unit
					Min.	Typ.	Max.	
Input Offset Voltage		V_{IO}	$R_S \le 10K\Omega$		-	2.0	6.0	mV
			$R_S \le 50\Omega$		-	-	-	
Input Offset Voltage Adjustment Range		$V_{IO(R)}$	$V_{CC} = \pm 20V$		-	±15	-	mV
Input Offset Current		I_{IO}	-		-	20	200	nA
Input Bias Current		I_{BIAS}	-		-	80	500	nA
Input Resistance (Note1)		R_I	$V_{CC} = \pm 20V$		0.3	2.0	-	MΩ
Input Voltage Range		$V_{I(R)}$	-		±12	±13	-	V
Large Signal Voltage Gain		G_V	$R_L \ge 2K\Omega$	$V_{CC} = \pm 20V$, $V_{O(P-P)} = \pm 15V$	-	-	-	V/mV
				$V_{CC} = \pm 15V$, $V_{O(P-P)} = \pm 10V$	20	200	-	
Output Short Circuit Current		I_{SC}	-		-	25	-	mA
Output Voltage Swing		$V_{O(P-P)}$	$V_{CC} = \pm 20V$	$R_L \ge 10K\Omega$	-	-	-	V
				$R_L \ge 2K\Omega$	-	-	-	
			$V_{CC} = \pm 15V$	$R_L \ge 10K\Omega$	±12	±14	-	
				$R_L \ge 2K\Omega$	±10	±13	-	
Common Mode Rejection Ratio		CMRR	$R_S \le 10K\Omega$, $V_{CM} = \pm 12V$		70	90	-	dB
			$R_S \le 50\Omega$, $V_{CM} = \pm 12V$		-	-	-	
Power Supply Rejection Ratio		PSRR	$V_{CC} = \pm 15V$ to $V_{CC} = \pm 15V$ $R_S \le 50\Omega$		-	-	-	dB
			$V_{CC} = \pm 15V$ to $V_{CC} = \pm 15V$ $R_S \le 10K\Omega$		77	96	-	
Transient Response	Rise Time	T_R	Unity Gain		-	0.3	-	μs
	Overshoot	OS			-	10	-	%
Bandwidth		BW	-		-	-	-	MHz
Slew Rate		SR	Unity Gain		-	0.5	-	V/μs
Supply Current		I_{CC}	$R_L = \infty\Omega$		-	1.5	2.8	mA
Power Consumption		P_C	$V_{CC} = \pm 20V$		-	-	-	mW
			$V_{CC} = \pm 15V$		-	50	85	

Note:
1. Guaranteed by design.

Electrical Characteristics

(0°C ≤T_A≤70 °C V_{CC} = ±15V, unless otherwise specified)
The following specification apply over the range of 0°C ≤ T_A ≤ +70 °C for the LM741C; and the -40°C ≤ T_A ≤ +85 °C for the LM741I

Parameter	Symbol	Conditions		LM741C/LM741I Min.	Typ.	Max.	Unit
Input Offset Voltage	V_{IO}	R_S≤50Ω		-	-	-	mV
		R_S≤10KΩ		-	-	7.5	
Input Offset Voltage Drift	$\Delta V_{IO}/\Delta T$	-		-	-		μV/ °C
Input Offset Current	I_{IO}	-		-	-	300	nA
Input Offset Current Drift	$\Delta I_{IO}/\Delta T$	-		-	-		nA/ °C
Input Bias Current	I_{BIAS}	-		-	-	0.8	μA
Input Resistance (Note1)	R_I	V_{CC} = ±20V		-	-	-	MΩ
Input Voltage Range	$V_{I(R)}$	-		±12	±13	-	V
Output Voltage Swing	$V_{O(P-P)}$	V_{CC} =±20V	R_S≥10KΩ	-	-	-	V
			R_S≥2KΩ	-	-	-	
		V_{CC} =±15V	R_S≥10KΩ	±12	±14	-	
			R_S≥2KΩ	±10	±13	-	
Output Short Circuit Current	I_{SC}	-		10	-	40	mA
Common Mode Rejection Ratio	CMRR	R_S≤10KΩ, V_{CM} = ±12V		70	90	-	dB
		R_S≤50Ω, V_{CM} = ±12V		-	-	-	
Power Supply Rejection Ratio	PSRR	V_{CC} = ±20V to ±5V	R_S≤50Ω	-	-	-	dB
			R_S≤10KΩ	77	96	-	
Large Signal Voltage Gain	G_V	R_S≥2KΩ	V_{CC} = ±20V, $V_{O(P-P)}$ = ±15V	-	-	-	V/mV
			V_{CC} = ±15V, $V_{O(P.P)}$ = ±10V	15	-	-	
			V_{CC} = ±15V, $V_{O(P-P)}$ = ±2V	-	-	-	

Note :
1. Guaranteed by design.

Typical Performance Characteristics

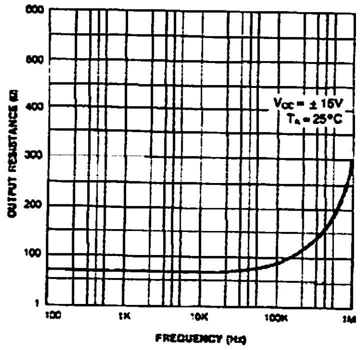


Figure 1. Output Resistance vs Frequency

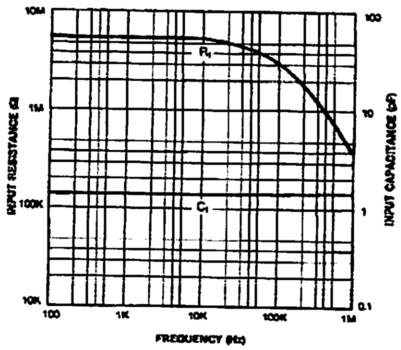


Figure 2. Input Resistance and Input Capacitance vs Frequency

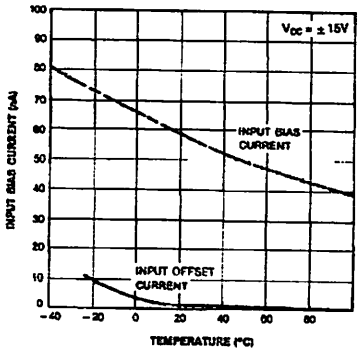


Figure 3. Input Bias Current vs Ambient Temperature

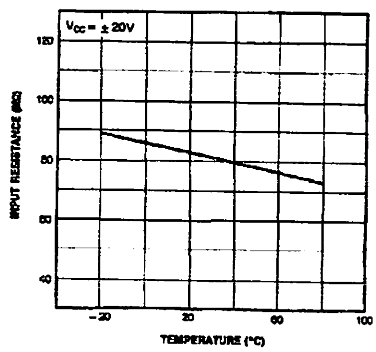


Figure 4. Power Consumption vs Ambient Temperature

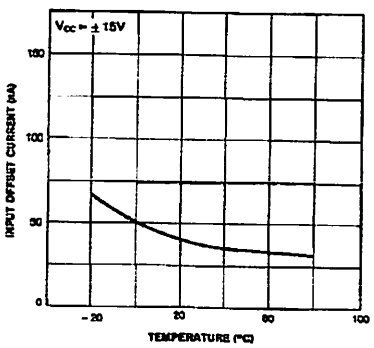


Figure 5. Input Offset Current vs Ambient Temperature

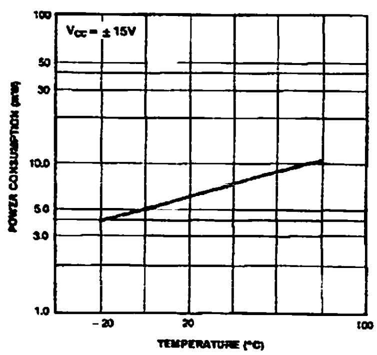


Figure 6. Input Resistance vs Ambient Temperature

Typical Performance Characteristics (continued)

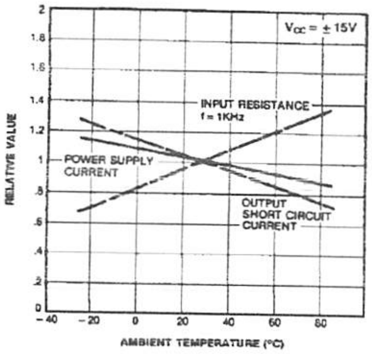


Figure 7. Normalized DC Parameters vs Ambient Temperature

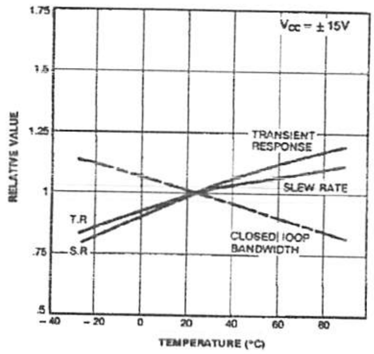


Figure 8. Frequency Characteristics vs Ambient Temperature

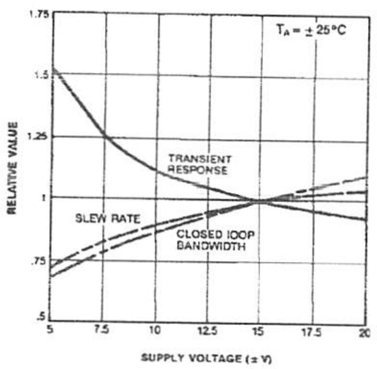


Figure 9. Frequency Characteristics vs Supply Voltage

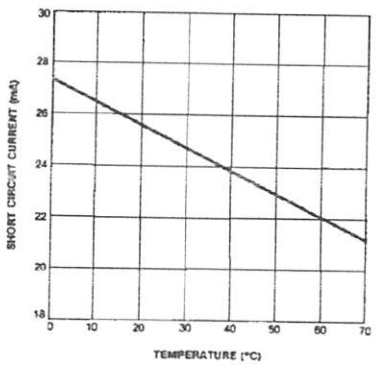


Figure 10. Output Short Circuit Current vs Ambient Temperature

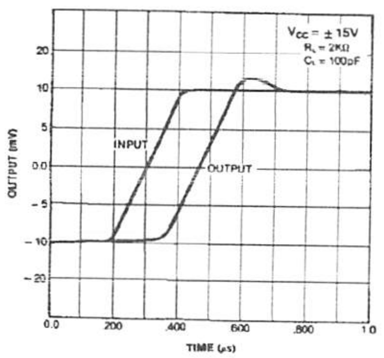


Figure 11. Transient Response

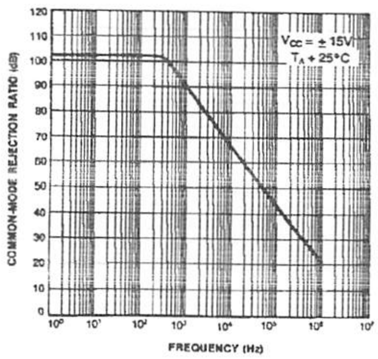


Figure 12. Common-Mode Rejection Ratio vs Frequency

Typical Performance Characteristics (continued)

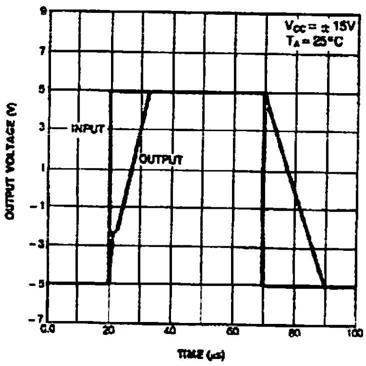


Figure 13. Voltage Follower Large Signal Pulse Response

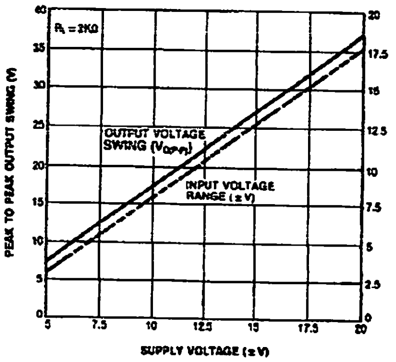
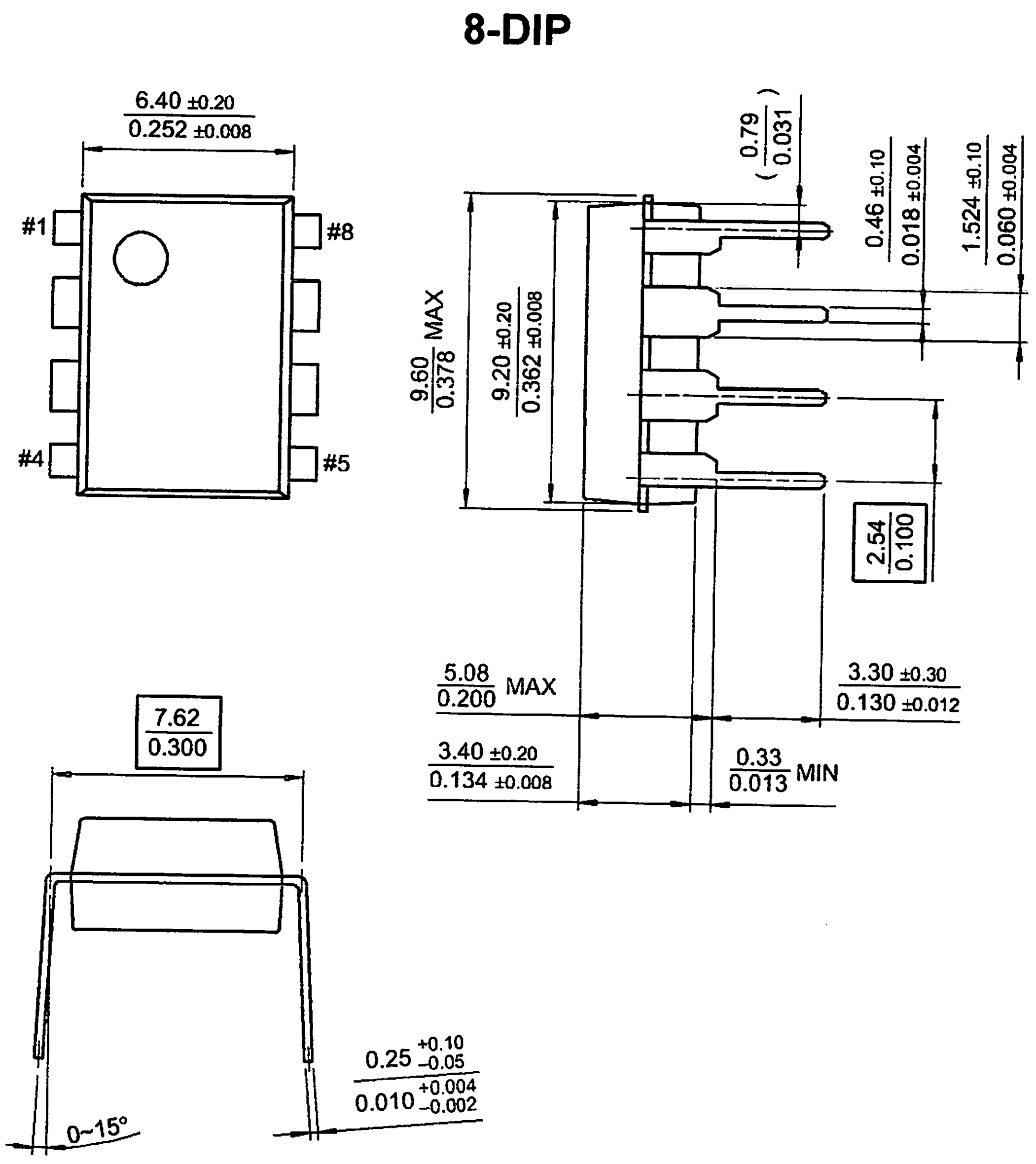


Figure 14. Output Swing and Input Range vs Supply Voltage

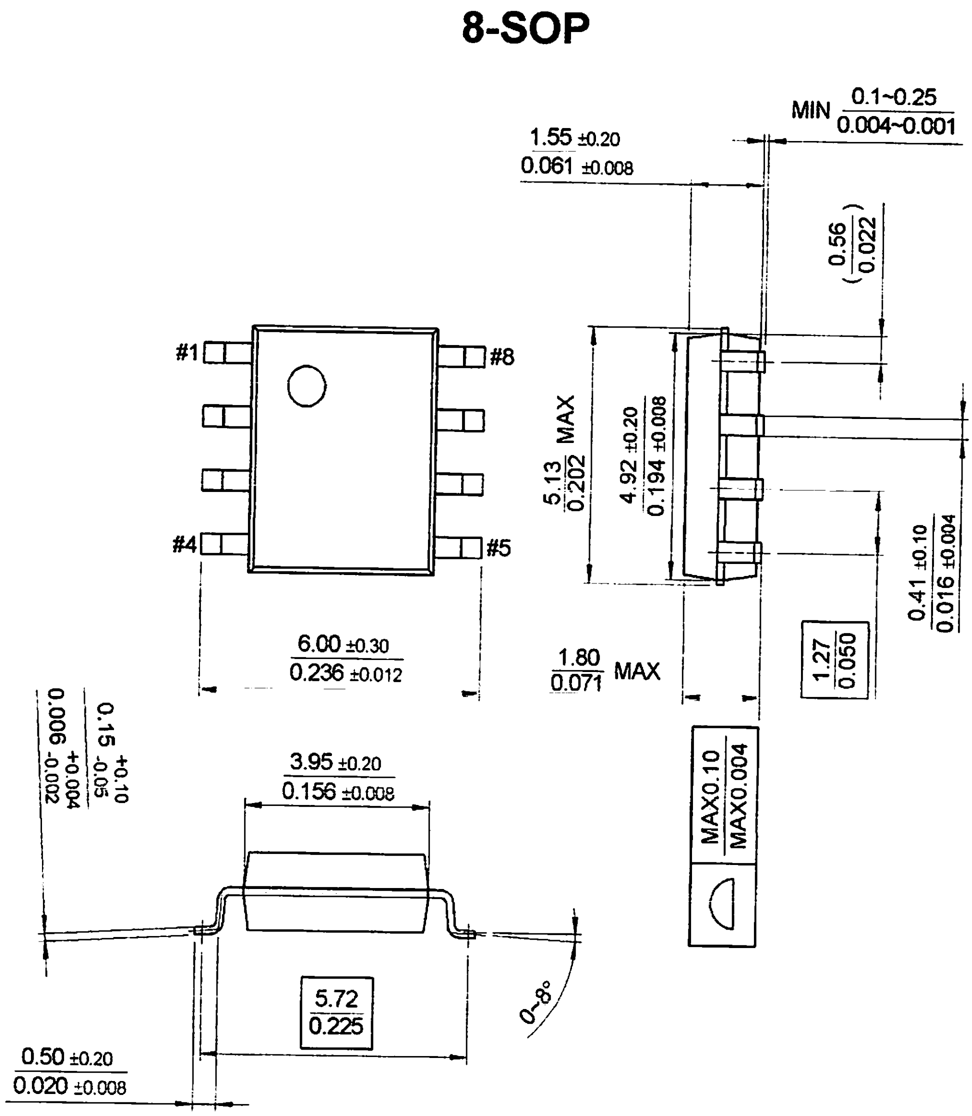
Mechanical Dimensions

Package



Mechanical Dimensions (Continued)

Package



Ordering Information

Product Number	Package	Operating Temperature
LM741CN	8-DIP	0 ~ + 70°C
LM741CM	8-SOP	
LM741IN	8-DIP	-40 ~ + 85°C

6/1/01 0.0m 001
Stock#DSxxxxxxxx