ALAT UKUR JARAK DENGAN MENGGUNAKAN SENSOR ULTRASONIK BERBASIS MIKROKONTROLLER AT89C51

TUGAS AKHIR

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JURUSAN TEKNIK ELEKTRO D III

FAKULTAS TEKNOLOGI INDUSTRI

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LEMBAR PERSETUJUAN

ALAT UKUR JARAK DENGAN MENGGUNAKAN SENSOR ULTRASONIK BERBASIS MIKRO KONTROLLER AT89C51

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2009

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ALAT UKUR JARAK DENGAN MENGGUNAKAN SENSOR ULTRASONIK BERBASIS MIKROKONTROLLER AT89C51

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JUDUL SKRIPSI : **ALAT UKUR JARAK DENGAN MENGGUNAKAN SENSOR ULTRASONIK BERBASIS MIKROKONTROLLER AT89C51**

Telah Dipertahankan Dihadapan Majelis Penguji Tugas Akhir
Jenjang Program Diploma Tiga (DIII)

Hari / Tanggal : **Jum'at / 02 Oktober 2009**

Dengan Nilai : **79,50 (B+)**

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ALAT UKUR JARAK DENGAN MENGGUNAKAN SENSOR ULTRASONIK BERBASIS MIKROKONTROLLER AT89C51

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Abstrak:

Dengan memanfaatkan gelombang ultrasonik, dapat dibuat sebuah alat ukur digital dengan menggunakan sensor ultrasonik berbasis mikrokontroller AT89C51. Gelombang ultrasonik itu sendiri adalah suatu gelombang akustik yang mempunyai frekuensi di atas ambang dengar manusia yaitu di atas 20.000 Hz. Gelombang ultrasonik sendiri merupakan gelombang longitudinal, karena membutuhkan suatu medium untuk perambatannya. Alat ukur ini menggunakan media frekuensi ultrasonik untuk mengukur jarak antara tranducer ultrasonik dengan penghalang yang memantulkan signal ultrasonik hingga diterima kembali oleh receiver ultrasonik. Cepat rambat ultrasonik telah ditetapkan 29 Mikrodetik untuk merambat sejauh 1 cm. Ketetapan cepat rambat ultrasonik digunakan sebagai dasar membangun sistem pengukuran jarak secara digital ini.

Adapun metode yang digunakan dalam penulisan tugas akhir ini adalah sebagai berikut: kajian literatur/referensi mengenai komponen-komponen yang digunakan dalam pembuatan alat, merencanakan dan membuat alat kemudian mencoba dalam papan percobaan dan seterusnya merakit alat tersebut dalam PCB, tanya jawab dengan dosen pembimbing tentang konsep teori/literatur.

Berdasarkan hasil penelitian dan pengujian alat,didapatkan bahwa sensor ultrasonik dapat dijadikan alat ukur yang linier untuk pengukuran jarak benda dengan sudut tegak lurus. Dan dengan teknik mengirimkan 12 *burse,* memiliki kekurangan yaitu batas ukur dari 10 cm (death zone) hingga 2 meter. Harapan dibuatnya alat ini adalah agar pengukuran jarak menjadi lebih cepat dan lebih praktis, sehingga dapat digunakan sebagai bahan pengembangan pemodelan sensor lebih lanjut, yaitu seperti pada bidang bidang robotika, sistem navigasi mobil dan aplikasi kepolisian (sebagai pengukur batas kecepatan).

Kata Kunci: *Sensor Ultrasonik, Mikrokontroller AT89C51*

KATA PENGANTAR

Segala puji dan syukur kehadirat Allah SWT atas segala rahmat, hidayah dan ridlo-Nya, sehingga penulis dapat menyelesaikan laporan Tugas Akhir dengan judul, **"ALAT UKUR JARAK DENGAN MENGGUNAKAN SENSOR ULTRASONIK BERBASIS MIKROKONTROLLER AT89C51"**

Pembuatan Tugas Ahkir ini disusun guna memenuhi syarat akhir kelulusan pendidikan jenjang Diploma-III di Institut Teknologi Nasional Malang. Laporan Tugas ahkir ini merupakan tanggung jawab tertulis atas ilmu pengetahuan yang didapat selama penyusun mengikuti kuliah.

Atas terselesaikannya Tugas ahkir ini, penulis mengucapkan terima kasih kepada :

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- Bapak Ir. Taufik Hidayat, MT selaku Ketua Jurusan Teknik Elektro Diploma-III.
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- Kedua Orang Tua penulis yang telah memberi dukungan baik materi maupun spiritual.

Penulis menyadari bahwa laporan ini masih banyak yang perlu disempurnakan. Oleh sebab itu kritik dan saran yang membangun sangat diharapkan.

Akhir kata, penulis mohan maaf kepada semua pihak bilamana selama penyusunan Tugas Ahkir ini penyusun membuat kesalahan secara tidak sengaja dan semoga Tugas Ahkir ini dapat bermanfaat bagi kita semua.

Malang, September 2009

Penulis

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BAB I

PENDAHULUAN

1.1 Latar Belakang

Alat ukur jarak konvensional yang ada sekarang ini adalah alat ukur yang berupa meteran (alat ukur konvensional menghitung jarak dengan manual mengunakan ruas-ruas sentimeter pada suatu bahan tertentu). Padahal pada teknologi yang tinggi, alat ukur jarak dapat berfungsi di berbagai bidang, misalnya; untuk aplikasi pada sistem navigasi mobil, untuk pengukuran jarak konvensional dengan output meter, dan dapat di aplikasikan dalam bidang robotika, misalnya untuk menentukan berapa jarak rintangan di depannya.

Pada tugas akhir ini akan dibuat desain prototipe alat ukur jarak menggunakan sensor ultrasonik berbasis mikrokontroller AT89C51. Dengan dibuatnya alat ini, maka diharapkan dapat memudahkan suatu pengukuran jarak. Karena pengukuran akan menjadi lebih praktis dan lebih cepat bila dibanding dengan alat ukur jarak yang berupa meteran. Ini terjadi karena semua data di proses secara digital dan ditampilkan pada LCD dengan output sentimeter (cm). Yang nantinya akan bisa ditindak lanjuti ke berbagai bidang pengukuran seperti yang saya sebutkan di atas.

1.2 Rumusan Masalah

Mengacu pada latar belakang dan permasalahan tersebut di atas maka perumusan masalah dapat dijabarkan sebagai berikut :

- Bagaimana merancanakan perangkat keras untuk merealisasikan sistem aplikasi.
- Bagaimana merencanakan perangkat lunak untuk mendukung operasi sistem aplikasi.

1.3 Tujuan

Merancang rangkaian perangkat keras alat ukur jarak dengan menggunakan sensor ultrasonik berbasis Mikrokontroler AT89C51.

1.4 Batasan Masalah

Desain dirancang masih berupa prototipe dengan output sentimeter (cm) yang ditampilkan pada LCD.

1.5 Metodologi

Penyusunan proposal tugas akhir melalui beberapa tahap agar dapat menghasilkan penulisan tugas akhir yang lengkap diantaranya melalui :

1. Studi literatur

   Mengumpulkan bahan - bahan literatur sebagai penunjang pembuatan peralatan ukur jarak menggunakan sensor ultrasonik berbasis mikrokontroller AT89C51.

BAB III PERENCANAAN PERANGKAT KERAS DAN PERNGKAT LUNAK

Berisi perencanaan perangkat keras antara lain: sensor ultrasonik, LCD dan Mikrokontroler.

Perencanaan perangkat lunak yang berupa flowchart dan bahasa interfacenya menggunakan bahasa Assembly.

BAB IV PENGUJIAN ALAT

Di dalam bab ini membahas tentang uji coba peralatan yang dibuat dan beberapa program yang sederhana untuk menguji alat tersebut.

BAB V PENUTUP

Bab ini berisikan kesimpulan akhir dari alat yang dibuat dan saran – saran untuk mengembangkan alat ini selanjutnya.

2. Penelitian

   Melaksanakan serangkaian percobaan untuk membuat perangkat keras dan perangkat lunak yang berhubungan dengan peralatan yang akan dibuat.

3. Pengujian

   Melakukan serangkaian pengujian dan analisa pada setiap blok rangkaian pada perangkat keras juga perangkat lunak untuk mengetahui keandalan kerja sistem.

4. Pembahasan

   Membahas semua prosedur dan dituangkan dalam bentuk karya tulis laporan Tugas Akhir.

1.6 Sistematika Penulisan

Untuk memberikan penjelasan yang menyeluruh dan terstruktur mengenai penyusunan tugas akhir ini, maka sistematika penulisan disusun sebagai berikut :

BAB I PENDAHULUAN

Bab ini berisikan latar belakang masalah, rumusan masalah, batasan masalah, tujuan dan manfaat penulisan, metode penulisan dan sistematika penulisan.

BAB II TINJAUAN PUSTAKA

Pada bab ini akan dibahas tentang teori dasar dan penjelasan mengenai komponen-komponen yang digunakan.

BAB II

TEORI PENUNJANG

3.1 Gelombang Ultrasonik

Kecepatan perambatan gelombang tergantung dari jenis gelombang, elastisitas medium, kepadatan medium dan pada beberapa kasus adalah frekuensi. Sejak gelombang ultrasonik merupakan bentuk energi yang dipancarkan sebagai gelombang tekanan, kecepatan suara juga tergantung dari bentuk getarannya.

Persamaan kecepatan ultrasonik dalam udara adalah sebagai berikut :

$$V=\lambda . f = \lambda / T \qquad (1)$$

Dimana : V = kecepatan gelombang (m/s)

kecepatan gelombang ultrasonik diudara 330 m/s.

λ = panjang gelombang (m)

T = periode gelombang (s)

f = frekuensi (Hz)

2.1.1 Pemancaran dan Pemantulan Gelombang Ultrasonik

Ketika sebuah gelombang datar pada keadaan normal melewati hubungan muka antara dua media setengah tak terbatas, seperti pada gambar dibawah energi dari gelombang yang terjadi (I) dipisahkan antara sebuah gelombang terpantul (R) dan sebuah gelombang terpancar (T). Pada batasnya, jumlah pemindahan (terpancar) sama dengan jumlah dalam medium yang lain.

2.1.2 Difraksi Gelombang Ultrasonik

Pengertian dari difraksi / lenturan adalah pembelokan cahaya ketika melewati sebuah penghalang, difraksi menunjukkan perubahan dari gelombang depan (front wave) dalam melewati tepi dari bagian yang gelap, melewati menembus celah yang sempit, atau menjadi terpantul atau terpancar dari permukaan. Dalam difraksi cahaya pada tepi dari sebuah objek yang gelap, sinar kelihatannya dibelokkan, menghasilkan rumbai-rumbai cahaya dan jalur gelap atau berwarna. Sebuah perubahan yang mirip dari gelombang lain (seperti suara dan gelombang elektromagnetik) yang terjadi dan menyebabkan lekukan gelombang disekitar objek dalam jalurnya. Difraksi mencegah penggunaan keseluruhan di sebuah gelombang depan atau membawa gelombang depan ke suatu tujuan.

Efek difraksi seringkali menjadi perhatian pada banyak penggunaan gelombang ultrasonik seperti pada pengukuran peredaman suara dalam material, pemeriksaan yang tidak merusak pada bahan material dan under water sound. Gelombang ultrasonik memancarkan gelombangnya tidak selalu lurus, tergantung pada permukaan penghalangnya. Apabila penghalang berbentuk bola maka gelombang yang memancar kepada bola akan mengikuti bentuk bola.

2.1.3 Tranduser Ultrasonik

Energi dari gelombang ultrasonik dapat dibangkitkan dan dideteksi oleh alat yang dinamakan transduser. Transduser adalah suatu alat yang dapat mengubah suatu bentuk energi ke bentuk energi yang lain. Pada transduser ultrasonik merubah energi listrik ke energi gelombang ultrasonik (transmitter) atau dari energi gelombang ultrasonik menjadi energi listrik (receiver). Transduser yang umum digunakan untuk membangkitkan gelombang ultrasonik adalah *piezoelectric, magnetostrictive, electromagnetic, pneumatic* (whistles).

Transduser yang sering dipakai untuk menerima energi ultrasonik adalah *piezoelectric, capacitive* atau *electrostatic* dan *magnetostrictive device.*

Piezoelectric transduser digunakan pada seluruh jangkauan frekuensi ultrasonik untuk membangkitkan dan mendeteksi energi ultrasonik pada semua level intensitas. Transduser ini menggunakan komponen-komponen *piezoelectric*, seperti plat tipis (membran) atau konfigurasi yang pantas yang menghasilkan suatu pengisian pada permukaan dibawah pengaruh tekanan atau perubahan dimensi saat tertuju pada suatu medan listrik. Aplikasi *piezoelectric* transduser dari pengukuran kecepatan ultrasonik yaitu pada diagnosa penyakit dan pemeriksaan yang tidak merusak pada intensitas rendah untuk membersihkan dan pengetesan pada intensitas tinggi. Alat ini menggunakan transduser jenis *piezoelectric* pada pemancar dan penerima, karena mempunyai daya deteksi yang baik pada semua level intensitas dan harganya terjangkau.

Transduser ultrasonik yang paling umum digunakan dari jenis *piezoelectric* ini ditinjau dari jenis bahannya adalah : *Barium Titanate, Lithium Sulfat, Quartz.*

Barium Titanate adalah salah satu kristal pembangkit sinyal ultrasonik yang paling efisien karena barium titanate banyak dipakai pada alat-alat yang memerlukan acoustic power yang besar. Tetapi, *barium titanate* mempunyai impedansi mekanik yang sangat tinggi, karena itu *barium titanate* merupakan penerima gelombang ultrasonik yang buruk.

Lithium Sulfat sangat baik bila digunakan sebagai pembangkit gelombang ultrasonik, karena *lithium sulfat* memiliki efisiensi yang lebih rendah dibandingkan dengan *barium titanate*. Jadi *lithium sulfat* paling cocok digunakan sebagai penerima gelombang ultrasonik dibanding transduser lain.

Quartz adalah pembangkit gelombang ultrasonik yang paling tidak efisien, tetapi *quartz* mempunyai impedansi mekanik yang lebih rendah dibandingkan dengan *barium titanate*. Jadi idealnya *barium titanate* digunakan sebagai pembangkit gelombang ultrasonik, sedangkan sebagai penerimanya digunakan *lithium sulfat*.

2.2 Efek Doppler

Efek doppler adalah perubahan tinggi nada dari suatu sumber. Efek doppler dalam kehidupan sehari-hari yang sering kita temui misalnya : nada sirine mobil pemadam kebakaran jatuh dengan mendadak saat melalui kita, perubahan tinggi nada bunyi klakson ketika mobil lewat melaju dengan cepat, tinggi nada bunyi dari mesin mobil balap berubah saat melalui penonton.

Efek Doppler memiliki beberapa keadaan seperti :

1. Sumber bunyi bergerak ke arah pengamat yang diam
2. Sumber bunyi bergerak menjauhi pengamat yang diam
3. Pengamat bergerak ke arah sumber bunyi yang diam
4. Pengamat bergerak menjauhi sumber bunyi yang diam
5. Sumber bunyi dan pengamat bergerak saling mendekat
6. Sumber bunyi dan pengamat bergerak saling menjauh

Semua fenomena-fenomena yang terjadi diatas dikenal dengan **Efek Doppler**.

Efek Doppler juga terjadi bila sumber diam dan pengamat bergerak. Jika pengamat bergerak ke arah sumber, tinggi nada akan lebih tinggi (keadaan 3); dan jika pengamat bergerak menjauh dari sumber, maka tinggi nada akan lebih rendah (keadaan 4). Secara kuantitatif, perubahan frekuensi sedikit berbeda dibanding untuk sumber yang bergerak. Dalam hal ini jarak antara puncak gelombang, yaitu panjang gelombang λ, tidak berubah. Namun kecepatan puncak gelombang terhadap pengamat berubah. Jika pengamat bergerakl ke arah sumber, kecepatan gelombang relatif ke pengamat sebesar $v' = v + v_0$, dengan v kecepatan bunyi di udara (kita asumsikan udara) dan v_0 adalah kecepatan pengamat. Karena itu, besarnya frekuensi baru adalah :

$$f' = \frac{v'}{\lambda} = \frac{v + v_0}{\lambda} \qquad (2)$$

atau, karena $\lambda = v / f$ (pengamat bergerak ke arah sumber diam)

$$f' = \left(1 + \frac{v_0}{v}\right) f \qquad (3)$$

Jika pengamat bergerak menjauhi sumber, kecepatan relatif adalah $v' = v - v_0$ dan persamaan menjadi :

$$f' = \left(1 - \frac{v_0}{v}\right) f \qquad (4)$$

Pada saat gelombang bunyi yang dipantulkan dari benda bergerak dihambat, maka frekuensi gelombang pantul akan menjadi, karena efek Doppler, berbeda dengan frekuensi gelombang datang.

Gelombang datang dan gelombang pantul, bila digabungkan (misalnya, secara elektronik), akan berinterferensi satu dengan yang lainnya dan layangan dihasilkan. Frekuensi layangan yang sama dengan selisih dua frekuensi. Teknik Doppler ini digunakan dalam berbagai aplikasi kedokteran, biasanya menggunakan gelombang ultrasonik dengan frekuensi megahertz. Sebagai contoh, gelombang ultrasonik dipantulkan dari sel darah merah yang dapat digunakan menghitung kecepatan aliran darah. Dan caranya sama, teknik ini dapat digunakan untuk mendetaksi gerakan dada dari janin muda dan memonitor denyut jantungnya. Untuk waktu sebaik-baiknya, dari persamaan diatas dapat dituliskan sebagai sebuah persamaan tunggal yang mencakup semua kejadian baik sumber maupun pengamat bergerak :

$$f' = f\left(\frac{v \pm v_0}{v \mp v_s}\right) \quad (5)$$

Tanda diatas digunakan jika sumber dan / atau pengamat bergerak ke arah satu sama lain; tanda bawah digunakan jika mereka bergerak saling menjauh.

Efek Doppler dapat terjadi pada semua jenis gelombang yang lain juga. Cahaya dan jenis gelombang elektromagnetik lain memperlihatkan efek Doppler, walaupun rumus untuk pergeseran frekuensi tidak sama dengan persamaan diatas, namun mempunyai efek yang sama. Aplikasi penting lainnya seperti pada astronomi, ketika kecepatan galaksi-galaksi terjauh dapat dihitung dari pergeseran efek Doppler. Cahaya dari galaksi-galaksi tersebut bergeser diubah ke arah frekuensi rendah, mengindikasikan bahwa galaksi bergerak menjauh dari kita. (Ini disebut pergeseran merah karena warna merah mempunyai frekuensi paling rendah dalam cahaya tampak). Makin besar pergeseran frekuensi, makin besar kecepatan resesi (menjauh). Diperoleh bahwa semakin jauh galaksi dari kita, semakin cepat mereka bergerak menjauh dari kita.

Pada dataran agak tinggi, radar polisi untuk perangkap kecepatan mobil memanfaatkan efek Doppler (juga gelombang elektromagnetik) untuk mengukur kecepatan mobil yang mendekat.

2.3 Liquid Crystal Display (LCD)

Rangkaian display pada tugas akhir ini kami memakai rangkaian atau modul display jenis M 1632 yang mempunyai 2 baris, dan setiap baris dapat menampilkan 16 karakter. Kapasitas ROM internalnya 192 karakter dengan 5x7 dot matrix.

Kapasitas ROM internalnya 80x8 bit data (40x8 bit tiap baris). Alamat yang digunakan untuk menampilkan data pada LCD adalah :

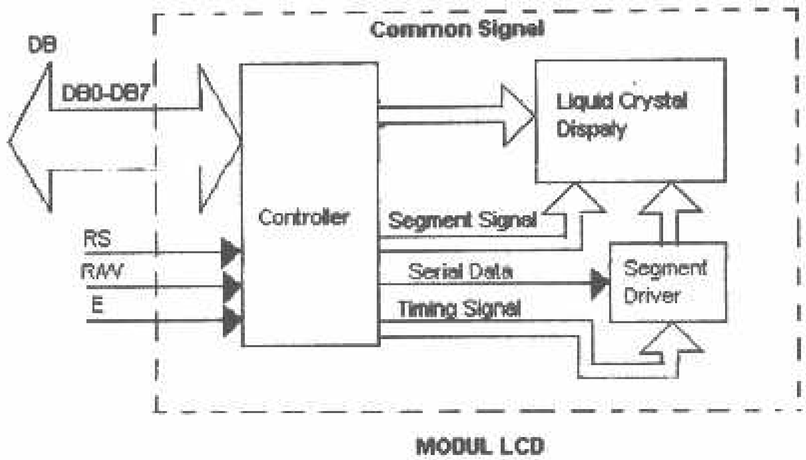
Baris 1, alamat 00H sampai 0FH.

Baris 2, alamat 40H sampai 4FH.

Tabel 2.1
Operasi Dasar LCD

RS	R/W	Operasi
0	0	Operasi internal
0	1	Baca kondisi sibuk
1	0	Tulis data
1	1	Baca data

Operasi dasar dari LCD M 1632 terdiri dari 4 kondisi, yaitu instruksi mengakses pemroses internal, instruksi membaca kondisi sibuk, instruksi menulis data dan instruksi membaca data. Pada tabel diatas dieprlihatkan operasi dasar LCD.



Gambar 2.1 Diagram Blok Penampil LCD

2.4 Rangkaian Bias Transistor

Gambar 2.2(a) adalah contoh dari *bias basis*. Sebuah sumber tegangan V_{BB} membias forward dioda emiter melalui resistor yang membatasi arus R_B. Hukum tegangan Kirchhoff menyatakan tegangan pada R_B adalah V_{BB} - V_{BE}.

Hukum Ohm memberikan arus basis. $I_B = \frac{V_{BB} - V_{BE}}{R_B}$ (6)

dimana V_{BE} = 0.7 V untuk transistor silikon (0,3 V untuk germanium).

2.4.1 Garis Beban dc

Dalam rangkaian kolektor, sumber tegangan V_{CC} membias reverse dioda kolektor melalui R_C. Dengan hukum tegangan Kirchhoff,

$$V_{CE} = V_{CC} - I_C R_C \quad (7)$$

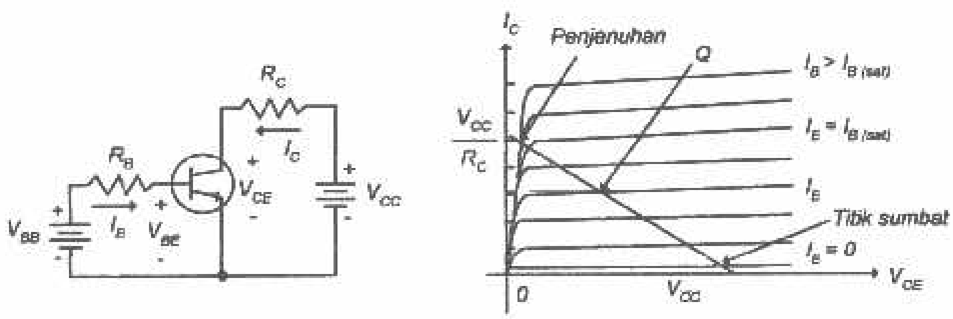
Dalam rangkaian yang diberikan, V_{CC} dan R_C adalah konstan, V_{CE} dan I_C adalah variabel.

Kita dapat menyusun kembali Persamaan (7) untuk mendapatkan :

$$I_C = -\frac{V_{CE}}{R_C} + \frac{V_{CC}}{R_C} \qquad (8)$$

Inilah adalah persamaan *linear*, serupa dengan

$$y = mx + b \qquad (9)$$



(a) (b)

Gambar 2.2 (a) Bias Basis (b) Garis Beban DC.

Seperti dibuktikan dalam matematik dasar, grafik dari persamaan linear selalu berupa garis lurus dengan kemiringan *m* dan perpotongan vertikal *b*.

Gambar 2.2(b) menunjukkan grafik dari Persamaan (8) memotong kurva-kurva dari kolektor. Perpotongan vertikal adalah pada V_{CC}/R_C. Perpotongan horizontal adalah pada V_{CC}, dan kemiringannya adalah $-1/R_C$. Garis ini disebut *garis beban dc* karena garis ini menyatakan semua titik operasi yang mungkin. Perpotongan dari garis beban dc dengan arus basis adalah titik operasi daripada transistor.

2.4.2 Titik Sumbat (*Cutoff*) dan Penjenuhan (*Saturation*)

Titik dimana garis beban memotong kurva $I_B = 0$ disebut *titik sumbat* (cutoff). Pada titik ini arus basis adalah nol dan arus kolektor kecil sehingga dapat diabaikan (hanya arus bocoran I_{CEO} yang ada). Pada titik sumbat, dioda emiter kehilangan forward bias, dan kerja transistor yang normal terhenti. Untuk perkiraan yang aproksimasi, tegangan kolektor-emiter adalah :

$$V_{CE(cutoff)} = V_{CC} \qquad (10)$$

Perpotongan dari garis beban dan kurva $I_B = I_{B(sat)}$ disebut *penjenuhan* (saturation). Pada titik ini arus basis sama dengan $I_{B(sat)}$ dan arus kolektor adalah *maksimum*. Pada penjenuhan, dioda kolektor kehilangan reverse bias dan kerja transistor yang normal terhenti. Untuk perkiraan yang aproksimasi, arus kolektor pada penjenuhan adalah :

$$I_{C(sat)} \cong \frac{V_{CC}}{R_C} \qquad (11)$$

dan arus basis yang tepat menimbulkan penjenuhan adalah :

$$I_{B(sat)} = \frac{I_{C(sat)}}{\beta_{dc}} \qquad (12)$$

Tegangan kolektor-emiter pada penjenuhan adalah :

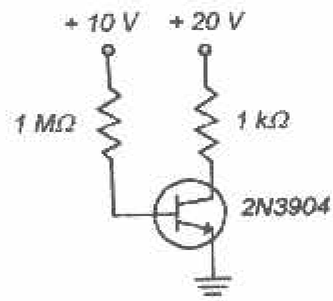
$$V_{CE} = V_{CE(sat)} \qquad (13)$$

dimana $V_{CE(sat)}$ diberikan pada lembar data, secara khusus beberapa persepuluh volt.

Jika arus basis besar daripada $I_{B(sat)}$, arus kolektor tak dapat bertambah karena dioda kolektor tidak lagi dibias reverse. Dengan perkataan lain, perpotongan dari garis beban dan kurva basis yang lebih tinggi masih menghasilkan titik penjenuhan yang sama dalam Gambar 2.2(b).

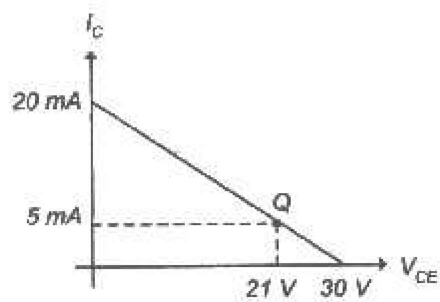
2.4.3 Daerah Aktif (*Actife Region*)

Semua titik operasi antara titik sumbat dan penjenuhan adalah *daerah aktif* dari transistor. Dalam daerah aktif, dioda emiter dibias forward dan dioda kolektor dibias reverse. Dengan persamaan (6) kita dapat menemukan arus basis dalam setiap rangkaian bias basis. Perpotongan dari arus basis dan garis beban adalah titik *stationer* (quiescent) *Q* dalam Gambar 2.2(b).



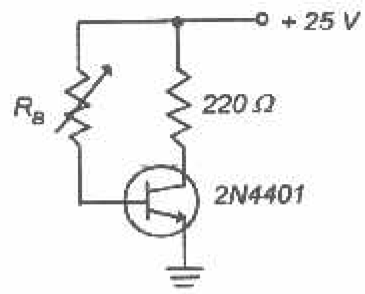
Gambar 2.3

Gambar 2.3 menunjukkan rangkaian yang sama dalam sistem pertanahan negatif (*negative-ground system*). Untuk menyederhanakan hanya kita perlihatkan tegangan catu +10 dan +20 V. Jika anda melihat skema yang disederhanakan seperti ini, ingat bahwa dalam hal ini berarti terminal-terminal negatif dari pencatu daya ditanahkan untuk mendapatkan lintasan yang lengkap untuk arus.



Gambar 2.4

Gambar 2.4 menunjukkan titik Q: Koordinatnya adalah I_C = 6 mA dan V_{CE} = 21 V. Ingat bahwa titik Q terletak pada garis beban dc karena garis beban menyatakan semua titik operasi yang mungkin. Jika kita mengubah harga dari R_B titik Q akan bergeser ke titik lain pada garis beban.



Gambar 2.5

Dalam transistor daya rendah, $V_{CE(sat)}$ hanya beberapa persepuluh volt, cukup kecil untuk diabaikan. Sebagai aproksimasi banyak orang membayangkan terminal kolektor-emitor *terhubung singkat*, ekivalen dengan V_{CE} = 0. Jika transistor dalam Gambar 2.5 jenuh, karena itu, kolektornya secara idealnya terhubung singkat ke tanah.

Arus kolektor melalui resistor 220 Ω mengalir ke bawah menghilang ke kolektor, serupa dengan air menghilang ke bawah melalui saluran buang. Inilah sebabnya transistor dengan emiter ditanahkan disebut *pelepas arus* (*current sink*); arus kolektor mengalir ke bawah melalui pelepas arus ke dalam tanah.

2.5 Mikrokontroller 89C51

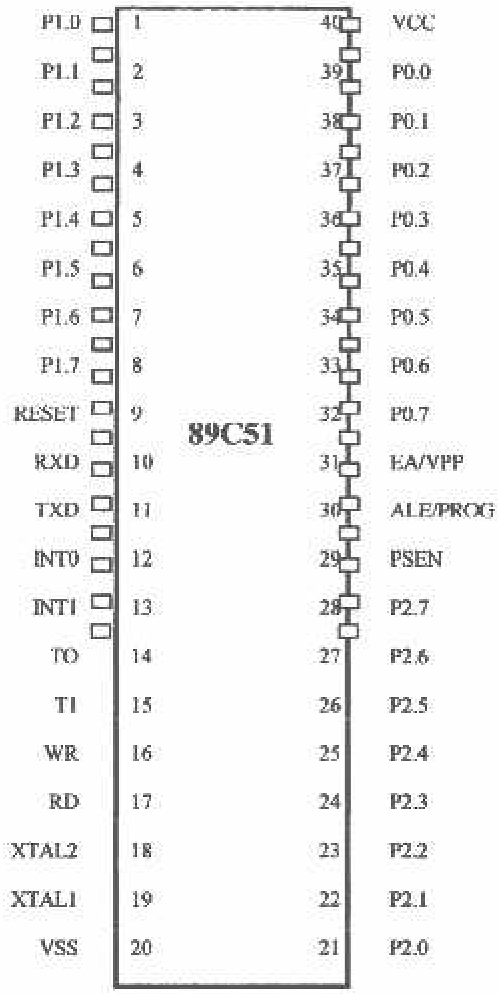
2.5.1 Arsitektur Mikrokontroller AT89C51

Mikrokontroler 89C51 memiliki spesifikasi secara umum sebagai berikut :

- Kompatibel dengan standar industri MCS-51.
- Microkontroller 8-bit dengan 4 Kbytes *Flash Programmable and Erasable Read Only Memory* (EPROM).
- 128 × 8-bit internal RAM
- 32 jalur *input/output*
- *Internal osilator* dan *timer circuit*.
- 1 buah jalur serial *input/output*.
- 256 set instruksi.

Mikrokontroller AT89C51 termasuk dalam keluarga IC microkontroller MCS-51 yang merupakan suatu kelompok produksi ATMEL yang berorientasi pada kontrol dan mempunyai 4 Kbyte *flash memory* yang dapat ditulis dan dibaca sampai 1000 kali yang dapat diprogram.

Mikrokontroller 89C51 memiliki 40 pin *dual in line package*, konfigurasi pin secara umum dapat dilihat di bawah ini :



Gambar 2.6 Konfigurasi Penyemat 89C51 [1]

Berikut ini adalah penjelasan fungsi dari masing-masing penyemat mikrokontroler 89C51.

- Penyemat 1 sampai 8 (*Port* 1)

  Merupakan *port* paralel 8 bit dua arah (*bidirectional*) yang dapat digunakan untuk berbagai keperluan.

---

(1) **Ibid, hal 2-24.**

- Penyemat 9

  Penyemat ini merupakan masukan Reset (RST). Logika tinggi yang dikenakan pada penyemat ini selama dua siklus mesin akan membuat mikrokontroler menjalankan rutin reset.

- Penyemat 10 sampai 17 (*Port* 3)

  Port 3 terdiri atas 8 saluran masukan/keluaran dua arah, juga dapat mempunyai fungsi-fungsi khusus.

- Penyemat 18 (XTAL 1) dan 19 (XTAL 2)

- XTAL1 merupakan masukan ke rangkaian osilator internal. Kaki ini dihubungkan dengan kristal. XTAL2 merupakan keluaran dari osilator.

- Penyemat 20 (*Ground*)

  Penyemat ini dihubungkan ke *ground* dari rangkaian.

- Penyemat 21 sampai 28 (*Port* 2)

  Port ini mengeluarkan alamat tinggi (A15-A8) selama dilakukan pengaksesan memori eksternal.

- Penyemat 29 (PSEN-*Program Store Enable*)

  Merupakan sinyal baca untuk mengeksekusi program eksternal.

- Penyemat 30 (ALE-*Address Latch Enable*)

  Untuk menahan alamat rendah (A0-A7) selama pengaksesan ke memori eksternal.

- Penyemat 31 (EA-*External Acces enable*)

  Digunakan untuk menentukan memori yang digunakan oleh MCS-51, memori program internal atau eksternal. Dicatu *high* jika menggunakan memori program internal dan *low* jika menggunakan memori program eksternal.

- Penyemat 32 sampai 39 (*Port* 0)

  Merupakan *port* I/O 8 bit dua arah. *Port* ini sebagai bus alamat rendah (A0-A7) dan bus data (D0-D7).

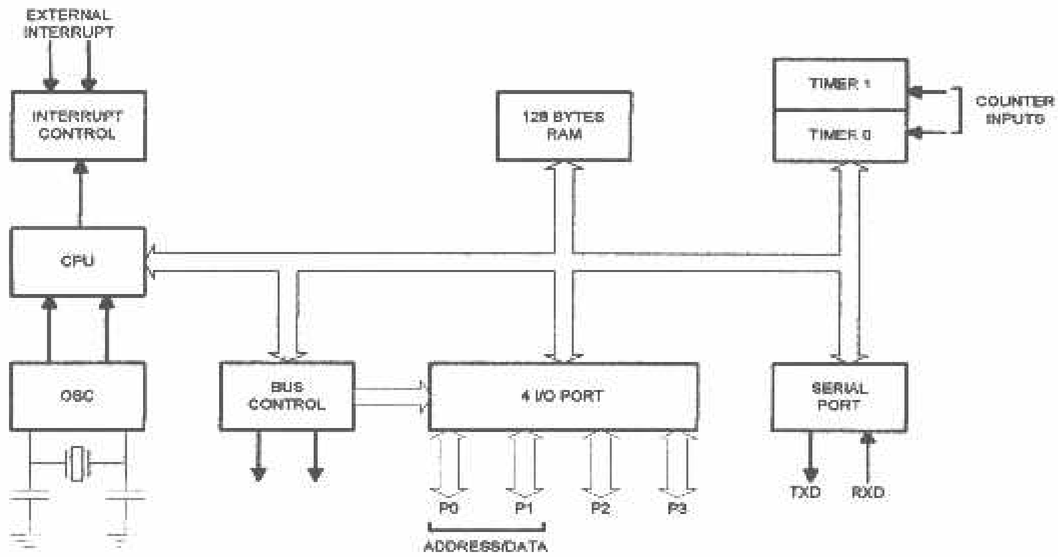
- Penyemat 40 (VCC)

  Merupakan masukan bagi catu daya positif sebesar 5 volt, dengan toleransi kurang lebih sebesar 10%.

Tabel 2.2
Keluarga MCS-51 [2]

Device	**ROMless Version**	**EPROM Version**	**ROM Bytes**	**RAM Bytes**	**8-bit I/O Port**	**16 bit Timer**
8051	89C51	-	4K	128	4	2
8051AH	89C51AH	89C51H	4K	128	4	2
8052AH	8032AH	8752BH	8K	256	4	3
80C51BH	80C31BH	87C51	4K	128	4	2
80C52	80C32	-	8K	256	4	3
83C51FA	80C51FA	87C51FA	8K	256	4	3
83C51FB	80C51FB	87C51FB	16K	256	4	3
83C152	80C152	-	8K	256	4	3

[2] **Embedded Controller Handbook**, Vol. 1, Intel Corp, 1988, hal 5-1



Gambar 2.7 Diagram Blok Mikrokontroler 89C51 [3)]

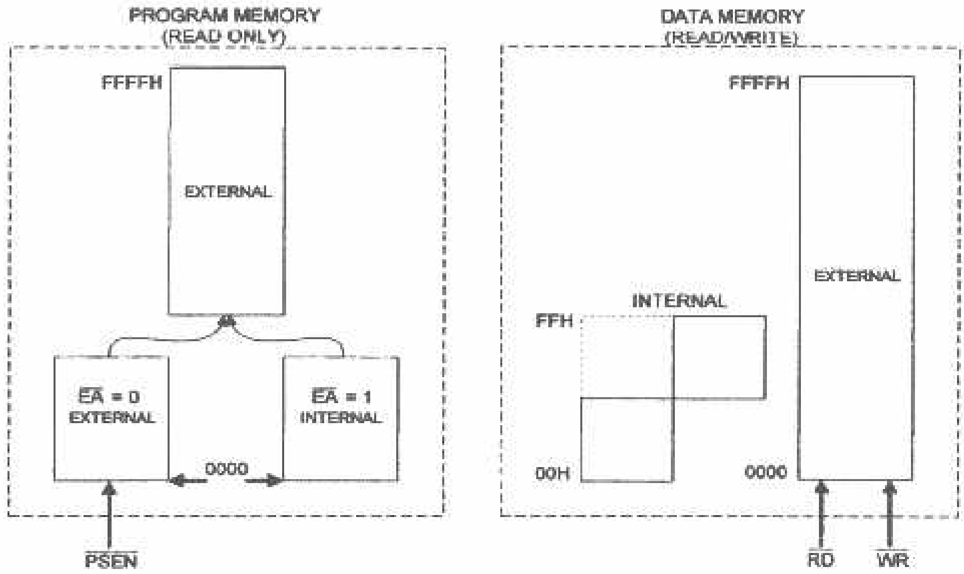
2.5.2 Memori

Semua mikrokontroler dalam keluarga MCS-51 memiliki pembagian ruang alamat (*address space*) untuk program dan data. Pemisahan memori program dan memori data membolehkan memori data untuk diakses oleh alamat 8 bit. Sekalipun demikian, alamat memori data 16 bit masih dapat dihasilkan melalui suatu register yang disebut DPTR (*Data Pointer Register*).

Memori program disimpan dalam ROM/EPROM dan memori data disimpan dalam RAM. Lebar alamat memori program adalah 16 bit tetapi alamat yang digunakan lebih kecil dari 64 kByte.

Gambar 2.8. menunjukkan struktur perbedaan memori program dan memori data. Pada memori program, ruang memori dapat diperluas (*expandable*) sampai 64 kByte. Untuk memilih penggunaan memori program internal (*on chip ROM*) atau memori program eksternal digunakan penyemat $\overline{EA}$ (*External*

Access enable). Setiap eksekusi memori program eksternal dipakai sinyal baca $\overline{PSEN}$ (*Program Store Enable*).



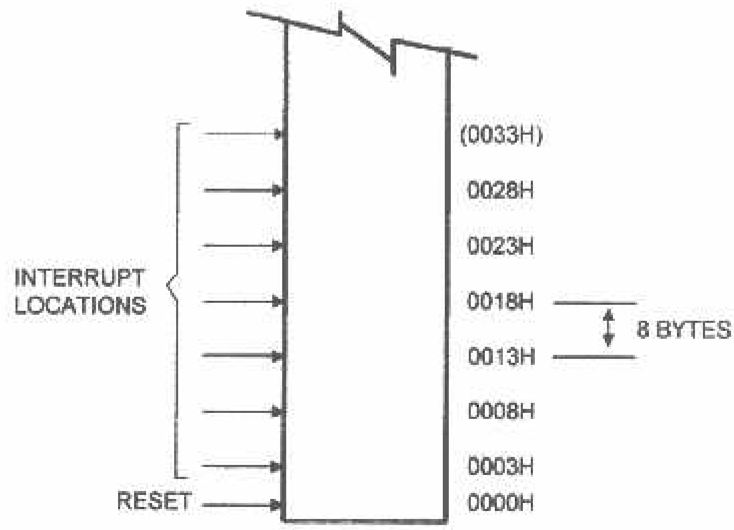
Gambar 2.8 Struktur Memori Mikrokontroler 89C51 [4)]

Memori data internal terdapat dalam chip berkapasitas antara 128 sampai 256 byte, tergantung jenisnya. Jika diperlukan, dapat dilakukan penambahan memori data eksternal, dengan maksimum sebesar 64 kByte. Untuk mengakses memori data eksternal digunakan sinyal baca ($\overline{RD}$) dan sinyal tulis ($\overline{WR}$).

2.5.2.1 Program Memori

Memori program internal mempunyai kapasitas 4 sampai 16 kByte, tergantung typenya. Khusus type 80C31 dan 80C32 tidak mempunyai memori program internal. Peta memori program bagian bawah ditunjukkan dalam Gambar 2.9.

[(3)] **Ibid**, hal 5-1



Gambar 2.9 Memori Program Bagian Bawah Mikrokontroler 89C51 [5]

Seperti dalam Gambar 9 setelah melaksanakan rutin reset, mikrokontroler memulai eksekusi program pada alamat 0000H. Setiap interupsi mempunyai lokasi yang tetap dalam memori program. Interupsi menyebabkan CPU melompat ke lokasi yang dituju di mana pada lokasi tersebut terdapat sub-routine yang harus dilaksanakan.

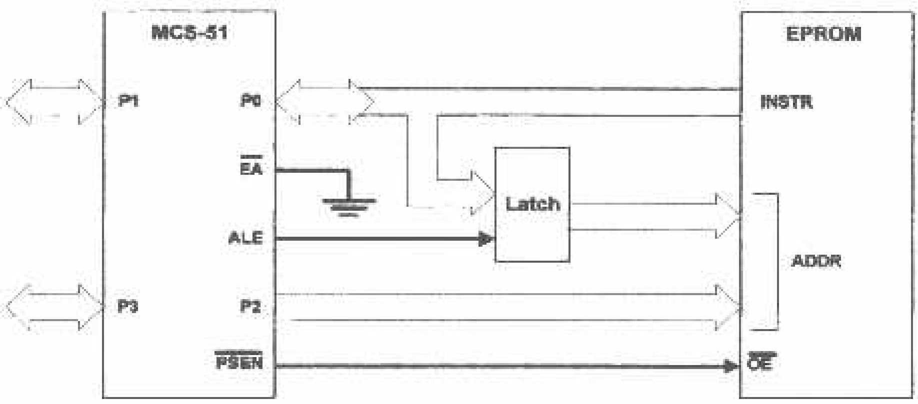
Pada mikrokontroler yang memiliki ROM/EPROM internal 4 kByte, apabila $\overline{EA}$ dihubungkan dengan V_{CC}, maka program memilih alamat 0000H sampai 1FFFH yaitu sebesar 4 kByte pada ROM internal.

Apabila $\overline{EA}$ dihubungkan dengan V_{SS} (ground), maka semua pengambilan program, mulai alamat 0000H sampai FFFFH (64 kByte) adalah pada ROM eksternal. Sinyal baca $\overline{PSEN}$ tidak aktif untuk pengambilan program pada ROM internal.

---

(4) **Ibid, hal 1-4.**
(5) **Ibid, hal 1-4.**

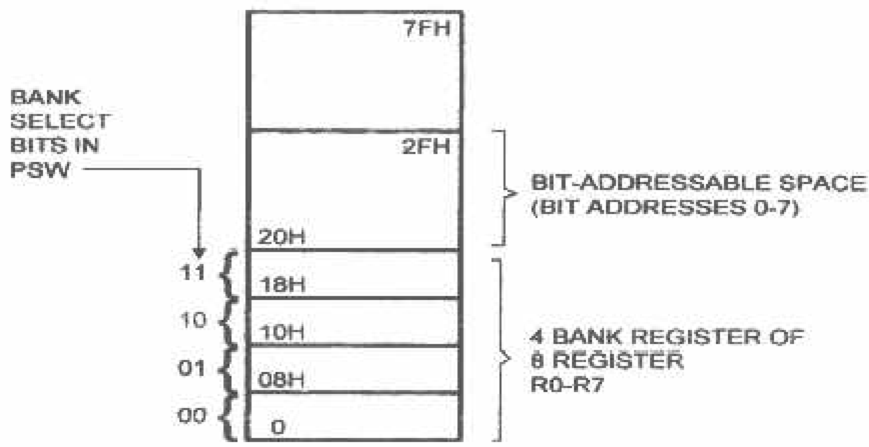
Konfigurasi perangkat keras yang diperlukan untuk mengeksekusi memori program eksternal terlihat dalam Gambar 2.10. Enam belas saluran I/O (pada *port P0* dan *port P2*) difungsikan sebagai bus selama pengambilan instruksi memori program eksternal. *Port P0* merupakan bus alamat yang dimultipleks dengan bus data. Sebagai bus alamat, *port P0* mengeluarkan alamat rendah (A0-A7) dari *Program Counter* (PC), dan kemudian berubah menjadi kondisi mengambang yang siap menerima memori program eksternal. Pada saat *port P0* mengeluarkan alamat rendah, sinyal ALE (*Address Latch Enable*) menahan alamat tersebut pada *latch*. *Port P2* merupakan alamat tinggi (A8-A15) yang bersama alamat rendah (A0-A7) membentuk alamat 16-bit.



Gambar 2.10 Konfigurasi Perangkat Keras untuk Eksekusi Memori Eksternal [6)]

2.5.2.2 Data Memori

Pada setiap keluarga mikrokontroler MCS-51 terdapat memori data yang berupa RAM internal sebesar 128 byte, seperti terlihat dalam Gambar 2.11. Dari jumlah tersebut 32 Byte terbawah dikelompokkan menjadi 4 bagian yang biasa disebut *bank*. Masing-masing *bank* tersebut terdiri dari 8 register yang dapat diakses program dengan cara pengalamatan register. Pemilihan *bank* tersebut dilakukan dengan melalui suatu register yang disebut *Program Status Word* (PSW). Sedangkan 16 Byte berikutnya di atas keempat bank register tersebut membentuk satu blok memori yang dapat dialamati per bit. Memori data ini dapat diakses dengan pengalamatan langsung atau pengalamatan tak langsung.



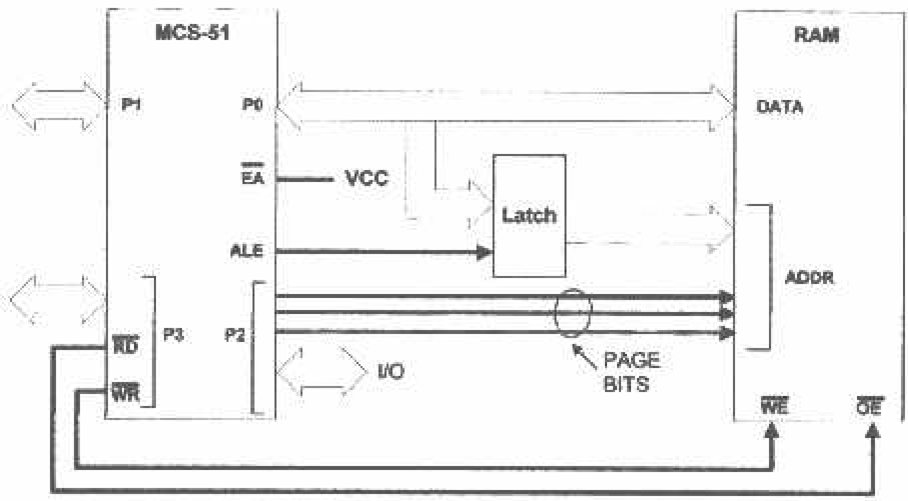
Gambar 2.11 Alamat Bawah Memori Data [7]

Konfigurasi perangkat keras yang diperlukan untuk mengakses memori data eksternal (RAM) ditunjukkan dalam Gambar 2.12.

---

[6] **Ibid**, hal 1-5

[7] **Ibid**, hal 1-6.

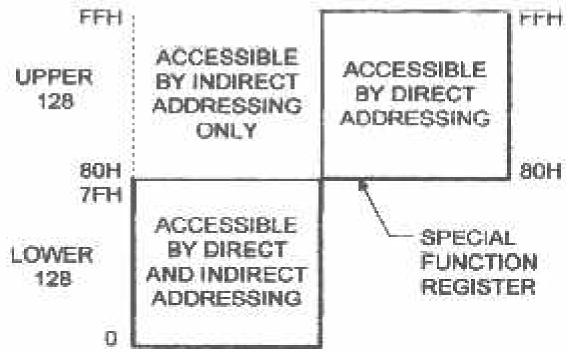


Gambar 2.12 Konfigurasi untuk Mengakses Memori Data Eksternal [8)]

2.5.3 Register Fungsi Khusus

Register dengan fungsi khusus, SFR (*Special Fuction Register*) adalah suatu register berisi register-register untuk pelayanan *latch port, timer, program status word,* kontrol peripheral dan lain sebagainya.yang terletak pada 128 Byte bagian atas memori data internal, yaitu pada alamat 80H sampai FFH seperti yang terlihat dalam Gambar 2.12. Pengalamatan SFR harus diakses secara langsung baik per bit atau per byte. Nama dan alamat register pada SFR ditunjukkan dalam Tabel 3. Ruang memori data internal dibagi menjadi 3 blok yaitu lower 128, upper 128, dan ruang SFR seperti yang terlihat pada Gambar 2.13

[(8)] **Ibid, hal 1-5**



Gambar 2.13 Peta Khusus untuk Fungsi Register [9)]

Tabel 2.3
Nama dan Alamat Register pada Register Fungsi Khusus [10)]

Simbol	Nama Register	Nilai setelah reset	Alamat
ACC	Accumulator	0000H	0E0H
B	B Register	00H	0F0H
PSW	Program Status Word	00H	0D0H
SP	Stack Pointer	07H	81H
DPTR	Data Pointer 2 bit		
DPL	Low Bytes	0000H	82H
DPH	High Bytes	0000H	83H
P0	Port 0	FFH	80H
P1	Port 1	FFH	90H
P2	Port 2	FFH	0A0H
P3	Port 3	FFH	0B0H
IP	Interupt Priority Control	XXX00000B	0B8H
IE	Interupt Enable Control	0XX00000B	0A8H
TMOD	*Timer/counter* Mode Control	00H	89H

(9) **Ibid, hal 1-6.**
(10) **Ibid, hal** 1-7.

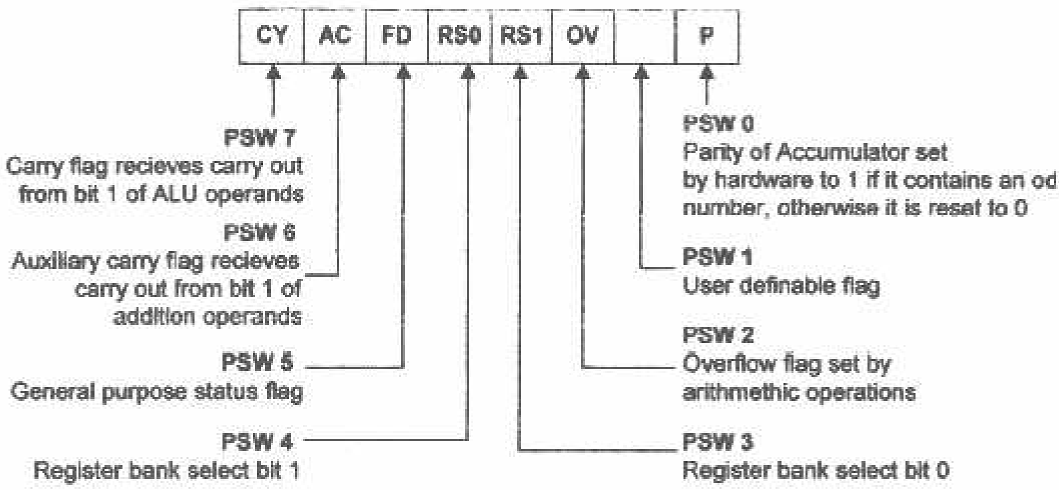
Simbol	Nama Register	Nilai setelah reset	Alamat
TCON	*Timer/counter* Control	00H	88H
TH0	*Timer/counter* 0 high byte	00H	8CH
TL0	*Timer/counter* 0 low byte	00H	8AH
TH1	*Timer/counter* 1 high byte	00H	8DH
TL1	*Timer/counter* 1 low byte	00H	8BH
SCON	Serial Control	00H	98H
SBUF	Serial Data Buffer	Independen	99H
PCON	Power Control	0XXXXXXX	87H

Beberapa kegunaan *Special Function Register* yang penting dapat dijelaskan sebagai berikut :

Accumulator (ACC) : merupakan register penting dalam operasi penambahan dan pengurangan.

Register B : merupakan register khusus yang berfungsi melayani operasi perkalian dan operasi pembagian.

Program Status Words (PSW) : terdiri dari beberapa bit status yang mencerminkan keadaan mikrokontroler. Terdiri dari *carry bit, Auxiliary Carry,* dua bit pemilih *bank,* bendera *overflow, parity bit,* dan dua bendera yang dapat didefinisikan sendiri oleh pemakai. Tabel 2.4 menunjukkan pemilihan register bank dengan RS0 dan RS1. Definisi bit register *Program Status Words* (PSW) diperlihatkan dalam Gambar 2.14.



Gambar 2.14 Susunan Bit Program Status Word [11]

Tabel 2.4
Pemilihan Register Bank dengan RS0 dan RS1 [12]

RS1	RS2	Register Bank	Alamat
0	0	0	00H – 07H
0	1	1	08H - 0FH
1	0	2	10H – 17H
1	1	3	18H - 1FH

Stack Pointer (SP) : merupakan register 8 bit. Register SP dapat diletakkan pada alamat manapun pada RAM internal. Isi register ini ditambah sebelum data

(11) **Ibid**, hal 2-11.
(12) **Ibid**, hal 2-12

disimpan, selama instruksi PUSH dan CALL. Pada saat *reset*, register SP diinisialisasi pada alamat 07H sehingga stack akan dimulai pada lokasi 08H.

Data Pointer (DPTR) : terdiri atas dua register, yaitu register byte tinggi (*Data Pointer High*, DPH) dan register byte rendah (*Data Pointer Low*, DPL). Fungsinya untuk menahan alamat 16 bit.

Port 0 sampai *Port 3* : merupakan register yang berfungsi untuk membaca dan mengeluarkan data pada *port 0, 1, 2* dan *3*. Masing-masing register ini dapat dialamati per bit maupun per byte.

Control Register : terdiri dari register yang mempunyai fungsi kontrol. Untuk mengontrol sistem interupsi, terdapat dua register khusus, yaitu register IP (*Interupt Priority*) dan register IE (*Interupt Enable*). Untuk mengontrol pelayanan *timer atau counter* terdapat register khusus, yaitu register TMOD (*Timer/counter Mode Control*) dan register TCON (*Timer/counter Control*), serta untuk pelayanan port serial menggunakan SCON (*Serial port Control*).

2.5.4 Interupsi

Pada saat mikrokontroler 89C51 sedang melaksanakan suatu program, kita dapat menghentikan pelaksanaan program tersebut secara sementara dengan instruksi interupsi (*Interrupt*).

Interupsi pada Mikrokontroler 89C51 dibedakan dalam 2 jenis, yaitu :

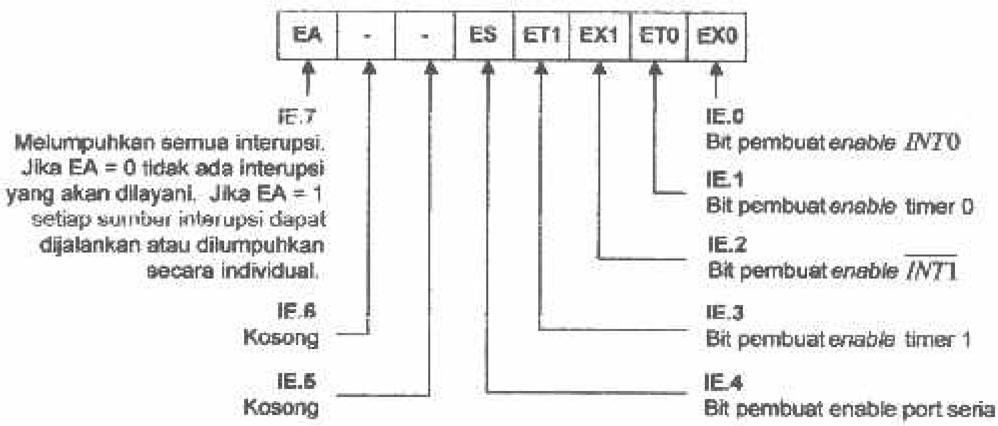
1. Interupsi yang tak dapat dihalangi oleh perangkat lunak (*non maskable interrupt*), misalnya Reset.
2. Interupsi yang dapat dihalangi oleh perangkat lunak (*maskable interrupt*). Contoh interupsi jenis ini adalah $\overline{INT0}$ dan $\overline{INT1}$ (eksternal) serta *Timer/counter* 0, *Timer/counter* 1, dan interupsi dari port serial (internal).

Mikrokontroler 89C51 menyediakan 5 sumber interupsi yaitu 2 interupsi eksternal, 2 interupsi *timer*, dan satu interupsi port serial. Alamat awal layanan rutin interupsi dari setiap sumber interupsi diperlihatkan dalam Tabel 2.5.

Masing-masing sumber interupsi dapat di *enable/disable* secara perangkat lunak yaitu dengan mengatur satu bit di SFR yang bernama IE (*Interrupt Enable*). Susunan bit register IE berikut penjelasan fungsi dari masing-masing bit diperlihatkan dalam Gambar 2.15. Sebagai contoh, jika akan mengaktifkan interupsi 0 ($\overline{INT0}$), maka nilai yang harus diberikan ke IE adalah 81H (yaitu memberikan logika 1 ke EA dan EX0). Kesensitifan interupsi ini dapat dipilih melalui bit IT 0 atau IT 1 pada register *Timer/counter Control Register* (TCON).

Tabel 2.5.
Alamat Layanan Rutin Interupsi [13)]

Nama	Lokasi	Alat interupsi
Reset	00H	Power on reset
$\overline{INT0}$	03H	INT 0
Timer 0	13H	*Timer* 0
$\overline{INT1}$	0BH	INT 1
Timer 1	1BH	*Timer* 1
Sint	23H	Port I/O serial



Gambar 2.15. Susunan Bit - Bit *Interrupt Enable* (IE) [14)]

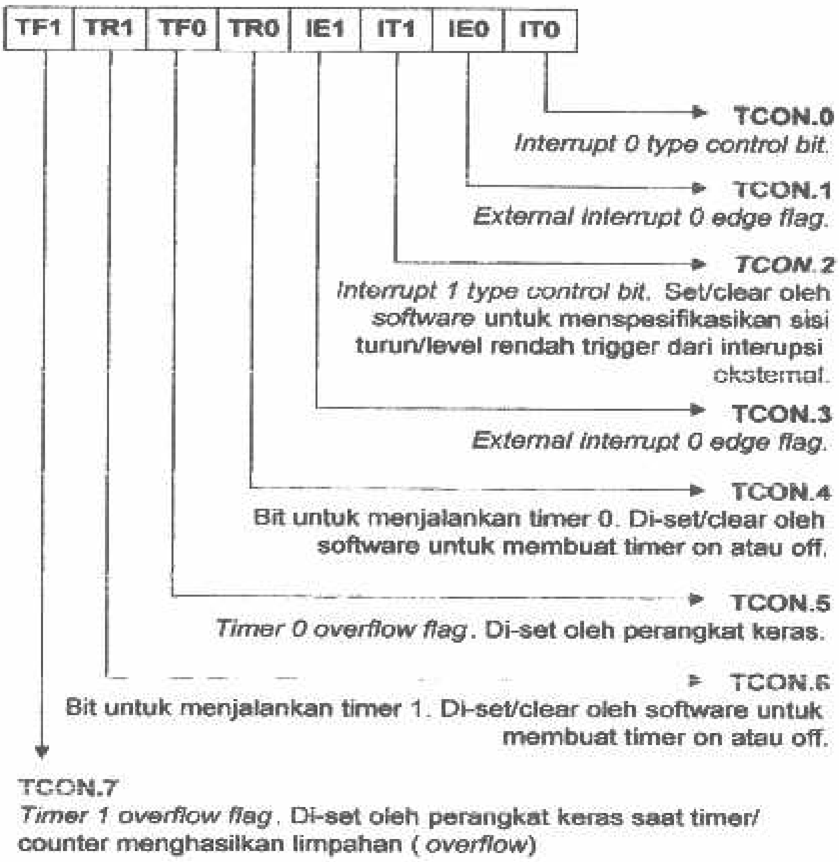
Interupsi eksternal $\overline{INT0}$ dan $\overline{INT1}$ masing-masing dapat diaktifkan berdasarkan level atau transisi, tergantung pada bit IT0 dan IT1 dalam register TCON. Flag yang menghasilkan interupsi ini adalah bit dalam IE0 dan IE1 dari register TCON.

---

(13) **Ibid, hal 2-23.**
(14) **Ibid, hal 2-23.**

2.5.5 Timer dan Counter

Pada mikrokontroler 89C51 terdapat dua buah *timer/counter* 16 bit yang dapat diatur melalui perangkat lunak, yaitu *timer/counter* 0 dan *timer/counter* 1. Pengontrol kerja *timer/counter* adalah register *Timer Control* (TCON) di mana susunan bit-bitnya ditunjukkan dalam Gambar 16.



Gambar 2.16. Susunan Bit - Bit TCON (*Timer Controller*) [15]

Kedua *timer* tersebut dapat dikonfigurasikan sebagai *timer* atau *counter*. Untuk fungsi *timer*, isi register *timer* ditambah 1 tiap siklus mesin sehingga dapat digunakan sebagai penghitung siklus mesin.

---

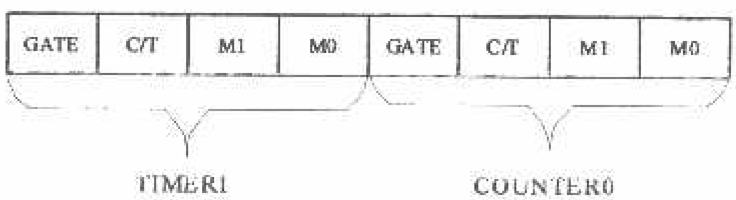
[15] **Ibid**, hal 2-23.

Sedang untuk fungsi *counter* isi register ditambah 1 setiap ada transisi 1 ke 0 pada pin masukan eksternal.

Mode penggunaan *timer* 0 dan 1 adalah sebagai berikut :

- MODE 0 : *timer* 13 bit dengan 5 bit *prescaler*.
- MODE 1 : *timer* 16 bit tanpa *prescaler*.
- MODE 2 : 8 bit *counter auto reload*.
- MODE 3 : *timer* 8 bit yang terpisah.

Pengontrol pemilihan mode operasi *timer/counter* adalah register *Timer Mode* (TMOD) di mana susunan bit-bitnya ditunjukkan dalam Gambar 2.17. Register ini tidak dapat dialamati dengan pengalamatan bit tetapi harus dengan pengalamatan byte.



GATE : Saat TRx (dalam TCON) di set 1 dan GATE = 1, TIMER/COUNTERx akan berjalan ketika TRx = 1 (timer dikontrol software).

C/T : Pemilihan fungsi timer atau counter, clear (0) untuk operasi timer dengan masukan dari sistem clock internal, set (1) untuk operasi counter dengan masukan dari pena T0 dan T1.

M : Bit pemilih mode.

Gambar 2.17. Susunan Bit - Bit Register Timer Mode (TMOD) [16]

[16] Ibid, hal 2-24.

2.5.6 Masukan dan Keluaran

Mikrokontroler 87C51 memiliki 32 saluran yang dibagi menjadi 4 buah port 8 bit. Masing-masing port ini bersifat dua arah (*bidirectional*) yaitu dapat digunakan sebagai masukan atau keluaran. *Port 0* dan *Port 2* digunakan sebagai saluran data (P0) dan saluran alamat (P0 dan P2) untuk mengakses memori eksternal. *Port 1* berfungsi sebagai *port* masukan atau keluaran yang dapat dialamati per-bit maupun per-byte. *Port 3* selain sebagai *port* masukan/keluaran biasa, juga mempunyai fungsi khusus seperti terlihat dalam Tabel 2.6.

Tabel 2.6.
Fungsi Khusus *Port 3* [17]

Nama	Fungsi Khusus
Port 3.0	RxD (*port* masukan serial)
Port 3.1	TxD (*port* keluaran serial)
Port 3.2	$\overline{INT0}$ (interupsi eksternal 0)
Port 3.3	$\overline{INT1}$ (interupsi eksternal 1)
Port 3.4	T0 (masukan eksternal *timer* 0)
Port 3.5	T1 (masukan eksternal *timer* 1)
Port 3.6	$\overline{WR}$ (sinyal tulis memori data eksternal)
Port 3.7	$\overline{RD}$ (sinyal baca memori data eksternal)

[17] **Ibid, hal 2-25**

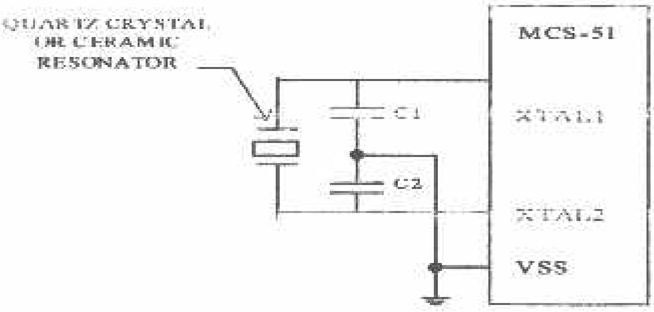
2.5.7 Reset

Untuk mereset rangkaian mikrokontroler, dipilih rangkaian *power-on* reset. Rangkaian ini akan mereset mikrokontroler secara otomatis setiap kali catu daya dinyalakan.

Prinsip kerja rangkaian reset adalah : saat catu daya diaktifkan, rangkaian reset akan menahan logika tinggi pada penyemat RST untuk jangka waktu tertentu. Jangka waktu tertentu tersebut ditentukan oleh pengosongan muatan pada kondensator. Untuk memastikan keabsahan reset, logika tinggi tersebut harus ditahan untuk waktu yang lebih lama dari dua siklus mesin ditambah waktu mulai hidup (*start on*) osilator (MCS-51 Family User's Manual, 1994 : 7-28).

2.5.8 Pewaktuan

Mikrokontroler 89C51 memiliki rangkaian osilator internal yang mengacu pada referensi frekuensi pada XTAL1 dan XTAL2. Referensi frekuensi berupa kristal dan kapasitor yang dihubungkan ke ground seperti yang ditunjukkan dalam Gambar 2.18. Frekuensi kerja osilator pada mikrokontroler 89C51 adalah 3,5 MHz sampai 12 MHz



Gambar 2.18. Pewaktuan melalui Osilator *On-Chip* [18]

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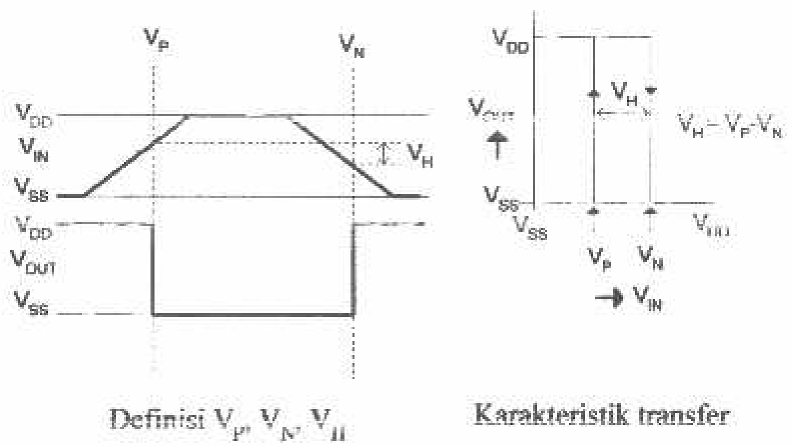
[18] **Ibid**, hal 2-23.

2.5.9 4093 Penyulut Schmitt NAND 2 input

IC 40934 adalah IC gerbang NAND dengan schmidt trigger. Schmitt Trigger berfungsi mengubah gelombang sinus menjadi square (squaring) . Dalam tugas akhir ini 4093 berfungsi sebagai rangkaian squaring. Gerbang NAND 4093 ditrigger di berbagai titik oleh input sinyal untuk isyarat menuju positif dan untuk isyarat menuju negatif. Selisih antara tegangan positif (Vp) dan tegangan negatif (V_N) dan tegangan negatif (V_N) ditentukan sebagai tegangan histerisis (V_H).

Gambar 2.19 menunjukkan definisi V_P, V_N, dan V_H serta karakteristik transfer dari gerbang 4093.



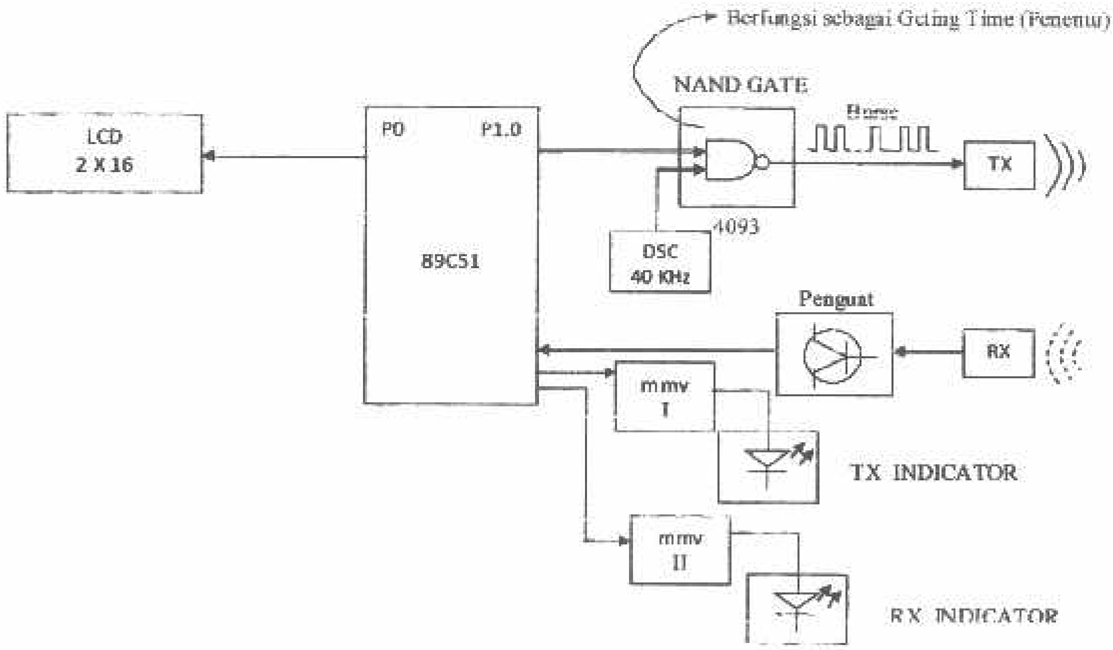
Gambar 2.19. Definisi V_P, V_N, dan V_H serta Karakteristik Transfer IC 4093 [19]

[19] Ibid, hal 266.

BAB III

PERANCANGAN ALAT

3.1 Konfigurasi Sistem



Gambar 3.1 Diagram Blok Sistem

Prinsip kerja dari alat ini adalah sebagai berikut :

1. Mikrokontroller akan mengirimkan sinyal start pada system.
2. Kemudian run counter
3. Ketika pantulan diterima, komparator memerintahkan stop pada system
4. Kemudian system akan mengambil nilai conter
5. Sistem akan menghitung jarak (S=V x t)
6. Hasil dari perhitungan jarak oleh system tersebut akan ditampilkan pada LCD

3.2 Perancangan Perangkat Keras *(Hardwere)*

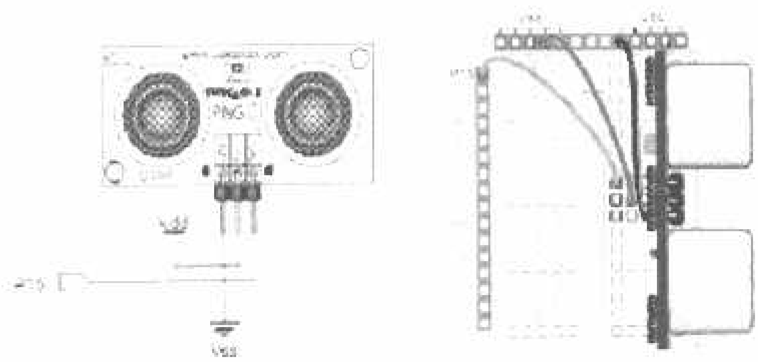
3.2.1 Sensor Ultrasonik

Sensor adalah peralatan yang digunakan untuk merubah suatu besaran fisik menjadi besaran listrik sehingga dapat dianalisa dengan rangkaian listrik tertentu. Pada perancangan alat kali ini menggunakan sensor ultrasonik sebagai pendeteksi jarak benda.

Sensor digunakan sebagai pemberi masukan data pada mikrokontroller. Data yang diterima dari sensor ini akan diproses oleh mikrokontroller untuk mengetahui jarak benda yang akan diukur, setelah itu mikrokontroller akan mengeluarkan data tersebut ke LCD yang akan menampilkan karakter berupa tulisan hasil dari pengukuran.

Sensor ultrasonik mendeteksi jarak objek dengan cara memancarkan gelombang 40 KHz kemudian mendeteksi pantulannya. Sensor ultrasonik memancarkan gelombang ultrasonik sesuai dengan kontrol dari mikrokontroler pengendali. Gelombang ultrasonik ini melalui udara dengan kecepatan 340 meter per detik pada suhu kamar, mengenai objek dan memantulkan kembali ke sensor. Sensor ultrasonik mengeluarkan pulsa output high setelah memancarkan gelombang ultrasonik dan setelah gelombang pantulan terdeteksi akan membuat output low. Lebar pulsa high akan sesuai dengan lama waktu tempuh gelombang ultrasonik untuk 2x jarak ukur dengan objek. Tegangan yang digunakan untuk mengaktifkan sensor ultrasinik adalah sebesar 5 volt. Sensor ultrasonik dihubungkan ke mikrokontroler, data yang dikirim merupakan data biner yaitu 0 dan 1, pada saat mendeteksi jarak pulsa yang digunakan adalah 1 (high).

Pengaktifan Sensor Ultrasonik

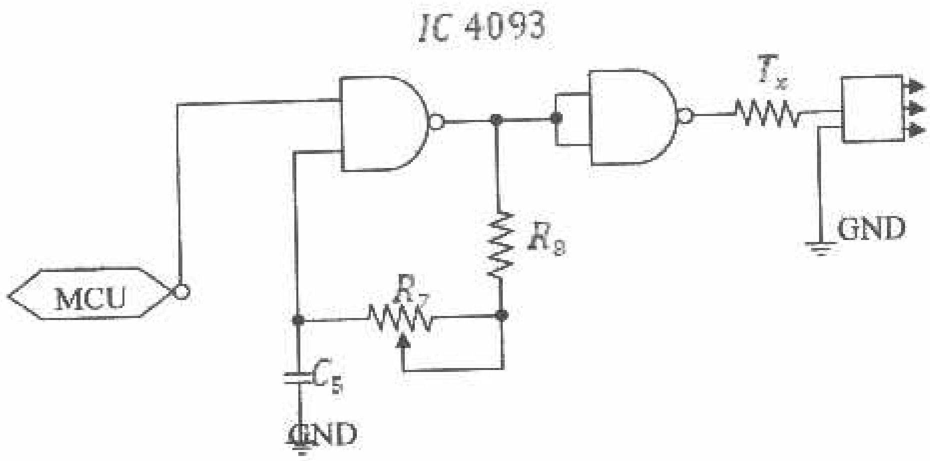


Gambar 3.2 Skematik hubungan pin

Untuk pengaktifan sensor ultrasonik, hubungkan Pin Vss ke Ground, kemudian pin Vdd ke catu daya yang keluarannya sudah diset 5V, setelah batere dihubungkan dengan IC Regulator 7805, tinggal Pin SIG dihubungkan ke pin di Mikrokontroller, buat sensor ke port P1.7, sedangkan indikator output P3.7

3.2.2 Rangkaian Pemancar *(Transmitter)*

Rangkaian pemancar berfungsi untuk memancarkan gelombang ultrasonik dengan menggunakan sensor ultrasonik (Tx) yang nantinya diterima oleh rangkaian penerima sensor ultrasonik (Rx).



Gambar 3.3 Rangkaian Pemancar Ultrasonik.

Mengacu pada gambar di atas, agar sensor ultrasonik dapat memancarkan gelombang ultrasonik diperlukan data biner 1 dan 0. Pada saat mendeteksi jarak pulsa yang digunakan adalah 0 (Low). Dan membutuhkan arus sebesar 20 mA dan tegangan (V ul) sebesar 1,2 Volt.

Maka dapat dihitung Rs sebagai berikut :

$$R_{tx} = \frac{V_{cc} - V_{ul}}{1}$$

$$R_{tx} = \frac{5 - 12}{20 \times 10^{-3}}$$

$$R_{tx} = \frac{3,8}{20 \times 10^{-3}}$$

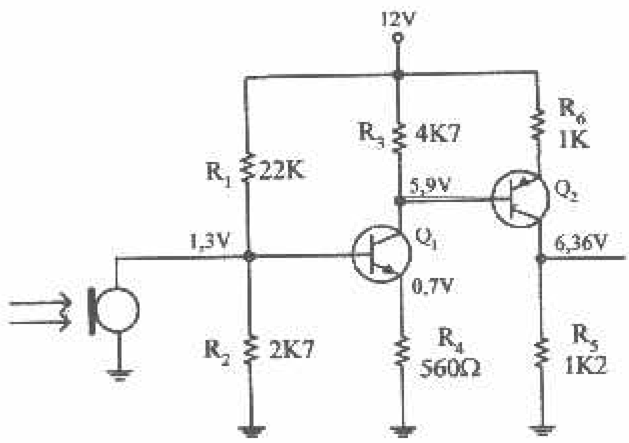
$$R_{tx} = \frac{3,8}{20 \times 10^{-3}}$$

$$R_{tx} = 190\Omega \doteq 120\Omega$$

Jadi resistor yang terpasang pada rangkaian pemancar adalah 220Ω

3.1.3. Perencanaan Rangkaian Penguat Ultrasonic Terima (RX)

Rangkaian penguat ultrasonic terima ditunjukkan pada Gambar 3.3. Penggunaan penguat transistor berkaskade bertujuan untuk mendapatkan gain yang tinggi dan stabil. Karena penggunaan penguat transistor tunggal dengan gain yang tinggi cenderung penguat mudah berosilasi.



Gambar 3.4 Penguat Ultrasonic terima (RX)

Gambar 3.4 adalah penguat kopling langsung dua tingkat disini nampak tidak digunakannya kapasitor kopling atau bypass, oleh karena itu tegangan dc diperkuat seperti halnya ac.

Dengan pembagi tegangan R_1 dan R_2, maka pada basis Q_1 terdapat tegangan

$$V_{BQ_1} = \frac{R_2}{R_1 + R_2} \times 12\ V$$

$$= \frac{2K7}{2K7 + 22K} \times 12\ V$$

$$= 1{,}3\ V$$

dan ini memberikan tegangan

$$V_{EQ_1} = V_{BQ_1} - 0{,}6\ V$$

$$= 1{,}3\ V - 0{,}6\ V$$

$$= 0{,}7\ V$$

dan $I_{EQ_1} = \frac{V_{EQ_1}}{R_4}$

$$= \frac{0{,}7\ V}{560\ \Omega}$$

$$= 1{,}27\ mA$$

karena $\alpha = 1$ maka

$$I_{EQ_1} = I_{CQ_1}$$

dan menyebabkan besar tegangan

$$V_{CQ_1} = I_{CQ_1} \times R_3$$

$$= 1{,}27\ mA \times 4{,}7 \cdot 10^3$$

$$= 5{,}9\ V$$

dan $V_{EQ_1} = V_{CQ_1} - 0{,}6\ V$

$$= 5{,}9\ V - 0{,}6\ V$$

$$= 5{,}3\ V$$

maka $I_{EQ_2} = \frac{5{,}3\ V}{1\ K}$

$$= 5{,}3\ mA$$

dan memberikan tegangan output tanpa sinyal

$$V_{CQ_2} = I_{EQ_2} \times R_5$$

$$= 5{,}3 \cdot 10^{-3}\ mA \times 1{,}2 \cdot 10^3$$

$$= 6{,}36\ V$$

Dari dua penguat Q_1 dan Q_2 memberikan penguatan A_1 dan A_2 dimana :

$$A = A_1 . A_2$$

$$\text{dimana } A_1 = \frac{R_3}{R_4}$$

$$= \frac{4K7}{560}$$

$$= 8{,}39 \text{ kali}$$

$$\text{dan } A_2 = \frac{R_5}{R_6}$$

$$= \frac{1K2}{1K}$$

$$= 1{,}2 \text{ kali}$$

$$\text{Jadi } A = 8{,}39 \times 1{,}2$$

$$= 10{,}068 \text{ kali}$$

$$\text{Maka } A = 20 \log 10{,}068Z$$

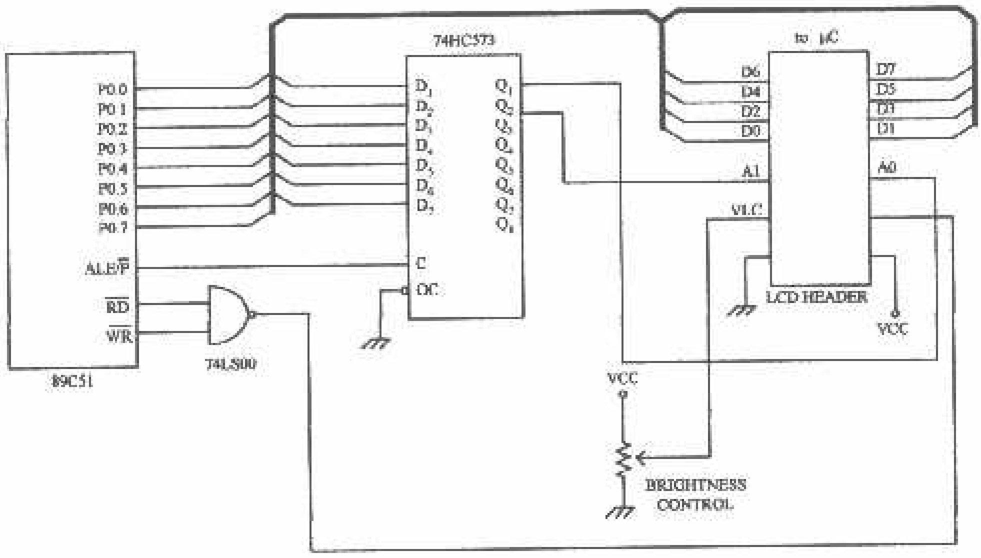
$$= 20 \text{ dB}$$

3.1.4 Perencanaan Rangkaian Peraga LCD

Dalam perencanaan rangkaian display LCD ditentukan sebagai berikut :

Alamat write control register	=	A000H
Alamat write data register	=	A001H
Alamat read control register	=	A002H
Alamat read data register	=	A003H

Realisasi dari perencanaan tersebut di atas ditunjukkan pada Gambar 3.5.



Gambar 3.5 Rangkaian Display LCD

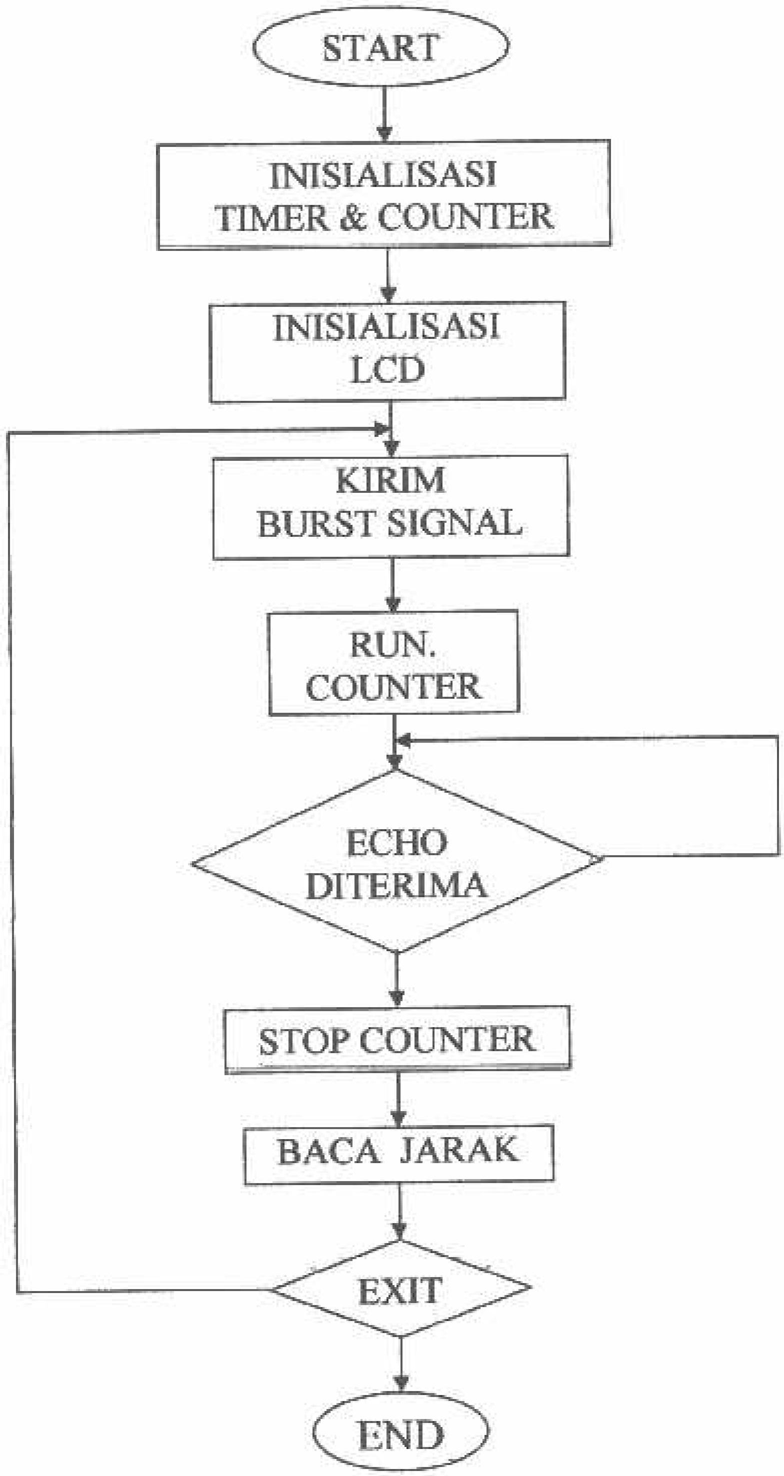
Gerbang NAND 7400 berfungsi untuk membangkitkan sinyal enable LCD.

3.3 Perancangan Perangkat Lunak

Dalam sub bab ini akan dijelaskan tentang kronologis proses pembuatan program dan rutin yang penting dari keseluruhan perangkat lunak yang telah dibuat dan langkah pertama yang dilakukan adalah menulis program dalam bahasa assembler, kemudian disimulasi secara software dengan menggunakan AVSTM51 (Avocet Simulator 51), suatu program yang mensimulasi kerja MCS51 pada komputer pribadi. Apabila program sudah benar, maka program di kompile dengan Cross Assembler 51 sehingga menjadi objek file. Bahasa mesin tersebut dapat dimasukkan ke dalam EPROM melalui EPROM Writter. Apabila masih terdapat kesalahan dalam pengendalian perangkat keras, maka proses diulang mulai dari langkah pertama, demikian seterusnya hingga perangkat lunak menjadi sempurna.

3.3.1 Flowchart

Adapun flowchart dari program yang dibuat ditunjukkan gambar 3.6 berikut ini



BAB IV

PENGUJIAN ALAT

4.1 Pengujian Osilator 40 kHz

Dalam bab ini akan dibahas tentang pengujian berdasarkan perencanaan dari sistem yang dibuat. Untuk mengetahui sistem aplikasi dapat bekerja sesuai dengan fungsi yang diharapkan, diperlukan pengujian terhadap sistem per modul (blok rangkaian) maupun pengujian secara keseluruhan, yaitu dengan kalibrasi membandingkan alat ukur jarak yang dirancang dengan alat ukur konvensional.

Alat – alat ukur yang dipakai dalam pengujian :

1. Multimeter digital UNI-T type UT30F
2. Osiloscope kenwood 1021
3. Alat ukur konvensional (meteran)

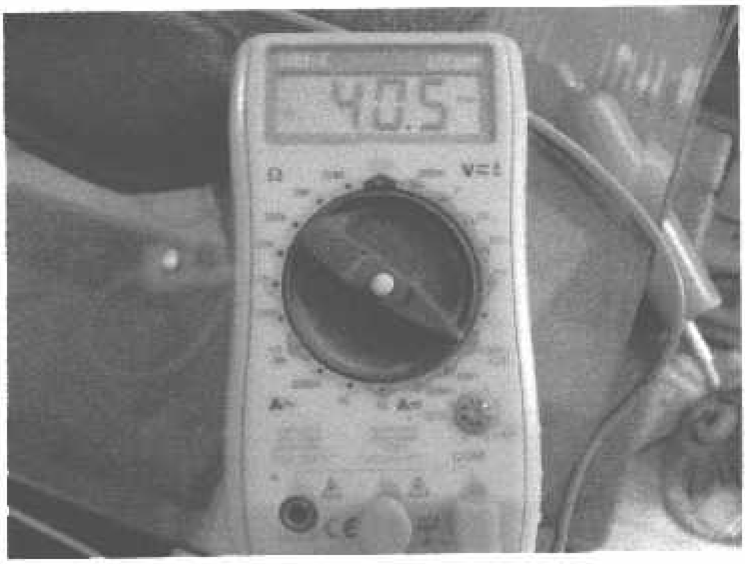
4.1.1 Pengujian Osilator 40 kHz

Pengujian osilator 40 Khz berfungsi untuk mengetahui bentuk sinyal osilator dengan menggunakan alat ukur osciloscop. Sehingga dapat diketahui optimum alat yang dirancang .

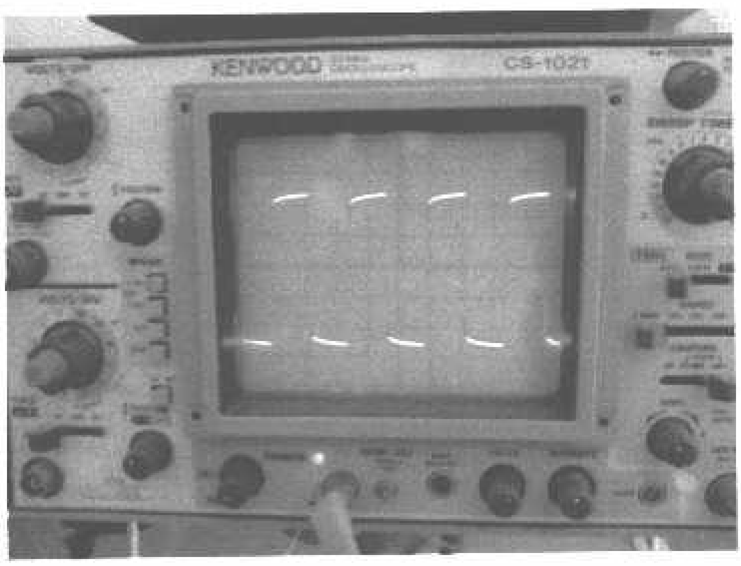
Prosedur pengujian osilator 40 kHz adalah sebagai berikut :

1. Hubungkan osilator CH1 pada pin 3 IC 4093
2. Hubungkan ground osilator ke ground sistem yang diuji
3. Amati bentuk gelombangnya
4. Hubungkan DFC (Digital Frekuensi Counter) pada pin 3 IC 4093

5. Baca frekuensi output



Gambar 4.1 Frekuensi osilator



Gambar 4.2 output sinyal osilator 40 kHz pada modus kontinyu

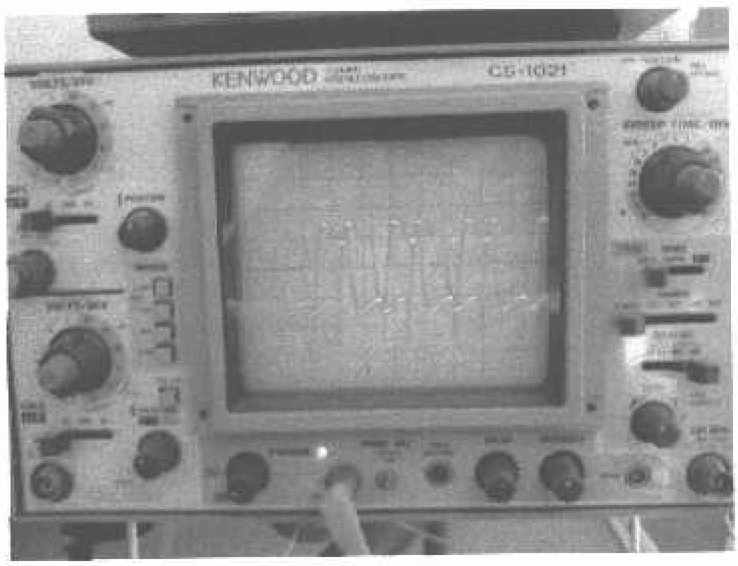
Analisa ganbar 4.2 :

Heat sinyal ini sesuai dengan output osilator yang digunakan, yaitu Astabil Multivibrator (Osilator 40 kHz)

4.1.2 Pengujian Rangkaian Tranduser Pancar

Prosedur pengujian rangkaian tranduser pancar adalah sebagai berikut :

1. Hubungkan osilator CH1 pada pin tranduser
2. Hubungkan ground asilator ke ground sistem yang diuji
3. Amati bentuk gelombangnya



Gambar 4.3 Bentuk Sinyal 40 kHz Pada Transduser Pancar Modus Kontinyu

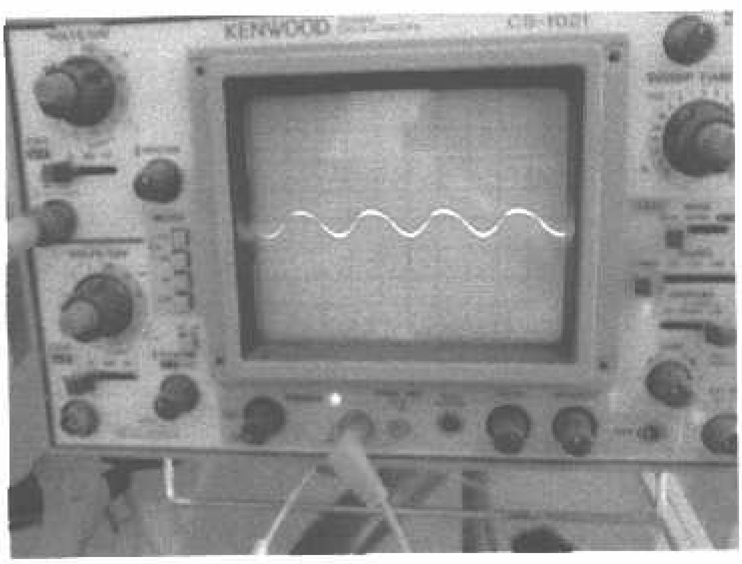
Analisa gambar 4.3 :

Ternyata bentuk sinyal yang masuk ke tranduser tidak sebaik dengan bentuk sinyal pada oscilator, ini disebabkan karenan tranduser ultrasonic terdiri dari rangkaian resistif, induktif dan kapasitif

4.1.3 Pengujian Rangkaian Tranduser Terima

Prosedur pengujian rangkaian tranduser terima adalah sebagai berikut :

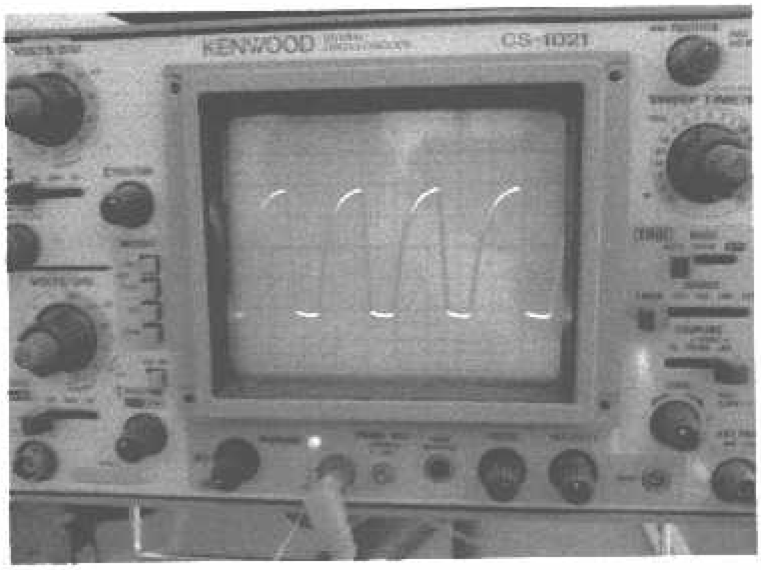
1. Hubungkan input ground osiloskop dengan ground sistem
2. Hubungkan input CH1 di osiloskop ke pin Rx
3. Amati bentuk gelombangnya
4. Hubungkan input CH1 di osiloskop ke output penguat Rx untuk objek 10 cm
5. Amati bentuk gelombangnya
6. Hubungkan input CH1 di osiloskop ke output penguat Rx untuk objek 2,1 m
7. Amati bentuk gelombangnya



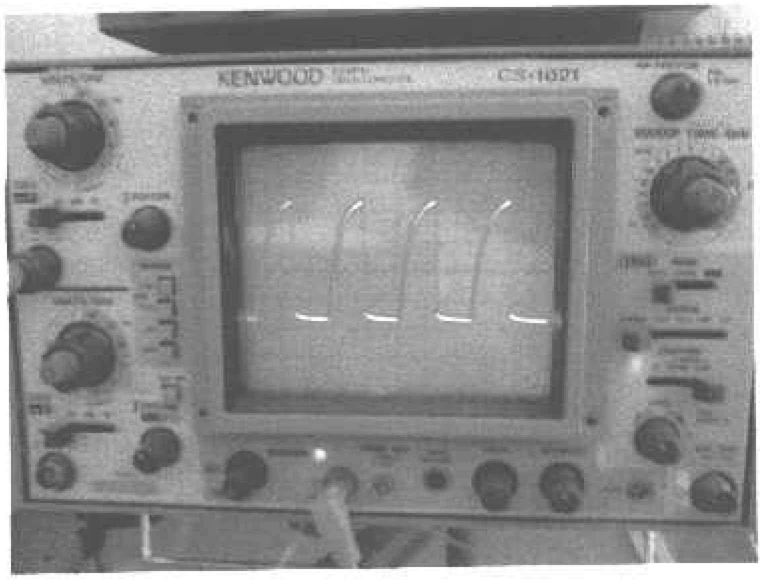
Gambar 4.4 Bentuk Sinyal Pada Rangkaian Transduser Terima

Analisa gambar 4.4 :

Bentuk sinyal yang diterima bukan square, melainkan sinus. Jadi yang diterima oleh tranduser terima adalah harmonisa pertama atau sinyal fundamental dari gelombang square.



Gambar 4.5 Bentuk Sinyal Pada Rangkaian Penguat Penerima Pada Objek 1,87 m



Gambar 4.6 Bentuk Sinyal Pada Rangkaian Penguat Penerima Pada

Objek 10 cm

Analisa gambar 4.5 dan 4.6 :

Input berupa gelombang sinus, tetapi outputnya berupa gelombang bukan sinus. Hal ini disebabkan penguat memiliki gain yang sangat besar, sehingga output menjadi cacat. Akan tetapi cacat ini tidak mempengaruhi terhadap pengukuran.

4.2 Pengujian Rangkaian Display

Untuk pengujian Rangkaian Display diperlukan program uji. Cuplikan program uji adalah sebagai berikut:

```
ACALL INIT_LCD
MOV R7,#0
ACALL LOCATE_ROW1
MOV DPTR,#WORD1
ACALL OUT_CHAR
MOV R7,#2
ACALL LOCATE_ROW2
MOV DPTR,#WORD2
```

WORD1: DB " ANDIKA PRASETYA "
WORD2: DB "D3 T. ENERGI LISTRIK"

Jika program uji ini dijalankan maka layar pada LCD akan muncul.

ANDIKA PRASETYA
D3 T. ENERGI LISTRIK

4.3 Pengujian Sistem Keseluruhan

Setelah Mengadakan pengujian terhadap sensor ultrasonik, maka selanjutnya diadakan uji keseluruhan sistem dengan cara mengadakan berbagai percobaan pengukuran yang dibandingkan dengan pengukur jarak konvensional. Data – data pengukuran adalah sebagai berikut :

Tabel 4.1
Data Perbandingan Pengukuran Antara Alat Ukur Menggunakan Sensor Ultrasonik dan Alat Ukur Konvensional

No. Urut	**Pengukuran Dengan Sensor Ultrasonik (cm)**	**Pengukuran Dengan Alat Ukur Konvensional (cm)**	**Kesalahan (%)**
1.	10	8	1,25
2.	20	18	1,111
3.	30	28	1,071
4.	40	38	1,052

5.	50	47,8	1,052
6.	60	58	1,029
7.	70	68	1.029
8.	80	78	1,025
9.	90	88,5	1,016
10.	100	98,8	1,012
11.	110	108,9	1,01
12.	120	119	1,008
13.	130	129	1,007
14.	140	139	1,007
15.	150	149	1,006
16.	160	159,5	1,003
17.	170	170	1
18.	180	180	1
19.	0	190	0
20.	0	200	0

Prosentase kesalahan diketahui dengan rumus :

$$Prosentase\ Kesalahan = \frac{Pengukuran\ Sensor\ Ultrasonik}{Pengukuran\ Alat\ Ukur\ Konvensional} \times 100\%$$

Dari Tabel diatas dapat disimpulkan bahwa :

1. Semakin kecil jarak yang diukur, maka prosentase kesalahan juga semakin besar.

2. Ternyata death note sensor ultrasonik hanya 187 cm, jadi kurang dari yang disebutkan di katalaog alat yaitu 2 m. Faktor – faktor yang mempengaru kurang maksimalnya kinerja sensor ultrasonik adalah seperti; kurangnya daya pantul benda terhadap gelombang ultrasonic yang dipancarkan oleh tranduser pancar (Tx), dsb.

BAB V

PENUTUP

5.1 Kesimpulan

Dari hasil perancangan dan pembuatan yang telah dilakukan dapat disimpulkan bahwa:

1. Sensor ultrasonik dapat dijadikan alat perngukur jarak yang linier untuk pengukuran jarak benda dengan sudut tegak lurus.
2. Dengan teknik mengirim 12 deretan lebar pulsa (*burst*), memiliki kekurangan yaitu batas ukur dari 10 cm (death zone) hingga 2 meter. Dengan memperkecil jumlah *burst*, maka death zone dapat diperkecil.
3. Sensor Ultrasonik dapat mengukur dengan batas paling jauh 1,87 meter dan paling pendek 10 cm.

5.2 Saran

Sebagai bahan pengembangan pemodelan sensor lebih lanjut, metode pengukuran ini dapat diimplementasikan pada aplikasi yang lebih lanjut, seperti bidang robotika, sistem navigasi mobil dan aplikasi kepolisian (sebagai pengukur batas kecepatan).

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PING)))™ Ultrasonic Distance Sensor (#28015)

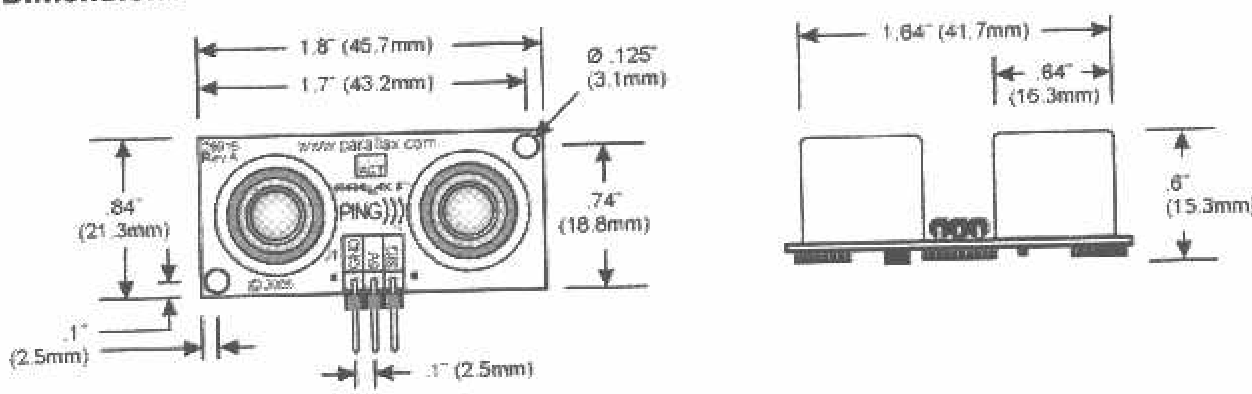
The Parallax PING))) ultrasonic distance sensor provides precise, non-contact distance measurements from about 2 cm (0.8 inches) to 3 meters (3.3 yards). It is very easy to connect to BASIC Stamp® or Javelin Stamp microcontrollers, requiring only one I/O pin.

The PING))) sensor works by transmitting an ultrasonic (well above human hearing range) burst and providing an output pulse that corresponds to the time required for the burst echo to return to the sensor. By measuring the echo pulse width the distance to target can easily be calculated.

Features

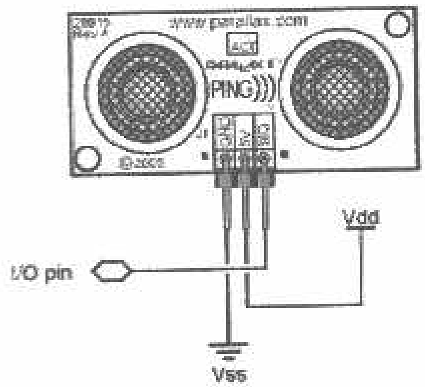
- Supply Voltage – 5 VDC
- Supply Current – 30 mA typ; 35 mA max
- Range – 2 cm to 3 m (0.8 in to 3.3 yrds)
- Input Trigger – positive TTL pulse, 2 uS min, 5 µs typ.
- Echo Pulse – positive TTL pulse, 115 uS to 18.5 ms
- Echo Hold-off – 750 µs from fall of Trigger pulse
- Burst Frequency – 40 kHz for 200 µs
- Burst Indicator LED shows sensor activity
- Delay before next measurement – 200 µs
- Size – 22 mm H x 46 mm W x 16 mm D (0.84 in x 1.8 in x 0.6 in)

Dimensions



Pin Definitions

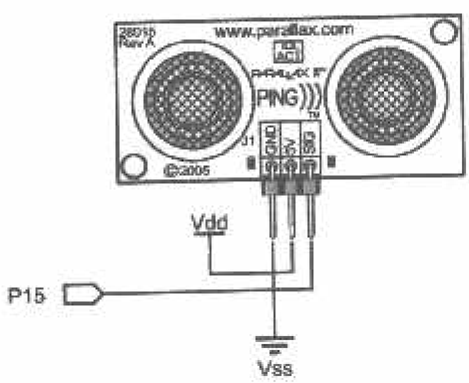
GND	Ground (Vss)
5 V	5 VDC (Vdd)
SIG	Signal (I/O pin)

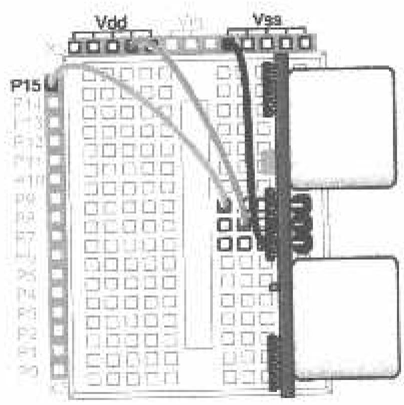


The PING))) sensor has a male 3-pin header used to supply power (5 VDC), ground, and signal. The header allows the sensor to be plugged into a solderless breadboard, or to be located remotely through the use of a standard servo extender cable (Parallax part #805-00002). Standard connections are show in the diagram to the right.

Quick-Start Circuit

This circuit allows you to quickly connect your PING))) sensor to a BASIC Stamp® 2 via the Board of Education® breadboard area. The PING))) module's GND pin connects to Vss, the 5 V pin connects to Vdd, and the SIG pin connects to I/O pin P15. This circuit will work with the example program Ping_Demo.BS2 listed on page 7.

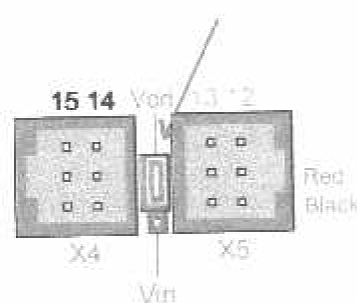




Servo Cable and Port Cautions

If you want to connect your PING))) sensor to a Board of Education using a servo extension cable, follow these steps:

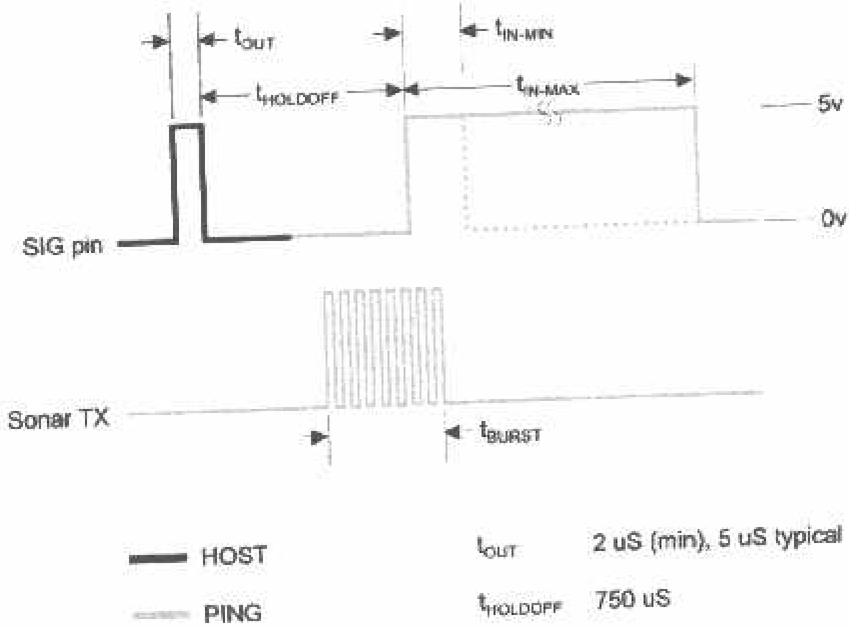
1. When plugging the cable onto the PING))) sensor, connect Black to GND, Red to 5 V, and White to SIG.
2. Check to see if your Board of Education servo ports have a jumper, as shown at right.
3. If your Board of Education servo ports have a jumper, set it to Vdd as shown.
4. If your Board of Education servo ports do not have a jumper, do not use them with the PING))) sensor. These ports only provide Vin, not Vdd, and this may damage your PING))) sensor. Go to the next step.
5. Connect the servo cable directly to the breadboard with a 3-pin header. Then, use jumper wires to connect Black to Vss, Red to Vdd, and White to I/O pin P15.



Board of Education Servo Port Jumper, Set to Vdd

Theory of Operation

The PING))) sensor detects objects by emitting a short ultrasonic burst and then "listening" for the echo. Under control of a host microcontroller (trigger pulse), the sensor emits a short 40 kHz (ultrasonic) burst. This burst travels through the air at about 1130 feet per second, hits an object and then bounces back to the sensor. The PING))) sensor provides an output pulse to the host that will terminate when the echo is detected, hence the width of this pulse corresponds to the distance to the target.



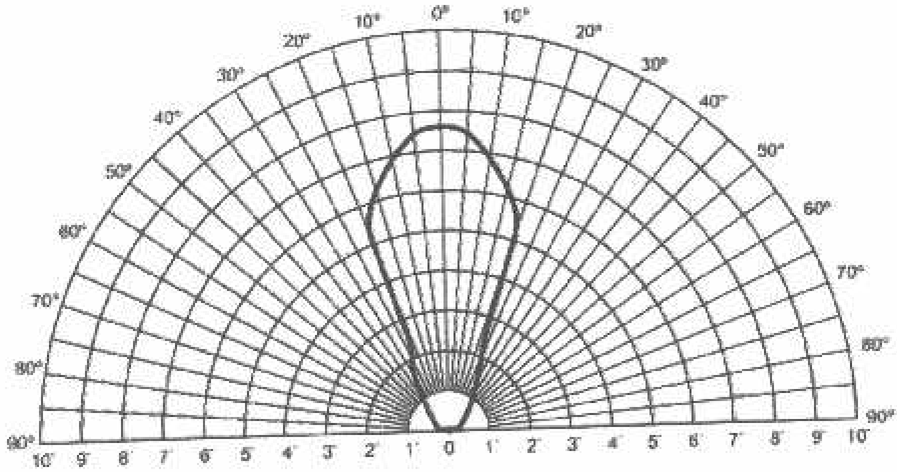
t_{OUT}	2 uS (min), 5 uS typical
$t_{HOLDOFF}$	750 uS
t_{BURST}	200 uS @ 40 kHz
t_{IN-MIN}	115 uS
t_{IN-MAX}	18.5 mS

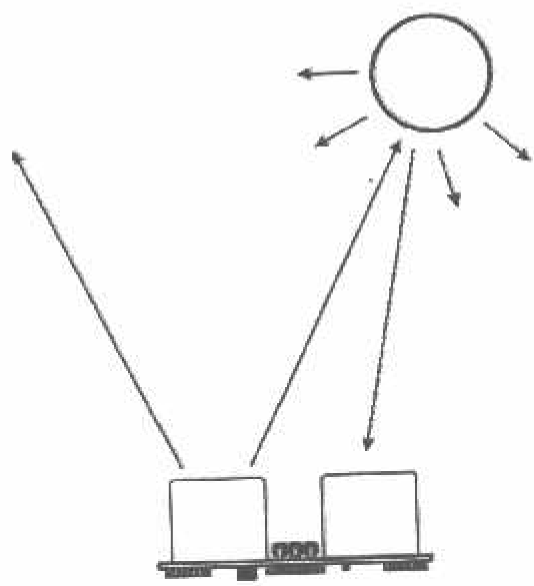
Test Data

The test data on the following pages is based on the PING))) sensor, tested in the Parallax lab, while connected to a BASIC Stamp microcontroller module. The test surface was a linoleum floor, so the sensor was elevated to minimize floor reflections in the data. All tests were conducted at room temperature, indoors, in a protected environment. The target was always centered at the same elevation as the PING))) sensor.

Test 1

Sensor Elevation: 40 in. (101.6 cm)
Target: 3.5 in. (8.9 cm) diameter cylinder, 4 ft. (121.9 cm) tall – vertical orientation

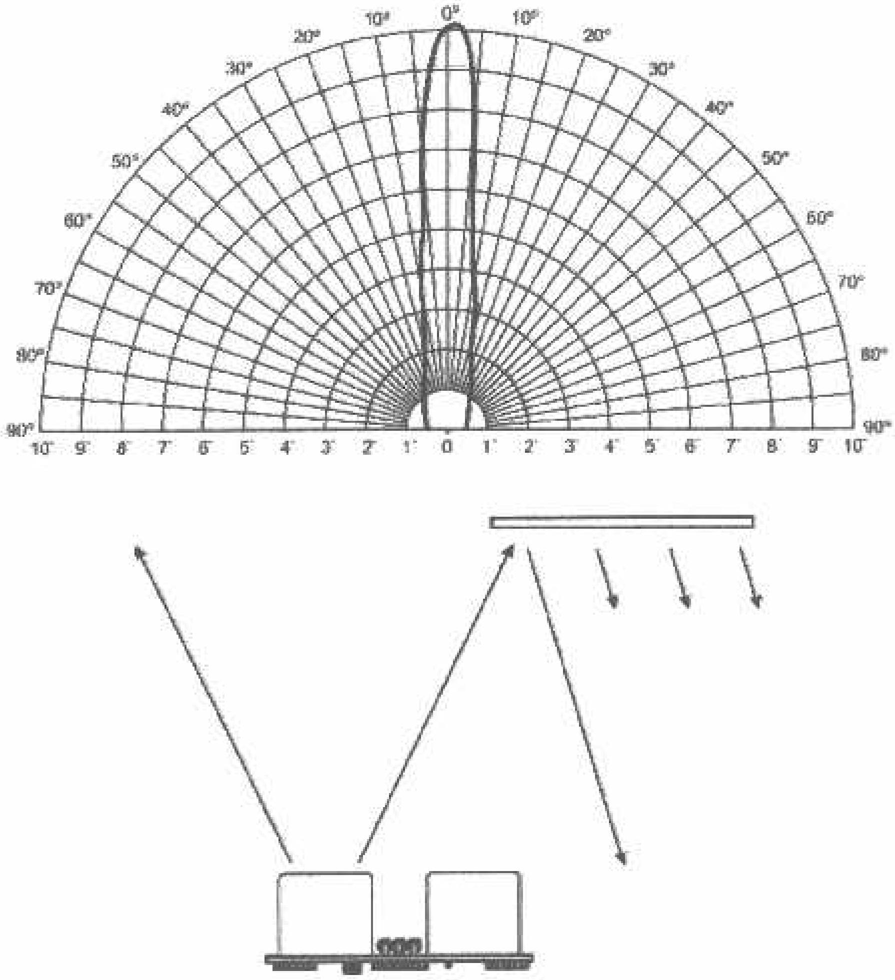




Test 2

Sensor Elevation: 40 in. (101.6 cm)
Target: 12 in. x 12 in. (30.5 cm x 30.5 cm) cardboard, mounted on 1 in. (2.5 cm) pole

- target positioned parallel to backplane of sensor



Program Example: BASIC Stamp 2 Microcontroller

The following program demonstrates the use of the PING))) sensor with the BASIC Stamp 2 microcontroller. Any model of BASIC Stamp 2 module will work with this program as conditional compilation techniques are used to make adjustments based on the module that is connected.

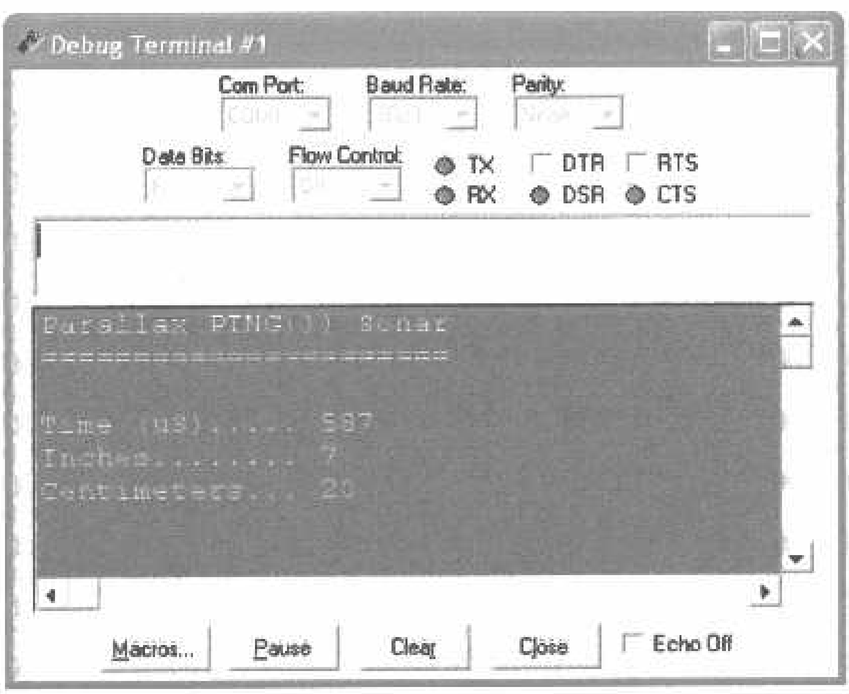
The heart of the program is the **Get_Sonar** subroutine. This routine starts by making the output bit of the selected IO pin zero – this will cause the successive **PULSOUT** to be low-high-low as required for triggering the PING))) sensor. After the trigger pulse falls the sensor will wait about 200 microseconds before transmitting the ultrasonic burst. This allows the BS2 to load and prepare the next instruction. That instruction, **PULSIN**, is used to measure the high-going pulse that corresponds to the distance to the target object.

The raw return value from **PULSIN** must be scaled due to resolution differences between the various members of the BS2 family. After the raw value is converted to microseconds, it is divided by two in order to remove the "return trip" of the echo pulse. The value now held in *rawDist* is the distance to the target in microseconds.

Conversion from microseconds to inches (or centimeters) is now a simple matter of math. The generally-accepted value for the speed-of-sound is 1130 feet per second. This works out to 13,560 inches per second or one inch in 73.746 microseconds. The question becomes, how do we divide our pulse measurement value by the floating-point number 73.746?

Another way to divide by 73.746 is to multiply by 0.01356. For new BASIC Stamp users this may seem a dilemma but in fact there is a special operator, **, that allows us to do just that. The ** operator has the affect of multiplying a value by units of 1/65,536. To find the parameter for ** then, we simply multiply 0.01356 by 65,536; the result is 888.668 (we'll round up to 889).

Conversion to centimeters uses the same process and the result of the program is shown below:



```
' =========================================================================
'
'   File....... Ping_Demo.BS2
'   Purpose.... Demo Code for Parallax PING))) Sonar Sensor
'   Author..... Parallax, Inc.
'   E-mail..... support@parallax.com
'   Started....
'   Updated.... 08 JUN 2005
'
'   {$STAMP BS2}
'   {$PBASIC 2.5}
'
' =========================================================================


' -----[ Program Description ]---------------------------------------------
'
' This program demonstrates the use of the Parallax PING))) sensor and then
' converting the raw measurement to English (inches) and Metric (cm) units.
'
' Sonar Math:
'
' At sea level sound travels through air at 1130 feet per second.  This
' equates to 1 inch in 73.746 uS, or 1 cm in 29.034 uS).
'
' Since the PING))) sensor measures the time required for the sound wave to
' travel from the sensor and back.  The result -- after conversion to
' microseconds for the BASIC Stamp module in use -- is divided by two to
' remove the return portion of the echo pulse.  The final raw result is
' the duration from the front of the sensor to the target in microseconds.


' -----[ I/O Definitions ]-------------------------------------------------

Ping            PIN     15


' -----[ Constants ]-------------------------------------------------------

#SELECT $STAMP
  #CASE BS2, BS2E
    Trigger     CON     5                       ' trigger pulse = 10 uS
    Scale       CON     $200                    ' raw x 2.00 = uS
  #CASE BS2SX, BS2P, BS2PX
    Trigger     CON     13
    Scale       CON     $0CD                    ' raw x 0.80 = uS
  #CASE BS2PE
    Trigger     CON     5
    Scale       CON     $1E1                    ' raw x 1.88 = uS
#ENDSELECT

RawToIn         CON     889                     ' 1 / 73.746 (with **)
RawToCm         CON     2257                    ' 1 / 29.034 (with **)

IsHigh          CON     1                       ' for PULSOUT
IsLow           CON     0
```

```
' -----[ Variables ]-------------------------------------------------------

rawDist         VAR     Word                    ' raw measurement
inches          VAR     Word
cm              VAR     Word


' -----[ Initialization ]--------------------------------------------------

Reset:
  DEBUG CLS,
        "Parallax PING))) Sonar", CR,           ' setup report screen
        "======================", CR,
        CR,
        "Time (uS).....         ", CR,
        "Inches........         ", CR,
        "Centimeters...         "


' -----[ Program Code ]----------------------------------------------------

Main:
  DO
    GOSUB Get_Sonar                             ' get sensor value
    inches = rawDist ** RawToIn                 ' convert to inches
    cm = rawDist ** RawToCm                     ' convert to centimeters

    DEBUG CRSRXY, 15, 3,                        ' update report screen
          DEC rawDist, CLREOL,
          CRSRXY, 15, 4,
          DEC inches, CLREOL,
          CRSRXY, 15, 5,
          DEC cm, CLREOL

    PAUSE 100
  LOOP
  END


' -----[ Subroutines ]-----------------------------------------------------

' This subroutine triggers the PING))) sonar sensor and measures
' the echo pulse.  The raw value from the sensor is converted to
' microseconds based on the Stamp module in use.  This value is
' divided by two to remove the return trip -- the result value is
' the distance from the sensor to the target in microseconds.

Get_Sonar:
  Ping = IsLow                                  ' make trigger 0-1-0
  PULSOUT Ping, Trigger                         ' activate sensor
  PULSIN  Ping, IsHigh, rawDist                 ' measure echo pulse
  rawDist = rawDist */ Scale                    ' convert to uS
  rawDist = rawDist / 2                         ' remove return trip
  RETURN
```

Program Example: BASIC Stamp 1 Microcontroller

```
' =========================================================================
'
'   File....... Ping_Demo.BS1
'   Purpose.... Demo Code for Parallax PING))) Sonar Sensor
'   Author..... Parallax, Inc.
'   E-mail..... support@parallax.com
'   Started....
'   Updated.... 06 JUN 2006
'
'   {$STAMP BS1}
'   {$PBASIC 1.0}
'
' =========================================================================


' -----[ Program Description ]---------------------------------------------
'
' This program demonstrates the use of the Parallax PING))) sensor and then
' converting the raw measurement to English (inches) and Metric (cm) units.
'
' Sonar Math:
'
' At sea level sound travels through air at 1130 feet per second.  This
' equates to 1 inch in 73.746 uS, or 1 cm in 29.034 uS).
'
' Since the PING))) sensor measures the time required for the sound wave to
' travel from the sensor and back.  The result -- after conversion to
' microseconds for the BASIC Stamp module in use -- is divided by two to
' remove the return portion of the echo pulse.  The final raw result is
' the duration from the front of the sensor to the target in microseconds.


' -----[ I/O Definitions ]-------------------------------------------------

SYMBOL  Ping            = 7


' -----[ Constants ]-------------------------------------------------------

SYMBOL  Trigger         = 1                     ' 10 uS trigger pulse
SYMBOL  Scale           = 10                    ' raw x 10.00 = uS

SYMBOL  RawToIn         = 889                   ' 1 / 73.746 (with **)
SYMBOL  RawToCm         = 2257                  ' 1 / 29.034 (with **)

SYMBOL  IsHigh          = 1                     ' for PULSOUT
SYMBOL  IsLow           = 0


' -----[ Variables ]-------------------------------------------------------

SYMBOL  rawDist         = W1                    ' raw measurement
SYMBOL  inches          = W2
SYMBOL  cm              = W3
```

```
' -----[ Program Code ]----------------------------------------------------

Main:
  GOSUB Get_Sonar                               ' get sensor value
  inches = rawDist ** RawToIn                   ' convert to inches
  cm = rawDist ** RawToCm                       ' convert to centimeters

  DEBUG CLS                                     ' report
  DEBUG "Time (uS)..... ", #rawDist, CR
  DEBUG "Inches........ ", #inches, CR
  DEBUG "Centimeters... ", #cm

  PAUSE 500
  GOTO Main

  END

' -----[ Subroutines ]-----------------------------------------------------

' This subroutine triggers the PING))) sonar sensor and measures
' the echo pulse.  The raw value from the sensor is converted to
' microseconds based on the Stamp module in use.  This value is
' divided by two to remove the return trip -- the result value is
' the distance from the sensor to the target in microseconds.

Get_Sonar:
  LOW Ping                                      ' make trigger 0-1-0
  PULSOUT Ping, Trigger                         ' activate sensor
  PULSIN  Ping, IsHigh, rawDist                 ' measure echo pulse
  rawDist = rawDist * Scale                     ' convert to uS
  rawDist = rawDist / 2                         ' remove return trip
  RETURN
```

Program Example: Javelin Stamp Microcontroller

This class file implements several methods for using the PING))) sensor:

```
package stamp.peripheral.sensor;

import stamp.core.*;


/**
 * This class provides an interface to the Parallax PING))) ultrasonic
 * range finder module.
 * <p>
 * <i>Usage:</i><br>
 * <code>
 *   Ping range = new Ping(CPU.pin0);        // trigger and echo on P0
 * </code>
 * <p>
 * Detailed documentation for the PING))) Sensor can be found at: <br>
 * http://www.parallax.com/detail.asp?product_id=28015
 * <p>
 *
 * @version 1.0 03 FEB 2005
 */
public final class Ping {

  private int ioPin;

  /**
   * Creates PING))) range finder object
   *
   * @param ioPin PING))) trigger and echo return pin
   */
  public Ping (int ioPin) {
    this.ioPin = ioPin;
  }


  /**
   * Returns raw distance value from the PING))) sensor.
   *
   * @return Raw distance value from PING)))
   */
  public int getRaw() {

    int echoRaw = 0;

    CPU.writePin(ioPin, false);                // setup for high-going pulse
    CPU.pulseOut(1, ioPin);                    // send trigger pulse
    echoRaw = CPU.pulseIn(2171, ioPin, true); // measure echo return

    // return echo pulse if in range; zero if out-of-range
    return (echoRaw < 2131) ? echoRaw : 0;
  }
```

```
  /*
   * The PING))) returns a pulse width of 73.746 uS per inch.  Since the
   * Javelin pulseIn() round-trip echo time is in 8.68 uS units, this is the
   * same as a one-way trip in 4.34 uS units.  Dividing 73.746 by 4.34 we
   * get a time-per-inch conversion factor of 16.9922 (x 0.058851).
   *
   * Values to derive conversion factors are selected to prevent roll-over
   * past the 15-bit positive values of Javelin Stamp integers.
   */

  /**
   * @return PING))) distance value in inches
   */
  public int getIn() {
    return (getRaw() * 3 / 51);                // raw * 0.058824
  }


  /**
   * @return PING))) distance value in tenths of inches
   */
  public int getIn10() {
    return (getRaw() * 3 / 5);                 // raw / 1.6667
  }


  /*
   * The PING))) returns a pulse width of 29.033 uS per centimeter.  As the
   * Javelin pulseIn() round-trip echo time is in 8.68 uS units, this is the
   * same as a one-way trip in 4.34 uS units.  Dividing 29.033 by 4.34 we
   * get a time-per-centimeter conversion factor of 6.6896.
   *
   * Values to derive conversion factors are selected to prevent roll-over
   * past the 15-bit positive values of Javelin Stamp integers.
   */

  /**
   * @return PING))) distance value in centimeters
   */
  public int getCm() {
    return (getRaw() * 3 / 20);                // raw / 6.6667
  }


  /**
   * @return PING))) distance value in millimeters
   */
  public int getMm() {
    return (getRaw() * 3 / 2);                 // raw / 0.6667
  }
}
```

This simple demo illustrates the use of the PING))) ultrasonic range finder class with the Javelin Stamp:

```
import stamp.core.*;
import stamp.peripheral.sensor.Ping;


public class testPing {

  public static final char HOME = 0x01;

  public static void main() {

    Ping range = new Ping(CPU.pin0);
    StringBuffer msg = new StringBuffer();

    int distance;

    while (true) {
      // measure distance to target in inches
      distance = range.getIn();

      // create and display measurement message
      msg.clear();
      msg.append(HOME);
      msg.append(distance);
      msg.append(" \"   \n");
      System.out.print(msg.toString());

      // wait 0.5 seconds between readings
      CPU.delay(5000);
    }
  }
}
```

FAIRCHILD SEMICONDUCTOR™

October 1987
Revised April 2002

CD4093BC
Quad 2-Input NAND Schmitt Trigger

General Description

The CD4093B consists of four Schmitt-trigger circuits. Each circuit functions as a 2-input NAND gate with Schmitt-trigger action on both inputs. The gate switches at different points for positive and negative-going signals. The difference between the positive (V_T^+) and the negative voltage (V_T^-) is defined as hysteresis voltage (V_H).

All outputs have equal source and sink currents and conform to standard B-series output drive (see Static Electrical Characteristics).

Features

- Wide supply voltage range: 3.0V to 15V
- Schmitt-trigger on each input with no external components
- Noise immunity greater than 50%
- Equal source and sink currents
- No limit on input rise and fall time
- Standard B-series output drive
- Hysteresis voltage (any input) $T_A = 25°C$

Typical	$V_{DD} = 5.0V$	$V_H = 1.5V$
	$V_{DD} = 10V$	$V_H = 2.2V$
	$V_{DD} = 15V$	$V_H = 2.7V$
Guaranteed		$V_H = 0.1\ V_{DD}$

Applications

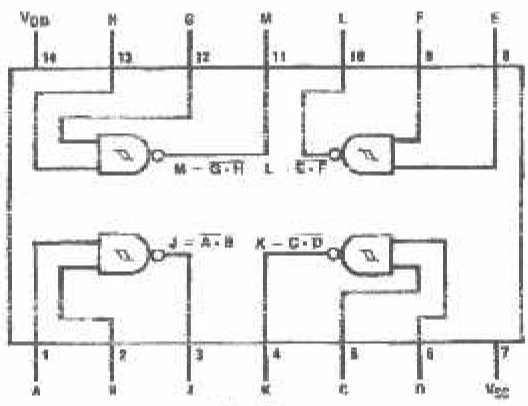
- Wave and pulse shapers
- High-noise-environment systems
- Monostable multivibrators
- Astable multivibrators
- NAND logic

Ordering Code:

Order Number	Package Number	Package Description
CD4093BCM	M14A	14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-012, 0.150" Narrow
CD4093BCN	N14A	14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300" Wide

Devices also available in Tape and Reel. Specify by appending the suffix letter "X" to the ordering code.

Connection Diagram



Top View

Absolute Maximum Ratings (Note 1)

(Note 2)

DC Supply Voltage (V_{DD})	−0.5 to +18 V_{DC}
Input Voltage (V_{IN})	−0.5 to V_{DD} +0.5 V_{DC}
Storage Temperature Range (T_S)	−65°C to +150°C
Power Dissipation (P_D)	
Dual-In-Line	700 mW
Small Outline	500 mW
Lead Temperature (T_L)	
(Soldering, 10 seconds)	260°C

Recommended Operating Conditions (Note 2)

DC Supply Voltage (V_{DD})	3 to 15 V_{DC}
Input Voltage (V_{IN})	0 to V_{DD} V_{DC}
Operating Temperature Range (T_A)	−55°C to +125°C

Note 1: "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed; they are not meant to imply that the devices should be operated at these limits. The table of "Recommended Operating Conditions" and "Electrical Characteristics" provides conditions for actual device operation.

Note 2: V_{SS} = 0V unless otherwise specified.

DC Electrical Characteristics (Note 2)

Symbol	Parameter	Conditions	−55°C		+25°C			+125°C		Units
			Min	Max	Min	Typ	Max	Min	Max	
I_{DD}	Quiescent Device Current	V_{DD} = 5V		0.25			0.25		7.5	µA
		V_{DD} = 10V		0.5			0.5		15.0	
		V_{DD} = 15V		1.0			1.0		30.0	
V_{OL}	LOW Level Output Voltage	V_{IN} = V_{DD}, $\|I_O\|$ < 1 µA								V
		V_{DD} = 5V		0.05		0	0.05		0.05	
		V_{DD} = 10V		0.05		0	0.05		0.05	
		V_{DD} = 15V		0.05		0	0.05		0.05	
V_{OH}	HIGH Level Output Voltage	V_{IN} = V_{SS}, $\|I_O\|$ < 1 µA								V
		V_{DD} = 5V	4.95		4.95	5		4.95		
		V_{DD} = 10V	9.95		9.95	10		9.95		
		V_{DD} = 15V	14.95		14.95	15		14.95		
V_{T-}	Negative-Going Threshold Voltage (Any Input)	$\|I_O\|$ < 1 µA								V
		V_{DD} = 5V, V_O = 4.5V	1.3	2.25	1.5	1.8	2.25	1.5	2.3	
		V_{DD} = 10V, V_O = 9V	2.85	4.5	3.0	4.1	4.5	3.0	4.65	
		V_{DD} = 15V, V_O = 13.5V	4.35	6.75	4.5	6.3	6.75	4.5	6.9	
V_{T+}	Positive-Going Threshold Voltage (Any Input)	$\|I_O\|$ < 1 µA								V
		V_{DD} = 5V, V_O = 0.5V	2.75	3.6	2.75	3.3	3.5	2.65	3.5	
		V_{DD} = 10V, V_O = 1V	5.5	7.15	5.5	6.2	7.0	5.35	7.0	
		V_{DD} = 15V, V_O = 1.5V	8.25	10.65	8.25	9.0	10.5	8.1	10.5	
V_H	Hysteresis (V_{T+} − V_{T-}) (Any Input)	V_{DD} = 5V	0.5	2.35	0.5	1.5	2.0	0.35	2.0	V
		V_{DD} = 10V	1.0	4.3	1.0	2.2	4.0	0.70	4.0	
		V_{DD} = 15V	1.5	6.3	1.5	2.7	6.0	1.20	6.0	
I_{OL}	LOW Level Output Current (Note 3)	V_{IN} = V_{DD}								mA
		V_{DD} = 5V, V_O = 0.4V	0.64		0.51	0.88		0.36		
		V_{DD} = 10V, V_O = 0.5V	1.6		1.3	2.25		0.9		
		V_{DD} = 15V, V_O = 1.5V	4.2		3.4	8.8		2.4		
I_{OH}	HIGH Level Output Current (Note 3)	V_{IN} = V_{SS}								mA
		V_{DD} = 5V, V_O = 4.6V	−0.64		0.51	−0.88		−0.36		
		V_{DD} = 10V, V_O = 9.5V	−1.6		−1.3	−2.25		−0.9		
		V_{DD} = 15V, V_O = 13.5V	−4.2		−3.4	−8.8		−2.4		
I_{IN}	Input Current	V_{DD} = 15V, V_{IN} = 0V		−0.1		-10^{-5}	−0.1		−1.0	µA
		V_{DD} = 15V, V_{IN} = 15V		0.1		10^{-5}	0.1		1.0	

Note 3: I_{OH} and I_{OL} are tested one output at a time.

AC Electrical Characteristics (Note 4)

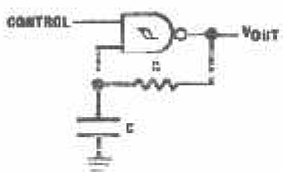
$T_A = 25°C$, $C_L = 50$ pF, $R_L = 200k$, Input t_r, $t_f = 20$ ns, unless otherwise specified

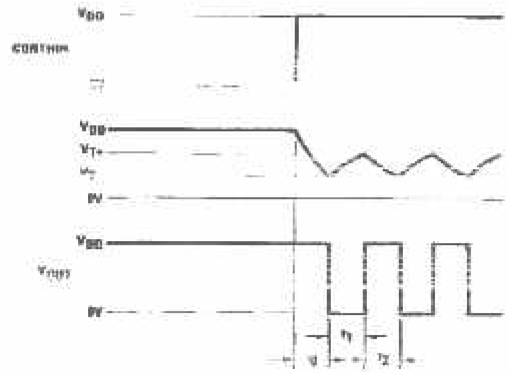
Symbol	Parameter	Conditions	Min	Typ	Max	Units
t_{PHL}, t_{PLH}	Propagation Delay Time	$V_{DD} = 5V$		300	450	
		$V_{DD} = 10V$		120	210	ns
		$V_{DD} = 15V$		80	160	
t_{THL}, t_{TLH}	Transition Time	$V_{DD} = 5V$		90	145	
		$V_{DD} = 10V$		50	75	ns
		$V_{DD} = 15V$		40	60	
C_{IN}	Input Capacitance	(Any Input)		5.0	7.5	pF
C_{PD}	Power Dissipation Capacitance	(Per Gate)		24		pF

Note 4: AC Parameters are guaranteed by DC correlated testing.

Typical Applications

Gated Oscillator





Assume $t_1 + t_2 >> t_{PHL} + t_{PLH}$ then:

$t_0 = RC \ln [V_{DD}/V_{T-}]$

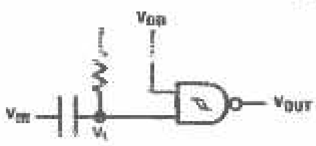
$t_1 = RC \ln [(V_{DD} - V_{T-})/(V_{DD} - V_{T+})]$

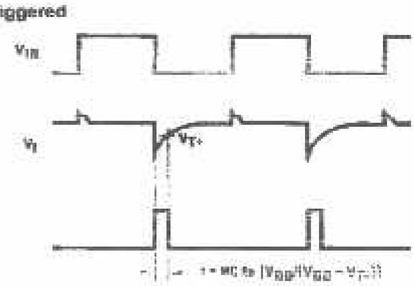
$t_2 = RC \ln [V_{T+}/V_{T-}]$

$$f = \frac{1}{t_1 + t_2} = \frac{1}{RC \ln \frac{(V_{T+})(V_{DD} - V_{T-})}{(V_{T-})(V_{DD} - V_{T+})}}$$

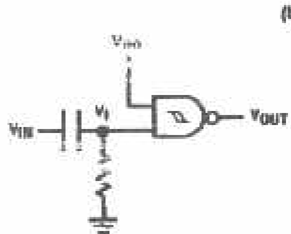
Gated One Shot

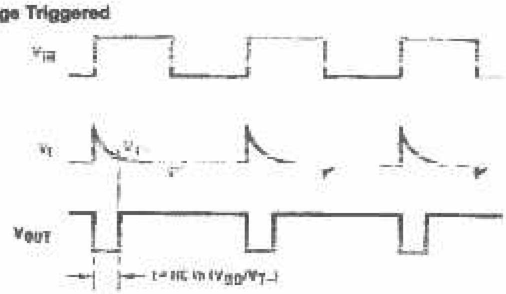
(a) Negative-Edge Triggered





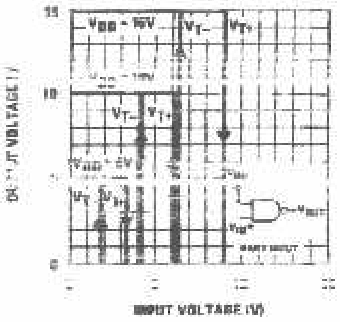
(b) Positive-Edge Triggered



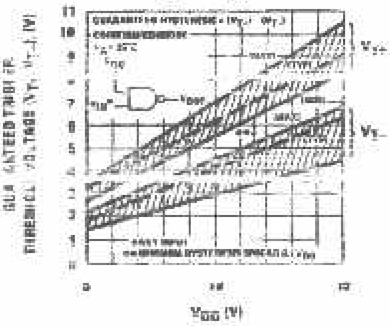


Typical Performance Characteristics

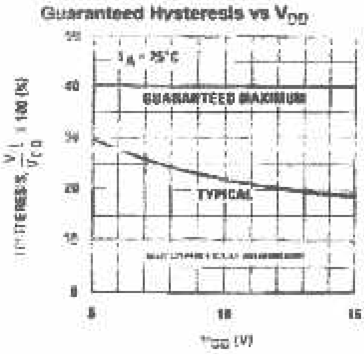
Typical Transfer Characteristics



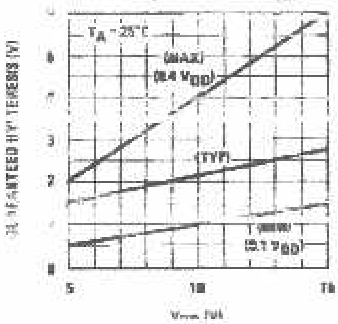
Guaranteed Trigger Threshold Voltage vs V_{DD}



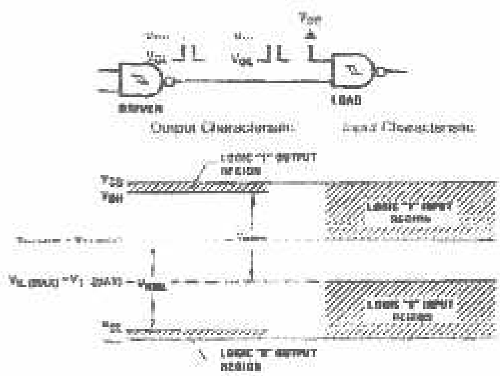
Guaranteed Hysteresis vs V_{DD}



Guaranteed Hysteresis vs V_{DD}



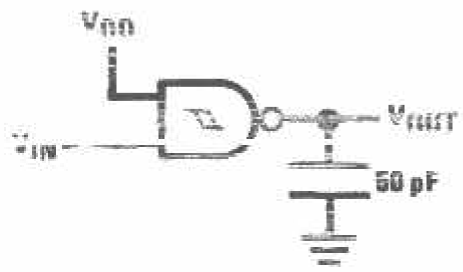
Input and Output Characteristics

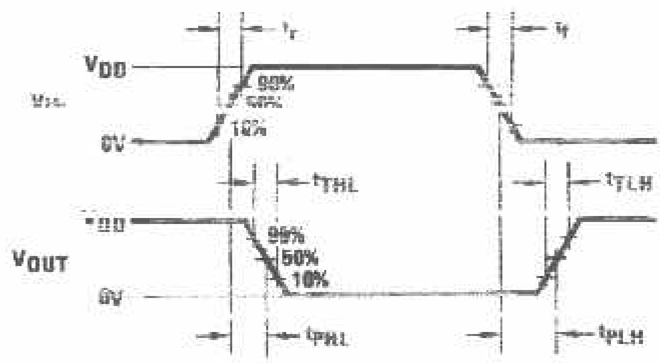


$V_{NML} = V_{IH(MIN)} - V_{OL} = V_{IH(MIN)} = V_{T+(MIN)}$

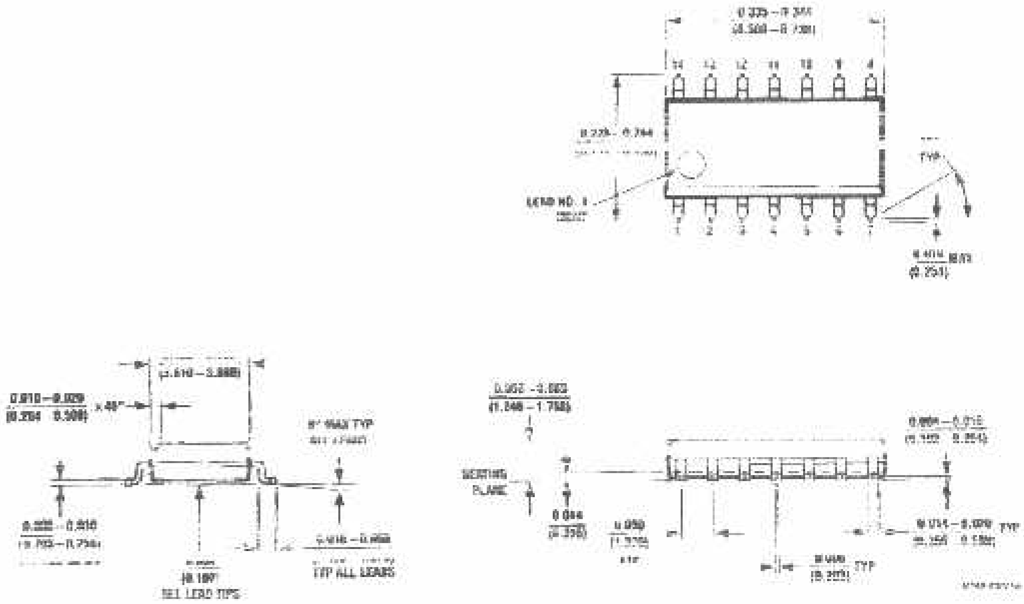
$V_{NMH} = V_{OH} - V_{IL(MAX)} = V_{DD} - V_{IL(MAX)} = V_{DD} - V_{T-(MAX)}$

AC Test Circuits and Switching Time Waveforms





Physical Dimensions inches (millimeters) unless otherwise noted



14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-012, 0.150" Narrow Package Number M14A

tures

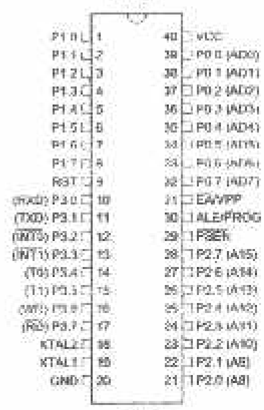
- npatible with MCS-51™ Products
- Bytes of In-System Reprogrammable Flash Memory
- Endurance: 1,000 Write/Erase Cycles
- y Static Operation: 0 Hz to 24 MHz
- ee-level Program Memory Lock
- x 8-bit Internal RAM
- 'rogrammable I/O Lines
- 16-bit Timer/Counters
- Interrupt Sources
- grammable Serial Channel
- -power Idle and Power-down Modes

cription

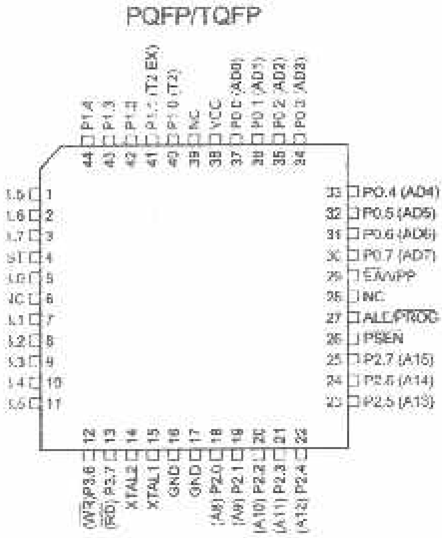
T89C51 is a low-power, high-performance CMOS 8-bit microcomputer with 4K of Flash programmable and erasable read only memory (PEROM). The device nufactured using Atmel's high-density nonvolatile memory technology and is atible with the industry-standard MCS-51 instruction set and pinout. The on-chip allows the program memory to be reprogrammed in-system or by a conven- nonvolatile memory programmer. By combining a versatile 8-bit CPU with Flash nonolithic chip, the Atmel AT89C51 is a powerful microcomputer which provides ly-flexible and cost-effective solution to many embedded control applications.

Configurations

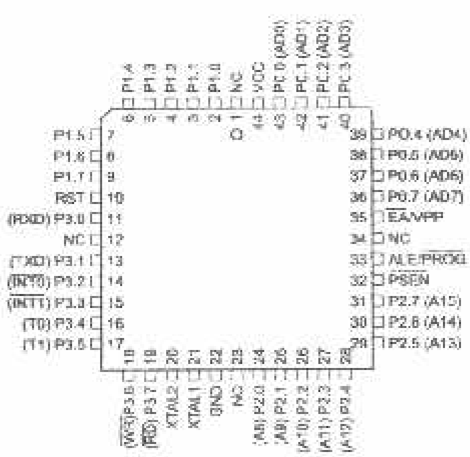
PDIP



PQFP/TQFP



PLCC



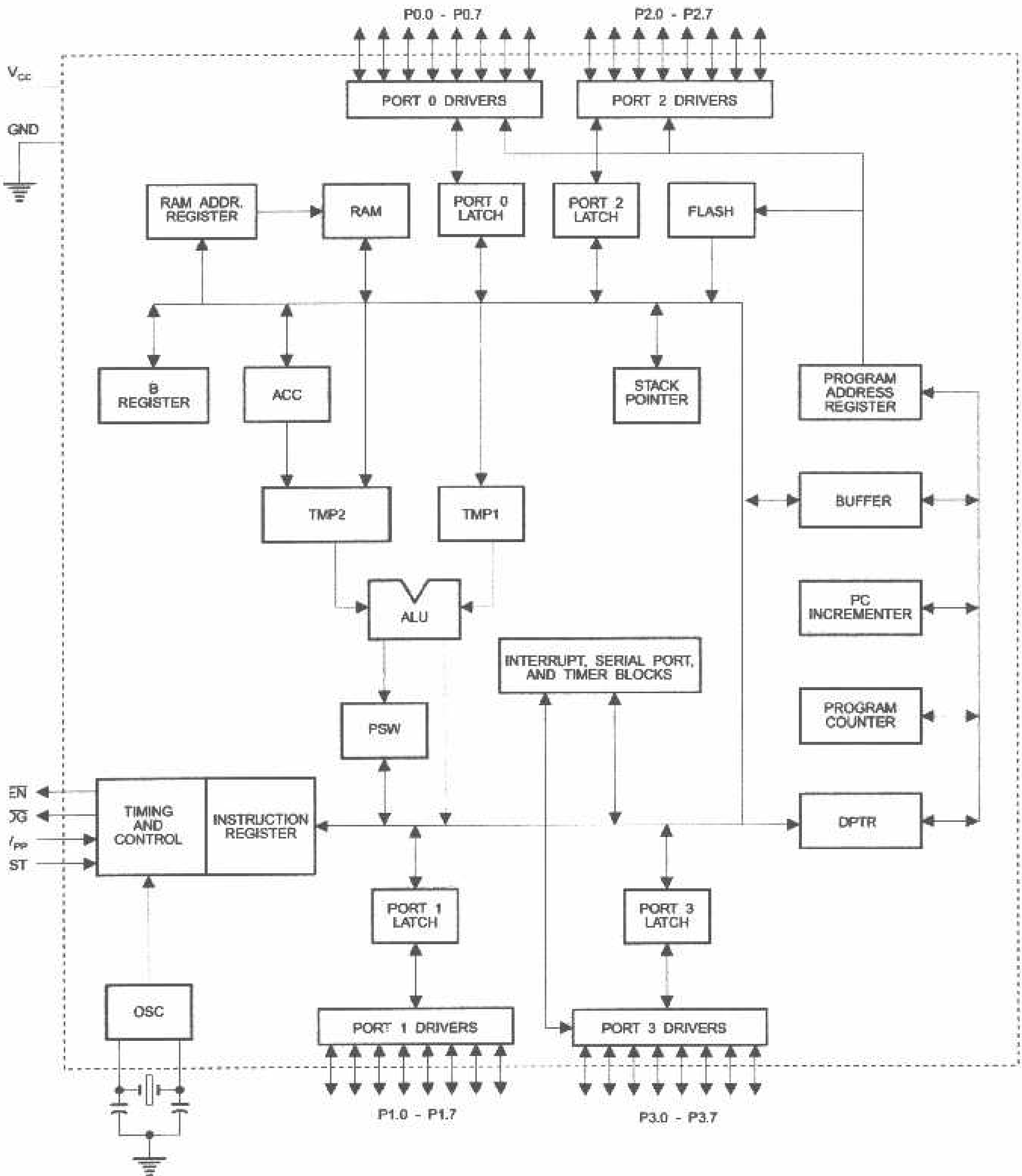
8-bit Microcontroller with 4K Bytes Flash

AT89C51

Not Recommended for New Designs. Use AT89S51.

Rev. 0265G–02/00

ck Diagram


P0.0 - P0.7
P2.0 - P2.7
VCC
GND
PORT 0 DRIVERS
PORT 2 DRIVERS
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
EN
OG
ST
TIMING AND CONTROL
INSTRUCTION REGISTER
DPTR
PORT 1 LATCH
PORT 3 LATCH
OSC
PORT 1 DRIVERS
PORT 3 DRIVERS
P1.0 - P1.7
P3.0 - P3.7

\T89C51 provides the following standard features: 4K of Flash, 128 bytes of RAM, 32 I/O lines, two 16-bit 'counters, a five vector two-level interrupt architecture, duplex serial port, on-chip oscillator and clock cir-. In addition, the AT89C51 is designed with static logic)eration down to zero frequency and supports two are selectable power saving modes. The Idle Mode the CPU while allowing the RAM, timer/counters, port and interrupt system to continue functioning. The r-down Mode saves the RAM contents but freezes .cillator disabling all other chip functions until the next 'are reset.

Description

y voltage.

d.

is an 8-bit open-drain bi-directional I/O port. As an : port, each pin can sink eight TTL inputs. When 1s itten to port 0 pins, the pins can be used as high-ance inputs.

may also be configured to be the multiplexed low-address/data bus during accesses to external pro-and data memory. In this mode P0 has internal 3.

also receives the code bytes during Flash program-and outputs the code bytes during program ation. External pullups are required during program ation.

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

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

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

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

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

Port 3

Port 3 is an 8-bit bi-directional I/O port with internal pullups. The Port 3 output buffers can sink/source four TTL inputs. When 1s are written to Port 3 pins they are pulled high by the internal 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 AT89C51 as listed below:

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

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

RST

Reset input. A high on this pin for two machine cycles while the oscillator is running resets the device.

ALE/$\overline{PROG}$

Address Latch Enable output pulse for latching the low byte of the address during accesses to external memory. This pin is also the program pulse input ($\overline{PROG}$) 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 is skipped during each access to external Data ory.

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

i

am Store Enable is the read strobe to external pro- memory.

the AT89C51 is executing code from external pro- memory, $\overline{PSEN}$ is activated twice each machine except that two $\overline{PSEN}$ activations are skipped during access to external data memory.

P

al Access Enable. $\overline{EA}$ must be strapped to GND in to enable the device to fetch code from external pro- memory locations starting at 0000H up to FFFFH. however, that if lock bit 1 is programmed, $\overline{EA}$ will be ally latched on reset.

hould be strapped to V_{CC} for internal program tions.

in also receives the 12-volt programming enable volt- (V_{PP}) during Flash programming, for parts that require t V_{PP}.

I

to the inverting oscillator amplifier and input to the il clock operating circuit.

2

t from the inverting oscillator amplifier.

illator Characteristics

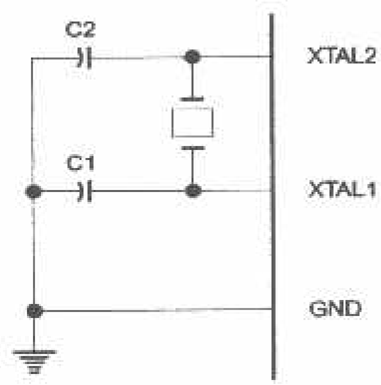
I and XTAL2 are the input and output, respectively, nverting amplifier which can be configured for use as chip oscillator, as shown in Figure 1. Either a quartz I or ceramic resonator may be used. To drive the from an external clock source, XTAL2 should be left unconnected while XTAL1 is driven as shown in Figure 2. There are no requirements on the duty cycle of the external clock signal, since the input to the internal clocking circuitry is through a divide-by-two flip-flop, but minimum and maximum voltage high and low time specifications must be observed.

Idle Mode

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

It should be noted that when idle is terminated by a hard ware reset, 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 is terminated by reset, the instruction following the one that invokes Idle should not be one that writes to a port pin or to external memory.

Figure 1. Oscillator Connections

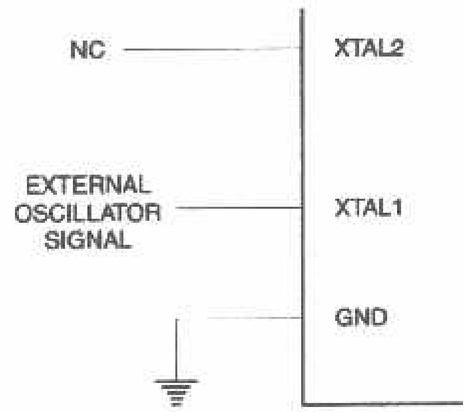


Note: C1, C2 = 30 pF ± 10 pF for Crystals
= 40 pF ± 10 pF for Ceramic Resonators

us of External Pins During Idle and Power-down Modes

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

·e 2. External Clock Drive Configuration



·er-down Mode

power-down mode, the oscillator is stopped, and the ction that invokes power-down is the last instruction ıted. The on-chip RAM and Special Function Registers retain their values until the power-down mode is terminated. The only exit from power-down is a hardware reset. Reset redefines the SFRs but does not change the on-chip RAM. The reset should not be activated before V_{CC} is restored to its normal operating level and must be held active long enough to allow the oscillator to restart and stabilize.

Program Memory Lock Bits

On the chip are three lock bits which can be left unprogrammed (U) or can be programmed (P) to obtain the additional features listed in the table below.

When lock bit 1 is programmed, the logic level at the $\overline{EA}$ 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. It is necessary that the latched value of $\overline{EA}$ be in agreement with the current logic level at that pin in order for the device to function properly.

k Bit Protection Modes

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

gramming the Flash

AT89C51 is normally shipped with the on-chip Flash ory array in the erased state (that is, contents = FFH) eady to be programmed. The programming interface ots either a high-voltage (12-volt) or a low-voltage program enable signal. The low-voltage program-mode provides a convenient way to program the C51 inside the user's system, while the high-voltage amming mode is compatible with conventional third-Flash or EPROM programmers.

AT89C51 is shipped with either the high-voltage or oltage programming mode enabled. The respective de marking and device signature codes are listed in llowing table.

	V_{PP} = 12V	V_{PP} = 5V
side Mark	AT89C51 xxxx yyww	AT89C51 xxxx-5 yyww
ature	(030H) = 1EH (031H) = 51H (032H) =F FH	(030H) = 1EH (031H) = 51H (032H) = 05H

T89C51 code memory array is programmed byte-by-n either programming mode. *To program any non-byte in the on-chip Flash Memory, the entire memory be erased using the Chip Erase Mode.*

ramming Algorithm: Before programming the C51, the address, data and control signals should be according to the Flash programming mode table and 3 and Figure 4. To program the AT89C51, take the ng steps.

put the desired memory location on the address es.

out the appropriate data byte on the data lines.

ctivate the correct combination of control signals.

aise $\overline{EA}$/V_{PP} to 12V for the high-voltage program-ing mode.

ulse ALE/$\overline{PROG}$ once to program a byte in the ash array or the lock bits. The byte-write cycle is lf-timed and typically takes no more than 1.5 ms.

epeat steps 1 through 5, changing the address and data for the entire array or until the end of the object file is reached.

$\overline{Data}$ Polling: The AT89C51 features $\overline{Data}$ Polling to indicate the end of a write cycle. During a write cycle, an attempted read of the last byte written will result in the complement of the written datum on PO.7. 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 can also be monitored by the RDY/$\overline{BSY}$ output signal. P3.4 is pulled low after ALE goes high during programming to indicate 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 data can be read back via the address and data lines for verification. The lock bits cannot be verified directly. Verification of the lock bits is achieved by observing that their features are enabled.

Chip Erase: The entire Flash array is erased electrically by using the proper combination of control signals and by holding ALE/$\overline{PROG}$ low for 10 ms. The code array is written with all "1"s. The chip erase operation must be executed before the code memory can be re-programmed.

Reading the Signature Bytes: The signature bytes are read by the same procedure as a normal verification of locations 030H, 031H, and 032H, except that P3.6 and P3.7 must be pulled to a logic low. The values returned are as follows.

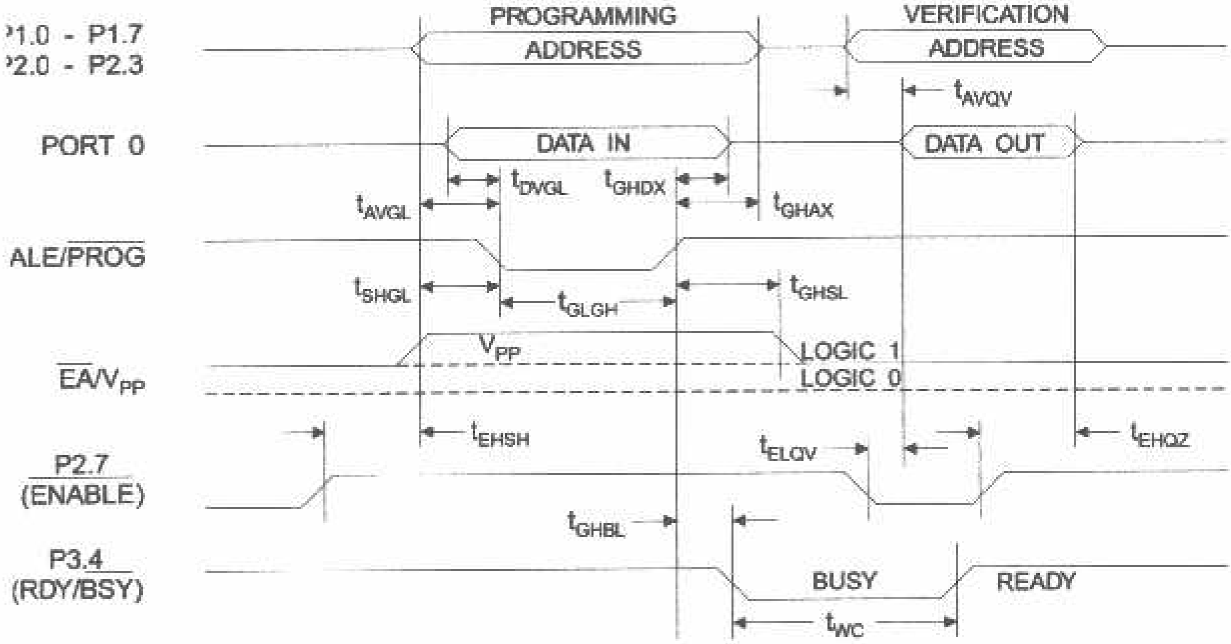
(030H) = 1EH indicates manufactured by Atmel
(031H) = 51H indicates 89C51
(032H) = FFH indicates 12V programming
(032H) = 05H indicates 5V programming

Programming Interface

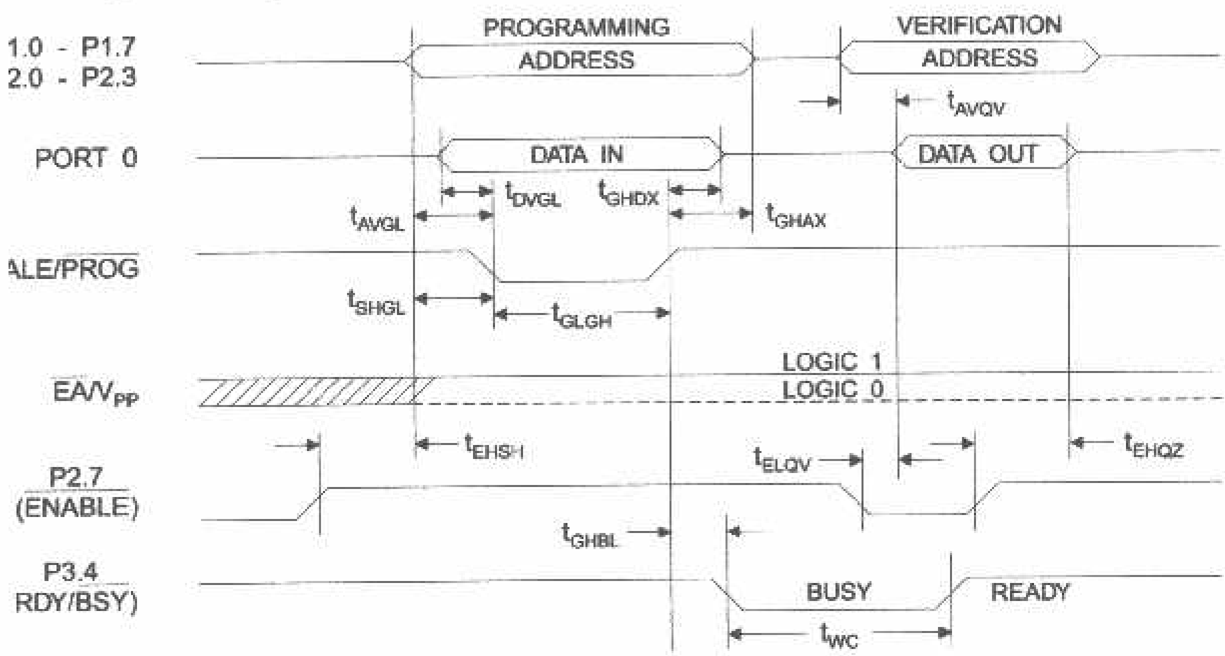
Every code byte in the Flash array can be written and the entire array can be erased by using the appropriate combination of control signals. The write operation cycle is self-timed and once initiated, will automatically time itself to completion.

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

sh Programming and Verification Waveforms - High-voltage Mode (V_{PP} = 12V)



;h Programming and Verification Waveforms - Low-voltage Mode (V_{PP} = 5V)



sh Programming and Verification Characteristics

)°C to 70°C, $V_{CC} = 5.0 \pm 10\%$

bol	Parameter	Min	Max	Units
)	Programming Enable Voltage	11.5	12.5	V
	Programming Enable Current		1.0	mA
CL	Oscillator Frequency	3	24	MHz
	Address Setup to $\overline{PROG}$ Low	$48t_{CLCL}$		
	Address Hold after $\overline{PROG}$	$48t_{CLCL}$		
	Data Setup to $\overline{PROG}$ Low	$48t_{CLCL}$		
	Data Hold after $\overline{PROG}$	$48t_{CLCL}$		
	P2.7 ($\overline{ENABLE}$) High to V_{PP}	$48t_{CLCL}$		
	V_{PP} Setup to $\overline{PROG}$ Low	10		µs
(1)	V_{PP} Hold after $\overline{PROG}$	10		µs
	$\overline{PROG}$ Width	1	110	µs
	Address to Data Valid		$48t_{CLCL}$	
	$\overline{ENABLE}$ Low to Data Valid		$48t_{CLCL}$	
	Data Float after $\overline{ENABLE}$	0	$48t_{CLCL}$	
	$\overline{PROG}$ High to $\overline{BUSY}$ Low		1.0	µs
	Byte Write Cycle Time		2.0	ms

1. Only used in 12-volt programming mode.

solute Maximum Ratings*

rating Temperature	-55°C to +125°C
age Temperature	-65°C to +150°C
ge on Any Pin Respect to Ground	-1.0V to +7.0V
mum Operating Voltage	6.6V
utput 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.

Characteristics

40°C to 85°C, V_{CC} = 5.0V ±20% (unless otherwise noted)

ol	Parameter	Condition	Min	Max	Units
	Input Low-voltage	(Except $\overline{EA}$)	-0.5	0.2 V_{CC} - 0.1	V
	Input Low-voltage ($\overline{EA}$)		-0.5	0.2 V_{CC} - 0.3	V
	Input High-voltage	(Except XTAL1, RST)	0.2 V_{CC} + 0.9	V_{CC} + 0.5	V
	Input High-voltage	(XTAL1, RST)	0.7 V_{CC}	V_{CC} + 0.5	V
	Output Low-voltage[1] (Ports 1,2,3)	I_{OL} = 1.6 mA		0.45	V
	Output Low-voltage[1] (Port 0, ALE, $\overline{PSEN}$)	I_{OL} = 3.2 mA		0.45	V
	Output High-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
	Output High-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
	Logical 0 Input Current (Ports 1,2,3)	V_{IN} = 0.45V		-50	µA
	Logical 1 to 0 Transition Current (Ports 1,2,3)	V_{IN} = 2V, VCC = 5V ±10%		-650	µA
	Input Leakage Current (Port 0, $\overline{EA}$)	0.45 < V_{IN} < V_{CC}		±10	µA
	Reset Pull-down Resistor		50	300	KΩ
	Pin Capacitance	Test Freq. = 1 MHz, T_A = 25°C		10	pF
	Power Supply Current	Active Mode, 12 MHz		20	mA
		Idle Mode, 12 MHz		5	mA
	Power-down Mode[2]	V_{CC} = 6V		100	µA
		V_{CC} = 3V		40	µA

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

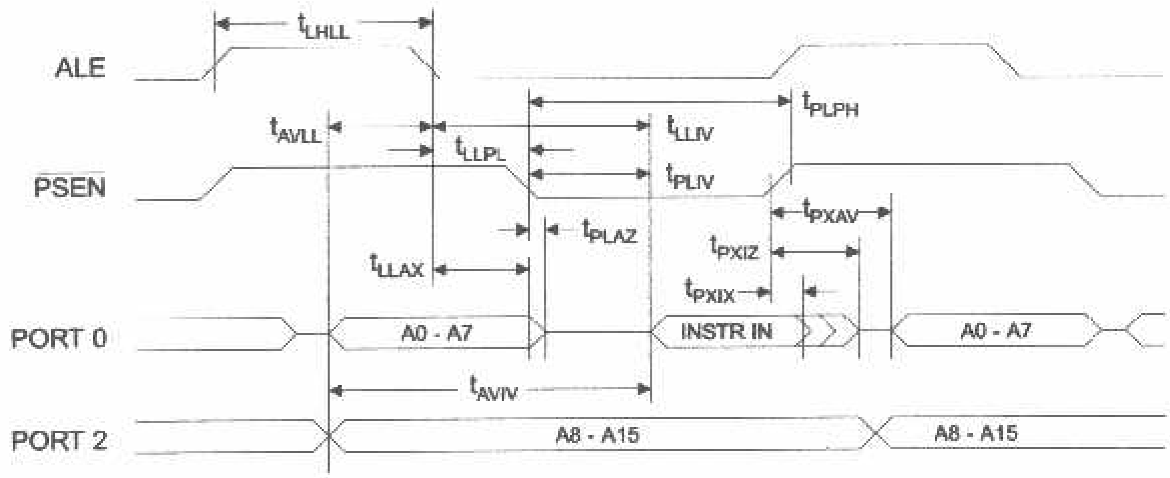
Characteristics

r operating conditions, load capacitance for Port 0, ALE/$\overline{\text{PROG}}$, and $\overline{\text{PSEN}}$ = 100 pF; load capacitance for all other ts = 80 pF.

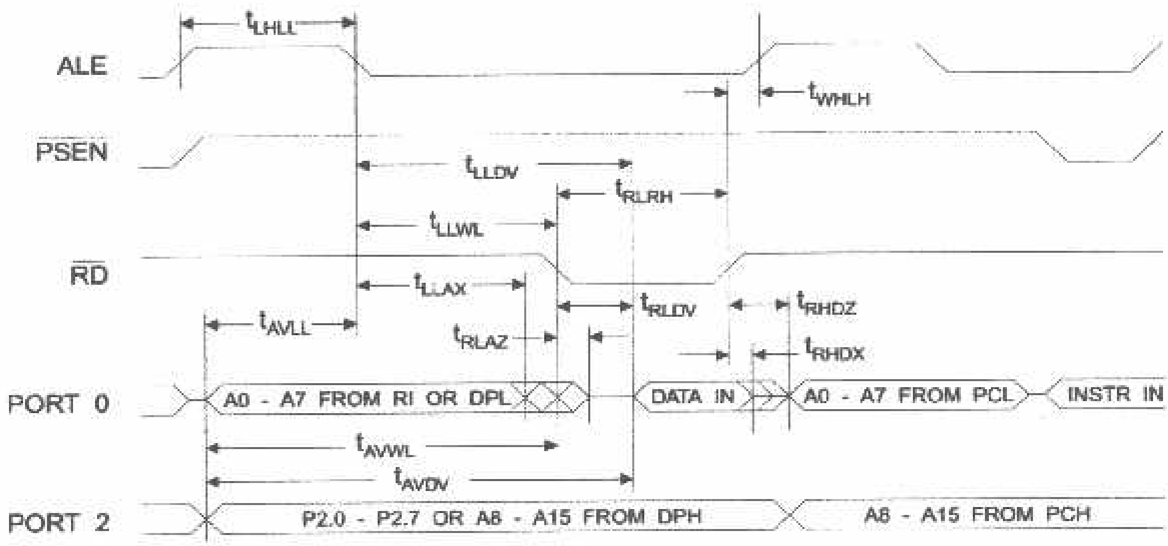
ernal Program and Data Memory Characteristics

		12 MHz Oscillator		16 to 24 MHz Oscillator		
bol	Parameter	Min	Max	Min	Max	Units
:L	Oscillator Frequency			0	24	MHz
	ALE Pulse Width	127		$2t_{CLCL}$-40		ns
	Address Valid to ALE Low	43		t_{CLCL}-13		ns
	Address Hold after ALE Low	48		t_{CLCL}-20		ns
	ALE Low to Valid Instruction In		233		$4t_{CLCL}$-65	ns
	ALE Low to $\overline{\text{PSEN}}$ Low	43		t_{CLCL}-13		ns
	$\overline{\text{PSEN}}$ Pulse Width	205		$3t_{CLCL}$-20		ns
	$\overline{\text{PSEN}}$ Low to Valid Instruction In		145		$3t_{CLCL}$-45	ns
	Input Instruction Hold after $\overline{\text{PSEN}}$	0		0		ns
	Input Instruction Float after $\overline{\text{PSEN}}$		59		t_{CLCL}-10	ns
	$\overline{\text{PSEN}}$ to Address Valid	75		t_{CLCL}-8		ns
	Address to Valid Instruction In		312		$5t_{CLCL}$-55	ns
	$\overline{\text{PSEN}}$ Low to Address Float		10		10	ns
	$\overline{\text{RD}}$ Pulse Width	400		$6t_{CLCL}$-100		ns
	$\overline{\text{WR}}$ Pulse Width	400		$6t_{CLCL}$-100		ns
	$\overline{\text{RD}}$ Low to Valid Data In		252		$5t_{CLCL}$-90	ns
	Data Hold after $\overline{\text{RD}}$	0		0		ns
	Data Float after $\overline{\text{RD}}$		97		$2t_{CLCL}$-28	ns
	ALE Low to Valid Data In		517		$8t_{CLCL}$-150	ns
	Address to Valid Data In		585		$9t_{CLCL}$-165	ns
	ALE Low to $\overline{\text{RD}}$ or $\overline{\text{WR}}$ Low	200	300	$3t_{CLCL}$-50	$3t_{CLCL}$+50	ns
	Address to $\overline{\text{RD}}$ or $\overline{\text{WR}}$ Low	203		$4t_{CLCL}$-75		ns
	Data Valid to $\overline{\text{WR}}$ Transition	23		t_{CLCL}-20		ns
	Data Valid to $\overline{\text{WR}}$ High	433		$7t_{CLCL}$-120		ns
	Data Hold after $\overline{\text{WR}}$	33		t_{CLCL}-20		ns
	$\overline{\text{RD}}$ Low to Address Float		0		0	ns
	$\overline{\text{RD}}$ or $\overline{\text{WR}}$ High to ALE High	43	123	t_{CLCL}-20	t_{CLCL}+25	ns

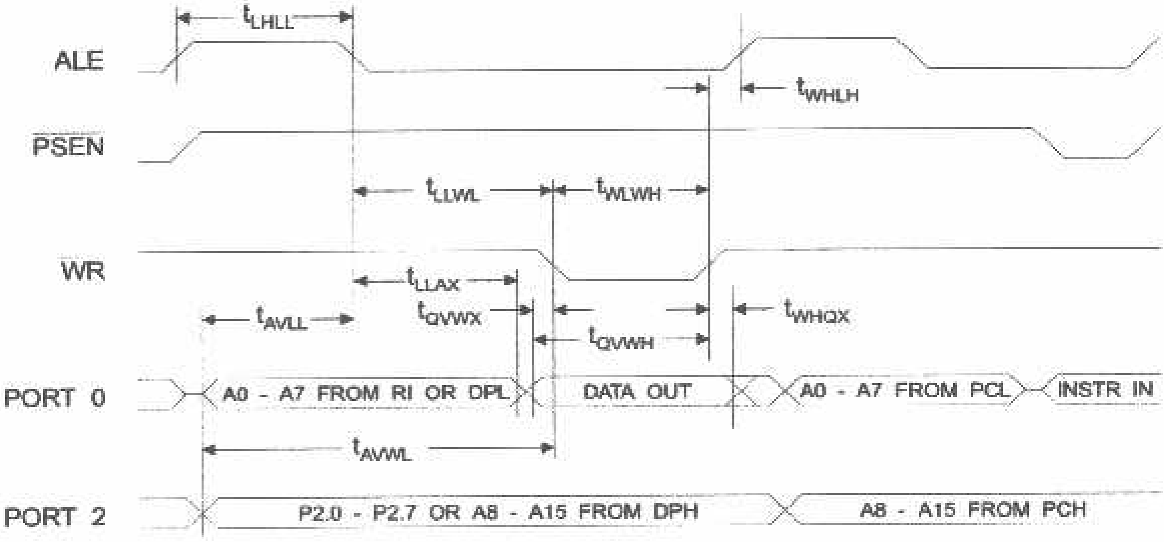
ernal Program Memory Read Cycle



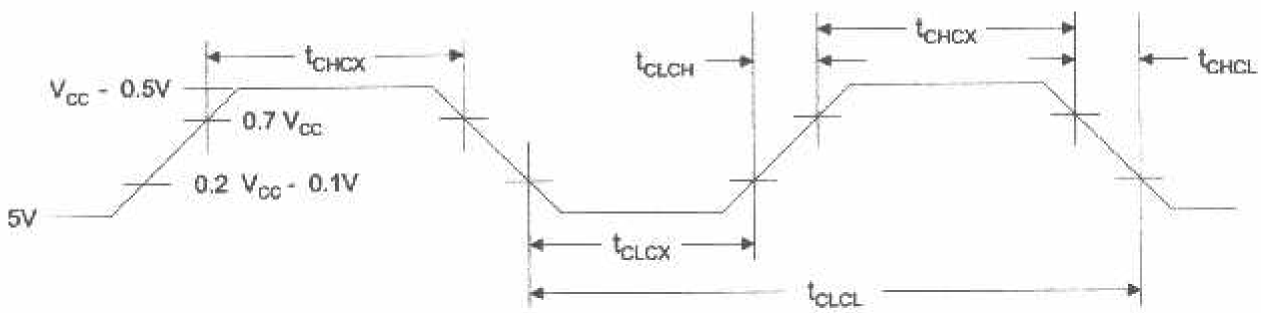
rnal Data Memory Read Cycle



ernal Data Memory Write Cycle



rnal Clock Drive Waveforms



rnal Clock Drive

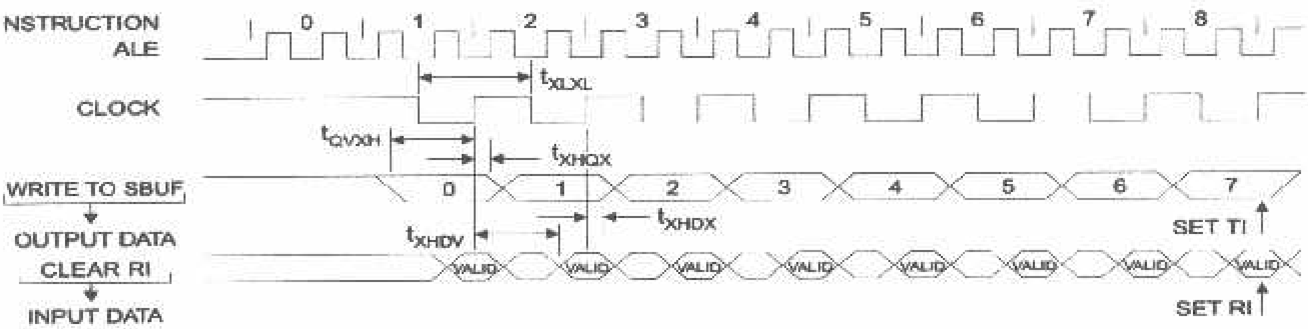
ol	Parameter	Min	Max	Units
	Oscillator Frequency	0	24	MHz
	Clock Period	41.6		ns
	High Time	15		ns
	Low Time	15		ns
	Rise Time		20	ns
	Fall Time		20	ns

al Port Timing: Shift Register Mode Test Conditions

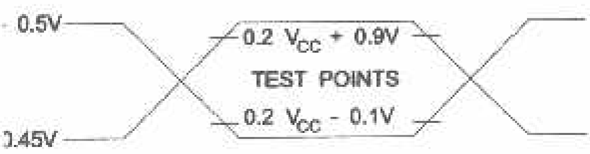
5.0 V ±20%; Load Capacitance = 80 pF)

bol	Parameter	12 MHz Osc		Variable Oscillator		Units
		Min	Max	Min	Max	
	Serial Port Clock Cycle Time	1.0		$12t_{CLCL}$		µs
	Output Data Setup to Clock Rising Edge	700		$10t_{CLCL}-133$		ns
	Output Data Hold after Clock Rising Edge	50		$2t_{CLCL}-117$		ns
	Input Data Hold after Clock Rising Edge	0		0		ns
	Clock Rising Edge to Input Data Valid		700		$10t_{CLCL}-133$	ns

t Register Mode Timing Waveforms



'esting Input/Output Waveforms(1)



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

Float Waveforms(1)

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

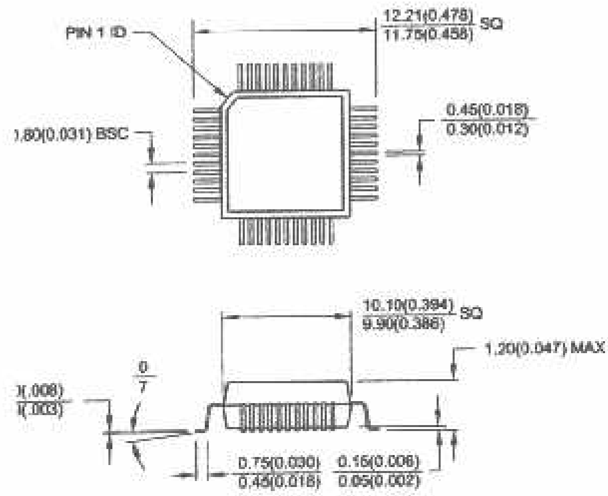
ering Information

eed Hz)	Power Supply	Ordering Code	Package	Operation Range
2	5V ±20%	AT89C51-12AC	44A	Commercial
		AT89C51-12JC	44J	(0° C to 70° C)
		AT89C51-12PC	40P6	
		AT89C51-12QC	44Q	
		AT89C51-12AI	44A	Industrial
		AT89C51-12JI	44J	(-40° C to 85° C)
		AT89C51-12PI	40P6	
		AT89C51-12QI	44Q	
6	5V ±20%	AT89C51-16AC	44A	Commercial
		AT89C51-16JC	44J	(0° C to 70° C)
		AT89C51-16PC	40P6	
		AT89C51-16QC	44Q	
		AT89C51-16AI	44A	Industrial
		AT89C51-16JI	44J	(-40° C to 85° C)
		AT89C51-16PI	40P6	
		AT89C51-16QI	44Q	
0	5V ±20%	AT89C51-20AC	44A	Commercial
		AT89C51-20JC	44J	(0° C to 70° C)
		AT89C51-20PC	40P6	
		AT89C51-20QC	44Q	
		AT89C51-20AI	44A	Industrial
		AT89C51-20JI	44J	(-40° C to 85° C)
		AT89C51-20PI	40P6	
		AT89C51-20QI	44Q	
4	5V ±20%	AT89C51-24AC	44A	Commercial
		AT89C51-24JC	44J	(0° C to 70° C)
		AT89C51-24PC	40P6	
		AT89C51-24QC	44Q	
		AT89C51-24AI	44A	Industrial
		AT89C51-24JI	44J	(-40° C to 85° C)
		AT89C51-24PI	40P6	
		AT89C51-24QI	44Q	

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

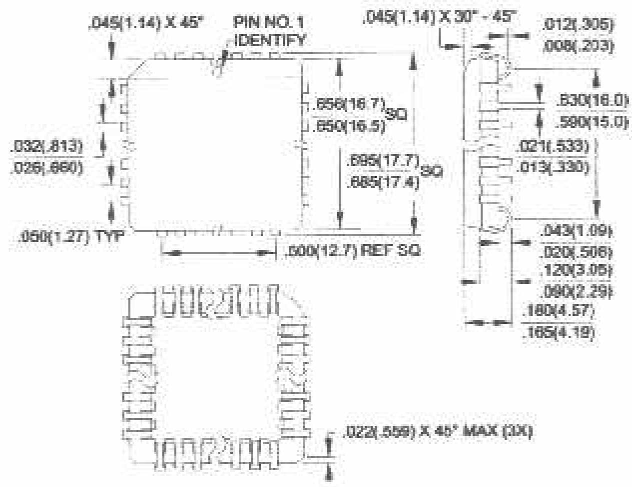
‹aging Information

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

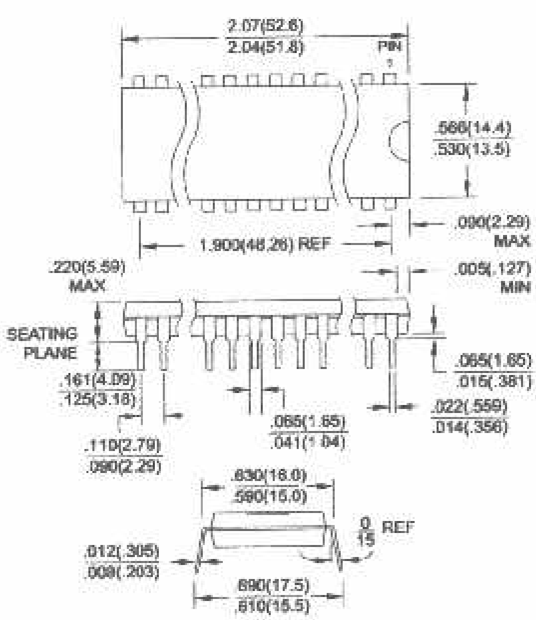


ntrolling dimension: millimeters

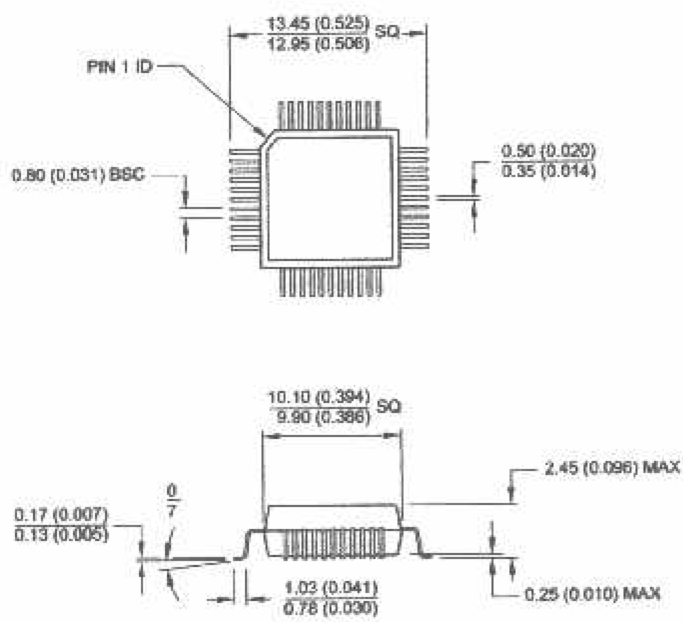
44J, 44-lead, Plastic J-leaded Chip Carrier (PLCC)
Dimensions in Inches and (Millimeters)
JEDEC STANDARD MS-018 AC



P6, 40-lead, 0.600" Wide, Plastic Dual Inline
ckage (PDIP)
nensions in Inches and (Millimeters)



44Q, 44-lead, Plastic Quad Flat Package (PQFP)
Dimensions in Millimeters and (Inches)*
JEDEC STANDARD MS-022 AB



Controlling dimension: millimeters

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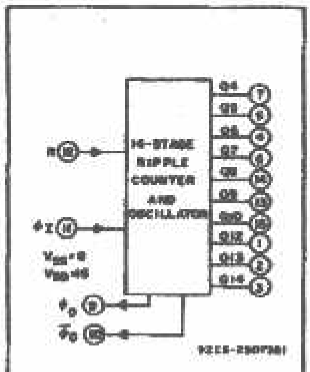
TEXAS
STRUMENTS
heet acquired from Harris Semiconductor
049

CD4060B Types

IOS 14-Stage Ripple-
ry Binary Counter/Divider
l Oscillator

Voltage Types (20-Volt Rating)



FUNCTIONAL DIAGRAM

■ CD4060B consists of an oscillator and 14 ripple-carry binary counter The oscillator configuration allows of either RC or crystal oscillator . A RESET input is provided which the counter to the all-0's state and the oscillator. A high level on the line accomplishes the reset function. nter stages are master-slave flip-flops. te of the counter is advanced one binary order on the negative transi- φI (and φO). All inputs and outputs ly buffered. Schmitt trigger action input-pulse line permits unlimited ulse rise and fall times.

D4060B-series types are supplied in hermetic dual-in-line ceramic pack- D and F suffixes), 16-lead dual-in-line packages (E suffix), and in chip form ix).

Features:

- 12 MHz clock rate at 15 V
- Common reset
- Fully static operation
- Buffered inputs and outputs
- Schmitt trigger input-pulse line
- 100% tested for quiescent current at 20 V
- Standardized, symmetrical output characteristics
- 5-V, 10-V, and 15-V parametric ratings
- Meets all requirements of JEDEC Tentative Standard No. 13B, "Standard Specifications for description of "B" Series CMOS Devices"

Oscillator Features:

- All active components on chip
- RC or crystal oscillator configuration
- RC oscillator frequency of 690 kHz min. at 15 V

Applications

- Control counters
- Timers
- Frequency dividers
- Time-delay circuits

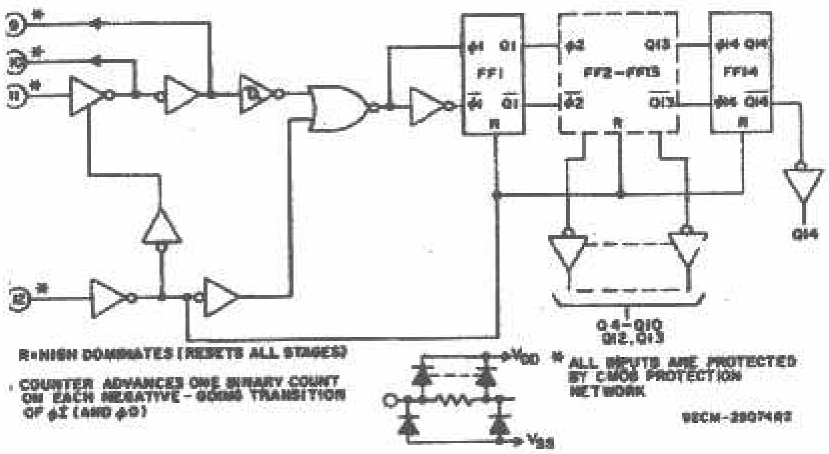


Fig. 1 – Logic diagram.

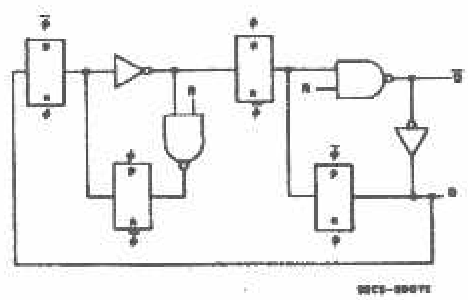


Fig. 2 – Detail of typical flip-flop stage.

M RATINGS, Absolute-Maximum Values:
PLY-VOLTAGE RANGE, (V_{DD})
es referenced to V_{SS} Terminal) .... −0.5V to +20V
OLTAGE RANGE, ALL INPUTS .... −0.5V to V_{DD} +0.5V
T CURRENT, ANY ONE INPUT .... ±10mA
DISSIPATION PER PACKAGE (P_D):
= −55°C to +100°C 500mW
= +100°C to +125°C .... Derate Linearity at 12mW/°C to 200mW
DISSIPATION PER OUTPUT TRANSISTOR
T_A = FULL PACKAGE-TEMPERATURE RANGE (All Package Types) 100mW
TING-TEMPERATURE RANGE (T_A) .... −55°C to +125°C
GE TEMPERATURE RANGE (T_{stg}) .... −65°C to +150°C
EMPERATURE (DURING SOLDERING):
ance 1/16 ± 1/32 inch (1.59 ± 0.79mm) from case for 10s max .... +265°C

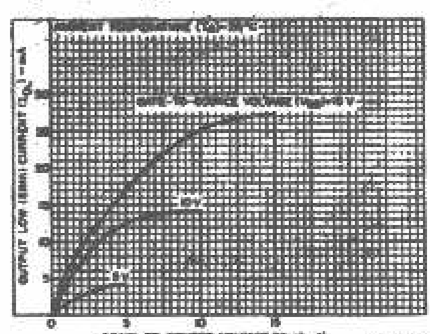


Fig. 3 – Typical n-channel output low (sink) current characteristics.

TIC ELECTRICAL CHARACTERISTICS

RAC-STIC	CONDITIONS			LIMITS AT INDICATED TEMPERATURES (°C)							UNITS
	V_O (V)	V_{IN} (V)	V_{DD} (V)	−55	−40	+85	+125	+25 Min.	+25 Typ.	+25 Max.	
cent ce ent, Max.	–	0,5	5	5	5	150	150	–	0.04	5	μA
	–	0,10	10	10	10	300	300	–	0.04	10	
	–	0,15	15	20	20	600	600	–	0.04	20	
	–	0,20	20	100	100	3000	3000	–	0.08	100	
ıt Low ()Current*, Min.	0.4	0,5	5	0.64	0.61	0.42	0.36	0.51	1	–	mA
	0.5	0,10	10	1.6	1.5	1.1	0.9	1.3	2.6	–	
	1.5	0,15	15	4.2	4	2.8	2.4	3.4	6.8	–	
ut High rce) rent*, Min.	4.6	0,5	5	−0.64	−0.61	−0.42	−0.36	−0.51	−1	–	
	2.5	0,5	5	−2	−1.8	−1.3	−1.15	−1.6	−3.2	–	
	9.5	0,10	10	−1.6	−1.5	−1.1	−0.9	−1.3	−2.6	–	
	13.5	0,15	15	−4.2	−4	−2.8	−2.4	−3.4	−6.8	–	
ıt Voltage: -Level, Max.	–	0,5	5	0.05				–	0	0.05	V
	–	0,10	10	0.05				–	0	0.05	
	–	0,15	15	0.05				–	0	0.05	
ut tage: -Level, Min.	–	0,5	5	4.95				4.95	5	–	
	–	0,10	10	9.95				9.95	10	–	
	–	0,15	15	14.95				14.95	15	–	
t Low tage Max.	0.5,4.5	–	5	1.5				–	–	1.5	V
	1,9	–	10	3				–	–	3	
	1.5,13.5	–	15	4				–	–	4	
t High tage, Min.	0.5,4.5	–	5	3.5				3.5	–	–	
	1,9	–	10	7				7	–	–	
	1.5,13.5	–	15	11				11	–	–	
t Current Max.	–	0,18	18	±0.1	±0.1	±1	±1	–	$\pm 10^{-5}$	±0.1	μA

not applicable to terminal 9 or 10.

OMMENDED OPERATING CONDITIONS

naximum reliability, nominal operating conditions should be selected so that operation is ys within the following ranges:

RACTERISTIC	V_{DD}	LIMITS MIN.	LIMITS MAX.	UNITS
ly-Voltage Range (For T_A = Full Package emperature Range)	–	3	18	V
t-Pulse Width, t_W (f = 100 kHz)	5 10 15	100 40 30	– – –	ns
t-Pulse Rise Time and Fall Time, $t_{r\phi}$, $t_{f\phi}$	5 10 15	Unlimited		
t-Pulse Frequency, $f_{\phi 1}$ (External pulse source)	5 10 15	– – –	3.5 8 12	MHz
t Pulse Width, t_W	5 10 15	120 60 40	– – –	ns

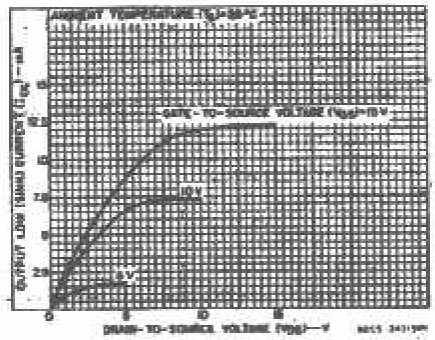


Fig. 4 – Minimum n-channel output low (sink) current characteristics.

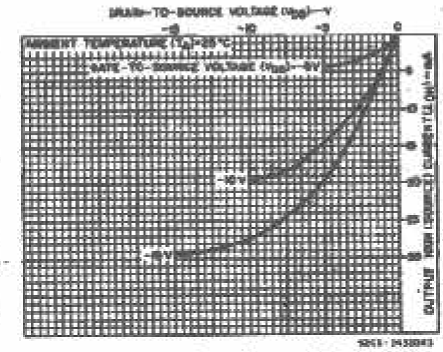


Fig. 5 – Typical p-channel output high (source) current characteristics.

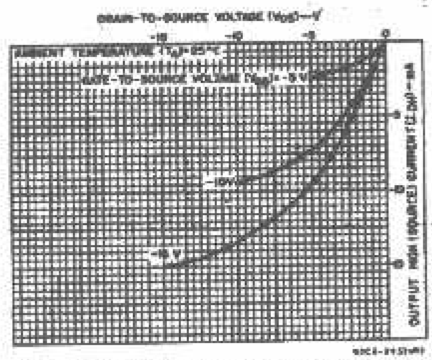


Fig. 6 – Minimum p-channel output high (source) current characteristics.

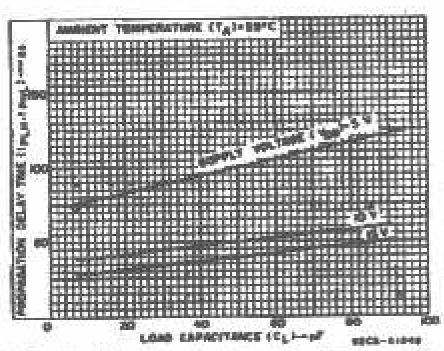


Fig. 7 – Typical propagation delay time (Q_n to Q_n+1) as a function of load capacitance.

3 COMMERCIAL CMOS

ELECTRICAL CHARACTERISTICS at T_A = 25°C, Input t_r, t_f = 20 ns, C_L = 50 pF, R_L = 200 kΩ

CTERISTIC	TEST CONDITIONS	V_{DD} (V)	LIMITS MIN.	TYP.	MAX.	UNITS
e Operation						
on Delay to Q4 Out; PLH		5	–	370	740	ns
		10	–	150	300	
		15	–	100	200	
on Delay to Q_{n+1}; PLH		5	–	100	200	
		10	–	50	100	
		15	–	40	80	
Time, TLH		5	–	100	200	
		10	–	50	100	
		15	–	40	80	
:-Pulse W	f = 100 kHz	5	–	50	100	
		10	–	20	40	
		15	–	15	30	
e Rise & Fall $t_{r\phi}$, $t_{f\phi}$		5	Unlimited			
		10				
		15				
t-Pulse cy, $f_{\phi I}$ l pulse		5	3.5	7	–	MHz
		10	8	16	–	
		15	12	24	–	
citance, C_I	Any Input		–	5	7.5	pF
ration						
n Delay HL		5	–	180	360	ns
		10	–	80	160	
		15	–	50	100	
Reset lth, t_W		5	–	60	120	
		10	–	30	60	
		15	–	20	40	

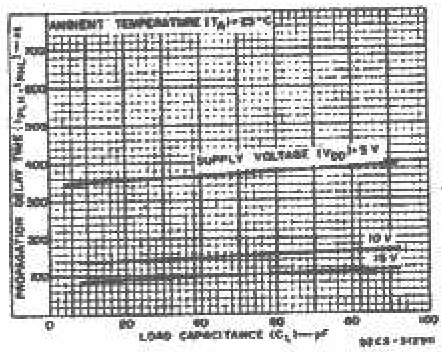


Fig. 8 – Typical propagation delay time (t_{PLH}) to Q_4 Output) as a function of load capacitance.

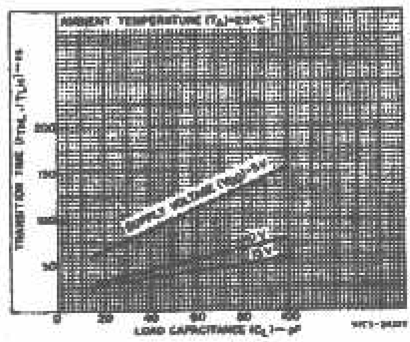


Fig. 9 – Typical transition time as a function of load capacitance.

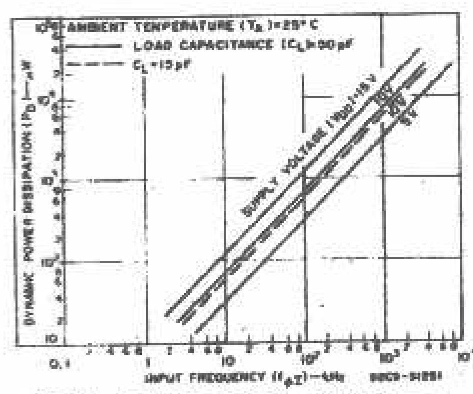
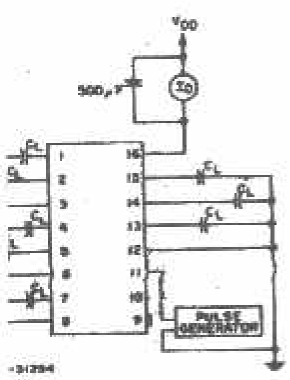


Fig. 10 – Typical dynamic power dissipation as a function of input frequency.



ynamic power dissipation test circuit.

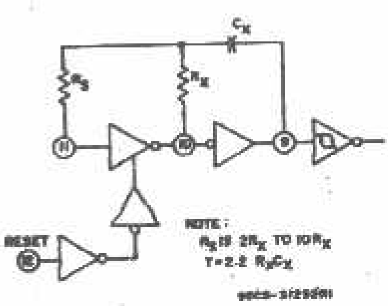


Fig. 12 – Typical RC circuit.

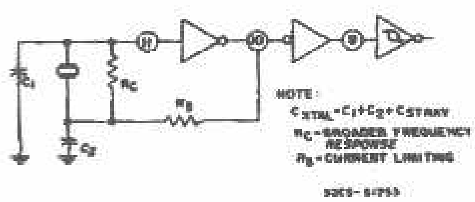


Fig. 13 – Typical crystal circuit.

...MIC ELECTRICAL CHARACTERISTICS at T_A = 25°C, Input t_r, t_f = 20 ns, ... = 50 pF, R_L = 200 kΩ (cont'd)

...ACTERISTIC	TEST CONDITIONS		VDD (V)	LIMITS Min.	Typ.	Max.	UNITS
...eration							
...ion of Fre-...cy (Unit-to-Unit)	C_X = 200 pF, R_S = 560 kΩ, R_X = 50 kΩ		5	—	23±10%	—	kHz
			10	—	24±10%	—	
			15	—	25±10%	—	
...ion of Fre-...cy with voltage ...ge (Same Unit)	C_X = 200 pF, R_S = 560 kΩ, R_X = 50 kΩ		5V to 10 V	—	1.5	—	
			10V to 15V	—	0.5	—	
...ax.	C_X = 10 µF		5	—	—	20	MΩ
	= 50 µF		10	—	—	20	
	= 10 µF		15	—	—	10	
...ax.	R_X = 500 kΩ		5	—	—	1000	µF
	= 300 kΩ		10	—	—	50	
	= 300 kΩ		15	—	—	50	
...num Oscillator ...uency*	R_X = 5 kΩ, R_S = 30 kΩ, C_X = 15 pF		10	530	650	810	kHz
			15	690	800	940	
...Current at ...(For Oscillator ...gn) I_{OL}	V_O = 0.4 V		5	0.16	0.36	—	mA
	= 0.5 V		10	0.42	0.8	—	
	= 1.5 V		15	1	2	—	
I_{OH}	V_O = 4.6 V		5	-0.16	-0.35	—	
	= 9.5 V		10	-0.42	-0.8	—	
	= 13.5 V		15	-1	-2	—	

...cillator applications are not recommended at supply voltages below 7 V for R_X < 50 kΩ.

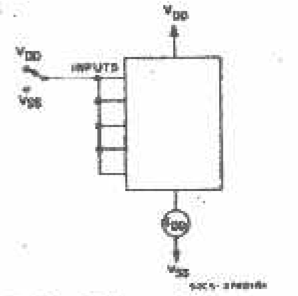


Fig. 14 – Quiescent device current.

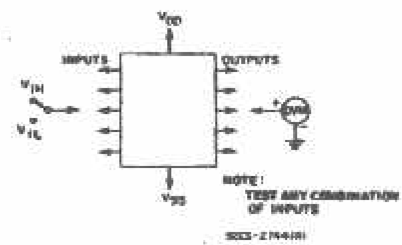


Fig. 15 – Input voltage.

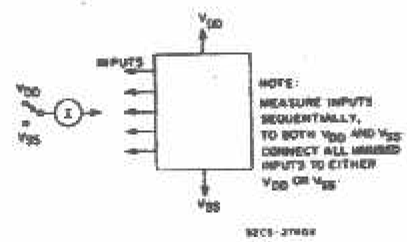
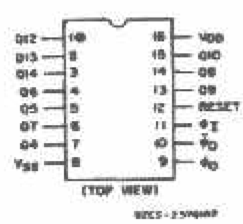
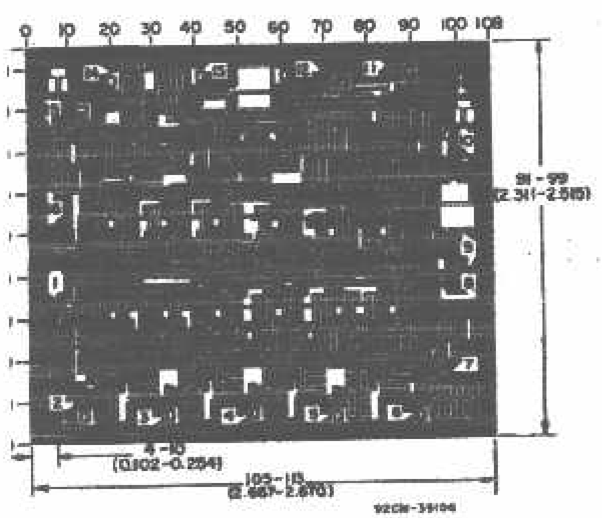


Fig. 16 – Input current.

TERMINAL DIAGRAM





Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated. Grid graduations are in mils (10^{-3} inch).

Chip dimensions and pad layout for CD4060B

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ual Precision etrriggerable/Resettable lonostable Multivibrator

ON Semiconductor

http://onsemi.com

The MC14538B is a dual, retriggerable, resettable monostable ltivibrator. It may be triggered from either edge of an input pulse, l produces an accurate output pulse over a wide range of widths, the ration and accuracy of which are determined by the external timing nponents, C_X and R_X.

Output Pulse Width = (Cx) (Rx) where:
Rx is in kΩ
Cx is in μF

- Unlimited Rise and Fall Time Allowed on the A Trigger Input
- Pulse Width Range = 10 μs to 10 s
- Latched Trigger Inputs
- Separate Latched Reset Inputs
- 3.0 Vdc to 18 Vdc Operational Limits
- Triggerable from Positive (A Input) or Negative–Going Edge (B–Input)
- Capable of Driving Two Low–power TTL Loads or One Low–power Schottky TTL Load Over the Rated Temperature Range
- Pin–for–pin Compatible with MC14528B and CD4528B (CD4098)
- Use the MC54/74HC4538A for Pulse Widths Less Than 10 μs with Supplies Up to 6 V.

AXIMUM RATINGS (Voltages Referenced to V_{SS}) (Note 2.)

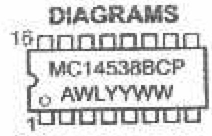
ymbol	Parameter	Value	Unit
V_{DD}	DC Supply Voltage Range	−0.5 to +18.0	V
V_{in}, V_{out}	Input or Output Voltage Range (DC or Transient)	−0.5 to V_{DD} + 0.5	V
I_{in}, I_{out}	Input or Output Current (DC or Transient) per Pin	±10	mA
P_D	Power Dissipation, per Package (Note 3.)	500	mW
T_A	Operating Temperature Range	−55 to +125	°C
T_{stg}	Storage Temperature Range	−65 to +150	°C
T_L	Lead Temperature (8–Second Soldering)	260	°C

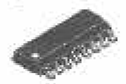
Maximum Ratings are those values beyond which damage to the device may occur.
Temperature Derating:
Plastic "P and D/DW" Packages: – 7.0 mW/°C From 65°C To 125°C

This device contains protection circuitry to guard against damage due to high atic voltages or electric fields. However, precautions must be taken to avoid plications of any voltage higher than maximum rated voltages to this gh–impedance circuit. For proper operation, V_{in} and V_{out} should be constrained the range $V_{SS} \le (V_{in}$ or $V_{out}) \le V_{DD}$.
Unused inputs must always be tied to an appropriate logic voltage level (e.g., ther V_{SS} or V_{DD}). Unused outputs must be left open.

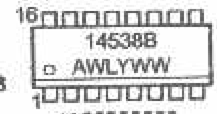
MARKING DIAGRAMS

PDIP–16
P SUFFIX
CASE 648

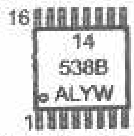


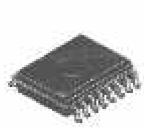


SOIC–16
D SUFFIX
CASE 751B

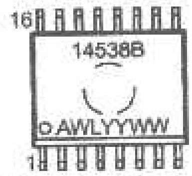


TSSOP–16
DT SUFFIX
CASE 948F

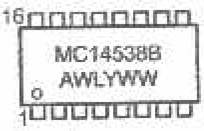




SOIC–16
DW SUFFIX
CASE 751G



SOEIAJ–16
F SUFFIX
CASE 966



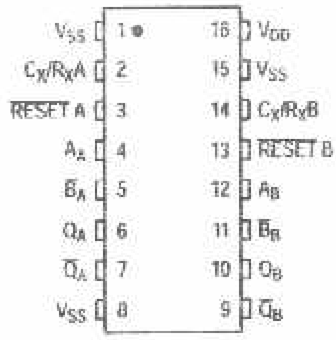
A = Assembly Location
WL or L = Wafer Lot
YY or Y = Year
WW or W = Work Week

ORDERING INFORMATION

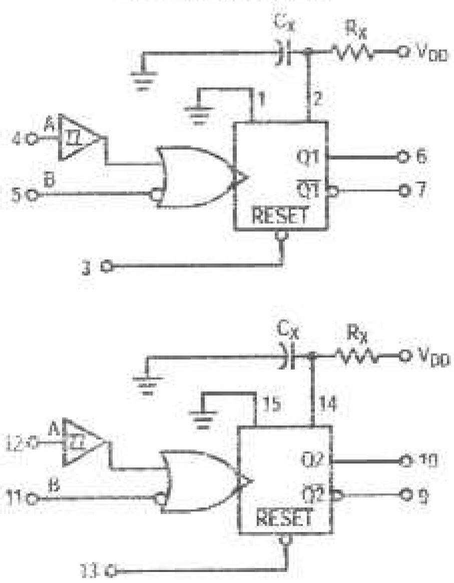
Device	Package	Shipping
MC14538BCP	PDIP–16	2000/Box
MC14538BD	SOIC–16	48/Rail
MC14538BDR2	SOIC–16	2500/Tape & Reel
MC14538BDT	TSSOP–16	96/Rail
MC14538BDTR2	TSSOP–16	2500/Tape & Reel
MC14538BDW	SOIC–16	47/Rail
MC14538BDWR2	SOIC–16	1000/Tape & Reel
MC14538BF	SOEIAJ–16	See Note 1.
MC14538BFEL	SOEIAJ–16	See Note 1.

1. For ordering information on the EIAJ version of the SOIC packages, please contact your local ON Semiconductor representative.

PIN ASSIGNMENT

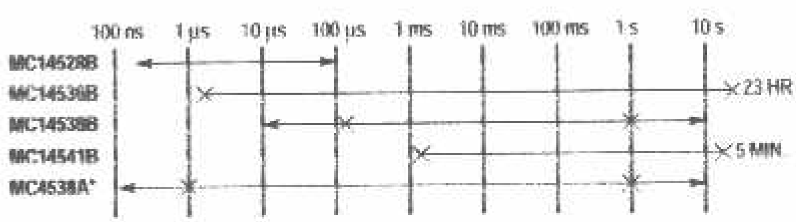


BLOCK DIAGRAM



R_X AND C_X ARE EXTERNAL COMPONENTS.
V_{DD} – PIN 16
V_{SS} – PIN 8, PIN 1, PIN 15

ONE–SHOT SELECTION GUIDE



*LIMITED OPERATING VOLTAGE (2 – 6 V)

TOTAL OUTPUT PULSE WIDTH RANGE

RECOMMENDED PULSE WIDTH RANGE

LECTRICAL CHARACTERISTICS (Voltages Referenced to V_{SS})

Characteristic	Symbol	V_{DD} Vdc	−55°C Min	−55°C Max	25°C Min	25°C Typ (4.)	25°C Max	125°C Min	125°C Max	Unit
Jutput Voltage "0" Level V_{in} = V_{DD} or 0	V_{OL}	5.0 10 15	— — —	0.05 0.05 0.05	— — —	0 0 0	0.05 0.05 0.05	— — —	0.05 0.05 0.05	Vdc
"1" Level V_{in} = 0 or V_{DD}	V_{OH}	5.0 10 15	4.95 9.95 14.95	— — —	4.95 9.95 14.95	5.0 10 15	— — —	4.95 9.95 14.95	— — —	Vdc
ıput Voltage "0" Level (V_O = 4.5 or 0.5 Vdc) (V_O = 9.0 or 1.0 Vdc) (V_O = 13.5 or 1.5 Vdc)	V_{IL}	5.0 10 15	— — —	1.5 3.0 4.0	— — —	2.25 4.50 6.75	1.5 3.0 4.0	— — —	1.5 3.0 4.0	Vdc
"1" Level (V_O = 0.5 or 4.5 Vdc) (V_O = 1.0 or 9.0 Vdc) (V_O = 1.5 or 13.5 Vdc)	V_{IH}	5.0 10 15	3.5 7.0 11	— — —	3.5 7.0 11	2.75 5.50 8.25	— — —	3.5 7.0 11	— — —	Vdc
utput Drive Current Source (V_{OH} = 2.5 Vdc) (V_{OH} = 4.6 Vdc) (V_{OH} = 9.5 Vdc) (V_{OH} = 13.5 Vdc)	I_{OH}	5.0 5.0 10 15	−3.0 −0.64 −1.6 −4.2	— — — —	−2.4 −0.51 1.3 −3.4	−4.2 −0.88 −2.25 −8.8	— — — —	−1.7 −0.36 −0.9 −2.4	— — — —	mAdc
Sink (V_{OL} = 0.4 Vdc) (V_{OL} = 0.5 Vdc) (V_{OL} = 1.5 Vdc)	I_{OL}	5.0 10 15	0.64 1.6 4.2	— — —	0.51 1.3 3.4	0.88 2.25 8.8	— — —	0.36 0.9 2.4	— — —	mAdc
put Current, Pin 2 or 14	I_{in}	15	—	±0.05	—	±0.00001	±0.05	—	±0.5	µAdc
put Current, Other Inputs	I_{in}	15	—	±0.1	—	±0.00001	±0.1	—	±1.0	µAdc
put Capacitance, Pin 2 or 14	C_{in}	—	—	—	—	25	—	—	—	pF
put Capacitance, Other Inputs (V_{in} = 0)	C_{in}	—	—	—	—	5.0	7.5	—	—	pF
uiescent Current (Per Package) Q = Low, $\overline{Q}$ = High	I_{DD}	5.0 10 15	— — —	5.0 10 20	— — —	0.005 0.010 0.015	5.0 10 20	— — —	150 300 600	µAdc
uiescent Current, Active State (Both) (Per Package) Q = High, $\overline{Q}$ = Low	I_{DD}	5.0 10 15	— — —	2.0 2.0 2.0	— — —	0.04 0.08 0.13	0.20 0.45 0.70	— — —	2.0 2.0 2.0	mAdc
tal Supply Current at an external ad capacitance (C_L) and at ternal timing network (R_X, C_X) (5.)	I_T	5.0 10	$I_T = (3.5 \times 10^{-2})\ R_XC_Xf + 4C_Xf + 1 \times 10^{-5}\ C_Lf$ $I_T = (8.0 \times 10^{-2})\ R_XC_Xf + 9C_Xf + 2 \times 10^{-5}\ C_Lf$ $I_T = (1.25 \times 10^{-1})\ R_XC_Xf + 12C_Xf + 3 \times 10^{-5}\ C_Lf$ where: I_T in µA (one monostable switching only), C_X in µF, C_L in pF, R_X in k ohms, and f in Hz is the input frequency.							µAdc

Data labelled "Typ" is not to be used for design purposes but is intended as an indication of the IC's potential performance.
The formulas given are for the typical characteristics only at 25°C.

SWITCHING CHARACTERISTICS (6.) (C_L = 50 pF, T_A = 25°C)

Characteristic	Symbol	V_{DD} Vdc	All Types Min	All Types Typ (7.)	All Types Max	Unit
Output Rise Time	t_{TLH}					ns
t_{TLH} = (1.35 ns/pF) C_L + 33 ns		5.0	—	100	200	
t_{TLH} = (0.60 ns/pF) C_L + 20 ns		10	—	50	100	
t_{TLH} = (0.40 ns/pF) C_L + 20 ns		15	—	40	80	
Output Fall Time	t_{THL}					ns
t_{THL} = (1.35 ns/pF) C_L + 33 ns		5.0	—	100	200	
t_{THL} = (0.60 ns/pF) C_L + 20 ns		10	—	50	100	
t_{THL} = (0.40 ns/pF) C_L + 20 ns		15	—	40	80	
Propagation Delay Time	t_{PLH},					ns
A or B to Q or $\overline{Q}$	t_{PHL}					
t_{PLH}, t_{PHL} = (0.90 ns/pF) C_L + 255 ns		5.0	—	300	600	
t_{PLH}, t_{PHL} = (0.36 ns/pF) C_L + 132 ns		10	—	150	300	
t_{PLH}, t_{PHL} = (0.26 ns/pF) C_L + 87 ns		15	—	100	220	
$\overline{Reset}$ to Q or $\overline{Q}$						ns
t_{PLH}, t_{PHL} = (0.90 ns/pF) C_L + 205 ns		5.0	—	250	500	
t_{PLH}, t_{PHL} = (0.36 ns/pF) C_L + 107 ns		10	—	125	250	
t_{PLH}, t_{PHL} = (0.26 ns/pF) C_L + 82 ns		15	—	95	190	
Input Rise and Fall Times	t_r, t_f	5	—	—	15	µs
$\overline{Reset}$		10	—	—	5	
		15	—	—	4	
B Input		5	—	300	1.0	ms
		10	—	1.2	0.1	
		15	—	0.4	0.05	
A Input		5				—
		10		No Limit		
		15				
Input Pulse Width	t_{WH},	5.0	170	85	—	ns
A, B, or Reset	t_{WL}	10	90	45	—	
		15	80	40	—	
Retrigger Time	t_{rr}	5.0	0	—	—	ns
		10	0	—	—	
		15	0	—	—	
Output Pulse Width — Q or $\overline{Q}$	T					µs
Refer to Figures 8 and 9						
C_X = 0.002 µF, R_X = 100 kΩ		5.0	198	210	230	
		10	200	212	232	
		15	202	214	234	
C_X = 0.1 µF, R_X = 100 kΩ		5.0	9.3	9.86	10.5	ms
		10	9.4	10	10.6	
		15	9.5	10.14	10.7	
C_X = 10 µF, R_X = 100 kΩ		5.0	0.91	0.965	1.03	s
		10	0.92	0.98	1.04	
		15	0.93	0.99	1.06	
Pulse Width Match between circuits in	100	5.0	—	± 1.0	± 5.0	%
the same package.	$[(T_1 - T_2)/T_1]$	10	—	± 1.0	± 5.0	
C_X = 0.1 µF, R_X = 100 kΩ		15	—	± 1.0	± 5.0	

The formulas given are for the typical characteristics only at 25°C.
Data labelled "Typ" is not to be used for design purposes but is intended as an indication of the IC's potential performance.

)PERATING CONDITIONS

External Timing Resistance	R_X	—	5.0	—	(8.)	kΩ
External Timing Capacitance	C_X	—	0	—	No Limit (9.)	µF

. The maximum usable resistance R_X is a function of the leakage of the capacitor C_X, leakage of the MC14538B, and leakage due to board layout and surface resistance. Susceptibility to externally induced noise signals may occur for $R_X > 1$ MΩ.

. If $C_X > 15$ µF, use discharge protection diode per Fig. 11.

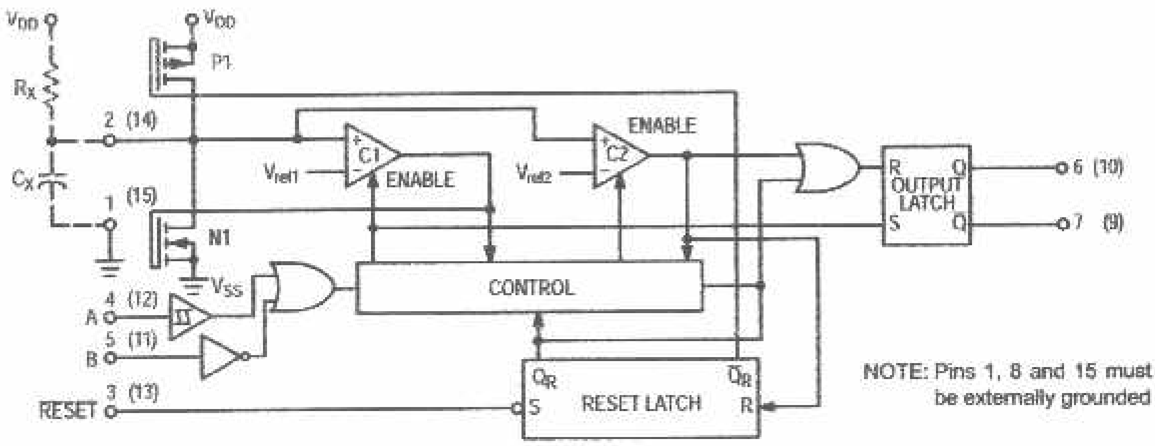


Figure 1. Logic Diagram (1/2 of Device Shown)

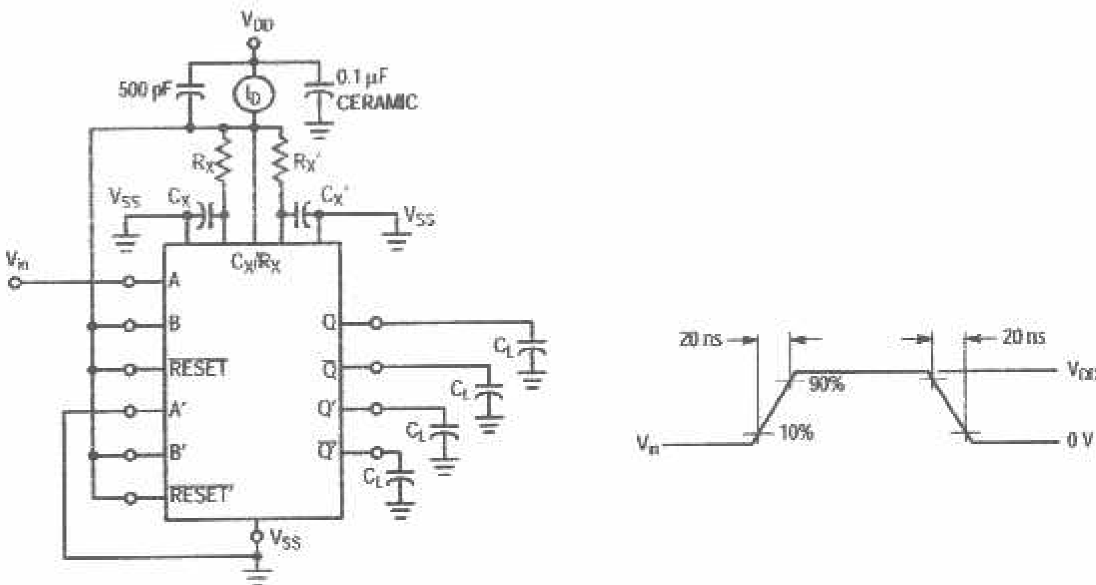
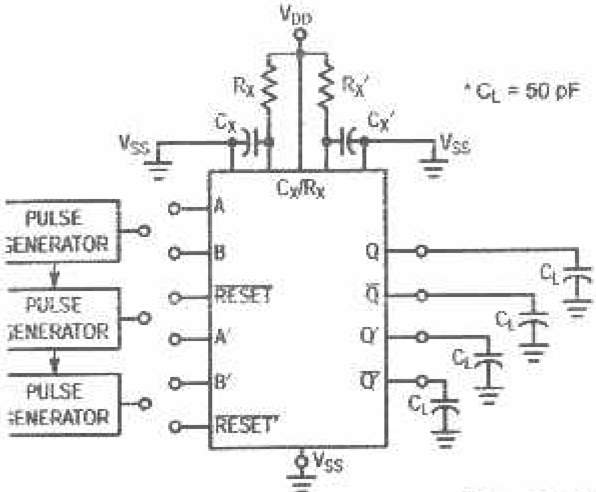


Figure 2. Power Dissipation Test Circuit and Waveforms



INPUT CONNECTIONS

Characteristics	$\overline{Reset}$	A	B
t_{PLH}, t_{PHL}, t_{TLH}, t_{THL}, T, t_{WH}, t_{WL}	V_{DD}	PG1	V_{DD}
t_{PLH}, t_{PHL}, t_{TLH}, t_{THL}, T, t_{WH}, t_{WL}	V_{DD}	V_{SS}	PG2
$t_{PLH(R)}$, $t_{PHL(R)}$, t_{WH}, t_{WL}	PG3	PG1	PG2

* Includes capacitance of probes, wiring, and fixture parasitic.

NOTE: Switching test waveforms for PG1, PG2, PG3 are shown in Figure 4.

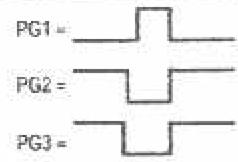


Figure 3. Switching Test Circuit

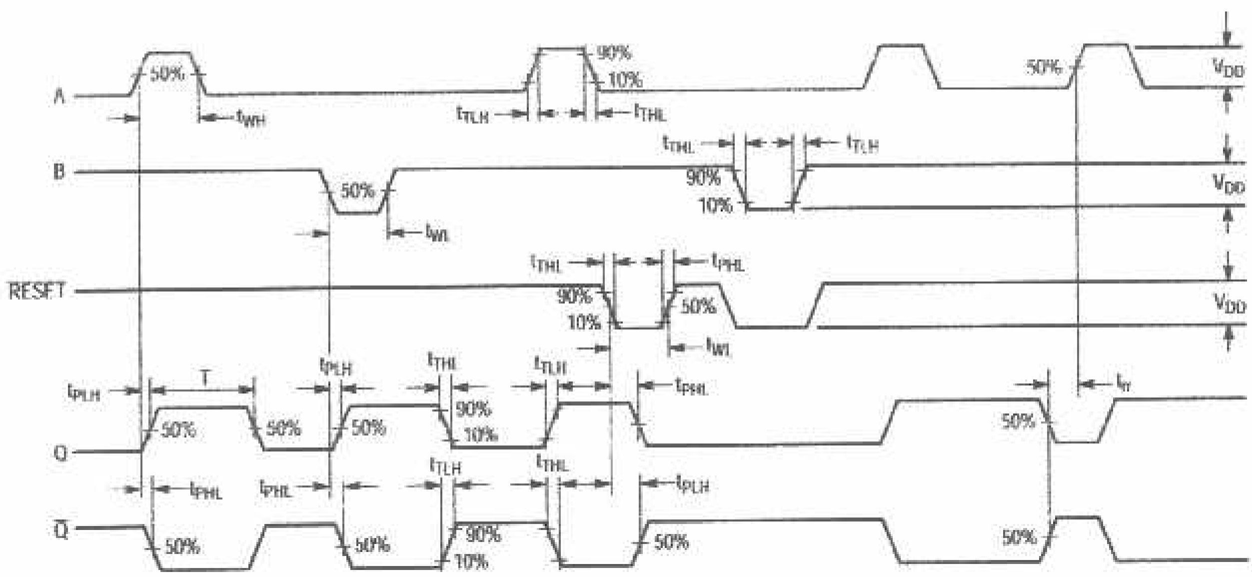


Figure 4. Switching Test Waveforms

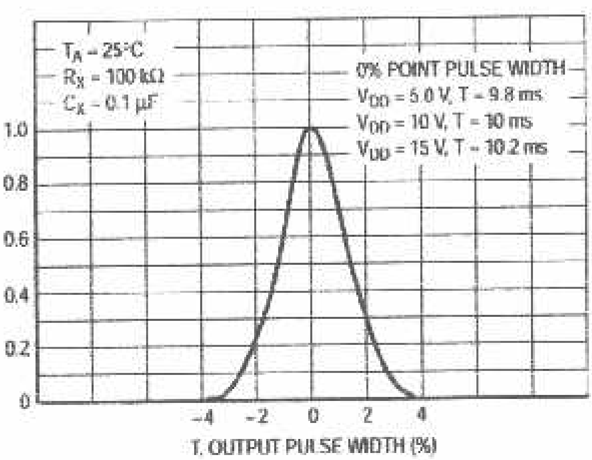


Figure 5. Typical Normalized Distribution of Units for Output Pulse Width

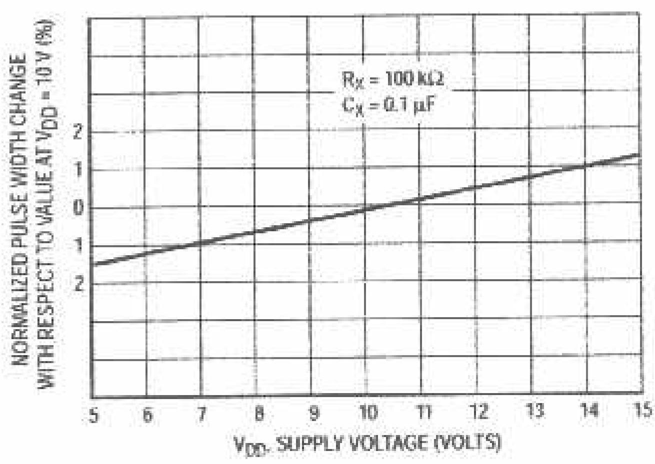


Figure 6. Typical Pulse Width Variation as a Function of Supply Voltage V_{DD}

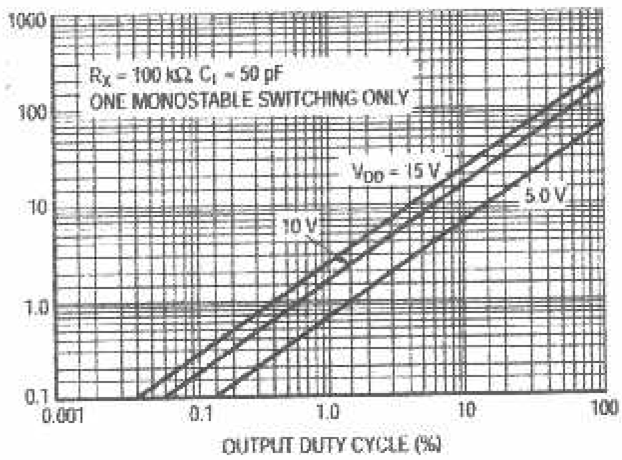


Figure 7. Typical Total Supply Current versus Output Duty Cycle

FUNCTION TABLE

Inputs			Outputs	
Reset	A	B	Q	$\overline{Q}$
H	↑	H	⊓	⊔
H	L	↓	⊓	⊔
H	↑ ↓	L	Not Triggered	
H	H	↑ ↓	Not Triggered	
H	L, H, ↓	H	Not Triggered	
H	L	L, H, ↑	Not Triggered	
L	X	X	L	H
↓ ↑	X	X	Not Triggered	

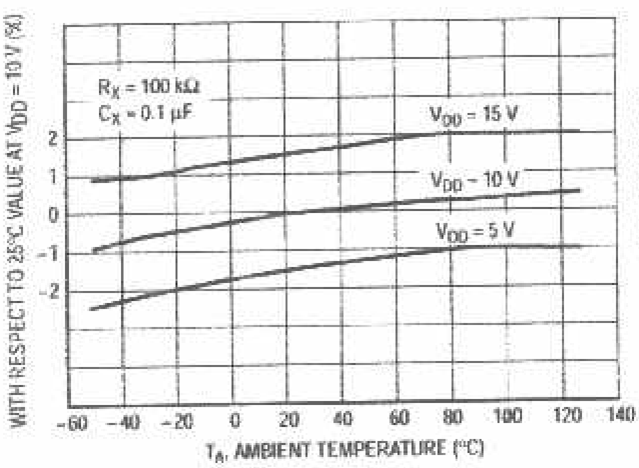


Figure 8. Typical Error of Pulse Width Equation versus Temperature

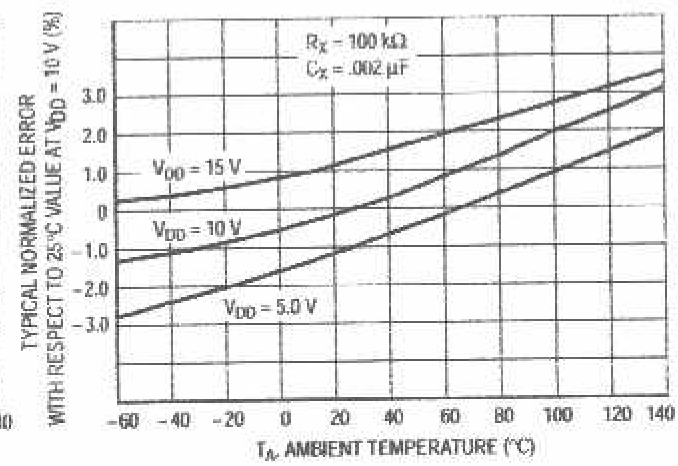


Figure 9. Typical Error of Pulse Width Equation versus Temperature

THEORY OF OPERATION

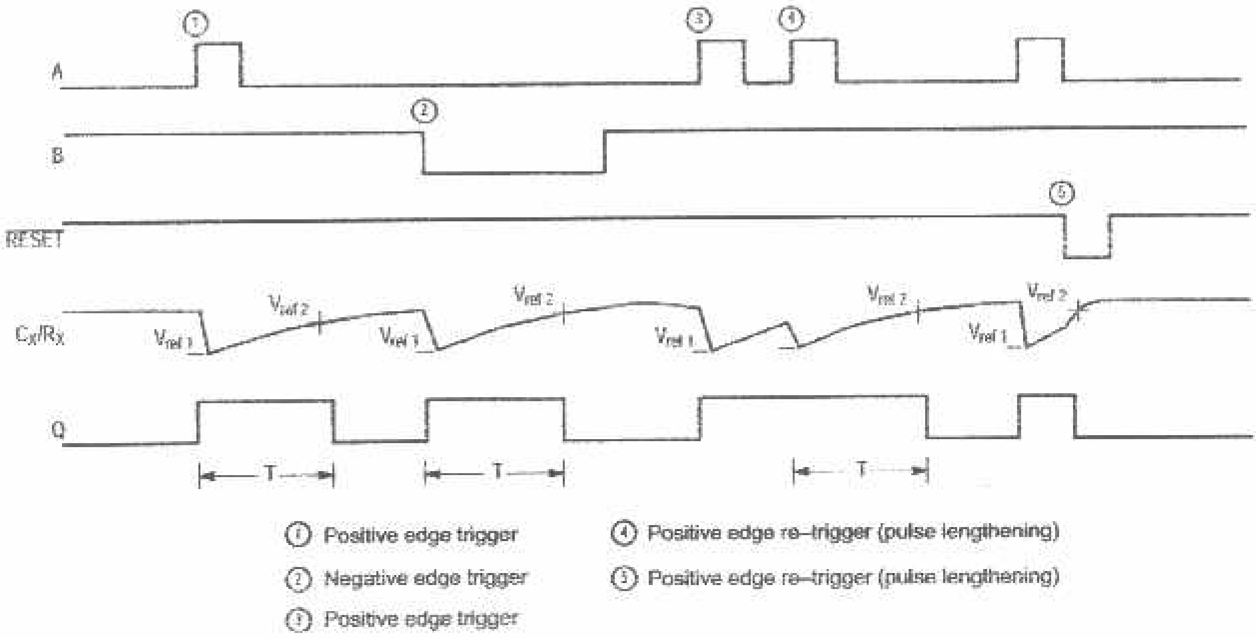


Figure 10. Timing Operation

ɌIGGER OPERATION

The block diagram of the MC14538B is shown in gure 1, with circuit operation following.

As shown in Figure 1 and 10, before an input trigger :curs, the monostable is in the quiescent state with the Q ıtput low, and the timing capacitor C_X completely charged V_{DD}. When the trigger input A goes from V_{SS} to V_{DD} /hile inputs B and $\overline{Reset}$ are held to V_{DD}) a valid trigger is cognized, which turns on comparator C1 and N–channel ansistor N1 . At the same time the output latch is set. With ansistor N1 on, the capacitor C_X rapidly discharges toward ss until V_{ref1} is reached. At this point the output of omparator C1 changes state and transistor N1 turns off. omparator C1 then turns off while at the same time omparator C2 turns on. With transistor N1 off, the capacitor x begins to charge through the timing resistor, R_X, toward DD. When the voltage across C_X equals V_{ref2}, comparator 2 changes state, causing the output latch to reset (Q goes w) while at the same time disabling comparator C2 . This ıds at the timing cycle with the monostable in the quiescent ate, waiting for the next trigger.

In the quiescent state, C_X is fully charged to V_{DD} causing e current through resistor R_X to be zero. Both comparators e "off" with total device current due only to reverse nction leakages. An added feature of the MC14538B is at the output latch is set via the input trigger without regard the capacitor voltage. Thus, propagation delay from gger to Q is independent of the value of C_X, R_X, or the duty ·cle of the input waveform.

RETRIGGER OPERATION

The MC14538B is retriggered if a valid trigger occurs followed by another valid trigger before the Q output has returned to the quiescent (zero) state. Any retrigger, after the timing node voltage at pin 2 or 14 has begun to rise from $V_{ref 1}$, but has not yet reached $V_{ref 2}$, will cause an increase in output pulse width T. When a valid retrigger is initiated , the voltage at C_X/R_X will again drop to $V_{ref 1}$ before progressing along the RC charging curve toward V_{DD}. The Q output will remain high until time T, after the last valid retrigger.

RESET OPERATION

The MC14538B may be reset during the generation of the output pulse. In the reset mode of operation, an input pulse on $\overline{Reset}$ sets the reset latch and causes the capacitor to be fast charged to V_{DD} by turning on transistor P1 . When the voltage on the capacitor reaches $V_{ref 2}$, the reset latch will clear, and will then be ready to accept another pulse. It the $\overline{Reset}$ input is held low, any trigger inputs that occur will be inhibited and the Q and $\overline{Q}$ outputs of the output latch will not change. Since the Q output is reset when an input low level is detected on the $\overline{Reset}$ input, the output pulse T can be made significantly shorter than the minimum pulse width specification.

OWER–DOWN CONSIDERATIONS

Large capacitance values can cause problems due to the rge amount of energy stored. When a system containing e MC14538B is powered down, the capacitor voltage may scharge from V_{DD} through the standard protection diodes pin 2 or 14. Current through the protection diodes should limited to 10 mA and therefore the discharge time of the $_{DD}$ supply must not be faster than (V_{DD}). (C)/(10 mA). r example, if V_{DD} = 10 V and C_X = 10 μF, the V_{DD} supply ould discharge no faster than (10 V) x (10 μF)/(10 mA) 10 ms. This is normally not a problem since power pplies are heavily filtered and cannot discharge at this rate.

When a more rapid decrease of V_{DD} to zero volts occurs, e MC14538B can sustain damage. To avoid this possibility e an external clamping diode, D_X, connected as shown in g. 11.

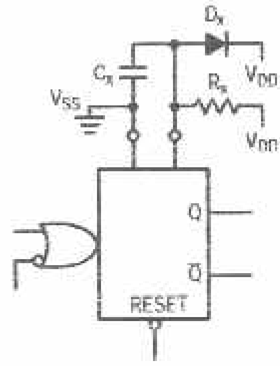


Figure 11. Use of a Diode to Limit Power Down Current Surge

TYPICAL APPLICATIONS

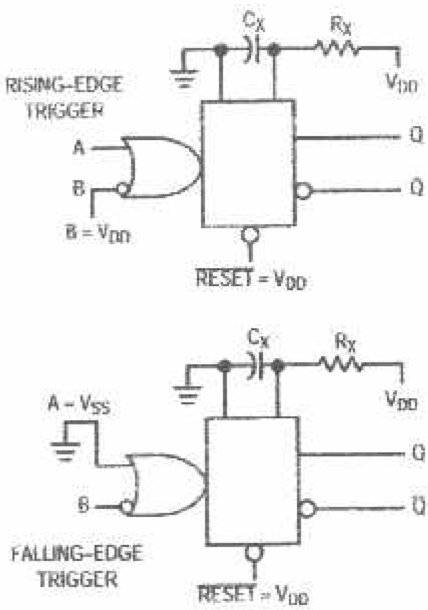


Figure 12. Retriggerable Monostables Circuitry

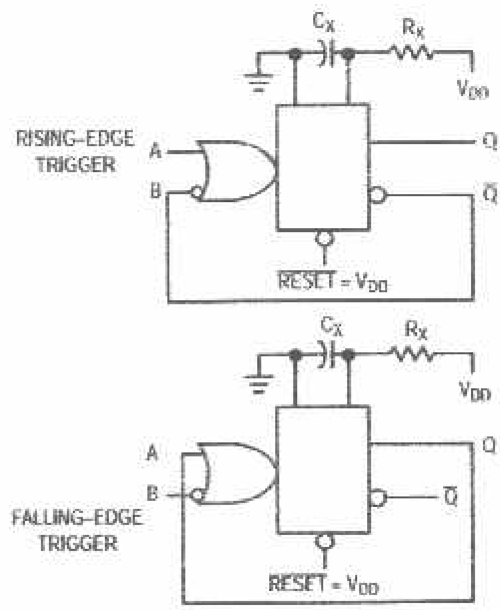


Figure 13. Non–Retriggerable Monostables Circuitry

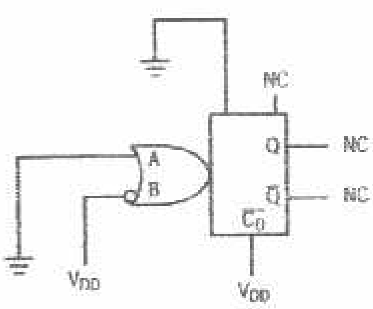
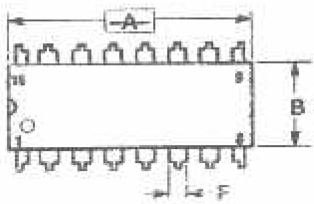
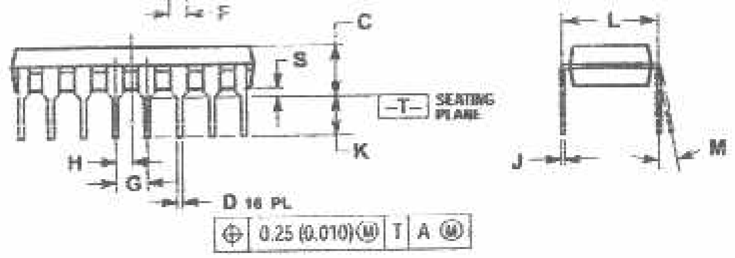


Figure 14. Connection of Unused Sections

PACKAGE DIMENSIONS

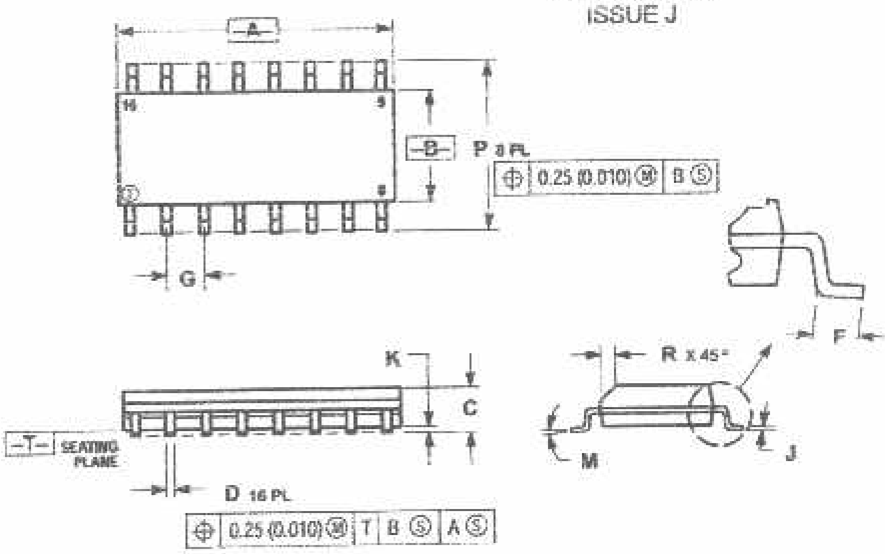
PDIP–16
P SUFFIX
PLASTIC DIP PACKAGE
CASE 648–08
ISSUE R

NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION L TO CENTER OF LEADS WHEN FORMED PARALLEL.
4. DIMENSION B DOES NOT INCLUDE MOLD FLASH.
5. ROUNDED CORNERS OPTIONAL.

DIM	INCHES MIN	INCHES MAX	MILLIMETERS MIN	MILLIMETERS MAX
A	0.740	0.770	18.80	19.55
B	0.250	0.270	6.35	6.85
C	0.145	0.175	3.69	4.44
D	0.015	0.021	0.39	0.53
F	0.040	0.70	1.02	1.77
G	0.100 BSC		2.54 BSC	
H	0.050 BSC		1.27 BSC	
J	0.008	0.015	0.21	0.38
K	0.110	0.130	2.80	3.30
L	0.295	0.305	7.50	7.74
M	0°	10°	0°	10°
S	0.020	0.040	0.51	1.01

SOIC–16
D SUFFIX
PLASTIC SOIC PACKAGE
CASE 751B–05
ISSUE J

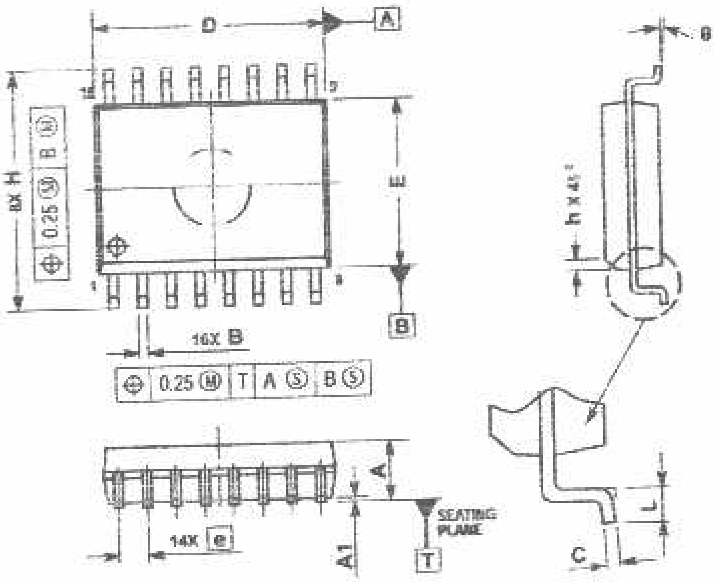


NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSIONS A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.

DIM	MILLIMETERS MIN	MILLIMETERS MAX	INCHES MIN	INCHES MAX
A	9.80	10.00	0.386	0.393
B	3.80	4.00	0.150	0.157
C	1.35	1.75	0.054	0.068
D	0.35	0.49	0.014	0.019
F	0.40	1.25	0.016	0.049
G	1.27 BSC		0.050 BSC	
J	0.19	0.25	0.008	0.009
K	0.10	0.25	0.004	0.009
M	0°	7°	0°	7°
P	5.80	6.20	0.229	0.244
R	0.25	0.50	0.010	0.019

PACKAGE DIMENSIONS

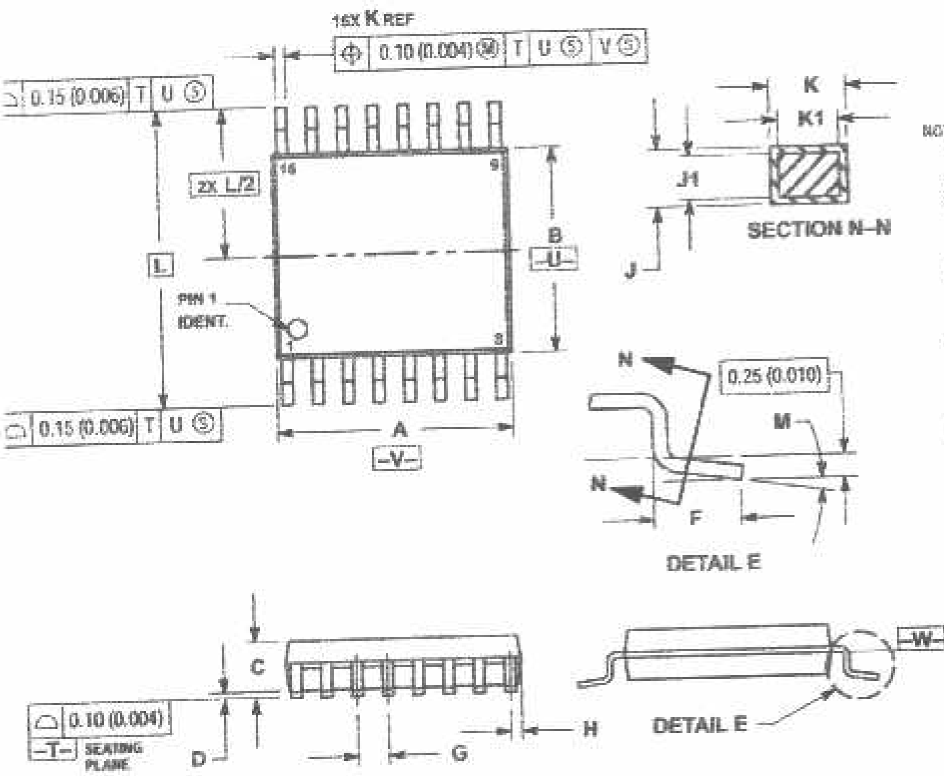
SOIC–16
DW SUFFIX
PLASTIC SOIC PACKAGE
CASE 751G–03
ISSUE B



NOTES:
1. DIMENSIONS ARE IN MILLIMETERS.
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M, 1994.
3. DIMENSIONS D AND E DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 PER SIDE.
5. DIMENSION B DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.13 TOTAL IN EXCESS OF THE B DIMENSION AT MAXIMUM MATERIAL CONDITION.

	MILLIMETERS	
DIM	MIN	MAX
A	2.35	2.65
A1	0.10	0.25
B	0.35	0.49
C	0.23	0.32
D	10.15	10.45
E	7.40	7.60
e	1.27 BSC	
H	10.05	10.55
h	0.25	0.75
L	0.50	0.90
θ	0°	7°

TSSOP–16
DT SUFFIX
PLASTIC TSSOP PACKAGE
CASE 948F–01
ISSUE O

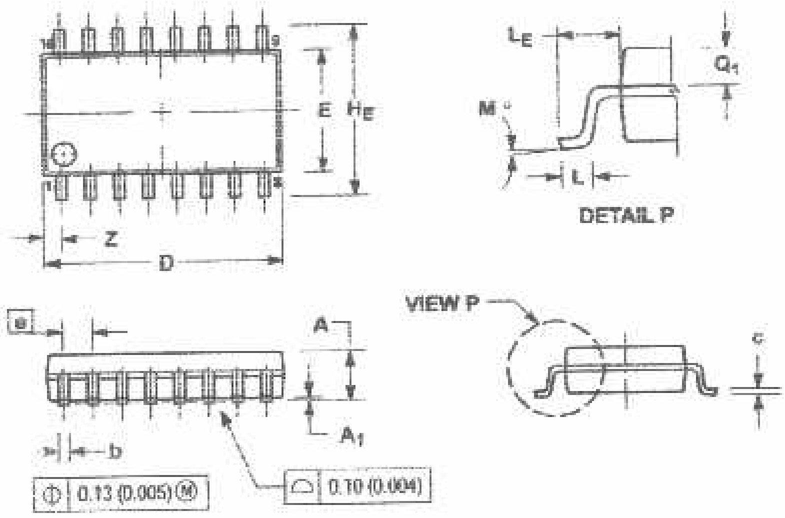


NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH OR GATE BURRS SHALL NOT EXCEED 0.15 (0.006) PER SIDE.
4. DIMENSION B DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION. INTERLEAD FLASH OR PROTRUSION SHALL NOT EXCEED 0.25 (0.010) PER SIDE.
5. DIMENSION K DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.08 (0.003) TOTAL IN EXCESS OF THE K DIMENSION AT MAXIMUM MATERIAL CONDITION.
6. TERMINAL NUMBERS ARE SHOWN FOR REFERENCE ONLY.
7. DIMENSION A AND B ARE TO BE DETERMINED AT DATUM PLANE –W–.

	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A	4.90	5.10	0.193	0.200
B	4.30	4.50	0.169	0.177
C	---	1.20	---	0.047
D	0.05	0.15	0.002	0.006
F	0.50	0.75	0.020	0.030
G	0.65 BSC		0.026 BSC	
H	0.18	0.28	0.007	0.011
J	0.09	0.20	0.004	0.008
J1	0.09	0.16	0.004	0.006
K	0.19	0.30	0.007	0.012
K1	0.19	0.25	0.007	0.010
L	6.40 BSC		0.252 BSC	
M	0°	8°	0°	8°

PACKAGE DIMENSIONS

SOEIAJ–16
F SUFFIX
PLASTIC EIAJ SOIC PACKAGE
CASE 966–01
ISSUE O



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSIONS D AND E DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS AND ARE MEASURED AT THE PARTING LINE. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.15 (0.006) PER SIDE.
4. TERMINAL NUMBERS ARE SHOWN FOR REFERENCE ONLY.
5. THE LEAD WIDTH DIMENSION (b) DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.08 (0.003) TOTAL IN EXCESS OF THE LEAD WIDTH DIMENSION AT MAXIMUM MATERIAL CONDITION. DAMBAR CANNOT BE LOCATED ON THE LOWER RADIUS OR THE FOOT. MINIMUM SPACE BETWEEN PROTRUSIONS AND ADJACENT LEAD TO BE 0.46 (0.018).

	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A		2.05	---	0.081
A_1	0.05	0.20	0.002	0.008
b	0.35	0.50	0.014	0.020
c	0.18	0.27	0.007	0.011
D	9.90	10.50	0.390	0.413
E	5.10	5.45	0.201	0.215
e	1.27 BSC		0.050 BSC	
H_E	7.40	8.20	0.291	0.323
L	0.50	0.85	0.020	0.033
L_E	1.10	1.50	0.043	0.059
M	0°	10°	0°	10°
Q_1	0.70	0.90	0.028	0.035
Z	---	0.78	---	0.031

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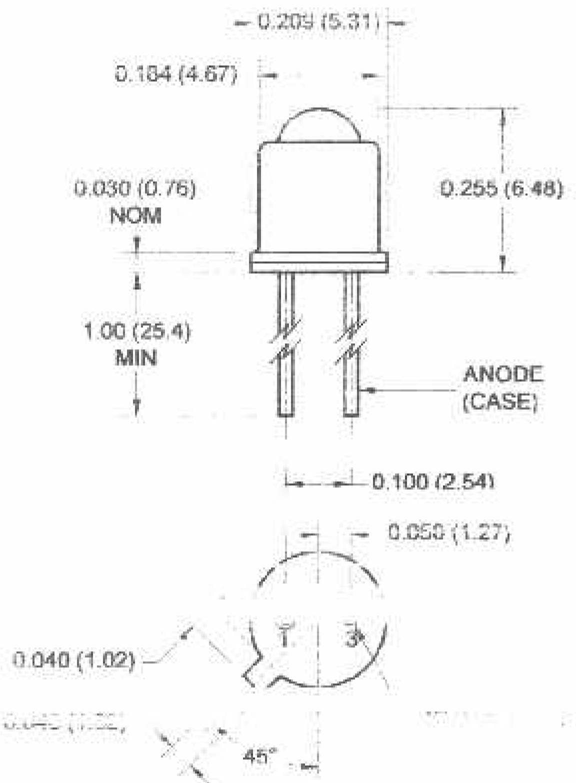

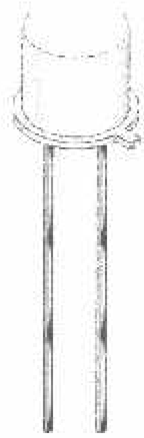

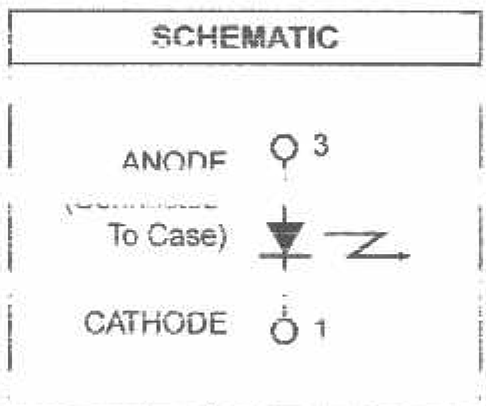

nensions for all drawings are in inches (mm).

less otherwise specified.

D55B/LED55C/LED56 are 940 nm LEDs in a narrow angle, TO-46 package.

optical to mechanical alignment

tically sealed package

radiance level

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LED55B LED55C LED56

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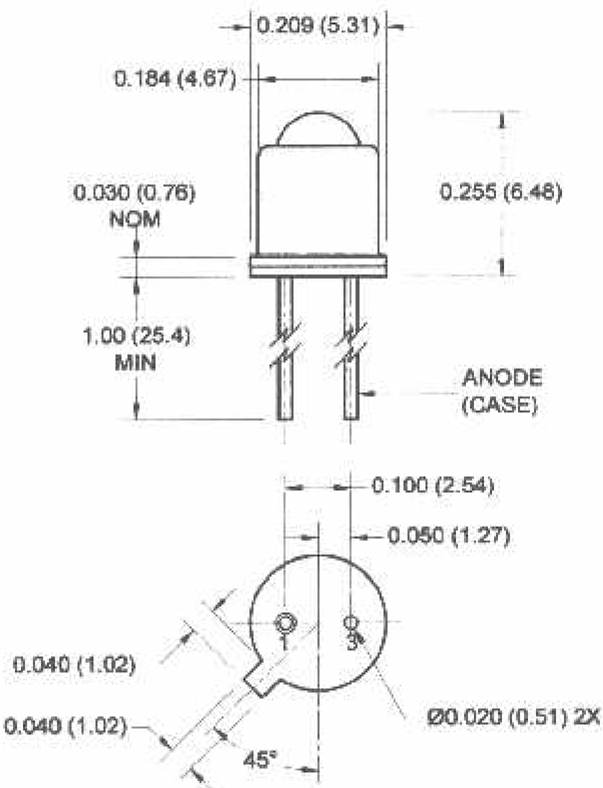

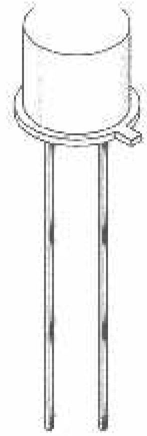

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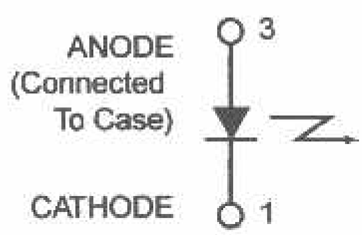


RIPTION

)55B/LED55C/LED56 are 940 nm LEDs in a narrow angle, TO-46 package.

JRES

ɔptical to mechanical alignment
nically and wavelength matched to the TO-18 series phototransistor
tically sealed package
radiance level

GaAs INFRARED EMITTING DIODE

LED55B LED55C LED56

SOLUTE MAXIMUM RATINGS (T_A = 25°C unless otherwise specified)

Parameter	Symbol	Rating	Unit
ating Temperature	T_{OPR}	-65 to +125	°C
ge Temperature	T_{STG}	-65 to +150	°C
ering Temperature (Iron)(3,4,5 and 6)	T_{SOL-I}	240 for 5 sec	°C
ering Temperature (Flow)(3,4 and 6)	T_{SOL-F}	260 for 10 sec	°C
inuous Forward Current	I_F	100	mA
ard Current (pw, 1µs; 200Hz)	I_F	10	A
rse Voltage	V_R	3	V
r Dissipation (T_A = 25°C)(1)	P_D	170	mW
r Dissipation (T_C = 25°C)(2)	P_D	1.3	W

e power dissipation linearly 1.70 mW/°C above 25°C ambient.
e power dissipation linearly 13.0 mW/°C above 25°C case.
flux is recommended.
anol or isopropyl alcohols are recommended as cleaning agents.
ring iron tip 1/16" (1.6mm) minimum from housing.
ng as leads are not under any stress or spring tension
power output, P_O, is the total power radiated by the device into a solid angle of 2 π steradians.

CTRICAL / OPTICAL CHARACTERISTICS (T_A =25°C) (All measurements made under pulse conditions)

METER	TEST CONDITIONS	SYMBOL	MIN	TYP	MAX	UNITS
Emission Wavelength	I_F = 100 mA	λ_P	—	940	—	nm
ion Angle at 1/2 Power	I_F = 100 mA	Θ	—	±8	—	Deg.
rd Voltage	I_F = 100 mA	V_F	—	—	1.7	V
se Leakage Current	V_R = 3 V	I_R	—	—	10	µA
ower LED55B(7)	I_F = 100 mA	P_O	3.5	—	—	mW
ower LED55C(7)	I_F = 100 mA	P_O	5.4	—	—	mW
ower LED56(7)	I_F = 100 mA	P_O	1.5	—	—	mW
ime 0-90% of output		t_r	—	1.0	—	µs
me 100-10% of output		t_f	—	1.0	—	µs

TYPICAL PERFORMANCE CURVES

Figure 1. Power Output vs. Input Current

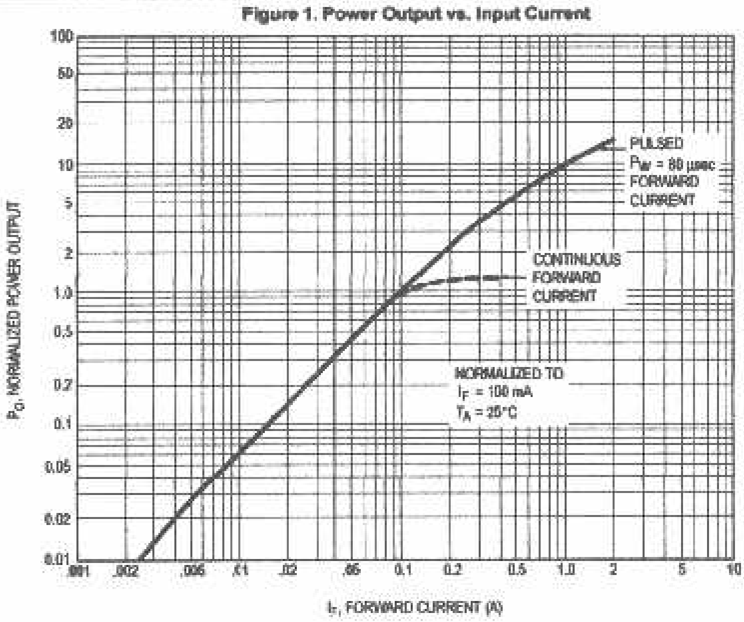


Figure 2. Power Output vs. Temperature

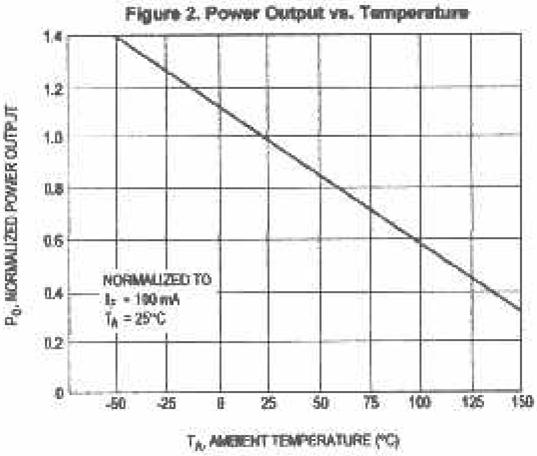


Figure 3. Forward Voltage vs. Forward Current

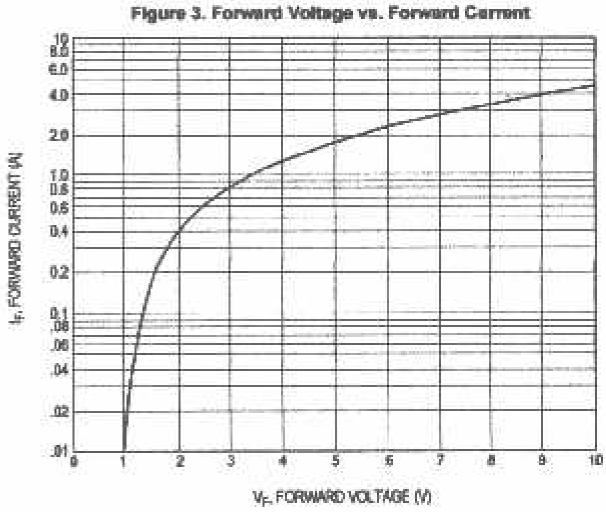


Figure 4. Forward Voltage vs. Forward Current

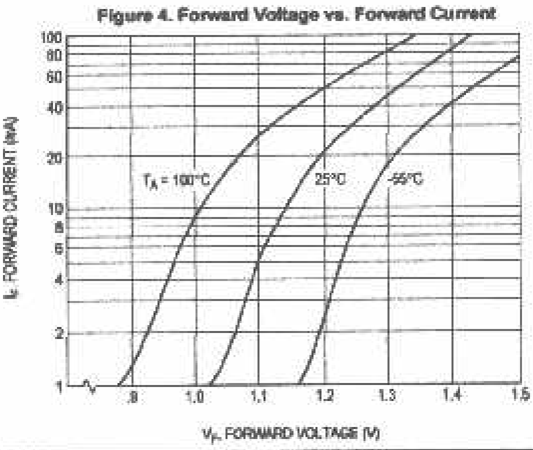
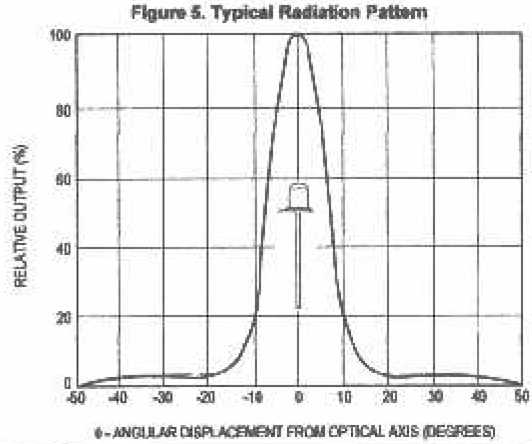


Figure 5. Typical Radiation Pattern



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LED55B LED55C LED56

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MOTOROLA

LM358, LM258, LM2904, LM2904V

ual Low Power perational Amplifiers

ltilizing the circuit designs perfected for recently introduced Quad rational Amplifiers, these dual operational amplifiers feature 1) low ver drain, 2) a common mode input voltage range extending to und/V_{EE}, 3) single supply or split supply operation and 4) pinouts npatible with the popular MC1558 dual operational amplifier. The LM158 es is equivalent to one–half of an LM124.

These amplifiers have several distinct advantages over standard rational amplifier types in single supply applications. They can operate at pply voltages as low as 3.0 V or as high as 32 V, with quiescent currents out one–fifth of those associated with the MC1741 (on a per amplifier is). The common mode input range includes the negative supply, thereby ninating the necessity for external biasing components in many plications. The output voltage range also includes the negative power pply voltage.

- Short Circuit Protected Outputs
- True Differential Input Stage
- Single Supply Operation: 3.0 V to 32 V
- Low Input Bias Currents
- Internally Compensated
- Common Mode Range Extends to Negative Supply
- Single and Split Supply Operation
- Similar Performance to the Popular MC1558
- ESD Clamps on the Inputs Increase Ruggedness of the Device without Affecting Operation

DUAL DIFFERENTIAL INPUT OPERATIONAL AMPLIFIERS

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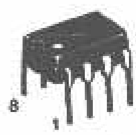
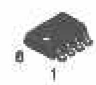
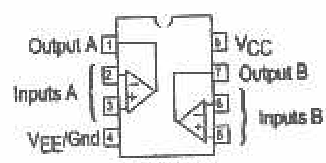


N SUFFIX
PLASTIC PACKAGE
CASE 626



D SUFFIX
PLASTIC PACKAGE
CASE 751
(SO–8)

PIN CONNECTIONS



(Top View)

AXIMUM RATINGS (T_A = +25°C, unless otherwise noted.)

Rating	Symbol	LM258 LM358	LM2904 LM2904V	Unit
Power Supply Voltages				Vdc
Single Supply	V_{CC}	32	26	
Split Supplies	V_{CC}, V_{EE}	±16	±13	
Input Differential Voltage Range (Note 1)	V_{IDR}	±32	±26	Vdc
Input Common Mode Voltage Range (Note 2)	V_{ICR}	–0.3 to 32	–0.3 to 26	Vdc
Output Short Circuit Duration	t_{SC}	Continuous		
Junction Temperature	T_J	150		°C
Storage Temperature Range	T_{stg}	–55 to +125		°C
Operating Ambient Temperature Range	T_A			°C
LM258		–25 to +85	–	
LM358		0 to +70	–	
LM2904		–	–40 to +105	
LM2904V		–	–40 to +125	

NOTES: 1. Split Power Supplies.
2. For Supply Voltages less than 32 V for the LM258/358 and 26 V for the LM2904, the absolute maximum input voltage is equal to the supply voltage.

ORDERING INFORMATION

Device	Operating Temperature Range	Package
LM2904D	T_A = –40° to +105°C	SO–8
LM2904N		Plastic DIP
LM2904VD	T_A = –40° to +125°C	SO–8
LM2904VN		Plastic DIP
LM258D	T_A = –25° to +85°C	SO–8
LM258N		Plastic DIP
LM358D	T_A = 0° to +70°C	SO–8
LM358N		Plastic DIP

Rev 2

ECTRICAL CHARACTERISTICS (V_{CC} = 5.0 V, V_{EE} = Gnd, T_A = 25°C, unless otherwise noted.)

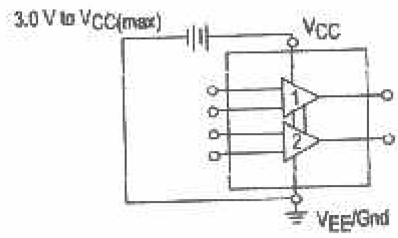
Characteristic	Symbol	LM258			LM358			LM2904			LM2904V			Unit
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
put Offset Voltage 'CC = 5.0 V to 30 V (26 V for M2904, V), V_{IC} = 0 V to V_{CC} −1.7 V, 'O = 1.4 V, R_S = 0 Ω T_A = 25°C T_A = T_{high} (Note 1) T_A = T_{low} (Note 1)	V_{IO}	– – –	2.0 – –	5.0 7.0 2.0	– – –	2.0 – –	7.0 9.0 9.0	– – –	2.0 – –	7.0 10 10	– – –	– – –	– 13 10	mV
erage Temperature Coefficient of Input)ffset Voltage T_A = T_{high} to T_{low} (Note 1)	$\Delta V_{IO}/\Delta T$	–	7.0	–	–	7.0	–	–	7.0	–	–	7.0	–	µV/°C
out Offset Current T_A = T_{high} to T_{low} (Note 1) put Bias Current T_A = T_{high} to T_{low} (Note 1)	I_{IO} I_{IB}	– – – –	3.0 – −45 −50	30 100 −150 −300	– – – –	5.0 – −45 −50	50 150 −250 −500	– – – –	5.0 45 −45 −50	50 200 −250 −500	– – – –	5.0 45 −45 −50	50 200 −250 −500	nA
erage Temperature Coefficient of Input)ffset Current T_A = T_{high} to T_{low} (Note 1)	$\Delta I_{IO}/\Delta T$	–	10	–	–	10	–	–	10	–	–	10	–	pA/°C
put Common Mode Voltage Range (Note 2),V_{CC} = 30 V (26 V for LM2904, V) V_{CC} = 30 V (26 V for LM2904, V), T_A = T_{high} to T_{low}	V_{ICR}	0 0	– –	28.3 28	0 0	– –	28.3 28	0 0	– –	24.3 24	0 0	– –	24.3 24	V
ifferential Input Voltage Range	V_{IDR}	–	–	V_{CC}	–	–	V_{CC}	–	–	V_{CC}	–	–	V_{CC}	V
arge Signal Open Loop Voltage Gain R_L = 2.0 kΩ, V_{CC} = 15 V, For Large V_O Swing, T_A = T_{high} to T_{low} (Note 1)	A_{VOL}	50 25	100 –	– –	25 15	100 –	– –	25 15	100 –	– –	25 15	100 –	– –	V/mV
hannel Separation 1.0 kHz ≤ f ≤ 20 kHz, Input Referenced	CS	–	−120	–	–	−120	–	–	−120	–	–	−120	–	dB
ommon Mode Rejection R_S ≤ 10 kΩ	CMR	70	85	–	65	70	–	50	70	–	50	70	–	dB
ower Supply Rejection	PSR	65	100	–	65	100	–	50	100	–	50	100	–	dB
utput Voltage–High Limit (T_A = T_{high} to T_{low}) (Note 1) V_{CC} = 5.0 V, R_L = 2.0 kΩ, T_A = 25°C V_{CC} = 30 V (26 V for LM2904, V), R_L = 2.0 kΩ V_{CC} = 30 V (26 V for LM2904, V), R_L = 10 kΩ	V_{OH}	3.3 26 27	3.5 – 28	– – –	3.3 26 27	3.5 – 28	– – –	3.3 22 23	3.5 – 24	– – –	3.3 22 23	3.5 – 24	– – –	V
utput Voltage–Low Limit V_{CC} = 5.0 V, R_L = 10 kΩ, T_A = T_{high} to T_{low} (Note 1)	V_{OL}	–	5.0	20	–	5.0	20	–	5.0	20	–	5.0	20	mV
utput Source Current V_{ID} = +1.0 V, V_{CC} = 15 V	I_{O+}	20	40	–	20	40	–	20	40	–	20	40		mA
Output Sink Current V_{ID} = −1.0 V, V_{CC} = 15 V V_{ID} = −1.0 V, V_O = 200 mV	I_{O-}	10 12	20 50	– –	10 12	20 50	– –	10 –	20 –	– –	10 –	20 –	– –	mA µA
Output Short Circuit to Ground (Note 3)	I_{SC}	–	40	60	–	40	60	–	40	60	–	40	60	mA
Power Supply Current (T_A = T_{high} to T_{low}) (Note 1) V_{CC} = 30 V (26 V for LM2904, V), V_O = 0 V, R_L = ∞ V_{CC} = 5 V, V_O = 0 V, R_L = ∞	I_{CC}	– –	1.5 0.7	3.0 1.2	– –	1.5 0.7	3.0 1.2	– –	1.5 0.7	3.0 1.2	– –	1.5 0.7	3.0 1.2	mA

IOTES: 1. T_{low} = −40°C for LM2904
= −40°C for LM2904V
= −25°C for LM258
= 0°C for LM358

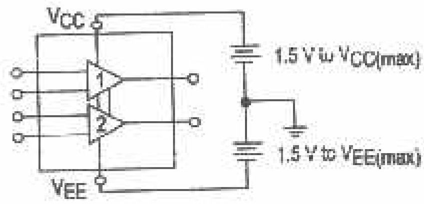
T_{high} = +105°C for LM2904
= +125°C for LM2904V
= +85°C for LM258
= +70°C for LM358

2. The input common mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3 V. The upper end of the common mode voltage range is V_{CC} −1.7 V.
3. Short circuits from the output to V_{CC} can cause excessive heating and eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

Single Supply

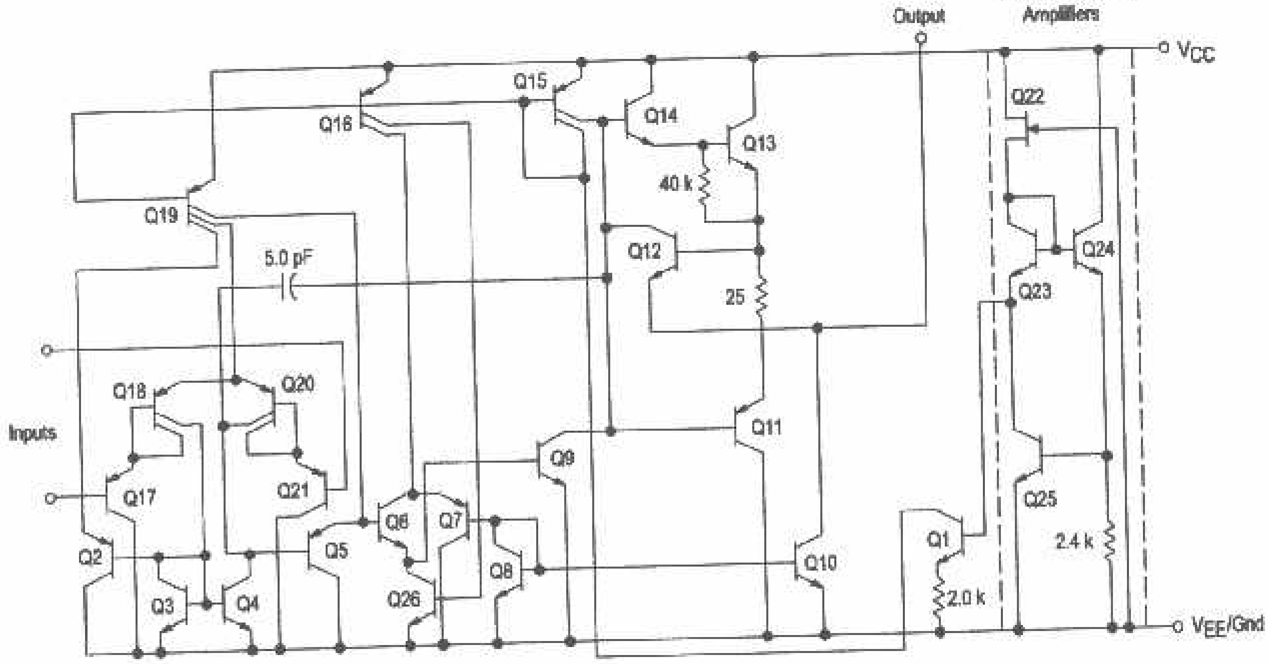


Split Supplies



Representative Schematic Diagram

(One–Half of Circuit Shown)



CIRCUIT DESCRIPTION

The LM258 series is made using two internally ›mpensated, two–stage operational amplifiers. The first ›age of each consists of differential input devices Q20 and 18 with input buffer transistors Q21 and Q17 and the fferential to single ended converter Q3 and Q4. The first age performs not only the first stage gain function but also ›rforms the level shifting and transconductance reduction nctions. By reducing the transconductance, a smaller ›mpensation capacitor (only 5.0 pF) can be employed, thus ›ving chip area. The transconductance reduction is ›complished by splitting the collectors of Q20 and Q18. nother feature of this input stage is that the input common ›ode range can include the negative supply or ground, in ngle supply operation, without saturating either the input evices or the differential to single–ended converter. The econd stage consists of a standard current source load mplifier stage.

Each amplifier is biased from an internal–voltage regulator ›hich has a low temperature coefficient thus giving each mplifier good temperature characteristics as well as xcellent power supply rejection.

Large Signal Voltage Follower Response

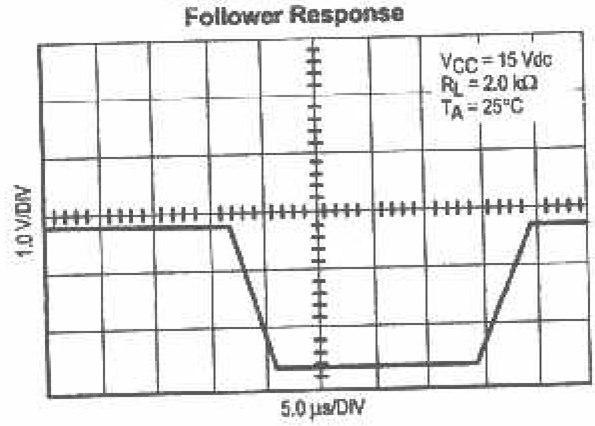


Figure 1. Input Voltage Range

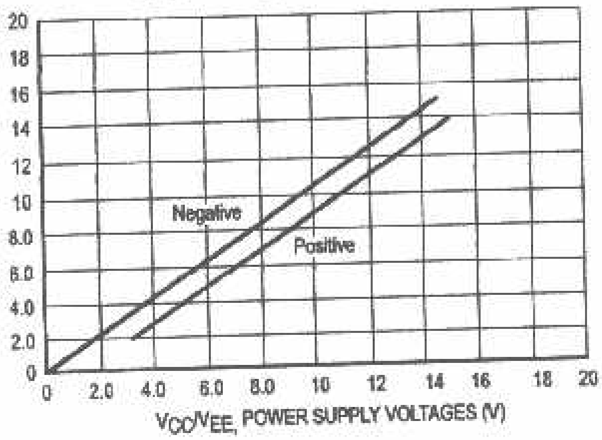


Figure 2. Large–Signal Open Loop Voltage Gain

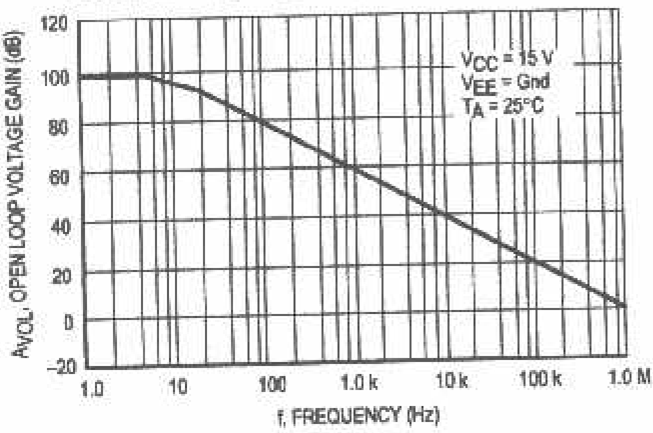


Figure 3. Large–Signal Frequency Response

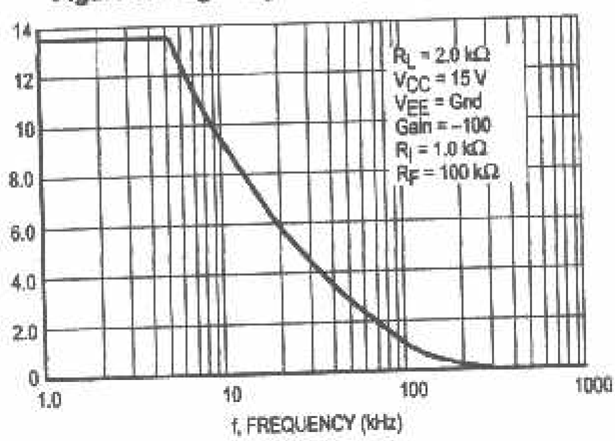


Figure 4. Small Signal Voltage Follower Pulse Response (Noninverting)

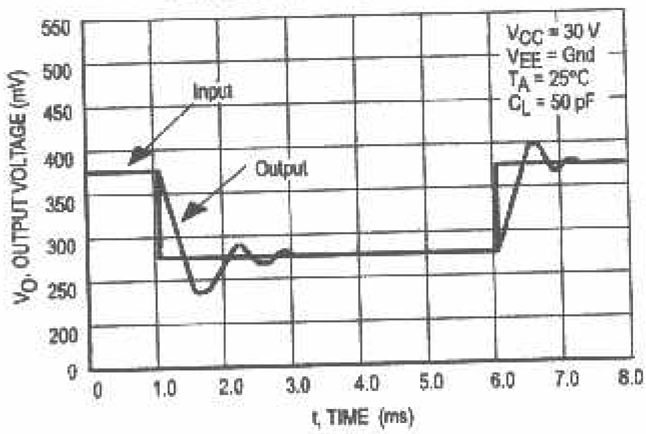


Figure 5. Power Supply Current versus Power Supply Voltage

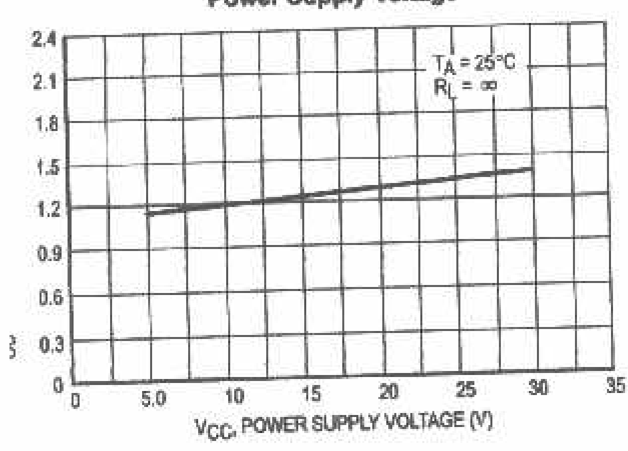


Figure 6. Input Bias Current versus Supply Voltage

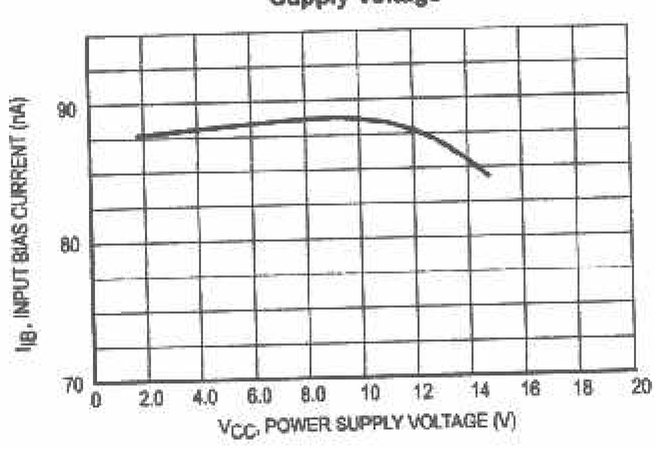
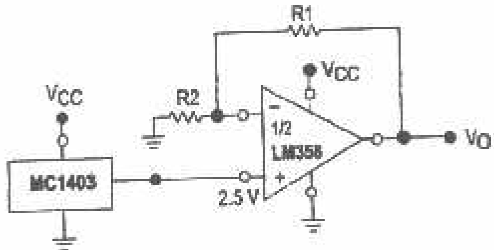


Figure 7. Voltage Reference



$$V_O = 2.5\,V\left(1 + \frac{R1}{R2}\right)$$

Figure 8. Wien Bridge Oscillator

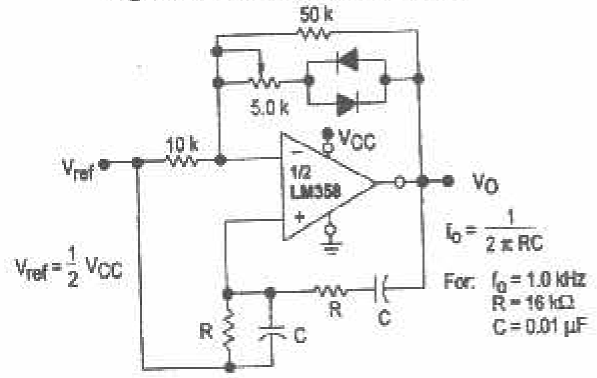
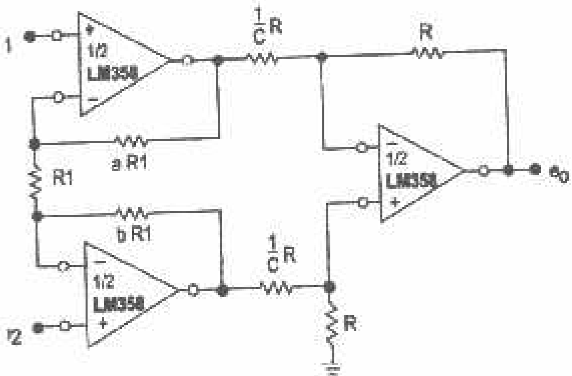
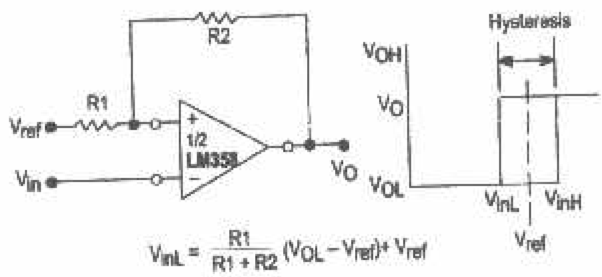


Figure 9. High Impedance Differential Amplifier



$$e_o = C\,(1 + a + b)\,(e_2 - e_1)$$

Figure 10. Comparator with Hysteresis



$$V_{inL} = \frac{R1}{R1 + R2}(V_{OL} - V_{ref}) + V_{ref}$$

$$V_{inH} = \frac{R1}{R1 + R2}(V_{OH} - V_{ref}) + V_{ref}$$

$$H = \frac{R1}{R1 + R2}(V_{OH} - V_{OL})$$

Figure 11. Bi–Quad Filter

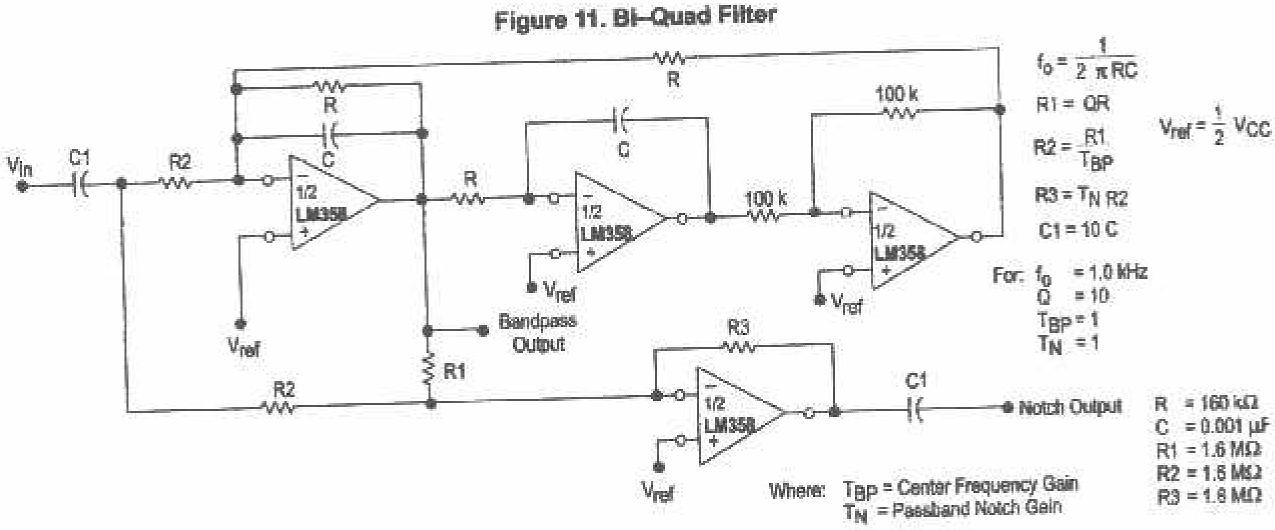
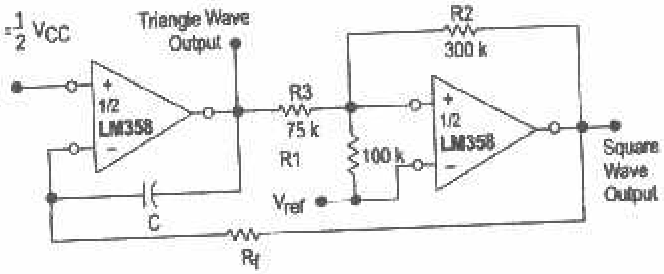
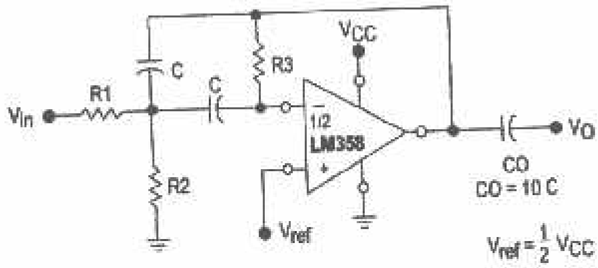


Figure 12. Function Generator



$$f = \frac{R1 + R_C}{4\,CR_f\,R1} \quad \text{if, } R3 = \frac{R2\,R1}{R2 + R1}$$

Figure 13. Multiple Feedback Bandpass Filter



Given: f_o = center frequency
$A(f_o)$ = gain at center frequency

Choose value f_o, C

Then: $R3 = \frac{Q}{\pi f_o C}$

$$R1 = \frac{R3}{2\,A(f_o)}$$

$$R2 = \frac{R1\,R3}{4Q^2\,R1 - R3}$$

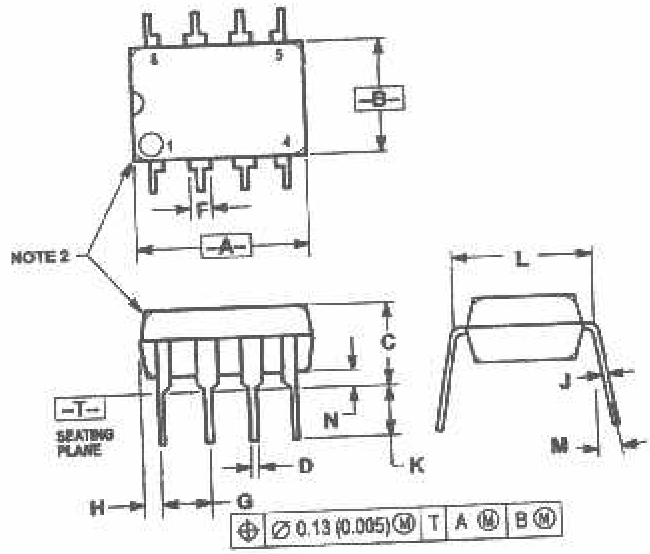
For less than 10% error from operational amplifier. $\frac{Q_o f_o}{BW} < 0.1$

Where f_o and BW are expressed in Hz.

If source impedance varies, filter may be preceded with voltage follower buffer to stabilize filter parameters.

OUTLINE DIMENSIONS

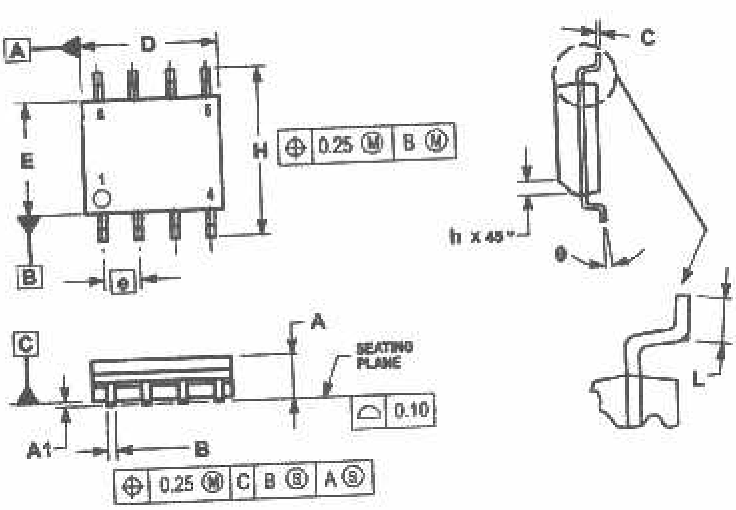
N SUFFIX
PLASTIC PACKAGE
CASE 626–05
ISSUE K



NOTES:
1. DIMENSION L TO CENTER OF LEAD WHEN FORMED PARALLEL.
2. PACKAGE CONTOUR OPTIONAL (ROUND OR SQUARE CORNERS).
3. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.

DIM	MILLIMETERS MIN	MILLIMETERS MAX	INCHES MIN	INCHES MAX
A	9.40	10.16	0.370	0.400
B	6.10	6.60	0.240	0.260
C	3.94	4.45	0.155	0.175
D	0.38	0.51	0.015	0.020
F	1.02	1.78	0.040	0.070
G	2.54 BSC		0.100 BSC	
H	0.76	1.27	0.030	0.050
J	0.20	0.30	0.008	0.012
K	2.92	3.43	0.115	0.135
L	7.62 BSC		0.300 BSC	
M	—	10°	—	10°
N	0.76	1.01	0.030	0.040

D SUFFIX
PLASTIC PACKAGE
CASE 751–05
(SO–8)
ISSUE R



NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. DIMENSIONS ARE IN MILLIMETERS.
3. DIMENSION D AND E DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 PER SIDE.
5. DIMENSION B DOES NOT INCLUDE MOLD PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 TOTAL IN EXCESS OF THE B DIMENSION AT MAXIMUM MATERIAL CONDITION.

DIM	MILLIMETERS MIN	MILLIMETERS MAX
A	1.35	1.75
A1	0.10	0.25
B	0.35	0.49
C	0.18	0.25
D	4.80	5.00
E	3.80	4.00
e	1.27 BSC	
H	5.80	6.20
h	0.25	0.50
L	0.40	1.25
θ	0°	7°

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MFAX: RMFAX0@email.sps.mot.com – TOUCHTONE 602–244–6609
NTERNET: http://Design–NET.com

JAPAN: Nippon Motorola Ltd.; Tatsumi–SPD–JLDC, 6F Seibu–Butsuryu–Center, 3–14–2 Tatsumi Koto–Ku, Tokyo 135, Japan. 03–81–3521–8315

ASIA / PACIFIC: Motorola Semiconductors H.K. Ltd.; 8B Tai Ping Industrial Park, 51 Ting Kok Road, Tai Po, N.T., Hong Kong. 852–26629298

MOTOROLA

◊

Lembar Asistensi

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Dosen Pembimbing : Bambang Prio Hartono, ST, MT

No	Tanggal Bimbingan	Keterangan	Paraf
		BAB I Abstrak di perbaiki	[signature]
		BAB II disempurnakan	[signature]
		BAB III	[signature]
		BAB IV data diperbaiki	[signature]
		BAB V. Acc	[signature]
		Acc ujian	[signature]

Malang, 29 Oktober 2009

Dosen Pembimbing

[signature]

Bambang Prio Hartono, ST, MT