PERANCANGAN DAN PEMBUATAN ALAT PENGHITUNG DETAK JANTUNG MANUSIA BERBASIS MIKROKONTROLLER PIC16F877A DENGAN DISPLAY PENGUKURAN MENGGUNAKAN APLIKASI STAMPPLOT

SKRIPSI

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PROGRAM STUDI TEKNIK ELEKTRO S-1

KONSENTRASI TEKNIK ELEKTRONIKA

FAKULTAS TEKNOLOGI INDUSTRI

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2016

LEMBAR PERSETUJUAN

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2016

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KRISMAS Y. ALLUNG

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ABSTRAK

Kesehatan merupakan elemen vital dalam segala aktivitas yang dilakukan oleh manusia. Denyut jantung merupakan salah satu parameter ukur dari tingkat kesehatan manusia. Namun untuk mengukur denyut jantung kita harus pergi ke rumah sakit atau klinik terdekat untuk bisa mendapatakan hasil pengukuran denyut jantung. Untuk itu pada laporan Skripsi ini akan dirancang sebuah *alat penhitung laju detak jantung*, yang mana alat ini dilengkapi dengan *sensor denyut jantung* (*Photodioda dan Infrared*) yang akan mendeteksi perubahan volume darah pada jari manusia. Alat ini juga menggunakan *komunikasi serial* sehingga penggunanya tidak akan kebingungan melihat hasilnya karena hasil dari pengukuran tersebut akan ditampilkan pada Aplikasi *Human Machine Interface* (HMI) *StampPlot* di komputer. Semua data tersebut dikontrol oleh *MIkrokontroller PIC16F877A*. Hasil tampilan pengukuran berupa grafik kestabilan denyut jantung dan angka hasil deteksi denyut jantung. Grafik kestabilan menunjukkan ada atau tidaknya denyut yang terdeteksi dan angka denyut jantung merupakan jumlah denyut jantung yang terdeteksi.

Kata kunci : *penhitung detak jantung, sensor Photodioda, MIkrokontroller PIC16F877A, Aplikasi StampPlot*

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Penulis

DAFTAR GAMBAR

DAFTAR TABEL

BAB I
PENDAHULUAN

1.1 Latar Belakang

Kesehatan merupakan elemen vital dalam segala aktivitas yang dilakukan oleh manusia. Namun, manusia sering tidak memahami arti sebenarnya dari kesehatan secara fisik. Sehat secara fisik berarti seluruh organ tubuh berada dalam ukuran sebenarnya dan berada dalam kondisi optimal, serta dapat berfungsi normal. Sehat secara fisik diukur dari parameter dasar nilai-nilai normal dari tanda-tanda vital tubuh seperti laju detak jantung manusia. Laju detak jantung itu sendiri biasa dinyatakan dalam BPM (*Beats per Minute*). Untuk mengukur kondisi tersebut manusia biasanya menggunakan *stetoscope* dan alat pengukur detak jantung lainnya yang umumnya hanya ditemukan di rumah sakit, puskesmas atau klinik kesehatan. Diharapkan manusia memiliki alat tersebut agar dapat mengetahui kondisi tubuhnya setiap saat. Pada kenyataanya, manusia yang memiliki alat-alat tersebut sangat sedikit karena harga yang mahal dan kurang praktis. Oleh karena itu, diperlukan suatu sistem yang dapat memeriksa kondisi tubuh secara praktis.

Dengan latar belakang seperti diatas dan dengan perkembangan dunia elektronika yang semakin pesat, tidak menutupi terciptanya alat pengukur detak jantung yang berbasis elektronika yang mudah digunakan oleh setiap pengguna yang ingin mengukur detak jantungnya sendiri. Salah satunya adalah alat pengukur detak jantung manusia berbasis mikrokontroller PIC16F877A dengan display pengukuran menggunakan aplikasi HMI StampPlot.

1.2 Rumusan Masalah

Permasalahan yang akan dibahas dalam skripsi ini adalah sebagai berikut :

1. Bagaimana membuat alat pengukur detak jantung ini lebih mudah dan gampang dimengerti untuk digunakan oleh pengguna.
2. Bagaimana menghubungkan alat pengukur detak jantung berbasis mikrokontroller PIC16F877A dengan komputer.

BAB II
KAJIAN PUSTAKA

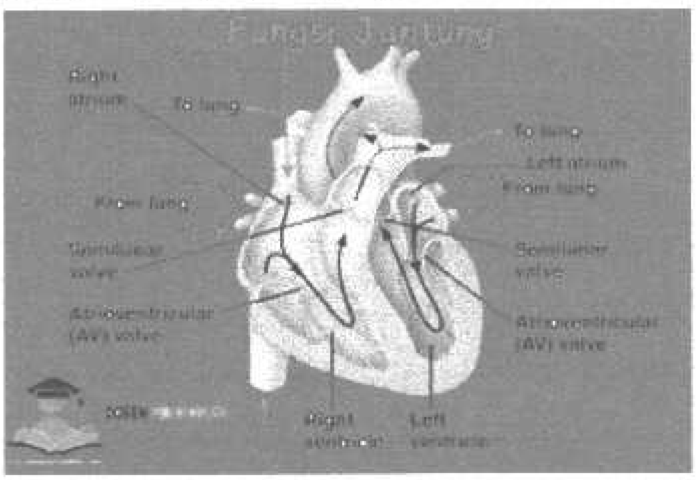
2.1. Jantung dan Fungsinya

2.1.1. Pengertian.

Jantung adalah organ vital dan merupakan pertahanan terakhir untuk hidup selain otak. Denyut yang ada di jantung ini tidak bisa dikendalikan oleh manusia. Denyut jantung biasanya mengacu pada jumlah waktu yang dibutuhkan oleh detak jantung per satuan waktu, secara umum direpresentasikan sebagai bpm (*beats per minute*). *[Ilmu kesehatan, 2013]*

2.1.2. Fungsi jantung

Fungsi utama jantung adalah menyediakan oksigen ke seluruh tubuh dan membersihkan tubuh dari hasil metabolisme (karbondioksida). Jantung melaksanakan fungsi tersebut dengan mengumpulkan darah yang kekurangan oksigen dari seluruh tubuh dan memompanya ke dalam paru-paru, dimana darah akan mengambil oksigen dan membuang karbondioksida; jantung kemudian mengumpulkan darah yang kaya oksigen dari paru-paru dan memompanya ke jaringan di seluruh tubuh.



Gambar 2.1 Jantung dan fungsinya. *[Ilmu kesehatan, 2013]*

Pada saat berdenyut, setiap ruang jantung mengendur dan terisi darah (disebut diastol); selanjutnya jantung berkontraksi dan memompa darah keluar dari ruang jantung (disebut sistol). Kedua atrium mengendur dan berkontraksi secara bersamaan, dan kedua ventrikel juga mengendur dan berkontraksi secara bersamaan. Darah yang kehabisan oksigen dan mengandung banyak karbondioksida dari seluruh tubuh mengalir melalui 2 vena besar (vena cava) menuju ke dalam atrium kanan. Setelah atrium kanan terisi darah, dia akan mendorong darah ke dalam ventrikel kanan.

Darah dari ventrikel kanan akan dipompa melalui katup pulmoner ke dalam arteri pulmonalis, menuju ke paru-paru. Darah akan mengalir melalui pembuluh yang sangat kecil (kapiler) yang mengelilingi kantong udara di paru-paru, menyerap oksigen dan melepaskan karbondioksida yang selanjutnya dihembuskan. Darah yang kaya akan oksigen mengalir di dalam vena pulmonalis menuju ke atrium kiri. Peredaran darah diantara bagian kanan jantung, paru-paru dan atrium kiri disebut sirkulasi pulmoner. Darah dalam atrium kiri akan didorong ke dalam ventrikel kiri, yang selanjutnya akan memompa darah yang kaya akan oksigen ini melewati katup aorta masuk ke dalam aorta (arteri terbesar dalam tubuh). Darah kaya oksigen ini disediakan untuk seluruh tubuh, kecuali paru-paru. *[Ilmu kesehatan, 2013]*

2.1.3. Denyut Jantung

Denyut jantung yang optimal untuk setiap individu berbeda-beda tergantung pada kapan waktu mengukur detak jantung tersebut (saat istirahat atau setelah berolahraga). Variasi dalam detak jantung sesuai dengan jumlah oksigen yang diperlukan oleh tubuh saat itu. Detak jantung atau juga dikenal dengan denyut nadi adalah tanda penting dalam bidang medis yang bermanfaat untuk mengevaluasi dengan cepat kesehatan atau mengetahui kebugaran seseorang secara umum.

Pada orang dewasa yang sehat, saat sedang istirahat maka denyut jantung yang normal adalah sekitar 60-100 denyut per menit (bpm). Jika didapatkan denyut jantung yang lebih rendah saat sedang istirahat, pada umumnya menunjukkan fungsi jantung yang lebih efisien dan lebih baik kebugaran kardiovaskularnya. Laskowski menambahkan ada banyak faktor yang dapat mempengaruhi jumlah denyut jantung seseorang, yaitu aktivitas fisik atau tingkat kebugaran seseorang, suhu udara disekitar, posisi tubuh (berbaring atau berdiri), tingkat emosi, ukuran tubuh serta obat yang sedang dikonsumsi.

Untuk mengukur denyut jantung di rumah bisa dengan cara memeriksa denyut nadi. Tempatkan jari telunjuk dan jari tengah pada pergelangan tangan atau tiga jari pada sisi leher. Saat merasakan denyut nadi, lihatlah jam untuk mneghitung jumlah denyut selama 15 detik. Hasil yang didapatkan di kalikan empat, maka didapatkan jumlah denyut jantung Anda per menit.

Berikut ini denyut jantung normal pada manusia sesuai dengan usianya:

- Bayi 0 - 1 bulan = 70 - 190 denyut per menit.
- Bayi 1 - 11 bulan = 80 - 160 denyut per menit.
- Anak-anak 1 - 2 tahun = 80 - 130 denyut per menit.
- Anak-anak 3 - 4 tahun = 80 - 120 denyut per menit.
- Anak-anak 5 - 6 tahun = 75 - 115 denyut per menit.
- Anak-anak 7 - 9 tahun = 70 - 110 denyut per menit.
- Anak-anak 10 tahun, lebih tua, dan orang dewasa (termasuk manula): 60 - 100 denyut per menit.
- Atlet terlatih = 40 - 60 denyut per menit.

Denyut jantung seseorang juga dipengaruhi oleh usia dan aktivitasnya. Olahraga atau aktivitas fisik dapat meningkatkan jumlah denyut jantung, namun jika jumlahnya terlalu berlebihan atau di luar batas sehat dapat menimbulkan bahaya. Untuk mendapatkan nilai denyut jantung maksimal dilakukan dengan cara mengurangi angka 220 dengan usia. Misal usianya 40 tahun, maka jumlah maksimalnya adalah 180 bpm. Dengan melakukan tes sederhana tersebut, seseorang bisa mengetahui apakah denyut jantunya normal atau tidak. Hal ini juga berguna sebagai diagnosis awal ada atau tidaknya gangguan kardiovaskuler. *[Ilmu kesehatan, 2013]*

2.2. MIKROKONTROLER PIC16F877A

Mikrokontroler PIC16F877A merupakan salah satu mikrokontroler dari keluarga PICmicro yang popular digunakan sekarang ini, mulai dari pemula hingga para profesional. Hal tersebut karena PIC16F877A sangat praktis dan menggunakan teknologi FLASH memori sehingga dapat di program-hapus hingga seribu kali. Keunggulan mikrokontroler jenis RISC ini dibanding dengan mikrokontroler 8-bit lain dikelasnya terutama terletak pada kecepatan dan kompresi kodenya. Selain itu, PIC116F877A juga tergolong praktis dan ringkas karena memiliki kemasan 40 pin dengan 33 jalur I/O.

Anggota keluarga PICmicro buatan Microchip Inc. cukup banyak. Ada yang menggunakan FLASH memori dan ada pula yang jenis OTP (*One Time Programmable*). Mikrontroler dari keluarga PICmicro yang popular, antara lain PIC2C08, PIC16C54, PIC16F84. Agar lebih mengenal PIC16F877A, berikut ini diberikan fitur-fitur penting yang terdapat pada PIC16F877A. *[Fahmizal, 2010]*

Gambar 2.2. Mikrokontroler PIC16F877A *[Fahmizal, 2010]*

2.2.1. Fitur-Fitur PIC16F877A

Sebenarnya, PIC16F877A bukanlah mikrokontroler yang istimewa dalam keluarga PICmicro. Namun demikian, PIC16F877A cukup mudah dipelajari dan dapat di bilang memiliki kemampuan yang handal sebagai mikrokontroler yang memiliki 40 pin. Mikrokontroler PIC16F877A memiliki fitur RISC CPU yang mempunyai performance tinggi. PIC16F877A juga hanya 35 jenis instruksi yang perlu dipelajari dan semua instruksi mempunyai siklus tunggal kecuali untuk instruksi percabangan. Kecepatan Instruksi: DC – 20 MHz *clock input* DC – 200 ns *instruction cycle* , 8K x *14 words of FLASH Program Memory*, 368 x 8 *bytes of Data Memory* (RAM) , 256 x 8 *bytes of EEPROM Data Memory*, *Pinout compatible* dengan PIC16C73B/74B/76/77, *Interrupt* (14 sumber interrupt), Delapan level *hardware stack*, *Direct*, *indirect* dan *relative addressing modes*, *Power-on Reset* (POR), *Power-up Timer* (PWRT) dan *Oscillator Start-up Timer* (OST), *Watchdog Timer* (WDT) dengan *on-chip RC oscillator*, *Programmable code protection*, *Power saving SLEEP mode*, *Selectable oscillator options*, *Low power*, *high speed CMOS FLASH/EEPROM technology*, *Fully static design*, *In-Circuit Serial Programming* (ICSP) hanya dengan dua pin, *Single* 5V *In-Circuit*

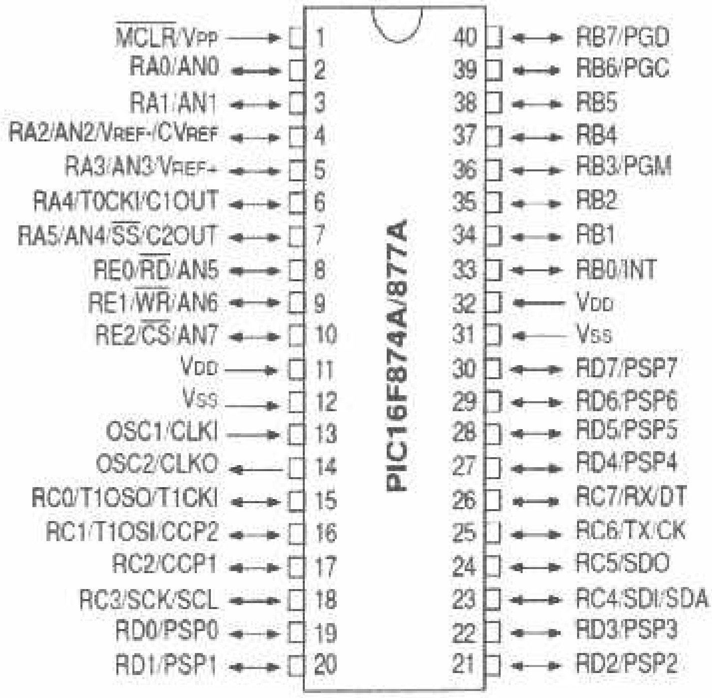
Serial Programming capability, Processor read/write access to program memory, Wide operating voltage range: 2.0V to 5.5V, *High Sink/Source Current:* 25 mA dan *Commercial, Industrial and Extended temperature ranges. [Fahmizal, 2010]*

2.2.2. Fitur Periferal:

1. *Timer0: 8-bit timer/counter* dengan 8-*bit prescaler*
2. Timer1: 16-*bit timer/counter* dengan *prescaler*, dapat di-*increment* selama proses *SLEEP* dengan *external crystal/clock*
3. *Timer2: 8-bit timer/counter* dengan *8-bit period register, prescaler* dan *postscaler*
4. Dua *Capture, Compare, PWM modules* (*Capture is 16-bit, max. resolution is 12.5 ns , Compare is 16-bit, max. resolution is 200 ns , PWM max. resolution is 10-bit)*
5. *10-bit multi-channel Analog-to-Digital converter* (ADC)
6. *Synchronous Serial Port* (SSP) dengan SPI (*Master mode*) dan I2C (*Master/Slave*)
7. *Universal Synchronous Asynchronous Receiver Transmitter* (USART/SCI) dengan 9-*bit address detection*
8. *Parallel Slave Port (PSP) 8-bits wide, dengan external RD, WR and CS controls (40/44-pin only)*
9. *Brown-out detection circuitry untuk Brown-out Reset* (BOR)

2.2.3. Deskripsi Pin-Pin

Mikrokontroler PIC16F877A di produksi dalam kemasan 40 pin PDIP (*Plastik Dual In Line*) maupun 40 pin SO (*Small Outline*). Namun yang banyak terdapat dipasaran adalah kemasan PDIP. Pin-pin untuk I/O sebanyak 33 pin, yang terdiri atas 6 pada Port A, 8 pada Port B, 8 pada Port C, 8 pada Port D, 3 pada Port E. Ada pula beberapa Pin pada mikrokontroler yang memiliki fungsi ganda.



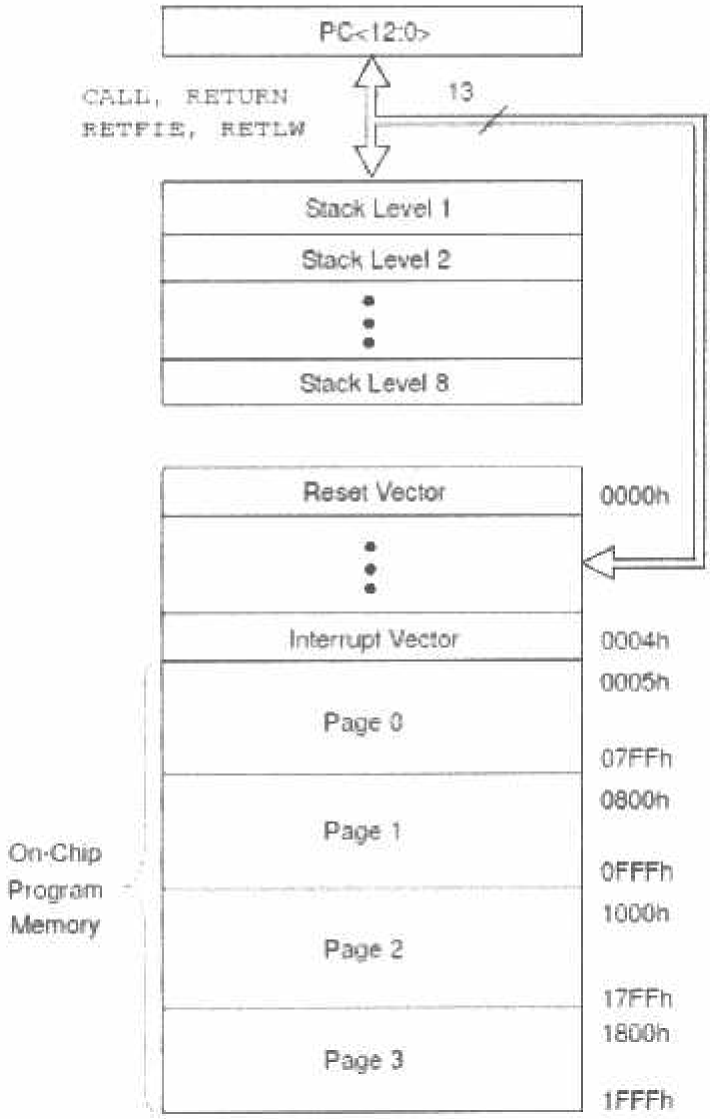
Gambar 2.3. Pin Mikrokontroler PIC16F877A *[Datasheet PIC16F877A]*

2.2.4. Organisasi Memori

Memori pada PIC16F877A dapat dipisahkan menjadi dua blok memori, satu untuk memori program dan satu untuk memori data. Memori EEPROM dan register GPR didalam RAM merupakan memori data, sedangkan memori FLASH merupakan memori program. *[Fahmizal, 2010]*

2.2.5. Memori Program

Memori program direalisasikan dalam teknologi FLASH memori yang memungkinkan pem-program melakukan program-hapus hingga seribu kali. Pemrograman PIC16F877A dilakukan sebelum dipasang pada rangkaian aplikasi, atau ketika sistem sudah terpasang namun dikehendaki adanya up-dating pada program didalamnya. Pemrograman berulang biasanya dilakukan pada saat pengembangan dan penyempurnaan sistem. Ukuran memori program untuk PIC16F877A adalah 8K lokasi dengan lebar kata 14 words. *[Fahmizal, 2010]*

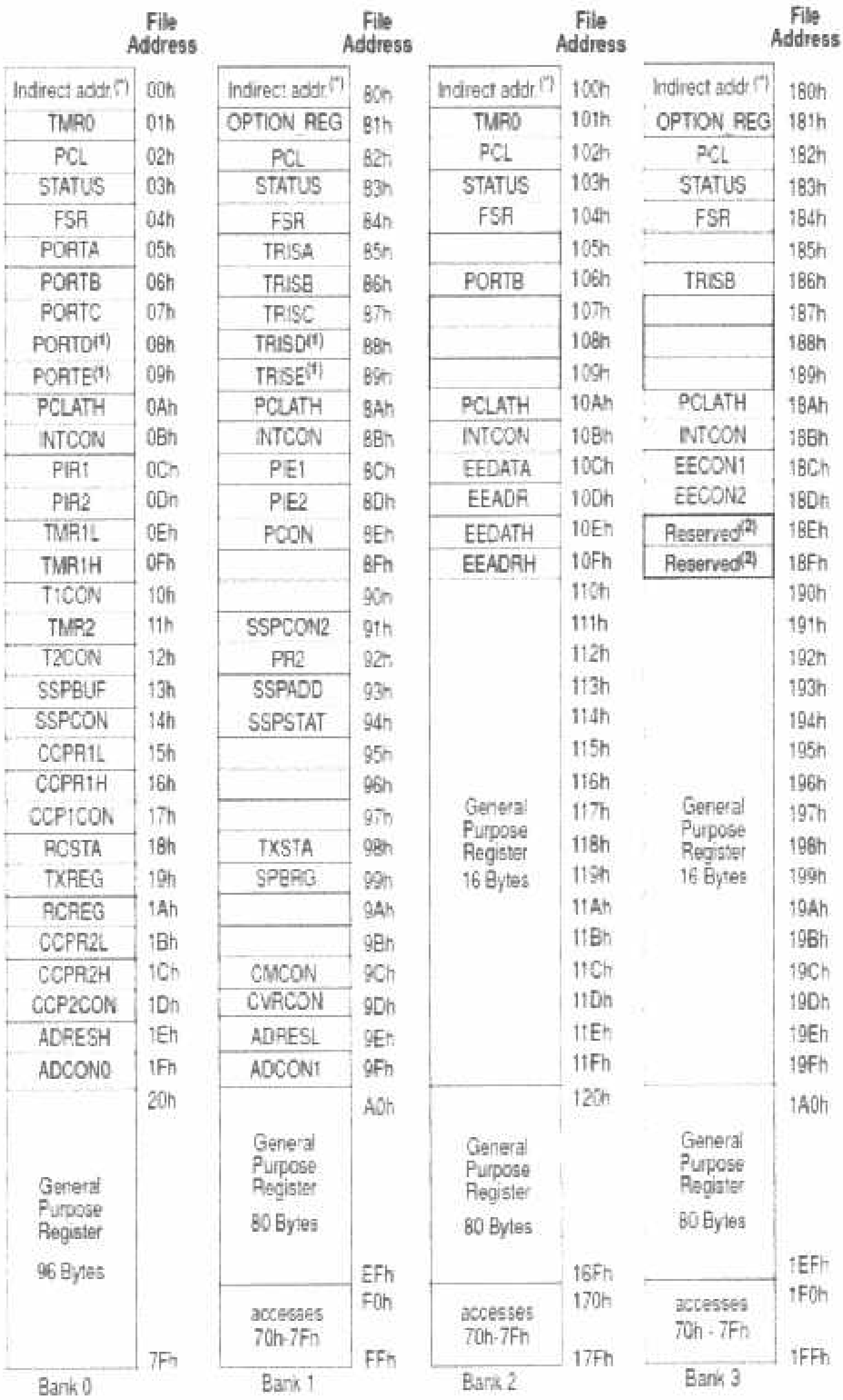


Gambar 2.4. Alokasi Memori Program Mikrokontroler PIC16F877A
[Datasheet PIC16F877A]

2.2.6. Memori Data

Memori data terbagi di dalam beberapa ruang (semacam halaman/bank) yang memuat register yang mempunyai fungsi-fungsi umum dan khusus yang tersendiri. Bit RP1 (STATUS<6>) dan RP0 (STATUS<5>) adalah bit yang menunjukan letak ruang yang dimaksud.

Setiap ruang mempunyai kapasitas di atas 7Fh (128 bytes). Lokasi paling bawah dari setiap ruang ditujukan untuk register yang mempunyai fungsi spesial.



Gambar 2.5. Alokasi Memori Data Mikrokontroler PIC16F877A
[Datasheet PIC16F877A]

2.2.7. Mode Pengalamatan

Lokasi memori RAM dapat di akses secara langsung atau tidak langsung :

1. Pengalamatan langsung

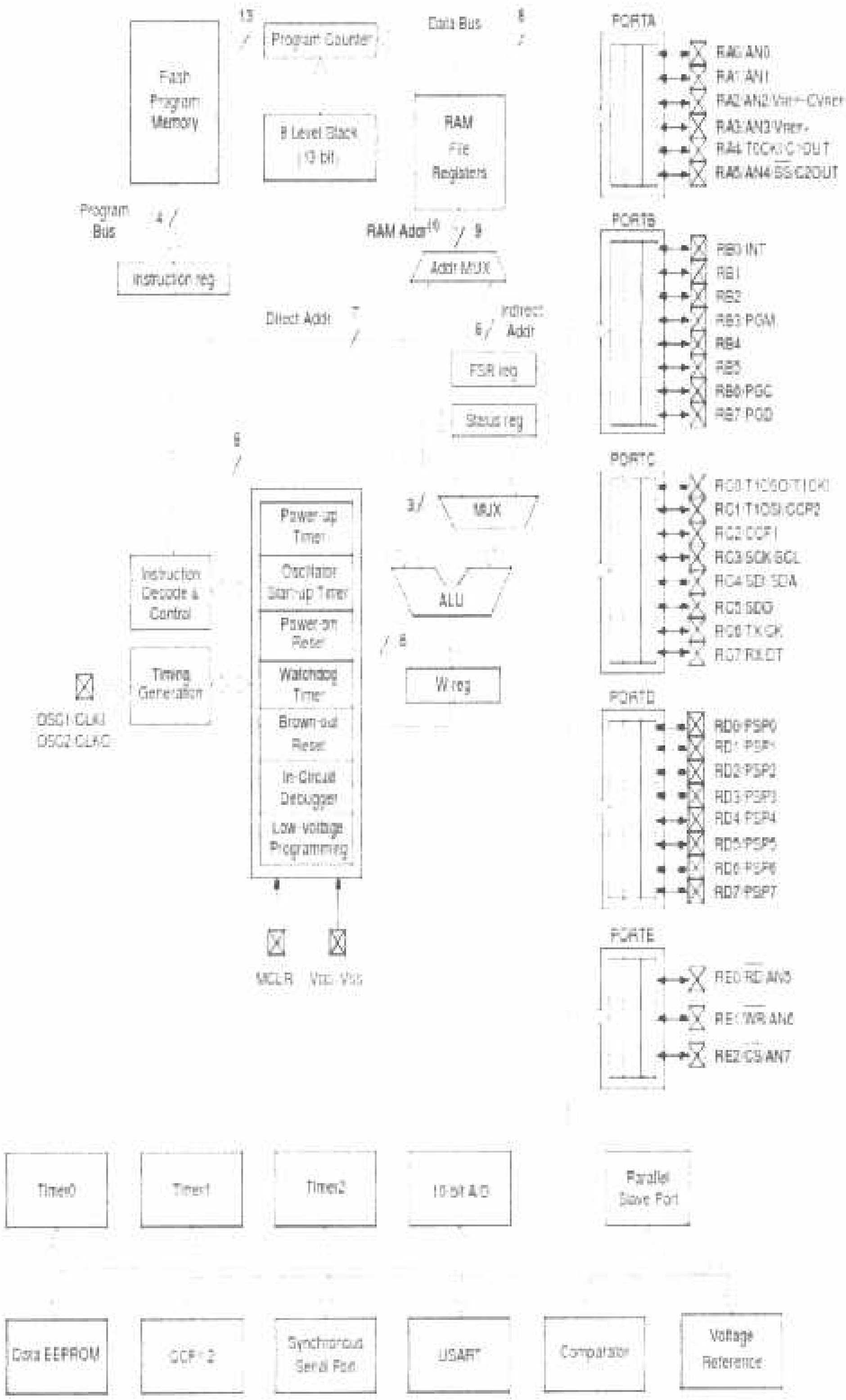
   Pengalamatan langsung dilakukan melalui alamat 9 bit. Alamat ini merupakan rangkaian dari 7 bit langsung dari instruksi dan 2 bit dari RP0 dan RP1 pada register STATUS. Contoh pengalamatan langsung adalah pengaksesan register FSR

2. Pengalamatan tidak langsung

   Berbeda dengan pengalamatan langsung, pengalamatan tidak langsung tidak mengambil alamat dari instruksi, tetapi menggunakan bit ke 7 (IRP) dari register status dan semua bit dari register FSR. Lokasi alamat di akses melalui register INDF yang didalamnya berisi alamat yang ditunjuk oleh FSR.

2.2.8. CPU (Central Processing Unit) PIC16F877A

CPU berperan sebagai otak dari mikrokontroler. Bagian ini bertanggung jawab untuk mengambil instruksi, melakukan decode, dan mengeksekusi instruksi. CPU terhubung ke semua bagian pada mikrokontroler. Fungsi terpenting dari CPU adalah melakukan dekode dan mengeksekusi suatu instruksi. Instruksi-instruksi dalam bahasa assembly terdiri atas opcode dan operan. Opcode menyatakan proses yang harus dilakukan mikrokontroler. Sedangkan operan adalah bagian yang dioperasikan pada aritmatika maupun logika. Agar mikrokontroler dapat mengerti perintah opcode, maka instruksi harus diterjemahkan ke dalam urutan biner dengan kode "0" dan "1". Tugas untuk menterjemahkan instruksi dari bahasa asembly ke bahasa mesin (bahasa yang di mengerti oleh mikrokontroler) dilakukan oleh translator (software assembler atau compiler). *[Fahmizal, 2010]*



Gambar 2.6. CPU Mikrokontroler PIC16F877A
[Datasheet PIC16F877A]

2.4. LED INFRA MERAH

Cahaya infra merah merupakan cahaya yang tidak tampak. Jika dilihat dengan dengan spektroskop cahaya maka radiasi cahaya infra merah akan nampak pada spektrum elektromagnet dengan panjang gelombang di atas panjang gelombang cahaya merah. Dengan panjang gelombang ini maka cahaya infra merah ini akan tidak tampak oleh mata namun radiasi panas yang ditimbulkannya masih terasa/dideteksi.

Pada dasarnya komponen yang menghasilkan panas juga menghasilkan radiasi infra merah termasuk tubuh manusia maupun tubuh binatang. Cahaya infra merah, walaupun mempunyai panjang gelombang yang sangat panjang tetap tidak dapat menembus bahan-bahan yang tidak dapat melewatkan cahaya yang nampak sehingga cahaya infra merah tetap mempunyai karakteristik seperti halnya cahaya yang nampak oleh mata.

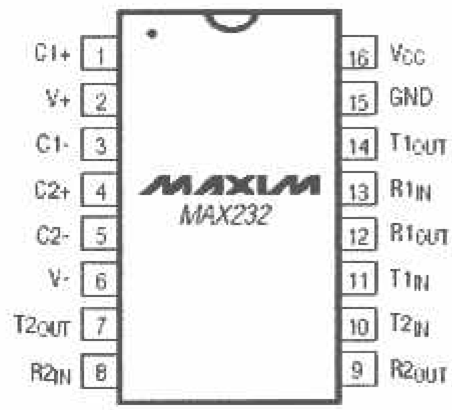
Gambar 2.8. Bentuk fisik LED Infra Merah *[Elektronika dasar, 2011]*

Pada pembuatan komponen yang dikhususkan untuk *penerima infra merah* lubang untuk menerima cahaya (*window*) sudah dibuat khusus sehingga dapat mengurangi interferensi dari cahaya non-infra merah. Oleh sebab itu sensor infra merah yang baik biasanya jendelanya (pelapis yang terbuat dari silikon) berwarna biru tua keungu-unguan. Sensor ini biasanya digunakan untuk *aplikasi inrfa merah* yang digunakan diluar rumah (*outdoor*).

Pada dasarnya penggunaan modulasi cahaya penggunaannya tidak ada batasnya namun modulasinya harus menggunakan sinyal carrier yang frekuensinya harus sangat tinggi yaitu dalam orde ribuan megahertz. Biasanya modulasi dengan frekuensi carrier yang tinggi ini digunakan untuk madulasi sinar laser atau pada transmisi data yang menggunakan media fiberoptic sebagai media perantaranya. *[Elektronika dasar, 2011]*

2.6. IC MAX232

MAX232 merupakan salah satu jenis IC rangkaian antar muka dual RS-232 transmitter / receiver yang memenuhi semua spesifikasi standar EIA-232-E. IC MAX232 hanya membutuhkan power supply 5V (single power supply) sebagai catu. IC MAX232 di sini berfungsi untuk merubah level tegangan pada COM1 menjadi level tegangan TTL / CMOS. IC MAX232 terdiri atas tiga bagian yaitu dual charge-pump voltage converter, driver RS232, dan receiver RS232. *[Jimmyrahdiansyah, 2010]*



Gambar 2.10 Konfigurasi Pin IC MAX232 *[Datasheet Max232]*

Fitur IC MAX232

1. Dual Charge-Pump Voltage Converter.

   IC MAX232 memiliki dua charge-pump internal yang berfungsi untuk menkonversi tegangan +5V menjadi ±10V (tanpa beban) untuk operasi driver RS232. Konverter pertama menggunakan kapasitor C1 untuk menggandakan tegangan input +5V menjadi +10V saat C3 berada pada output V+. Konverter kedua menggunakan kapasitor C2 untuk merubah +10V menjadi -10V saat C4 berada pada output V-.

2. Driver RS232

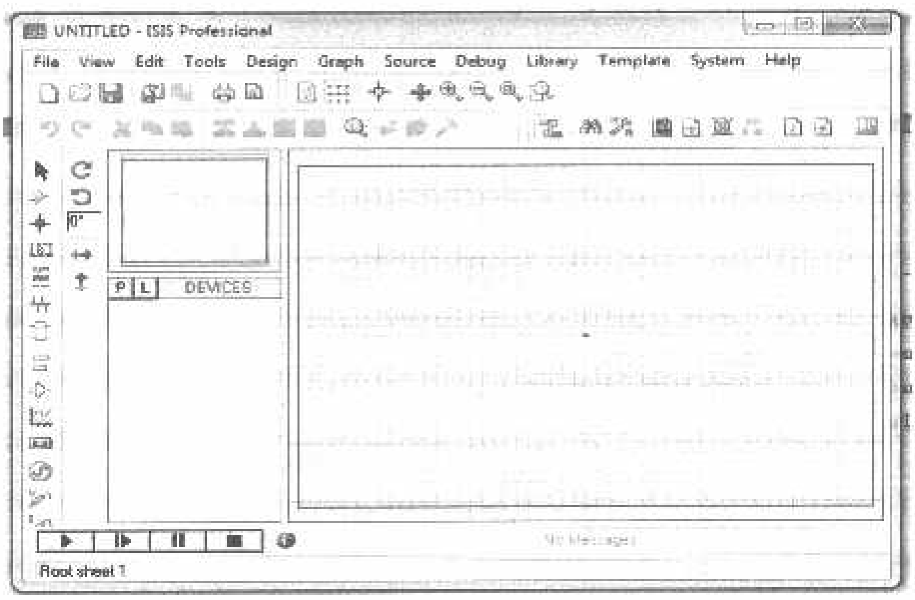
   Output ayunan tegangan (voltage swing) driver typical adalah ±8V. Nilai ini terjadi saat driver dibebani dengan beban nominal receiver RS232 sebesar 5kΩ atau Vcc = 5V. Input pada driver yang tidak digunakan bisa dibiarkan tidak terhubung kemana – mana. Hal ini dapat terjadi karena dalam kaki input driver IC MAX232 terdapat resistor pull-up sebesar 400kΩ yang terhubung keVcc. Resistor pull-up mengakibatkan output driver yang tidak terpakai menjadi low karena semua output driver diinversikan.

3. Receiver RS232

   EIA mendefinisikan level tegangan lebih dari 3V sebagai logic 0, berdasarkan hal tersebut semua receiver diinversikan. Input receiver dapat menahan tegangan input sampai dengan ±25V dan menyiapkan resistor terminasi input dengan nilai nominal 5k. Nilai input receiver hysteresis typical adalah 0,5V dengan nilai minimum 0,2V, dan nilai delay propogasi typicalnya adalah 600ns.

2.7. PROTEUS 7.0 PROFESIONAL

Proteus adalah sebuah software untuk mendesain PCB yang juga dilengkapi dengan simulasi PSpice pada level skematik sebelum rangkaian skematik di-upgrade ke PCB sehingga sebelum PCBnya di cetak kita akan tahu apakah PCB yang akan kita cetak apakah sudah benar atau tidak. Proteus mampu mengkombinasikan program ISIS untuk membuat skematik desain rangkaian dengan program ARES untuk membuat layout PCB dari skematik yang kita buat. Software Proteus ini bagus digunakan untuk desain rangkaian mikrokontroller.



Gambar 2.11 Tampilan Aplikasi Proteus Profesional.

5. Memiliki fasilitas report terhadap kesalahan-kesalahan perancangan dan simulasi elektrik.
6. Mendukung fasilitas interkoneksi dengan program pembuat PCB-ARES.
7. Memiliki fasilitas untuk menambahkan package dari komponen yang belum didukung.

2.7.2 Mode ARES (Advanced Routing and Editing Software)

ARES (Advanced Routing and Editing Software) digunakan untuk membuat modul layout PCB. Adapun fitur-fitur dari ARES adalah sebagai berikut :

1. Memiliki database dengan tingkat keakuratan 32-bit dan memberikan resolusi sampai 10 nm, resolusi angular 0,1 derajat dan ukuran maksimum board sampai 10 m.
2. ARES mendukung sampai 16 layer.
3. Terintegrasi dengan program pembuat skematik ISIS, dengan kemampuan untuk menentukan informasi routing pada skematik.
4. Visualisasi board 3-Dimensi.
5. Penggambaran 2-Dimensi dengan simbol library.

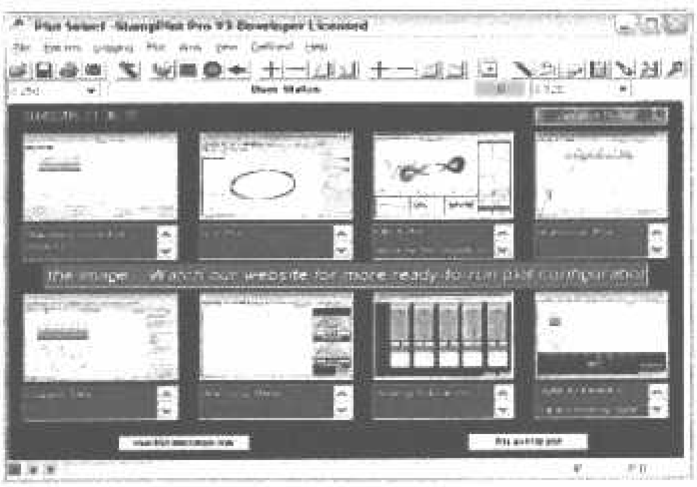
Proteus lebih memiliki kelebihan pada desainnya yang sederhana, sangat mudah dan bagus digunakan untuk perancangan rangkaian mikrokontroller yang akan sangat membantu digunakan oleh mahasiswa yang mengambil mata kuliah berhubungan dengan mikrokontroller. Kelebihannya yang lain adalah sebelum PCB dicetak skematiknya bisa disimulasikan dulu. Desain-desainnya bisa digabungkan dan masih banyak lagi kelebihan yang dimiliki Proteus.

2.8. APLIKASI HMI (Human Machine Interface) STAMPPLOT

Salah satu penggunaan mikrokontroler adalah sebagai antarmuka antara PC (Personal Computer) dengan berbagai macam sensor ataupun aktuator. Dengan biaya yang tidak terlalu mahal dapat dibuat berbagai macam sistem instrumentasi ataupun kendali sederhana yang dapat menampilkan dan merekam data dari sensor serta mengendalikan berbagai aktuator pada PC melalui port serial. Untuk itu diperlukan pemrograman pada PC yang dapat menerima dan mengirim data pada port serial. Banyak bahasa pemrograman yang dapat digunakan untuk mengakses port serial, misalnya C++, Visual Basic, Delphi, ataupun Matlab.

Stampplot adalah sebuah software aplikasi computer untuk akuisisi data dan pengendalian input output mikrkontroler melalui komunikasi serial. Aplikasi ini mampu menampilkan grafik dan menyediakan pembuatan user interfaces untuk pemantauan dan pengendalian, serta penyimpanan data yang akan dikirimkan oleh mikrokontroler. Sebenarnya software ini dibuat khusus untuk basic stamp. Namun, pada perkembangannya, software ini juga dapat digunakan untuk mikrokontroler lain, asalkan computer tersebut dapat melakukan komunikasi serial dengan computer.

StampPlot adalah salah satu perangkat lunak alternatif yang dapat digunakan sebagai alat bantu akuisisi data yang dikirimkan oleh mikrokontroler melalui port serial. Fasilitas yang terdapat pada StampPlot memungkinkan kita untuk membuat plotting, menampilkan indikator, merekam, dan melakukan perhitungan dari data, serta melakukan kendali melalui PC. *[Nugroho, 2009]*



Gambar 2.12. Tampilan Aplikasi StampPlot *[Nugroho, 2009]*

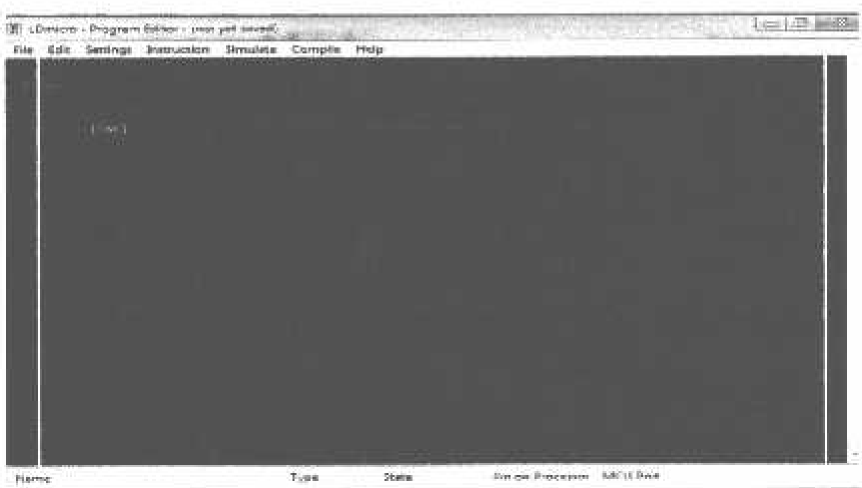
Beberapa fitur dari StampPlot antara lain :

1. Dapat menampilkan plotting data dari maksimal 8 data digital dan 10 data analog.
2. Data dan gambar plot yang diperoleh dapat disimpan dalam bentuk file .txt ataupun .jpg.
3. Plotting dapat dilakukan menggunakan skala linear ataupun logaritma
4. Dapat dilakukan berbagai perhitungan matematika

5. Terdapat berbagai antarmuka dalam bentuk grafis untuk monitoring data maupun kendali interaktif, misalnya text box, list box, meter, alarm, tombol, lampu, slider, progress bar, dan bahkan joystick.
6. Terdapat instruksi untuk memainkan file suara .wav maupun menampilkan gambar.
7. Mampu menyimpan data(Log) dan gambar grafik(Snap)
8. Terdapat fasilitas software Serial – TCP sebagai perangkat penghubung dengan jaringan komputer.
9. Tonfigurasi dapat dilakukan menggunakan perintah dari mikrokontroler ataupun dalam bentuk makro.
10. StampPlot bebas digunakan untuk pengguna pendidikan dan pribadi. Perbedaannya dengan versi Profesional adalah tidak ada fasilitas drag and drop dalam pembuatan macro dan waktu koneksi menggunakan Serial-TCP dibatasi hanya 3 menit.

2.9. LADDER DIAGRAM MICRO (LDMICRO)

LDMicro adalah sebuah software IDE yang menghasilkan kode mesin (file *Hex) untuk mikrokontroler. Software IDE (Integrated Development Environment) adalah software yang menggabungkan Editor, Assembler, Compiler dan Debugger dalam satu lingkungan kerja. Tdiak seperti Editor pada umumnya yang berbentuk teks, Editor LDMicro berbentuk diagram tangga.

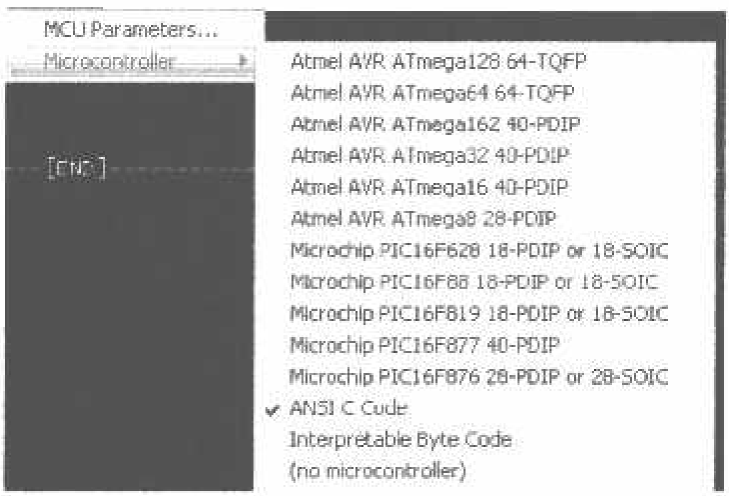


Gambar 2.13 Tampilam Aplikasi LDMicro

Cara penggunaan program ini pun sama dengan memprogram Ladder diagram PLC, sama dengan CodeSys pada Wago, Syswin pada Omron, AB,dll. software ini juga dilengkapi dengan proses simulasi sehingga memudahkan kita untuk melakukan *check error* program yang telah kita buat. program yang telah dibuat dalam bentuk ladder dengan LdMikro ini ketika di *compile* juga menghasilkan file (*hex) yang nantinya kita gunakan untuk men*download*kan ke mikrokontroler atau mensimulasikan dengan program tambahan semisal simulasidengan RealPicSimulator atau dengan Proteus.

Ada beberapa jenis mikrokontroler yang bisa dibuat kode mesinnya di LDMicro yaitu:

1. Untuk keluarga PIC: PIC16F628(A), PIC16F88, PIC16F819, PIC16F877(A), PIC16F876(A), PIC16F877, dan PIC16F86.
2. Untuk keluarga AVR : ATmega128, ATmega64, ATmega162, ATmega32, ATmega16 dan ATmega8.



Gambar 2.15 Mikrokontroler yang Support Program LdMicro

LdMicro, Program yang dikembangkan oleh Jonathan W dapat menjadi solusi baru bagi penggiat ataupun pembelajar di dunia kontrol ataupun otomasi, bisa dibilang terdapat *dualisme positif*mempelajari program ini, pertama dapat menjadi pengembangan dalam mepelajari mikrokontroler dengan metode program Ladder pada PLC atau juga dapat menjadi metode mempelajari PLC dengan Mikrokontroler (sebagai *Hardware* nya).

Porgram Ladder LdMikro ini bukan hanya dapat mengolah data digital (high and low logic) tetapi juga data analog karena sebagaimana kita ketahui

BAB III
PERANCANGAN SISTEM

Dalam perancangan sistem ini mnejelaskan tentang bagaimana merancang alat denyut jantung berbasis mikrokontroller PIC16F877A, baik itu merancang skematik rangkaian, diagram block rangkaian, perancangan program yang akan dimasukkan kedalam mikrokontroller PIC16F877A dan flowchart perancangan alat tersebut.

3.1 Diagram Blok

Dalam setiap perencanaan dan pembuatan suatu alat diperlukan sebuah diagram blok, yang berfungsi untuk mempermudah dalam menentukan alur kerja dari system pada alat tersebut. Selain itu diagram blok juga berguna untuk mengetahui bagian-bagian sytem dari suatu alat, berikut ini adalah diagram blok dari alat dalam laporan skripsi ini.

Gambar 3.1 Blok Diagram

1. Sensor Denyut jantung

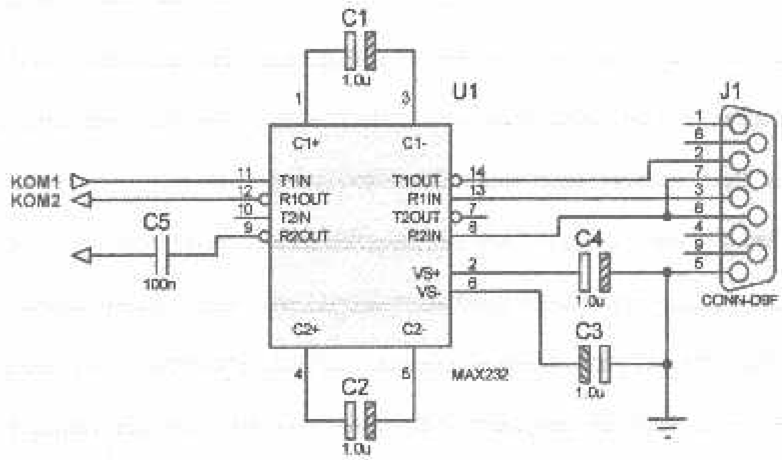
   Untuk mendeteksi denyut jantung manusia melalaui perubahan volume darah manusia dan mengubah hasil deteksi tersebut dalam berntuk sinyal pulsa.

2. Penguat LM358.

   Berfungsi untuk menguatkan sinyal yang diterima dari hasil deteksi sensor photodioda dan diteruskan ke mikrokontroller PIC16F877A.

3. Mikrokontroller PIC16F877A.

   Mikrokontroler yang digunakan adalah PIC16F877A.digunakan untuk menerima data dari rangkaian sensor photodioda, diolah dan ditampilkan.



Gambar 3.3 Rangkaian Komunikasi Serial

Alat dan bahan yang digunakan untuk rangkaian ini yaitu:

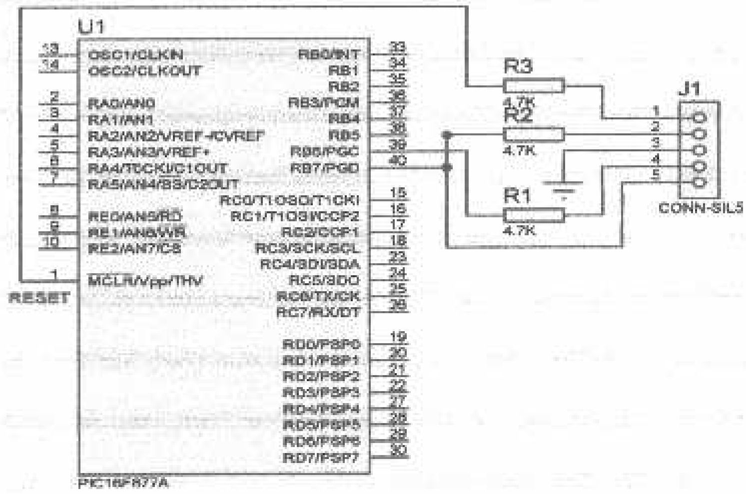
- IC MAX232
- Capasitor 1 uF (4 Buah)
- Capasitor 100uF
- Konektor DB9 Female
- Socket IC 16 Pin

Untuk melakukan komunikasi serial dengan standar RS-232, harus dilakukan penyesuaian level sinyal dari level TTL menjadi level RS-232 menggunakan IC tertentu, misalnya DS 275 atau MAX232. Penggunaan IC MAX232 untuk menyesuaikan tegangan dari prosesor dengan tegangan standar RS-232 yang melalui konektor DB9.

Pada RS232, 1s (high) direpresentasikan dengan tegangan -3 s/d -25V, dan 0s (low) direpresentasikan sebagai +3 s/d +25V. Sedang diantara -3 dan +3V dianggap sebagai status mengambang dan tidak dianggap. Atas alasan ini, untuk menghubungkan mikrokontroller yang ber-standar TTL dengan komputer (atau alat lain) yang menggunakan RS232, kita harus menggunakan peralatan tambahan misalnya dengan chip MAX232 untuk mengkonversi level TTL ke RS232 dan level RS232 ke level TTL.

3. Rangkaian ICSP (In Circuit System Program)

Sesuai dengan namanya rangkaian ini berfungsi sebagai jalur untuk memasukkan program ke mikrokontroller yang terintegrasi langsung dengan rangkaian minimum system mikrokontroller PIC16F877A yang mana rangkaian ini terhubung dengan pin 39 dan pin 40 mikrokontroller PIC16F877A sebagai jalur komunikasi dan rangkaian ini terhubung dengan rangkaian reset.Rangkaian ini terhubung ke pin 3,4,5,7 dan 8 dari kabel serial DB9.

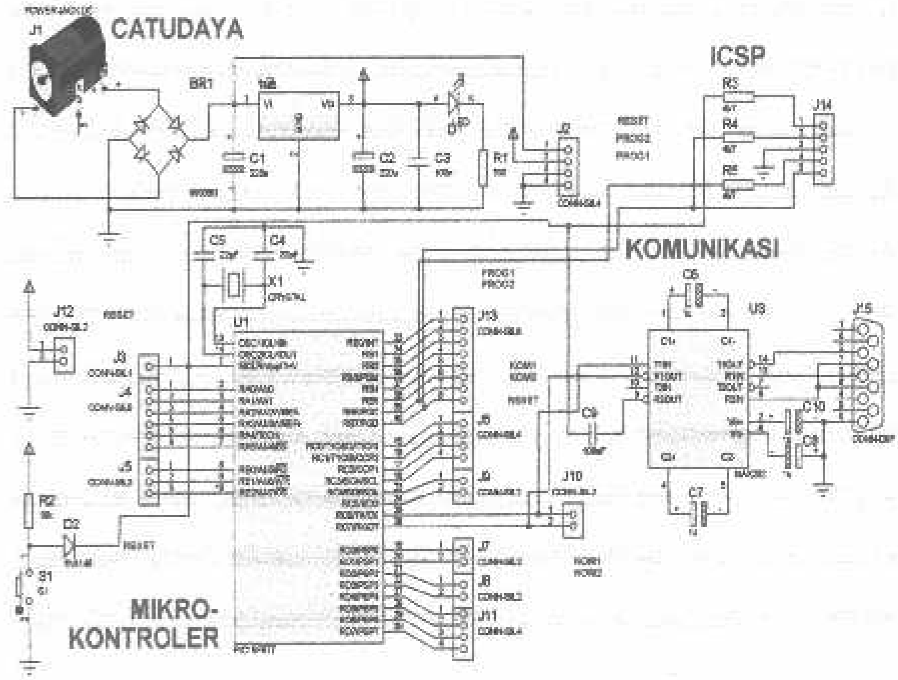


Gambar 3.4 Rangkaian ICSP

Alat dan bahan yang digunakan dalam rangkaian ini yaitu:

- Socket IC 40 pin
- Resistor 4.7k (3 buah)
- Kabel serial DB9
- Pin Header

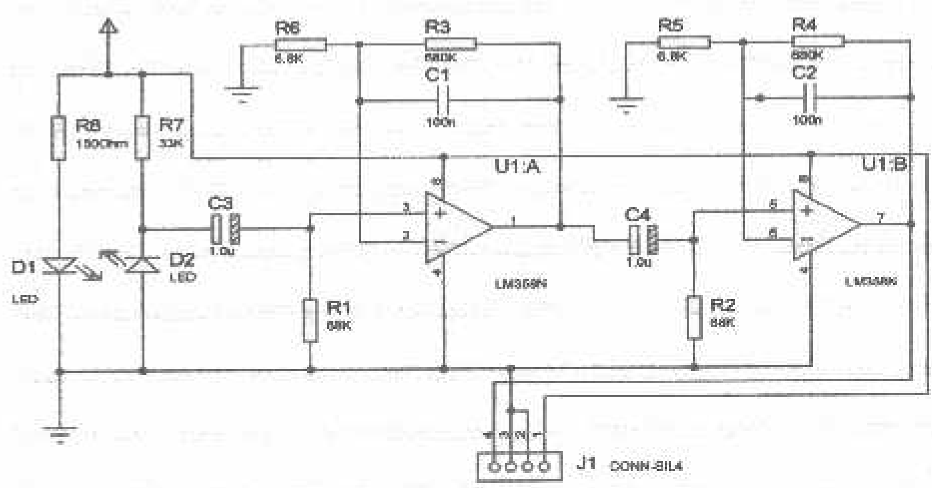
4. Rangkaian secara keseluruhan.



Gambar 3.5 Rangkaian secara keseluruhan

5. Rangkaian Sensor Denyut Jantung

Rangkaian ini berfungsi untuk menerima data melalui proses pendeteksian volume darah melalui Infrared (D1) dan photodiode (D2). Sinyal yang diterima dkuatkan oleh IC OP-AMP LM358 untuk diteruskan ke pin 2 mikrokontroller PIC16F877A .Sistem kerja rangkaian ini adalah mendeteksi perubahan volume darah manusia pada kulit jari menggunakan photodiode dan Infrared.



Gambar 3.6 Rangkaian Sensor Cahaya

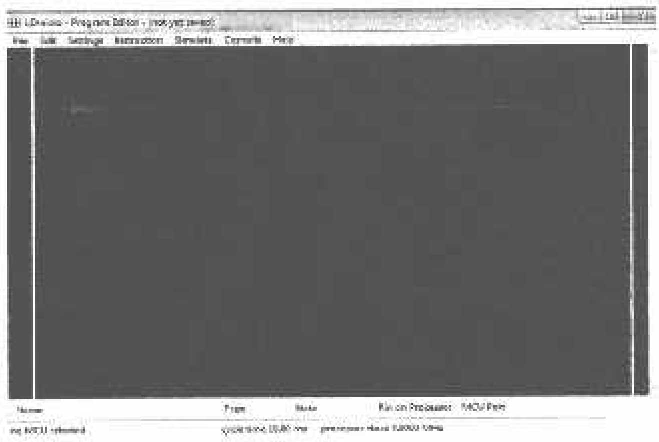
tegangan. Tujuan penggunaan IC LM358 ini adalah agar sinyal yang diterima oleh Photodioda dipastikan terlebih dahulu oleh penguat ini sebagai logika 1 atau 0. Karena dalam proses mikrokontroller membutuhkan sinyal logika 1 dan 0 untuk menjalankan program. Sinyal yang diterima oleh photodiode terkadang untuk membedakan logika 1 dan 0 nilainya sangat kecil maka digunakan IC LM358 untuk memastikan sinyal yang masuk berupa logika 1 atau 0.

3.4 Perancangan Program / Software

Untuk perancangan sosftware terdapat beberapa aplikasi yang mendukung untuk terselesaikan skripsi ini. Aplikasi tersebut adalah sebagai berikut :

3.4.1. Aplikasi Ladder Diagram Micro

Aplikasi berfungsi untuk membuat program yang akan dimasukkan kedalam mikrokontroller PIC16F877A yang berguna untuk mengolah data yang diterima dari sensor denyut jantung dan di tampilkan ke display. Aplikasi ini akan menghasilkan file berekstensi .HEX agar dapat diterima dan bekerja pada mikrokontroller PIC16F877A.



Gambar 3.7 Aplikasi Ladder Diagram

Intruksi Yang digunakan dalam perancangan program ini adalah sebagai berikut :

- Instruksi Read A/D Converter.

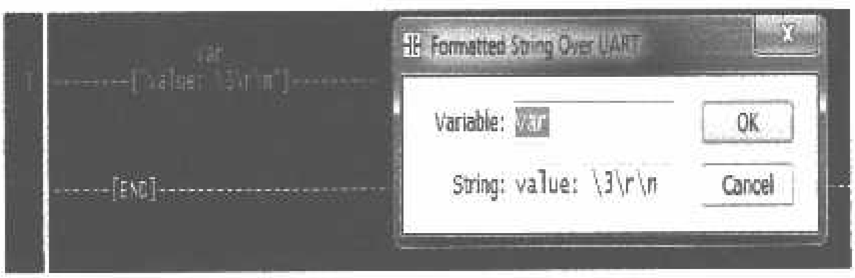
  Instruksi ini digunakan untuk membaca tegangan analog antara 0-5v, dengan ketelitian pembacaan sebesar 10 bit, atau nilai antara 0-1023. Jadi untuk tegangan 0V akan terbaca nilai 0 dan untuk tegangan 5V akan terbaca nilai 1023. Sedangkan untuk tegangan 2V akan terbaca 2/5x1023 = 409 dan seterusnya untuk tegangan 3V dan 4V.

Pembacaan dilakukan ketika instruksi ini mendapatkan nilai 1. Nilai hasil pembacaan tersebut kemudian disimpan kedalam sebuah variable yang namanya selalu diawali dengan huruf A. Huruf A ini secara otomatis ditambahkan untuk mengindikasikan bahwa variable tersebut adalah hasil instruksi ADC.

Gambar 3.8 Kotak instruksi dan Simbol READ A/D Converter

- Instruksi Formatted String Over UART.

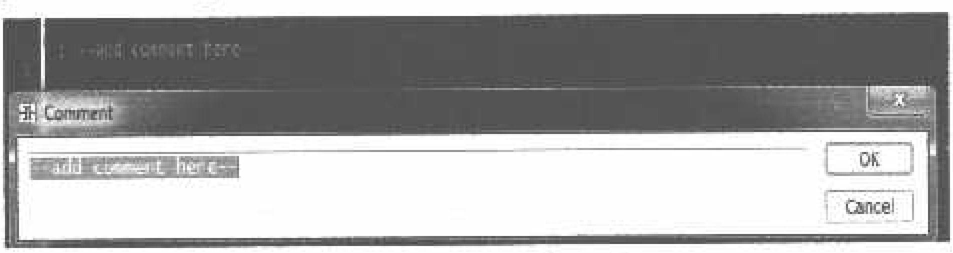
  Instruksi ini akan mengirimkan data berupa variable dan teks (string) melalui komunikasi serial UART ke computer. Pengaturan kecepatan pengiriman (baud rate) dapat dilakukan pada menu MCU Parameters. Data akan dikirimkan ketika instruksi ini mendapat sisi naik pulsa (dari 0 ke 1).



Gambar 3.9 Simbol dan kotak Intruksi Formatted String Over UART

- Instruksi Comment

  Instruksi ini berfungsi untuk member keterangan mengenai isi program pada Ladder Diagram Micro.



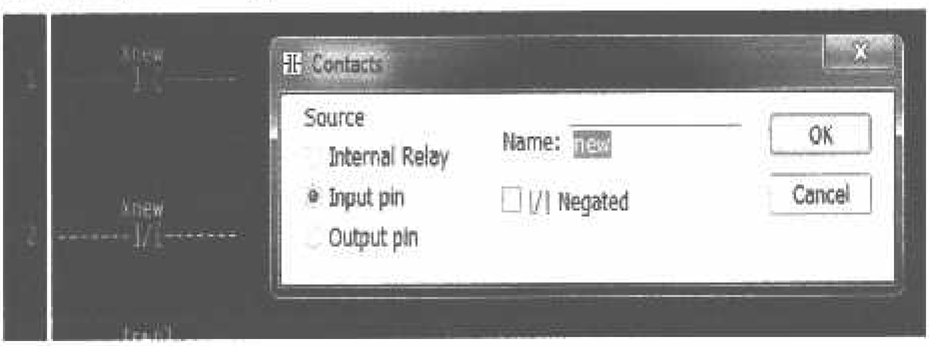
Gambar 3.10 Simbol dan Kotak Intruksi Comment

➢ Instruksi Contact

Instruksi ini memiliki 2 status yaitu NO (Normally Open) dan NC (Normally Close). Untuk status NO apabila mendapat nilai 1 maka contact akan terhubung, sedangkan bila mendapat nilai 0 maka contact akan terbuka. Sebaliknya untuk status NC bila mendapat nilai 0 maka contact akan terhubung dan bila mendapat nilai 1 maka contact akan terbuka.

Sumber contact ada 3 yaitu internal relay, Input Pin dan Output Pin. Untuk contact Input Pin dan Output Pin, kedua contact ini terhubung dengan kaki mikrokontroler sedangkan untuk contact Internal Relay tidak terhubung dengan kaki mikrokontroler, tetapi menggunakan Internal memory atau RAM sehingga bisa menghemat kebutuhan kaki mikrokontroler.

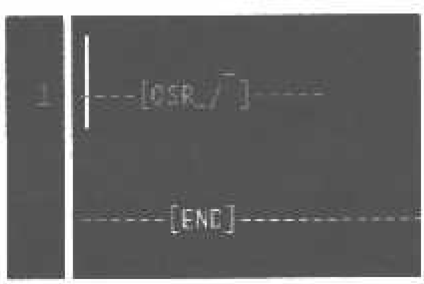
Untuk Contact Input pin akan membaca sinyal yang diberikan pada kaki mikrokontroler sedangkan untuk contact Internal Relay dan contact Output pin akan membaca status coil Internal Relay dan Output pin yang memiliki nama yang sama dengan contact tersebut.



Gambar 3.11 Simbol NO, NC dan Kotak Intruksi Contacts.

➢ Instruksi OSR (One Shot Rising).

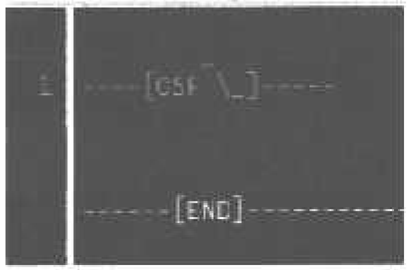
Instruksi ini mendeteksi sisi naik sebuah input pulsa yaitu perubahan kondisi dari nilai 0 ke 1.



Gambar 3.12 Simbol Instruksi OSR

- Instruksi OSF (One Shot Falling)

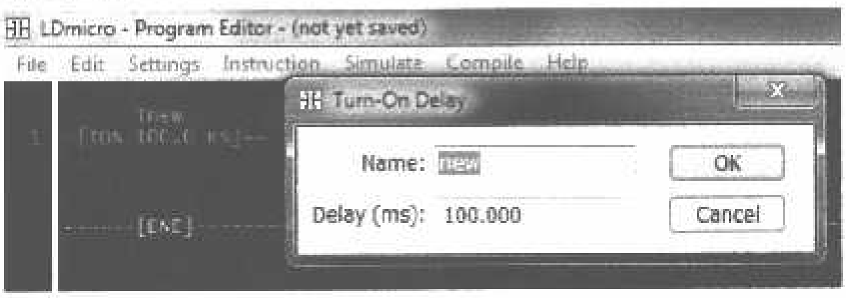
Instruksi ini mendeteksi sisi turun sebuah input pulsa yaitu perubahan kondisi dari nilai 1 ke 0.



Gambar 3.13 Simbol Intruksi OSF

- Instruksi TON (Delayed Turn On)

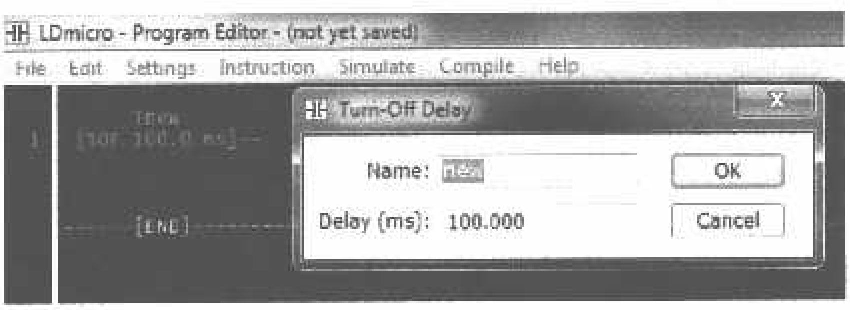
Instruksi ini berfungsi untuk menunda kondisi 1 hingga waktu delay yang ditentukan telah habis.



Gambar 3.14 Simbol dan Kotak Instruksi TON

- Instruksi TOF (Delayed Turn Off)

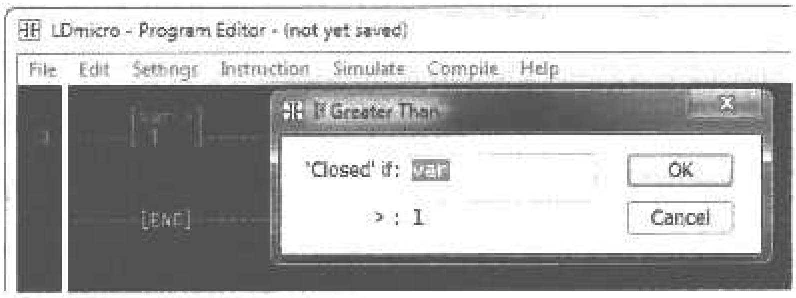
Instruksi ini berfungsi untuk menunda kondisi 0 hingga waktu delay yang ditentukan telah habis.



Gambar 3.15 Simbol dan Kotak Instruksi TOF

- Instruksi GRT (Compare For Greather Than)

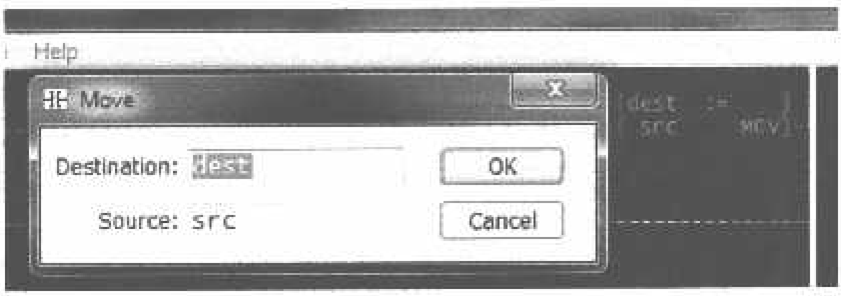
Instruksi ini menhasilkan kondisi 1 ketika nilai variable lebih besar dari nilai yang ditentukan.



Gambar 3.16 Simbol dan Kotak instruksi GRT

- Instruksi MOV (Move)

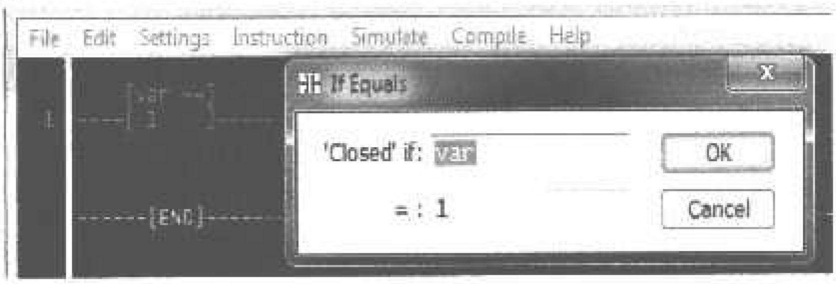
Jika instruksi ini bernilai 1, maka akan memasukkan nilai atau variable pada kolom source ke dalam variable pada kolom destination.



Gambar 3.17 Simbol dan Kotak Instruksi MOV

- Instruksi EQU (Compare If Equals)

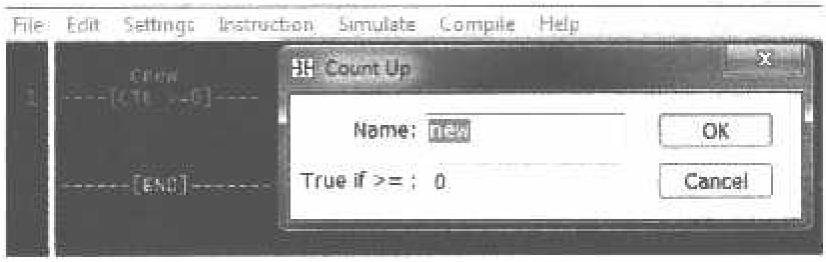
Instruksi ini menghasilkan kondisi 1 ketika nilai variable sama dengan nilai yang ditentukan.



Gambar 3.18 Simbol dan Kotak Instruksi EQU

- Instruksi CTU (Count Up)

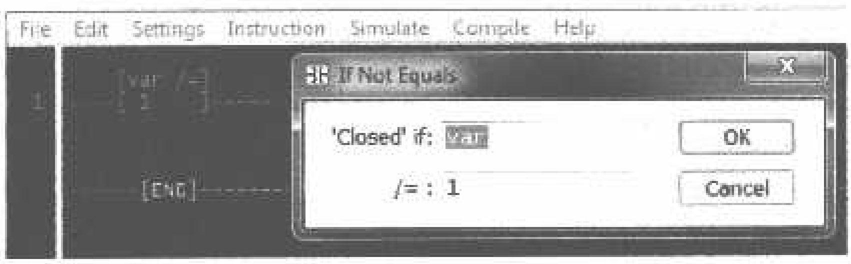
Instruksi ini menyimpan jumlah pulsa yang masuk dengan hitungan naik (increment) ke dalam sebuah variable, dan menghasilkan kondisi 1 bila nilai variable tersebut lebih besar atau sama dengan angka yang telah ditentukan.



Gambar 3.19 Simbol dan kotak instruksi CTU

- Instruksi NEQ (Compare If Not Equals)

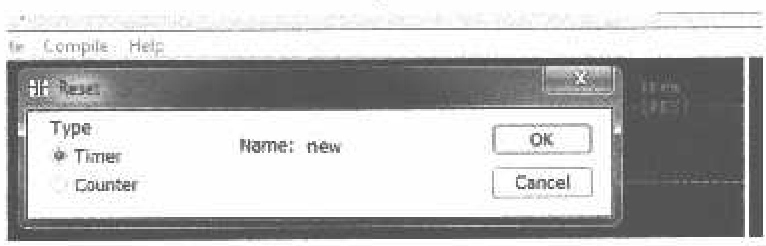
  Instruksi ini menghasilkan kondisi 1 ketika nilai variable tidak sama dengan nilai yang sudah ditentukan.



Gambar 3.20 Simbol dan Kotak instruksi NEQ

- Instruksi RES (Reset)

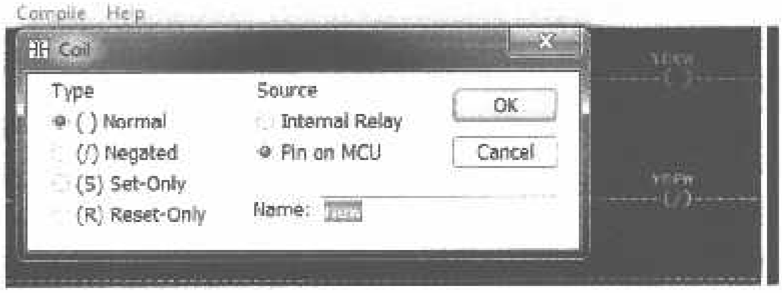
  Instruksi ini berfungsi jika instruksi ini bernilai 1, maka akan membuat nilai variable suatu timer atau counter menjadi 0 atau di- Reset.



Gambar 3.21 Simbol dan kotak instruksi RES

- Instruksi Coil

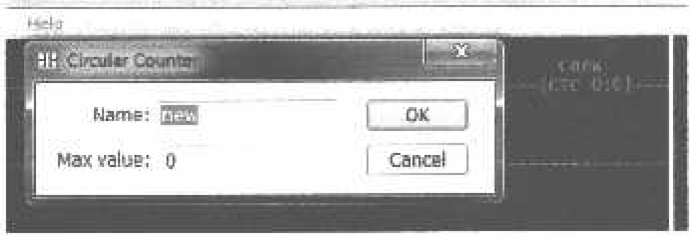
  Instruksi ini berfungsi sebagai output dari program. Semua contact yang namanya sama dengan output ini akan diberi nilai 1 bila Output ini bernilai 1 dan diberi 0 bila Output ini bernilai 0. Jika pilhan Source = Pin On MCU, maka nilai 1 atau 0 yang dihasilkan tersebut akan diteruskan ke piranti di luar melalui sebuah kaki mikrokontroler yang ditugaskan untuk Output ini.



Gambar 3.22 Simbol dan Kotak Instruksi COIL.

➢ Instruksi CTC (Count Circular)

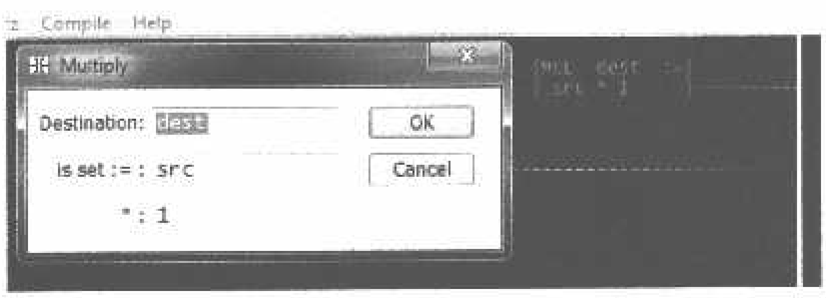
Instruksi ini berfungsi menyimpan jumlah pulsa yang masuk dengan hitungan naik (increment) kedalam sebuah variable, yang akan direset ke nilai 0 ketika mencapai nilai maksimum yang telah ditentukan dan kembali menghitung naik.



Gambar 3.23 Simbol dan Kotak Instruksi CTC.

➢ Instruksi MUL (Multiply)

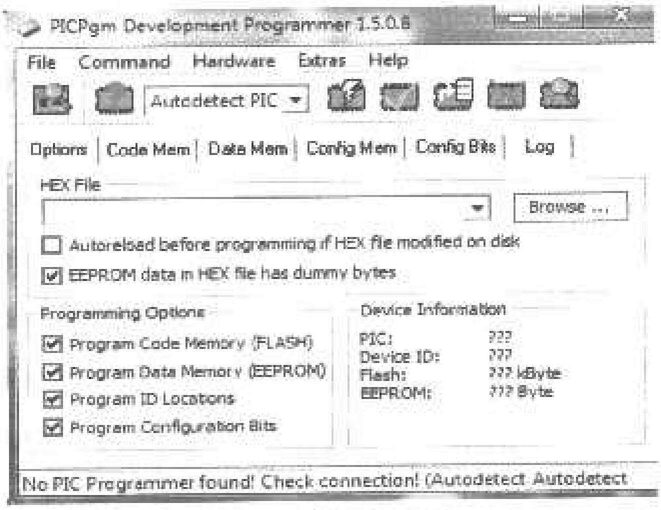
Jika instruksi ini bernilai 1, maka akan membuat nilai atau variable pada kolom kedua dikalikan dengan kolom 3. Hasil perkalian tersebut dimasukkan kedalam variable dikolom pertama atau dikolom destination.



Gambar 3.24 Simbol dan Kotak instruksi MUL.

3.4.2. Aplikasi Human Machine Interfaces (HMI) StampPlot.

Sesuai dengan namanya, aplikasi ini berfungsi untuk menampilkan hasil pengukuran yang telah dilakukan oleh mikrokontroller PIC16F877A. Aplikasi ini menggunakan komunikasi serial sehingga memudahkan untuk langsung dengan pin 39 dan 40 dari mikrokontroller PIC16f877A yang mana pin-pin tersebut berfungsi sebagai mode programming.



Gambar 3.27 Tampilan aplikais PICPgm Programmer

3.5 Flowchart

Gambar 3.28 Flowchart pembuatan alat.

BAB IV

PENGUJIAN DAN ANALISA

4.1. Pengujian Alat.

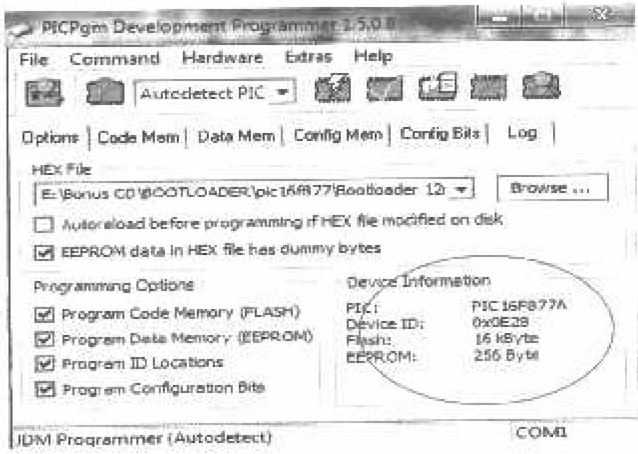
Pada bab ini akan membahas tentang hasil Pengujian dan analisa dari alat pengukur detak jantung ini. Baik itu pengujian secara keseluruhan rangkaian dan masing-masing blok rangkaian kerja alat pengukur detak jantung ini. Untuk pengujian perblok yaitu rangkaian komunikasi dan rangkaian Sensor denyut jantung. Dan untuk pengujian secara keseluruhan rangkaian yaitu pengujian alat pengukur detak jantung ini dapat terdeteksi oleh komputer dan data yang diterima oleh sensor denyut jantung dapat terbaca oleh aplikasi StampPlot.

4.1.1 Pengujian rangkaian ICSP (In Circuit Serial Programing).

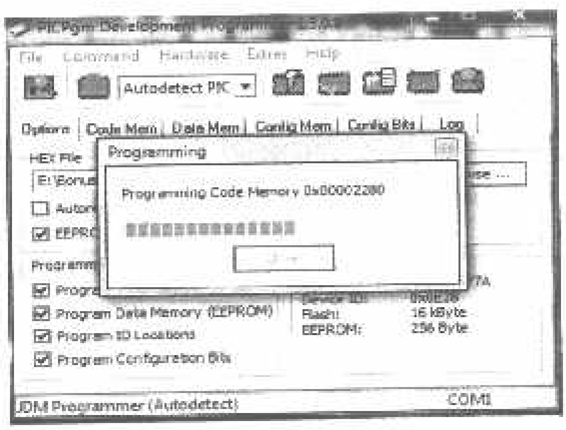
Rangkaian ICSP menggunakan komponen Resistor dengan nilai 4,7 k dan kabel komunikasi serial DB9. Dan rangkaian ICSP ini membutuhkan tegangan 5v DC.

1. Tujuan Penelitian.

   Untuk mengetahui rangkaian ini bekerja dengan baik atau tidak dan rangkaian ini berfungsi untuk mengisi program kedalam mikrokontroller PIC16f877A.
2. Alat yang digunakan.
   - Power Supply 5v DC
   - Rangkaian ICSP
   - Kabel Serial DB9
   - IC Mikrokontroller PIC16f877A
   - Aplikasi PICPgm Programmer.
3. Prosedur Pengujian
   - Pasang IC Mikrokontroller PIC16f877A pada rangkaian ICSP.
   - Sambungkan kabel serial DB9 dari rangkaian ICSP ke komputer dan pasang catu daya.
   - Buka aplikasi PICPgm Programmer untuk melihat IC mikrokontroller PIC16f877A terdeteksi atau tidak.



Gambar 4.1 Mikrokontroller terdeteksi aplikasi PICPgm Programer



Gambar 4.2 Proses memasukkan program ke mikrokontroller.

4. Analisa.

Tabel 4.1 Konfigurasi pin rangkaian ICSP (In Circuit Serial Programing)

Kabel DB9	Mikrokontroller PIC16f877A
Pin 3 (TD)	Pin 1
Pin 7 (RTS)	Pin 39 (PGC)
Pin 4 (DTR)	Pin 40 (PGD)
Pin 8 (CTS)	Pin 40 (PGD)
Pin 5 (Ground)	

Untuk melakukan programming, aplikasi PICPgm Programmer akan mendeteksi mikrokontroller PIC16f877A. Dan saat proses memasukkan program, mikrokontroller akan mengirimkan sinyal ke aplikasi PICPGm Programmer melalui pin 39 ke pin 7 RTS (Request To Send) komunikasi serial bahwa mikrokontroller siap melakukan pertukaran data.Feedback dari komunikasi serial akan mengrimkan sinyal melalui pin 4 DTR (Data Terminal Ready) dan pin 8 CTS (Clear To Send) ke pin 40 (PGD) bahwa data telah siap untuk dikirimkan dan proses pengiriman data pun berlangsung melalui pin 3 TD (Transmit Data) ke pin 1 mikrokontroller PIC16f877A.

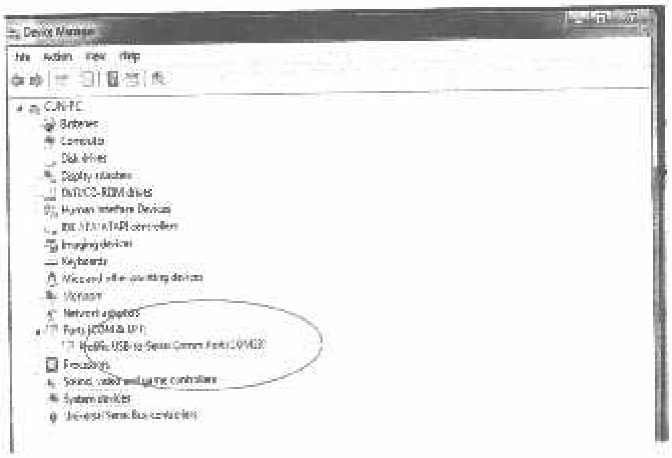
4.1.2 Pengujian Rangkaian Komunikasi Serial RS232

Rangkaian ini menggunakan IC komunikasi serial MAX232 yang berfungsi sebagai jembatan untuk menghubugkan mikrokontroller PIC16f877A dengan komputer. Rangkaian ini membutuhkan tegangan kerja 5v DC.

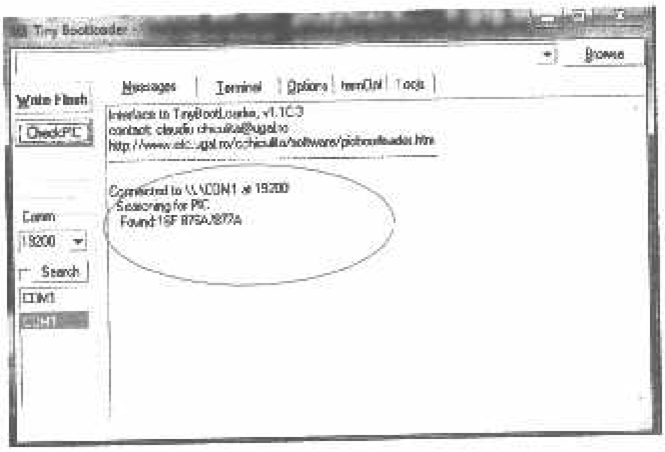
1. Tujuan Penelitian.

Rangkaian komunikasi ini berfungsi untuk menghubungkan alat pengukur detak jantung ini dengan komputer agar proses penampilan data hasil pengolahan data mikrokontroller PIC16f877A dan proses pemrograman pun bisa dilakukan dengan menggunakan program TinyBootloader.

2. Alat yang digunakan
   - Mikrokontroller PIC16f877A
   - IC MAX232
   - Converter serial to USB
   - Capasitor 1uF/16v x4 buah
   - Capasitor 100nF
   - Aplikasi TinyBootloader
3. Prosedur Pengujian
   - Sambungkan kabel DB9 dari rangkaian komunikasi ke komputer
   - Hubungkan rangkaian dengan catu daya 5v DC.
   - Buka Device Manager dan lihat Comunication Port sudah terhubung atau belum.
   - Buka aplikasi TinyBootloader dan set mode COMM pada nilai 19200 untuk mengecek mikrokontroller PIC16f877A terdeteksi atau tidak



Gambar 4.3 Comunication Port



Gambar 4.4 Mikrokontroller terdeteksi.

4. Analisa

Tabel 4.2 konfigurasi Pin IC PIC16F877A dan IC MAX232

PIC16F877A	MAX232
Pin 25 (TX)	Pin 11 (T1IN)
Pin 26 (RX)	Pin 12 (R1OUT)
Pin 1 (MCLR)	Pin 9 (R2OUT)

Tabel 4.3 konfigurasi Pin IC MAX232 dan Konektor RS232

MAX232	KONEKTOR RS232
Pin 13 (R1IN)	Pin 3 (RD)
Pin 14 (T1OUT)	Pin 2 (TD)
Pin 8 (R2IN)	Pin 7 (RTS) dan Pin 8 (CTS)

Untuk melakukan komunikasi antara mikrokontroller dan komputer digunakan komunikasi serial yang dimana pin 25 (TX) dan pin 26 (RX) berfungsi sebagai jalur komunikasi keluar masuk data dari mikrokontroller PIC16f877A yang dihubungkan ke pin 11 (T1IN) dan pin 12 (R1OUT) dari IC Max232. Dan jalur komunikasi tersebut akan diteruskan ke komputer menggunakan kabel DB9 dari pin 13 (R1IN) dan pin 14 (T1OUT) ke pin 2 (RD) dan pin 3 (TD) dari konektor serial 232.

4.1.3 Pengujian Rangkaian Sensor Photodioda.

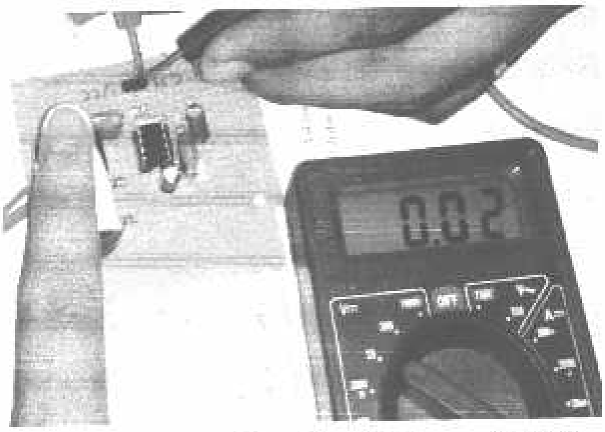
1. Tujuan Pengujian

   Dalam pengujian rangkaian ini bertujuan untuk mengetahui sinyal analog yang diterima oleh sensor photodioda yang merupakan hasil deteksi volume darah pada kulit jari manusia. Rangkaian ini menggunakan penguat LM358 yang akan meneruskan sinyal analog tersebut ke mikrokontroler untuk diproses menjadi tampilan hasil deteksi denyut jantung.

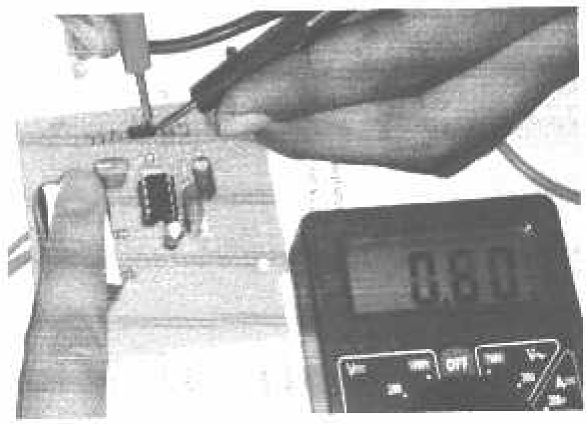
2. Alat yang digunakan
   - Photodioda
   - LED Infrared
   - IC OP-AMP LM358
   - Kapasitor 1uF (2 buah) dan 100nF (2 buah)
   - Resistor 68k (2 buah), 6.8k (2 buah) dan 680k (2 buah)
   - Resistor 150Ω dan 33k

3. Prosedur Pengujian
   - Hidupkan rangkaian sensor denyut jantung dengan catu daya 5V
   - Tempatkan kabel avometer (-) pada ground dan (+) pada pin 7 ic LM358 yang mana pin ini berfungsi sebagai output keluaran sinyal analog.

- Tempatkan jari telunjuk pada sensor photodioda untuk melihat sinyal yang diterima dari hasil deteksi.



Gambar 4.5 Pengujian Sinyal Keluaran LM358



Gambar 4.6 Pengujian Sinyal Keluaran saat deteksi denyut

4. Analisa

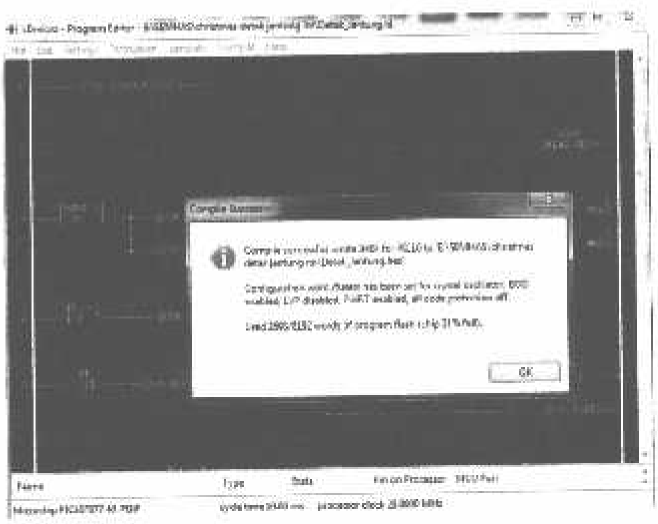
Untuk pengujian yang pertama yaitu sinyal analog pada IC LM358, sinyal yang dihasilkan berasal dari sensor photodiode yang mendeteksi volume darah pada kulit jari manusia. Sinyal analog ini akan bernilai tinggi jika sensor photodiode mendapat deteksi volume darah pada kulit jari manusia dan akan bernilai rendah jika sensor photodiode tidak mendeteksi volume darah pada jari manusia. Sinyal inilah yang akan diteruskan ke mikrokontroler untuk diproses menjadi hasil denyut jantung yang kemudian akan ditampilkan pada tampilan StampPlot.

4.2.Pengujian Program.

Dalam perancangan program ini menggunakan aplikasi Ladder Diagram Micro yang mana aplikasi ini dapat membuat Ladder diagram PLC untuk dimasukkan kedalam mikrokontroler untuk dijalankan sebagai sebuah PLC Mkrokontroler.

4.2.1 Meng-Compile Program.

Setelah instruksi program untuk mendeteksi dan memproses denyut jantung ini dirangkai akan di konversikan ke dalam bentuk file berekstensi *.HEX untuk dimasukkan kedalam mikrokontroller PIC16F877A. Program inilah yang akan memproses data yang diterima dari sensor denyut jantung menajdi hasil tampilan denyut jantung . Proses compile dilakukan dengan menggunakan tool Compile pada aplikasi LD Micro. Masukkan nama file dan tekan tombol Save untuk meng-Compile Program.

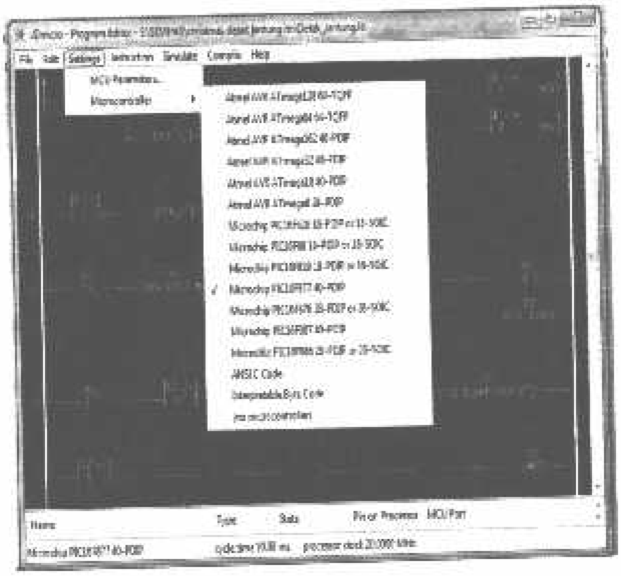


Gambar 4.7 Proses Compile berhasil

4.2.2 Simulasi Program.

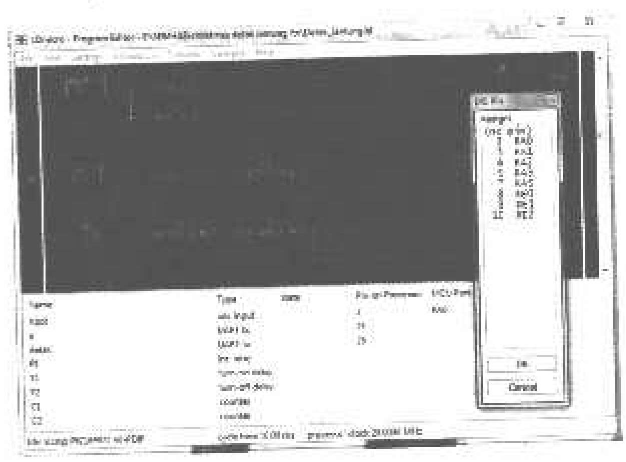
Sebelum program dimasukkan ke Mikrokontroller, terlebih dahulu disimulasikan untuk mengetahui program sudah berjalan dengan baik atau belum. Untuk melakukan simulasi, ada beberapa hal yang perlu diperhatikan yaitu memilih jenis mikrokontroller yang digunakan, kemudian menentukan port Input data dan pin Output data dan frekuensi transfer data yang digunakan dalam rangkaian Minimum sistem Mikrokontroller PIC16F877A.

Untuk memilih jenis Mikrokontroler yang akan digunakan dapat dilakukan pada tools Settings-Microcontroller.



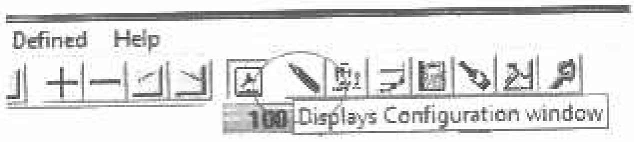
Gambar 4.8 Memilih Mikrokontroller

Setelah memilih jenis mikrokontroller yang digunakan maka sekarang harus menentukan pin input dan output data. Dapat dilakukan pada bagian bawah jendela kerja dari LDMicro. Untuk menentukan pin yang digunakan dapat dilakukan dengan meng-klik 2 kali pada instruksi untuk menerima dan mengirim data. Untuk pin komunikasinya kana secara otomatis terdeteksi ketika kita memilih jenis mikrokontroller yang akan digunakan.



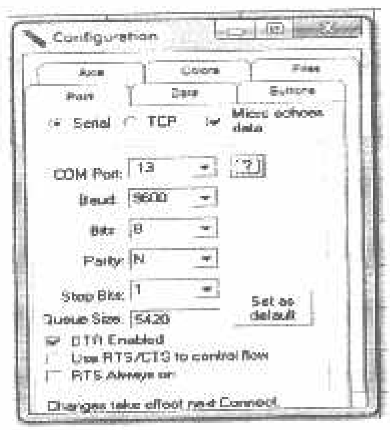
Gambar 4.9 Menentukan Pin Input

3. Sambungkan catu daya ke rangkaian minimum sitstem mikrokontroller PIC16F877A dan rangkaian sensor denyut jantung.
4. Buka aplikasi HMI StampPlot dan buka tampilan yang telah dibuat untuk menampilkan hasil dari pengukuran detak jantung.
5. Untuk aplikasi HMI StampPlot dapat terkoneksi dengan rangkaian pengukur detak jantung maka perlu setingan untuk mencari port yang digunakan.



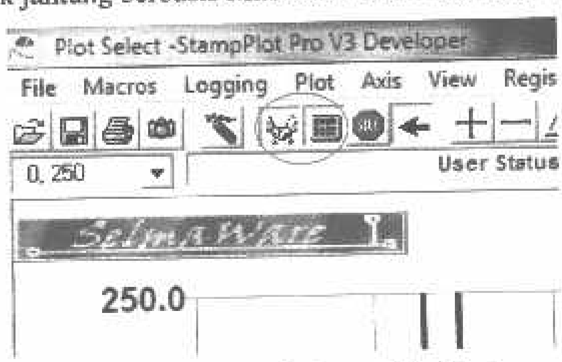
Gambar 4.12 Tools Display Configuration Window

6. Pada tab Port klik tombol ? (tanda Tanya) untuk mendeteksi port yang digunakan.



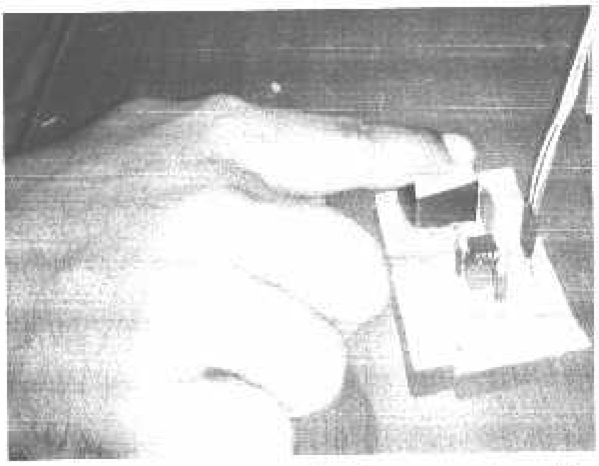
Gambar 4.13 Configuration Port

7. Setelah port dideteksi maka klik tombol connect to the port untuk menghubungkan aplikasi StampPlot dan port yang digunakan oleh alat pengukur detak jantung berbasis Mikrokontroler PIC16F877A



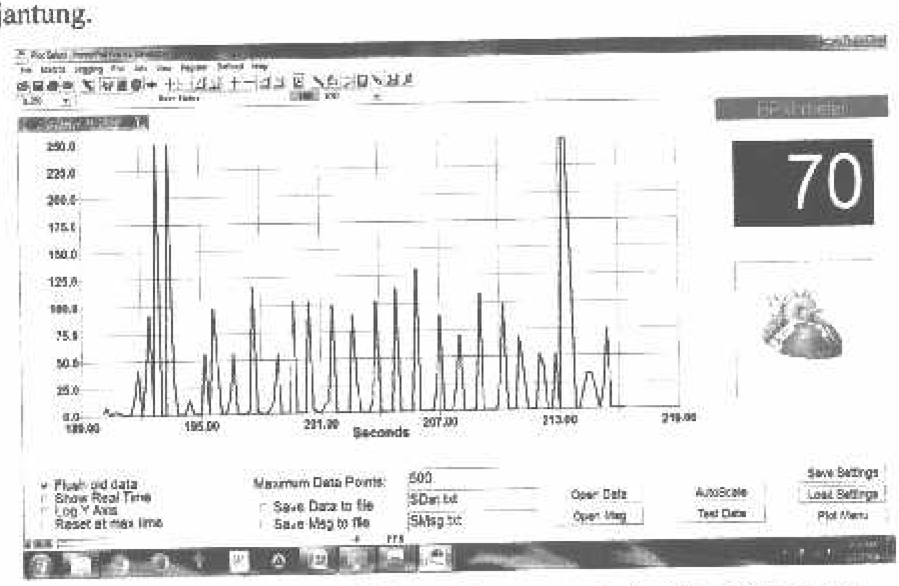
Gambar 4.14 tools Conect To Port

8. Tempatkan jari telunjuk pada sensor denyut jantung untuk mendeteksi volume darah pada jari tersebut.



Gambar 4.15 Menempatkan jari pada sensor denyut jantung

9. Klik tombol start untuk menjalankan program untuk mendeteksi denyut jantung.



Gambar 4.16 Hasil deteksi denyut jantung pada Aplikasi StampPlot

4.4.4. Analisa.

Terdapat beberapa analisa untuk rangkaian pengukur laju detak jantung ini yaitu sebagai berikut

1. Untuk menerima data dari sensor denyut jantung, jalur datanya menggunakan pin 2(RA0) yang merupakan port A dari mikrokontroller PIC16F877A.

2. Data yang dikirimkan sensor denyut jantung ini masi berupa data analog yang kemudian akan dikonversikan ke bentuk data digital pada list program yang telah dibuat menggunakan aplikasi LD Micro.
3. Jalur komunikasi data yang digunakan dalam menghubungkan alat pengukur detak jantung dengan computer terdapat pada pin 25 (TX) yang berfungsi menerima data dan pin 26 (RX) yang berfungsi mengirim data ke computer pada mikrokontroler PIC16F877A.
4. Data akan diteruskan ke computer menggunakan IC MAX232 melalui koneksi serial yang terhubung pada pin 2(RX) dan Pin 3(TX) port serial 232 yang berfungsi untuk mengirim dan menerima data,
5. Converter Serial to USB digunakan untuk mengubah koneksi dari serial ke USB agar dapat digunakan ke computer ataupun Laptop yang tidak mempunyai port Serial DB9.
6. Untuk menampilkan hasil yang diproses mikrokontroler PIC16F877A, aplikasi StampPlot menggunakan tools komunikasi serial yang mneghubungkan aplikasi tersebut dan port yang digunakan oleh alat pengukur detak jantung tersebut.
7. Data yang ditampilkan sudah berupa data digital yang mana aplikasi StampPlot akan menampilkan grafik kestabilan denyut jantung dan nilai jumlah denyut jantung
8. Terdapat 2 tampilan hasil denyut jantung yaitu Grafik Kestabilan denyut jantung dan hasil perhitungan denyut jantung yang mana sudah diatur pada program yang telah dibuat pada LD Micro.
9. Grafik kestabilan denyut jantung menunjukkan ada atau tidaknya denyut pada jari manusia sedangkan angka hasil pengukuran denyut jantung menunjukkan hasil perhitungan denyut jantung oleh mikrokontroller.
10. Untuk memproses hasil denyut jantung, mikrokontroller akan menerima data dari sensor photodiode sebanyak 60 kali scan dengan waktu scan 10 (ms) yang bila dinyatakan dalam waktu nyata mikrokontroller akan menerima sinyal masukkan tersebut dalam waktu 20 detik.
11. Data yang diterima mikrokontroller akan diproses oleh program yang sudah dimasukkan untuk menampilkan hasil denyut jantung manusia.

5. Terdapat selisi 2 denyut jantung antara pengukuran menggunakan perhitungan secara manual dan menggunakan alat penghitung denyut jantung.
6. Untuk menghitung secara manual terdapat kelemahan yaitu jika dalam perhitungan selama 15 detik mendapatkan 17 denyut maka hasil denyut jantung adalah 68 denyut permenit.
7. Dan jika dalam 15 detik perhitungan mendapatkan 18 denyut maka hasil denyut jantung adalah 72 denyut permenit. Perhitungan secara manual tidak dapat mendeteksi perhitungan denyut jantung untuk angka 69, 70 dan 71 denyut permenit.

BAB V
PENUTUP

5.1. KESIMPULAN

Dari hasil pengujian dan analisa yang telah dibahas pada bab sebelumnya, maka dapat diambil kesimpulan sebagai berikut :

1. Alat penghitung detak jantung berbasis mikrokontroller PIC16F877A ini mampu menampilkan hasil perhitungan denyut jantung. Namun masi terdapat factor eror dalam perhitungan denyut jantung jika dibandingkan dengan metode perhitungan secara manual.
2. Data yang dikirim sensor denyut jantung masih berupa data analog yang akan dikonversi ke data digital oleh mikrokontroler PIC16F877A dengan program yang telah dibuat sebelumnya pada aplikasi LD Micro.
3. Sensor denyut jantung mempunyai peranan penting dalam alat pengukur detak jantung ini, karena data yang akan diproses oleh mikrokontroler PIC16F877A ini berasal dari sensor denyut jantung ini,
4. Aplikasi HMI StampPlot berfungsi untuk menampilkan grafik kestabilan denyut jantung dan menampilkan angka dari hasil denyut jantung yang diproses oleh mikrokontroller PIC16F877A.

5.2.SARAN

Adapun saran yang penulis masukkan dalam penulisan laporan skripsi ini karena penulis menyadari laporan ini masih memiliki banyak kekurangan, sehingga masih banyak yang bisa dikembangkan untuk kesempurnaan alat ini :

1. Sensor denyut jantung ini masih terlalu sensitive dengan cahaya maupun keadaan bergerak disekitar. Sehingga data yang diterima tidak hanya hasil deteksi volume darah pada kulit darah manusia.

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LAMPIRAN

PERKUMPULAN PENGELOLA PENDIDIKAN UMUM DAN TEKNOLOGI NASIONAL MALANG

INSTITUT TEKNOLOGI NASIONAL MALANG

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

PT. BNI (PERSERO) MALANG
BANK NIAGA MALANG

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

Nomor Surat : ITN-412/EL-FTI/2015 — 21 Oktober 2015

Lampiran : -

Perihal : BIMBINGAN SKRIPSI (**Baru**)

Kepada : Yth. Bapak/Ibu **Dr. Ir. F. Yudi Limpraptono,MT**
Dosen Teknik Elektro S-1
ITN MALANG

Dengan Hormat

Sesuai dengan permohonan dan persetujuan dalam Proposal Skripsi untuk mahasiswa:

Nama	: KRISMAS YOSIAS ALLUNG
Nim	: 1312905
Fakultas	: **Teknologi Industri**
Program Studi	: **Teknik Elektro S-1**
Konsentrasi	: T. Elektronika

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

" Semester Ganjil Tahun Akademik 2015-2016 "

Demikian atas perhatian serta bantuannya kami sampaikan terima kasih.

Mengetahui
Ketua Program Studi Teknik Elektro S-1

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

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

INSTITUT TEKNOLOGI NASIONAL
FAKULTAS TEKNOLOGI INDUSTRI
JURUSAN TEKNIK ELEKTRO S-1
Jl. Raya Karanglo, Km. 2 MALANG

PERMOHONAN PERSETUJUAN SKRIPSI

Yang Bertanda Tangan Dibawah Ini:

Nama : KRISMAS YOSIAS ALLUNG
NIM : 1312905
Semester : VII
Fakultas : Teknologi Industri
Jurusan : Teknik Elektro S-I
Konsentrasi : **TEKNIK ENERGI LISTRIK**
TEKNIK ELEKTRONIKA
TEKNIK KOMPUTER DAN INFORMATIKA
TEKNIK KOMPUTER
TEKNIK TELEKOMUNIKASI
Alamat : Perumahan BCT N2 A6

Dengan ini kami mengajukan permohonan untuk mendapatkan persetujuan untuk membuat SKRIPSI Tingkat Sarjana. Untuk melengkapi permohonan tersenut, bersama ini kami lampirkan persyaratan-persyaratan yang harus dipenuhi.
Adapun persyaratan- persyaratan pengambilan SKRIPSI adalah sebagai berikut:

1. Telah melaksanakan semua praktikum sesui dengan konsentrasinya (......)
2. Telah lulus dan menyerahkan laporan Praktek Kerja (......)
3. Telah lulus seluruh mata kuliah keahlian (MKB)sesuai konsentrasinya (......)
4. Telah menempuh matakuliah> 134 sks dengan IPK > 2 dan tidak ada nilai E (......)
5. Telah mengikuti secara aktif kegiatan seminar Skripsi yang diadakan Jurusan (.........)
6. Memenuhi persyaratan administrasi (.........)

Demikian permohonan ini untuk mendapatkan penyelesaian lebih lanjut dan atas perhatiannya kami ucapkan terima kasih.

Telah diteliti kebenarannya data tersebut diatas
Recording Teknik Elektro S-I

Malang,..........................201
Pemohon

Bag perset. 1 2 3

BERITA ACARA RAPAT PERSETUJUAN JUDUL/PROPOSAL SKRIPSI
PROGRAM STUDI TEKNIK ELEKTRO S-1
SEMESTER GANJIL 2015/2016

Konsentrasi : T. Elektronika S-1

Tanggal : 10 Oktober 2015

1.	NIM	1312905
2.	Nama	KRISMAS Y. ALLUNG.
3.	Judul yang diajukan	Perancangan dan Pembuatan Alat Pengukur Detak Jantung Manusia Berbasis PIC-Mikrokontroler PIC16F877A Dengan Display Pengukuran Menggunakan Aplikasi STAMPLOT.
4.	**Disetujui/Ditolak** *	
5.	Catatan:	
6.	Pembimbing yang diusulkan: 1. M. Ibrahim A. [illegible] 2. Dr. F. Yudi L, ST MT	

Menyetujui

1. Koordinator Dosen Kelompok Keahlian

Dosen Kelompok Keahlian (Terlampir)

* : Coret yang tidak perlu

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

BERITA ACARA SEMINAR PROPOSAL SKRIPSI
PROGRAM STUDI TEKNIK ELEKTRO S1

KONSENTRASI	T. Elektronika

1.	Nama Mahasiswa	Krismas Yastas A.			NIM	1312905	
2.	Keterangan Pelaksanaan	Tanggal		Waktu		Tempat / Ruang	
3.	Spesifikasi Judul (berilah tanda silang) *)						
	a.	Sistem Tenaga Elektrik	e.	Embbeded System	i.	Sistem Informasi	
	b.	Konversi Energi	f.	Antar Muka	j.	Jaringan Komputer	
	c.	Sistem Kendali	g.	Elektronika Telekomunikasi	k.	Web	
	d.	Tegangan Tinggi	h.	Elektronika Instrumentasi	l.	Algoritma Cerdas	
4.	Judul Proposal yang diseminarkan Mahasiswa	Perancangan & Pembuatan Alat Pengukur Detak Jantung Manusia Berbasis Mikrocontroller PIC16F877A dengan display Pengukuran Menggunakan Aplikasi Stamplot					
5.	Perubahan Judul yang diusulkan oleh Kelompok Dosen Keahlian						
6.	Catatan :						
	Catatan :						

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

BERITA ACARA SEMINAR PROGRESS SKRIPSI
PROGRAM STUDI TEKNIK ELEKTRO S1

KONSENTRASI	Elektronika

1.	Nama Mahasiswa	krismas y allung.	NIM	
2.	Keterangan Pelaksanaan	Tanggal: 17 Des. 2016	Waktu:	Tempat / Ruang: 2.1
3.	Judul Skripsi	Perancangan dan Pembuatan alat Pengukur Detak jantung manusia Berbasis mikrokontroler PIC 16F877A dgn display pengukuran menggunakan aplikasi Stamplot.		
4.	Perubahan Judul			
5.	Catatan :			
6.	Mengetahui, Ketua Jurusan M. Ibrahim Ashari, ST, MT	Disetujui, Dosen Pembimbing Pembimbing I M. Ibrahim Ashari	Pembimbing II	

INSTITUT TEKNOLOGI NASIONAL
FAKULTAS TEKNOLOGI INDUSTRI
JURUSAN TEKNIK ELEKTRO S-1
Jl. Raya Karanglo, Km. 2 MALANG

Formulir Perbaikan Ujian Skripsi

Dalam Pelaksanaan Ujian Skripsi Jenjang Strata 1 Jurusan Teknik Elektro Konsentrasi T.Energi Listrik,/ T. Elektronika, /T. Komputer, / T.Telekomunikasi, Maka Perlu Adanya Perbaikan Skripsi Untuk Mahasiswa:

Nama : KRISMAS YOSIAS ALLANG
NIM : 13.12 905
Perbaikan Meliputi :

- Konsep penghitungan detail [illegible] (Perumusan)
- Judul pengukur → penghitung

Malang, 30 - 01 2016

(..)

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

MONITORING BIMBINGAN SKRIPSI

SEMESTER GANJIL TAHUN AKADEMIK 2015-2016

Nama Mahasiswa : KRISMAS Y. ALLUNG
NIM : 1312905
Nama Pembimbing : M. Ibrahim Ashari, ST, MT
Judul Skripsi : PERANCANGAN DAN PEMBUATAN ALAT PENGUKUR DETAK JANTUNG MANUSIA BERBASIS MIKROKONTROLLER PIC16F877A DENGAN DISPLAY PENGUKURAN MENGGUNAKAN APLIKASI STAMPPLOT

Minggu Ke-	Hari, Tanggal	Waktu Bimbingan	Materi Bimbingan	Paraf
1	10 Des 2015	11.00 11.45	acc Bab I Revisi Bab II dan III	[signature]
2	11 Des 2015	10.30 11.00	acc Bab II dan III Revisi makalah progres	[signature]
3	12 Des 2015	10.00 10.05	ACC makalah progres	[signature]
4	11 Jan 2015	11.00 11.15	Revisi Bab IV	[signature]
5	15 Jan 2015	09.45 10.00	lanjutkan bab IV	[signature]
6	18 Jan 2015	08.10 08.15	acc makalah seminar hasil	[signature]
7	27 Jan 2015	10.00 10.45	acc Bab IV dan bab V	[signature]

Malang, ...

Pembimbing

[signature]

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

PROGRAM STUDI TEKNIK ELEKTRO S-1
FAKULTAS TEKNOLOGI INDUSTRI
INSTITUT TEKNOLOGI NASIONAL MALANG
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MONITORING BIMBINGAN SKRIPSI

SEMESTER GANJIL TAHUN AKADEMIK 2015-2016

Nama Mahasiswa : KRISMAS Y. ALLUNG
NIM : 1312905
Nama Pembimbing : Dr. F. Yudi Limpraptono, ST, MT
Judul Skripsi : PERANCANGAN DAN PEMBUATAN ALAT PENGUKUR DETAK JANTUNG MANUSIA BERBASIS MIKROKONTROLLER PIC16F877A DENGAN DISPLAY PENGUKURAN MENGGUNAKAN APLIKASI STAMPPLOT

Minggu Ke-	Hari, Tanggal	Waktu Bimbingan	Materi Bimbingan	Paraf
1	10. Des 2015	11.00	Bab I — III Ada revisi	[signature]
2	11/12 2015	10.40	Revisi bab III	[signature]
3	14/12 2015	10.40	Sensor program	[signature]
4	11/1 2016	10.00	Bab IV (Tambahkan pengujian alat)	[signature]
5	15/1 2016	10.00	Bab IV Perubahan judul .	[signature]
6	23/1 2016	9.00	Ada revisi bab IV, V	[signature]
7	25/1 2016	10.30	Acc	[signature]

Malang, ...

Pembimbing

[signature]

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

LADDER DIAGRAM:

```
   ||                                                                                        ||
 1 ||--------{"!o a.set=0\r\n"}--------                                                      ||
   ||                                                                                        ||
   ||                                                                                 Apot   ||
 2 ||-----------------------------------------------------------------------------{READ ADC}----||
   ||                                                                                        ||
   ||   [Apot >]                                                              {b  :=      }  ||
 3 ||----[ 30   ]----+----[OSR_/‾]------------------------------------------------{ 1     MOV}--||
   ||                |                                                                       ||
   ||                +----[OSF‾\_]------------------------------------------------{b  :=      }  ||
   ||                                                                             { 0     MOV}--||
   ||                                                                                        ||
   ||    [b ==]                        C1                                                    ||
 4 ||-----[ 1  ]----------[OSR_/‾]---------[CTU >=0]----                                     ||
   ||                                                                                        ||
   ||        R1             T1              T2                                   R1          ||
 5 ||-------]/[--------[TON 100.0 ms]---[TOF 100.0 ms]-+----------------------------( )-------||
   ||                                                  |                                     ||
   ||                                                  |                          C2         ||
   ||                                                  +------------------------{CTC 0:60}----||
   ||                                                                                        ||
   ||        R1            [C2 /=]                 Apot                        b             ||
 6 ||-------] [------------[ 60  ]-----------------{"\4\r\n"}-----------------{"!o b.set=\1\r\n"}--------||
   ||                                                                                        ||
```

MICROCHIP

PIC16F87XA

28/40/44-Pin Enhanced Flash Microcontrollers

Devices Included in this Data Sheet:

- PIC16F873A
- PIC16F874A
- PIC16F876A
- PIC16F877A

High-Performance RISC CPU:

- Only 35 single-word instructions to learn
- All single-cycle instructions except for program branches, which are two-cycle
- Operating speed: DC – 20 MHz clock input
  DC – 200 ns instruction cycle
- Up to 8K x 14 words of Flash Program Memory, Up to 368 x 8 bytes of Data Memory (RAM), Up to 256 x 8 bytes of EEPROM Data Memory
- Pinout compatible to other 28-pin or 40/44-pin PIC16CXXX and PIC16FXXX microcontrollers

Peripheral Features:

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during Sleep via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. resolution is 12.5 ns
  - Compare is 16-bit, max. resolution is 200 ns
  - PWM max. resolution is 10-bit
- Synchronous Serial Port (SSP) with SPI (Master mode) and I^2C™ (Master/Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection
- Parallel Slave Port (PSP) – 8 bits wide with external $\overline{RD}$, $\overline{WR}$ and $\overline{CS}$ controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

Analog Features:

- 10-bit, up to 8-channel Analog-to-Digital Converter (A/D)
- Brown-out Reset (BOR)
- Analog Comparator module with:
  - Two analog comparators
  - Programmable on-chip voltage reference (VREF) module
  - Programmable input multiplexing from device inputs and internal voltage reference
  - Comparator outputs are externally accessible

Special Microcontroller Features:

- 100,000 erase/write cycle Enhanced Flash program memory typical
- 1,000,000 erase/write cycle Data EEPROM memory typical
- Data EEPROM Retention > 40 years
- Self-reprogrammable under software control
- In-Circuit Serial Programming™ (ICSP™) via two pins
- Single-supply 5V In-Circuit Serial Programming
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving Sleep mode
- Selectable oscillator options
- In-Circuit Debug (ICD) via two pins

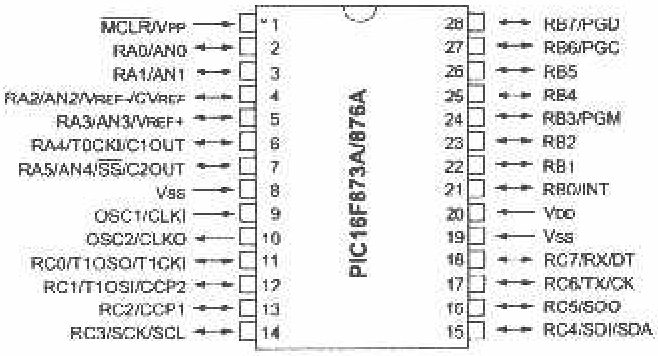
CMOS Technology:

- Low-power, high-speed Flash/EEPROM technology
- Fully static design
- Wide operating voltage range (2.0V to 5.5V)
- Commercial and Industrial temperature ranges
- Low-power consumption

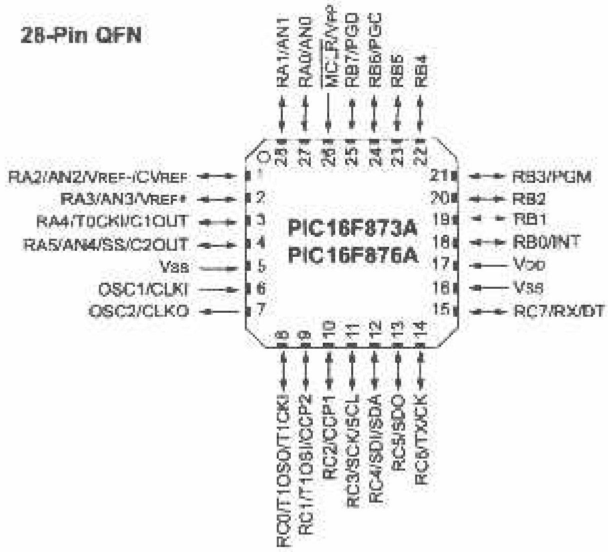
Device	Program Memory		Data SRAM (Bytes)	EEPROM (Bytes)	I/O	10-bit A/D (ch)	CCP (PWM)	MSSP		USART	Timers 8/16-bit	Comparators
	Bytes	# Single Word Instructions						SPI	Master I^2C			
PIC16F873A	7.2K	4096	192	128	22	5	2	Yes	Yes	Yes	2/1	2
PIC16F874A	7.2K	4096	192	128	33	8	2	Yes	Yes	Yes	2/1	2
PIC16F876A	14.3K	8192	368	256	22	5	2	Yes	Yes	Yes	2/1	2
PIC16F877A	14.3K	8192	368	256	33	8	2	Yes	Yes	Yes	2/1	2

Pin Diagrams

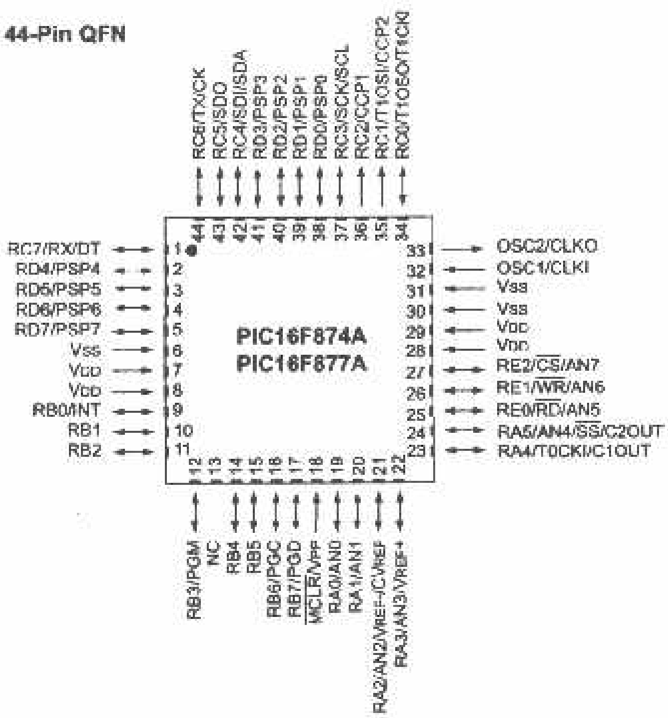
28-Pin PDIP, SOIC, SSOP



28-Pin QFN

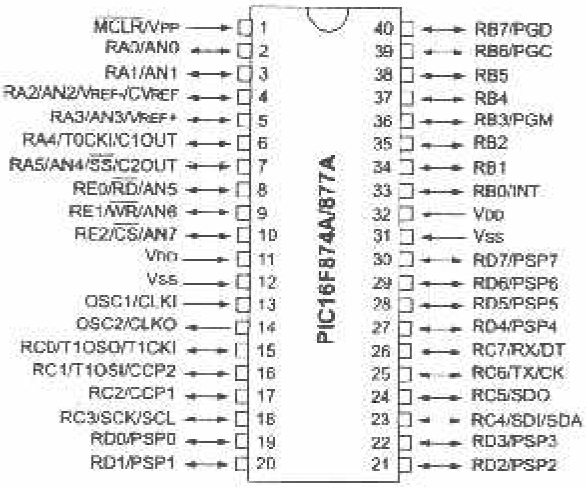


44-Pin QFN

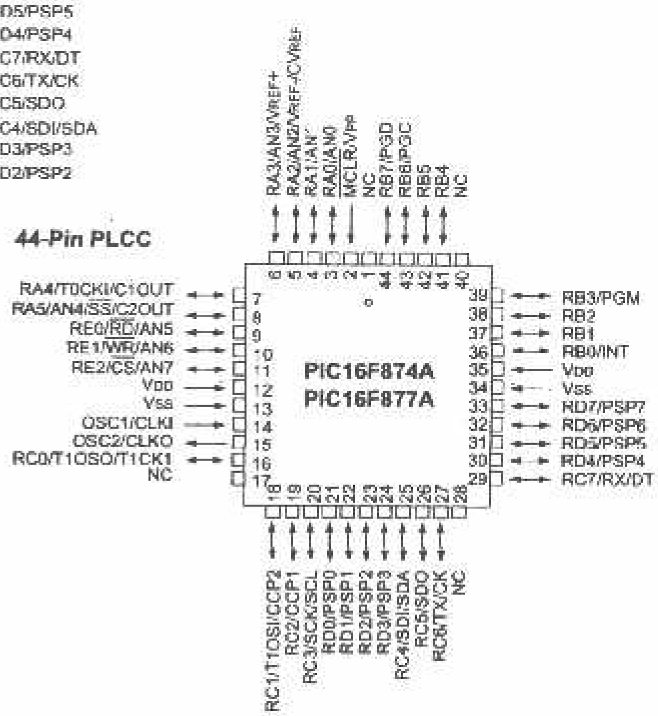


Pin Diagrams (Continued)

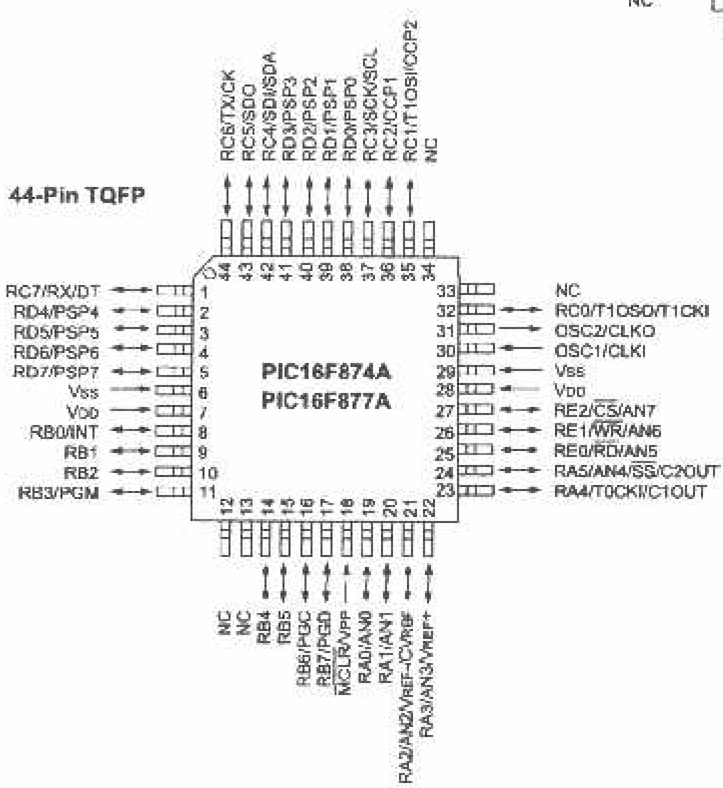
40-Pin PDIP



44-Pin PLCC



44-Pin TQFP



1.0 DEVICE OVERVIEW

This document contains device specific information about the following devices:

- PIC16F873A
- PIC16F874A
- PIC16F876A
- PIC16F877A

PIC16F873A/876A devices are available only in 28-pin packages, while PIC16F874A/877A devices are available in 40-pin and 44-pin packages. All devices in the PIC16F87XA family share common architecture with the following differences:

- The PIC16F873A and PIC16F874A have one-half of the total on-chip memory of the PIC16F876A and PIC16F877A
- The 28-pin devices have three I/O ports, while the 40/44-pin devices have five
- The 28-pin devices have fourteen interrupts, while the 40/44-pin devices have fifteen
- The 28-pin devices have five A/D input channels, while the 40/44-pin devices have eight
- The Parallel Slave Port is implemented only on the 40/44-pin devices

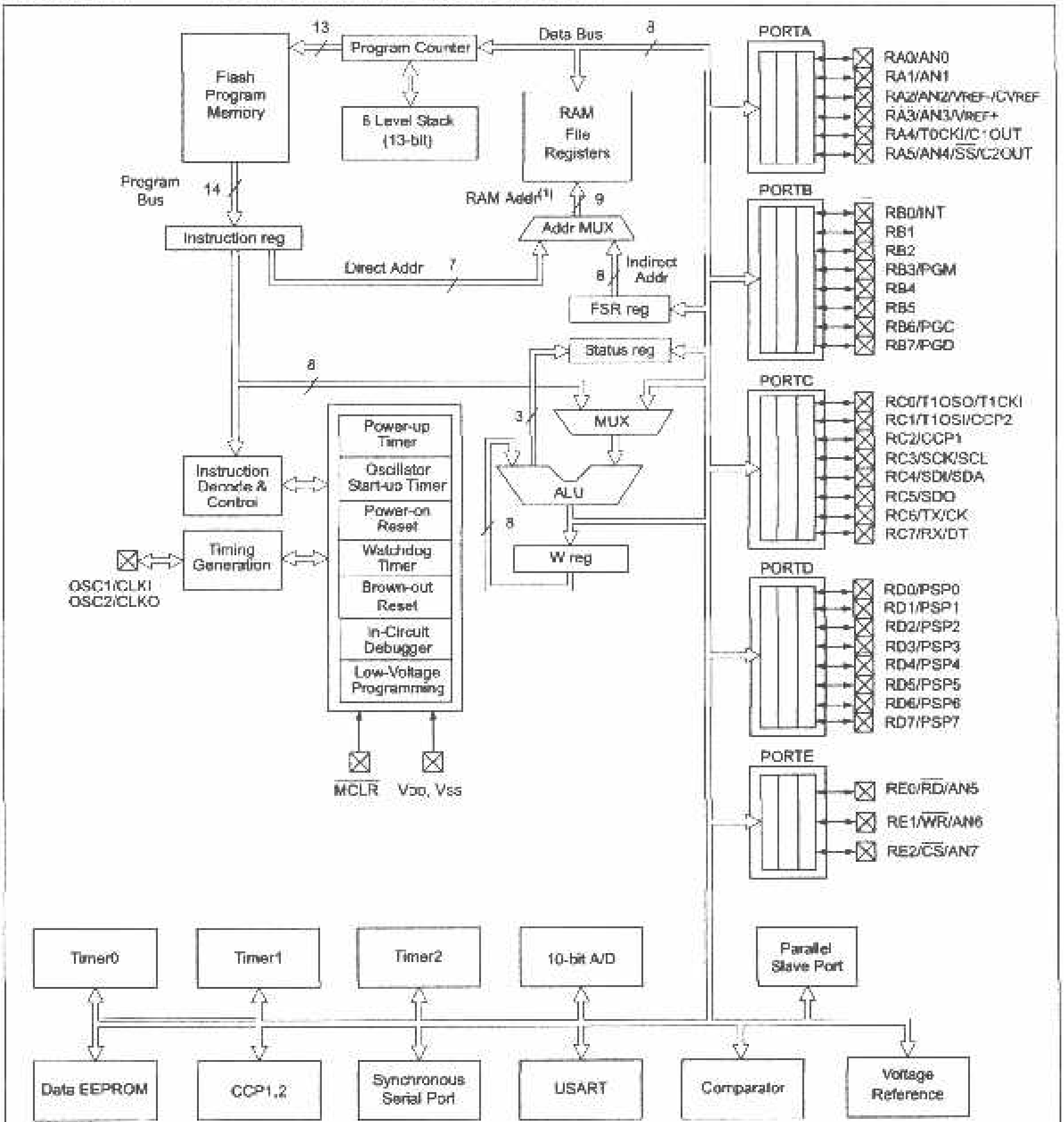
The available features are summarized in Table 1-1. Block diagrams of the PIC16F873A/876A and PIC16F874A/877A devices are provided in Figure 1-1 and Figure 1-2, respectively. The pinouts for these device families are listed in Table 1-2 and Table 1-3.

Additional information may be found in the PIC® Mid-Range Reference Manual (DS33023), which may be obtained from your local Microchip Sales Representative or downloaded from the Microchip web site. The Reference Manual should be considered a complementary document to this data sheet and is highly recommended reading for a better understanding of the device architecture and operation of the peripheral modules.

TABLE 1-1: PIC16F87XA DEVICE FEATURES

Key Features	PIC16F873A	PIC16F874A	PIC16F876A	PIC16F877A
Operating Frequency	DC – 20 MHz	DC – 20 MHz	DC – 20 MHz	DC – 20 MHz
Resets (and Delays)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)
Flash Program Memory (14-bit words)	4K	4K	8K	8K
Data Memory (bytes)	192	192	368	368
EEPROM Data Memory (bytes)	128	128	256	256
Interrupts	14	15	14	15
I/O Ports	Ports A, B, C	Ports A, B, C, D, E	Ports A, B, C	Ports A, B, C, D, E
Timers	3	3	3	3
Capture/Compare/PWM modules	2	2	2	2
Serial Communications	MSSP, USART	MSSP, USART	MSSP, USART	MSSP, USART
Parallel Communications	—	PSP	—	PSP
10-bit Analog-to-Digital Module	5 input channels	8 input channels	5 input channels	8 input channels
Analog Comparators	2	2	2	2
Instruction Set	35 Instructions	35 Instructions	35 Instructions	35 Instructions
Packages	28-pin PDIP 28-pin SOIC 28-pin SSOP 28-pin QFN	40-pin PDIP 44-pin PLCC 44-pin TQFP 44-pin QFN	28-pin PDIP 28-pin SOIC 28-pin SSOP 28-pin QFN	40-pin PDIP 44-pin PLCC 44-pin TQFP 44-pin QFN

FIGURE 1-2: PIC16F874A/877A BLOCK DIAGRAM



Device	Program Flash	Data Memory	Data EEPROM
PIC16F874A	4K words	192 Bytes	128 Bytes
PIC16F877A	8K words	368 Bytes	256 Bytes

Note 1: Higher order bits are from the Status register.

TABLE 1-2: PIC16F873A/876A PINOUT DESCRIPTION

Pin Name	PDIP, SOIC, SSOP Pin#	QFN Pin#	I/O/P Type	Buffer Type	Description
OSC1/CLKI	9	6		ST/CMOS(3)	Oscillator crystal or external clock input.
OSC1			I		Oscillator crystal input or external clock source input. ST buffer when configured in RC mode; otherwise CMOS.
CLKI			I		External clock source input. Always associated with pin function OSC1 (see OSC1/CLKI, OSC2/CLKO pins).
OSC2/CLKO	10	7		—	Oscillator crystal or clock output.
OSC2			O		Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode.
CLKO			O		In RC mode, OSC2 pin outputs CLKO, which has 1/4 the frequency of OSC1 and denotes the instruction cycle rate.
$\overline{\text{MCLR}}$/VPP	1	26		ST	Master Clear (input) or programming voltage (output).
$\overline{\text{MCLR}}$			I		Master Clear (Reset) input. This pin is an active low Reset to the device.
VPP			P		Programming voltage input.
					PORTA is a bidirectional I/O port.
RA0/AN0	2	27		TTL	
RA0			I/O		Digital I/O.
AN0			I		Analog input 0.
RA1/AN1	3	28		TTL	
RA1			I/O		Digital I/O.
AN1			I		Analog input 1.
RA2/AN2/VREF-/CVREF	4	1		TTL	
RA2			I/O		Digital I/O.
AN2			I		Analog input 2.
VREF-			I		A/D reference voltage (Low) input.
CVREF			O		Comparator VREF output.
RA3/AN3/VREF+	5	2		TTL	
RA3			I/O		Digital I/O.
AN3			I		Analog input 3.
VREF+			I		A/D reference voltage (High) input.
RA4/T0CKI/C1OUT	6	3		ST	
RA4			I/O		Digital I/O – Open-drain when configured as output.
T0CKI			I		Timer0 external clock input.
C1OUT			O		Comparator 1 output.
RA5/AN4/$\overline{\text{SS}}$/C2OUT	7	4		TTL	
RA5			I/O		Digital I/O.
AN4			I		Analog input 4.
$\overline{\text{SS}}$			I		SPI slave select input.
C2OUT			O		Comparator 2 output.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured in RC Oscillator mode and a CMOS input otherwise.

TABLE 1-2: PIC16F873A/876A PINOUT DESCRIPTION (CONTINUED)

Pin Name	PDIP, SOIC, SSOP Pin#	QFN Pin#	I/O/P Type	Buffer Type	Description
					PORTB is a bidirectional I/O port. PORTB can be software programmed for internal weak pull-ups on all inputs.
RB0/INT	21	18		TTL/ST[1]	
RB0			I/O		Digital I/O.
INT			I		External interrupt.
RB1	22	19	I/O	TTL	Digital I/O.
RB2	23	20	I/O	TTL	Digital I/O.
RB3/PGM	24	21		TTL	
RB3			I/O		Digital I/O.
PGM			I		Low-voltage (single-supply) ICSP programming enable pin.
RB4	25	22	I/O	TTL	Digital I/O.
RB5	26	23	I/O	TTL	Digital I/O.
RB6/PGC	27	24		TTL/ST[2]	
RB6			I/O		Digital I/O.
PGC			I		In-circuit debugger and ICSP programming clock.
RB7/PGD	28	25		TTL/ST[2]	
RB7			I/O		Digital I/O.
PGD			I/O		In-circuit debugger and ICSP programming data.
					PORTC is a bidirectional I/O port.
RC0/T1OSO/T1CKI	11	8		ST	
RC0			I/O		Digital I/O.
T1OSO			O		Timer1 oscillator output.
T1CKI			I		Timer1 external clock input.
RC1/T1OSI/CCP2	12	9		ST	
RC1			I/O		Digital I/O.
T1OSI			I		Timer1 oscillator input.
CCP2			I/O		Capture2 input, Compare2 output, PWM2 output.
RC2/CCP1	13	10		ST	
RC2			I/O		Digital I/O.
CCP1			I/O		Capture1 input, Compare1 output, PWM1 output.
RC3/SCK/SCL	14	11		ST	
RC3			I/O		Digital I/O.
SCK			I/O		Synchronous serial clock input/output for SPI mode.
SCL			I/O		Synchronous serial clock input/output for I^{2}C mode.
RC4/SDI/SDA	15	12		ST	
RC4			I/O		Digital I/O.
SDI			I		SPI data in.
SDA			I/O		I^{2}C data I/O.
RC5/SDO	16	13		ST	
RC5			I/O		Digital I/O.
SDO			O		SPI data out.
RC6/TX/CK	17	14		ST	
RC6			I/O		Digital I/O.
TX			O		USART asynchronous transmit.
CK			I/O		USART1 synchronous clock.
RC7/RX/DT	18	15		ST	
RC7			I/O		Digital I/O.
RX			I		USART asynchronous receive.
DT			I/O		USART synchronous data.
V_{SS}	8, 19	5, 6	P	—	Ground reference for logic and I/O pins.
V_{DD}	20	17	P	—	Positive supply for logic and I/O pins.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL Input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured in RC Oscillator mode and a CMOS input otherwise.

TABLE 1-3: PIC16F874A/877A PINOUT DESCRIPTION

Pin Name	PDIP Pin#	PLCC Pin#	TQFP Pin#	QFN Pin#	I/O/P Type	Buffer Type	Description
OSC1/CLKI	13	14	30	32		ST/CMOS[4]	Oscillator crystal or external clock input.
OSC1					I		Oscillator crystal input or external clock source input. ST buffer when configured in RC mode; otherwise CMOS.
CLKI					I		External clock source input. Always associated with pin function OSC1 (see OSC1/CLKI, OSC2/CLKO pins).
OSC2/CLKO	14	15	31	33		—	Oscillator crystal or clock output.
OSC2					O		Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode.
CLKO					O		In RC mode, OSC2 pin outputs CLKO, which has 1/4 the frequency of OSC1 and denotes the instruction cycle rate.
$\overline{MCLR}$/VPP	1	2	18	18		ST	Master Clear (input) or programming voltage (output).
$\overline{MCLR}$					I		Master Clear (Reset) input. This pin is an active low Reset to the device.
VPP					P		Programming voltage input.
							PORTA is a bidirectional I/O port.
RA0/AN0	2	3	19	19		TTL	
RA0					I/O		Digital I/O.
AN0					I		Analog input 0.
RA1/AN1	3	4	20	20		TTL	
RA1					I/O		Digital I/O.
AN1					I		Analog input 1.
RA2/AN2/VREF-/CVREF	4	5	21	21		TTL	
RA2					I/O		Digital I/O.
AN2					I		Analog input 2.
VREF-					I		A/D reference voltage (Low) input.
CVREF					O		Comparator VREF output.
RA3/AN3/VREF+	5	6	22	22		TTL	
RA3					I/O		Digital I/O.
AN3					I		Analog input 3.
VREF+					I		A/D reference voltage (High) input.
RA4/T0CKI/C1OUT	6	7	23	23		ST	
RA4					I/O		Digital I/O – Open-drain when configured as output.
T0CKI					I		Timer0 external clock input.
C1OUT					O		Comparator 1 output.
RA5/AN4/$\overline{SS}$/C2OUT	7	8	24	24		TTL	
RA5					I/O		Digital I/O.
AN4					I		Analog input 4.
$\overline{SS}$					I		SPI slave select input.
C2OUT					O		Comparator 2 output.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured in RC Oscillator mode and a CMOS input otherwise.

TABLE 1-3: PIC16F874A/877A PINOUT DESCRIPTION (CONTINUED)

Pin Name	PDIP Pin#	PLCC Pin#	TQFP Pin#	QFN Pin#	I/O/P Type	Buffer Type	Description
							PORTB is a bidirectional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs.
RB0/INT	33	36	8	9		TTL/ST(1)	
RB0					I/O		Digital I/O.
INT					I		External interrupt.
RB1	34	37	9	10	I/O	TTL	Digital I/O.
RB2	35	38	10	11	I/O	TTL	Digital I/O.
RB3/PGM	36	39	11	12		TTL	
RB3					I/O		Digital I/O.
PGM					I		Low-voltage ICSP programming enable pin.
RB4	37	41	14	14	I/O	TTL	Digital I/O.
RB5	38	42	15	15	I/O	TTL	Digital I/O.
RB6/PGC	39	43	16	16		TTL/ST(2)	
RB6					I/O		Digital I/O.
PGC					I		In-circuit debugger and ICSP programming clock.
RB7/PGD	40	44	17	17		TTL/ST(2)	
RB7					I/O		Digital I/O.
PGD					I/O		In-circuit debugger and ICSP programming data.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured in RC Oscillator mode and a CMOS input otherwise.

TABLE 1-3: PIC16F874A/877A PINOUT DESCRIPTION (CONTINUED)

Pin Name	PDIP Pin#	PLCC Pin#	TQFP Pin#	QFN Pin#	I/O/P Type	Buffer Type	Description
							PORTC is a bidirectional I/O port.
RC0/T1OSO/T1CKI	15	16	32	34		ST	
RC0					I/O		Digital I/O.
T1OSO					O		Timer1 oscillator output.
T1CKI					I		Timer1 external clock input.
RC1/T1OSI/CCP2	16	18	35	35		ST	
RC1					I/O		Digital I/O.
T1OSI					I		Timer1 oscillator input.
CCP2					I/O		Capture2 input, Compare2 output, PWM2 output.
RC2/CCP1	17	19	36	36		ST	
RC2					I/O		Digital I/O.
CCP1					I/O		Capture1 input, Compare1 output, PWM1 output.
RC3/SCK/SCL	18	20	37	37		ST	
RC3					I/O		Digital I/O.
SCK					I/O		Synchronous serial clock input/output for SPI mode.
SCL					I/O		Synchronous serial clock input/output for I^2C mode.
RC4/SDI/SDA	23	25	42	42		ST	
RC4					I/O		Digital I/O.
SDI					I		SPI data in.
SDA					I/O		I^2C data I/O.
RC5/SDO	24	26	43	43		ST	
RC5					I/O		Digital I/O.
SDO					O		SPI data out.
RC6/TX/CK	25	27	44	44		ST	
RC6					I/O		Digital I/O.
TX					O		USART asynchronous transmit.
CK					I/O		USART1 synchronous clock.
RC7/RX/DT	26	29	1	1		ST	
RC7					I/O		Digital I/O.
RX					I		USART asynchronous receive.
DT					I/O		USART synchronous data.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL Input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured in RC Oscillator mode and a CMOS input otherwise.

TABLE 1-3: PIC16F874A/877A PINOUT DESCRIPTION (CONTINUED)

Pin Name	PDIP Pin#	PLCC Pin#	TQFP Pin#	QFN Pin#	I/O/P Type	Buffer Type	Description
							PORTD is a bidirectional I/O port or Parallel Slave Port when interfacing to a microprocessor bus.
RD0/PSP0	19	21	38	38		ST/TTL(3)	
RD0					I/O		Digital I/O.
PSP0					I/O		Parallel Slave Port data.
RD1/PSP1	20	22	39	39		ST/TTL(3)	
RD1					I/O		Digital I/O.
PSP1					I/O		Parallel Slave Port data.
RD2/PSP2	21	23	40	40		ST/TTL(3)	
RD2					I/O		Digital I/O.
PSP2					I/O		Parallel Slave Port data.
RD3/PSP3	22	24	41	41		ST/TTL(3)	
RD3					I/O		Digital I/O.
PSP3					I/O		Parallel Slave Port data.
RD4/PSP4	27	30	2	2		ST/TTL(3)	
RD4					I/O		Digital I/O.
PSP4					I/O		Parallel Slave Port data.
RD5/PSP5	28	31	3	3		ST/TTL(3)	
RD5					I/O		Digital I/O.
PSP5					I/O		Parallel Slave Port data.
RD6/PSP6	29	32	4	4		ST/TTL(3)	
RD6					I/O		Digital I/O.
PSP6					I/O		Parallel Slave Port data.
RD7/PSP7	30	33	5	5		ST/TTL(3)	
RD7					I/O		Digital I/O.
PSP7					I/O		Parallel Slave Port data.
							PORTE is a bidirectional I/O port.
RE0/$\overline{RD}$/AN5	8	9	25	25		ST/TTL(3)	
RE0					I/O		Digital I/O.
$\overline{RD}$					I		Read control for Parallel Slave Port.
AN5					I		Analog input 5.
RE1/$\overline{WR}$/AN6	9	10	26	26		ST/TTL(3)	
RE1					I/O		Digital I/O.
$\overline{WR}$					I		Write control for Parallel Slave Port.
AN6					I		Analog input 6.
RE2/$\overline{CS}$/AN7	10	11	27	27		ST/TTL(3)	
RE2					I/O		Digital I/O.
$\overline{CS}$					I		Chip select control for Parallel Slave Port.
AN7					I		Analog input 7.
V_{SS}	12, 31	13, 34	6, 29	6, 30, 31	P	—	Ground reference for logic and I/O pins.
V_{DD}	11, 32	12, 35	7, 28	7, 8, 28, 29	P	—	Positive supply for logic and I/O pins.
NC	—	1, 17, 28, 40	12,13, 33, 34	13	—	—	These pins are not internally connected. These pins should be left unconnected.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

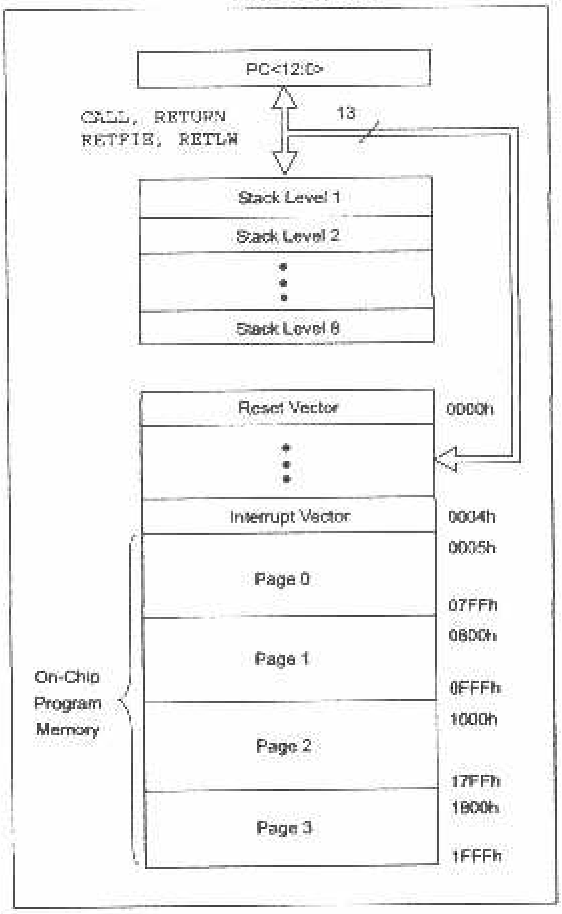
Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured in RC Oscillator mode and a CMOS input otherwise.

2.0 MEMORY ORGANIZATION

There are three memory blocks in each of the PIC16F87XA devices. The program memory and data memory have separate buses so that concurrent access can occur and is detailed in this section. The EEPROM data memory block is detailed in **Section 3.0 "Data EEPROM and Flash Program Memory"**.

Additional information on device memory may be found in the PIC® Mid-Range MCU Family Reference Manual (DS33023).

FIGURE 2-1: PIC16F876A/877A PROGRAM MEMORY MAP AND STACK

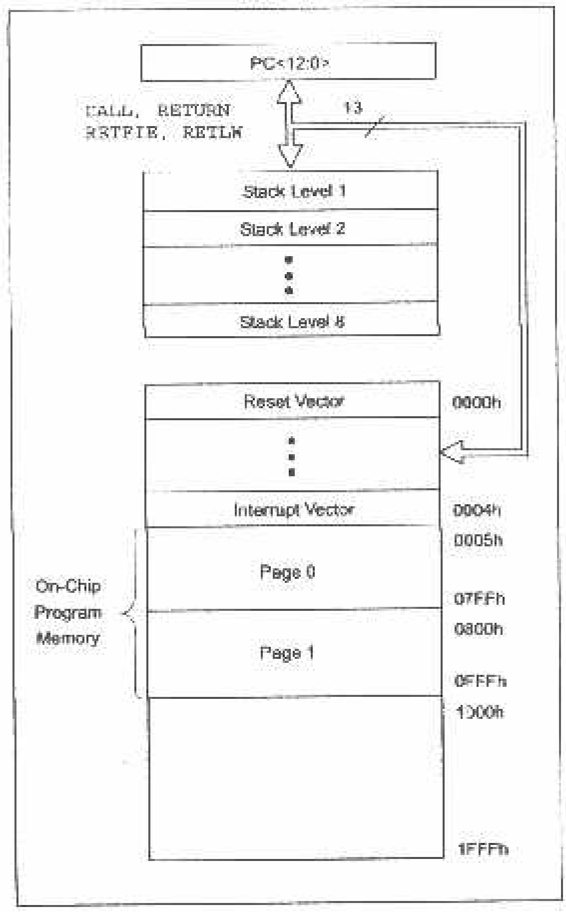


2.1 Program Memory Organization

The PIC16F87XA devices have a 13-bit program counter capable of addressing an 8K word x 14 bit program memory space. The PIC16F876A/877A devices have 8K words x 14 bits of Flash program memory, while PIC16F873A/874A devices have 4K words x 14 bits. Accessing a location above the physically implemented address will cause a wraparound.

The Reset vector is at 0000h and the interrupt vector is at 0004h.

FIGURE 2-2: PIC16F873A/874A PROGRAM MEMORY MAP AND STACK



2.2 Data Memory Organization

The data memory is partitioned into multiple banks which contain the General Purpose Registers and the Special Function Registers. Bits RP1 (Status<6>) and RP0 (Status<5>) are the bank select bits.

RP1:RP0	Bank
00	0
01	1
10	2
11	3

Each bank extends up to 7Fh (128 bytes). The lower locations of each bank are reserved for the Special Function Registers. Above the Special Function Registers are General Purpose Registers, implemented as static RAM. All implemented banks contain Special Function Registers. Some frequently used Special Function Registers from one bank may be mirrored in another bank for code reduction and quicker access.

Note:	The EEPROM data memory description can be found in **Section 3.0 "Data EEPROM and Flash Program Memory"** of this data sheet.

2.2.1 GENERAL PURPOSE REGISTER FILE

The register file can be accessed either directly, or indirectly, through the File Select Register (FSR).

FIGURE 2-3: PIC16F876A/877A REGISTER FILE MAP

Bank 0	File Address	Bank 1	File Address	Bank 2	File Address	Bank 3	File Address
Indirect addr.[*]	00h	Indirect addr.[*]	80h	Indirect addr.[*]	100h	Indirect addr.[*]	180h
TMR0	01h	OPTION_REG	81h	TMR0	101h	OPTION_REG	181h
PCL	02h	PCL	82h	PCL	102h	PCL	182h
STATUS	03h	STATUS	83h	STATUS	103h	STATUS	183h
FSR	04h	FSR	84h	FSR	104h	FSR	184h
PORTA	05h	TRISA	85h		105h		185h
PORTB	06h	TRISB	86h	PORTB	106h	TRISB	186h
PORTC	07h	TRISC	87h		107h		187h
PORTD[1]	08h	TRISD[1]	88h		108h		188h
PORTE[1]	09h	TRISE[1]	89h		109h		189h
PCLATH	0Ah	PCLATH	8Ah	PCLATH	10Ah	PCLATH	18Ah
INTCON	0Bh	INTCON	8Bh	INTCON	10Bh	INTCON	18Bh
PIR1	0Ch	PIE1	8Ch	EEDATA	10Ch	EECON1	18Ch
PIR2	0Dh	PIE2	8Dh	EEADR	10Dh	EECON2	18Dh
TMR1L	0Eh	PCON	8Eh	EEDATH	10Eh	Reserved[2]	18Eh
TMR1H	0Fh		8Fh	EEADRH	10Fh	Reserved[2]	18Fh
T1CON	10h		90h	General Purpose Register 16 Bytes	110h	General Purpose Register 16 Bytes	190h
TMR2	11h	SSPCON2	91h		111h		191h
T2CON	12h	PR2	92h		112h		192h
SSPBUF	13h	SSPADD	93h		113h		193h
SSPCON	14h	SSPSTAT	94h		114h		194h
CCPR1L	15h		95h		115h		195h
CCPR1H	16h		96h		116h		196h
CCP1CON	17h		97h		117h		197h
RCSTA	18h	TXSTA	98h		118h		198h
TXREG	19h	SPBRG	99h		119h		199h
RCREG	1Ah		9Ah		11Ah		19Ah
CCPR2L	1Bh		9Bh		11Bh		19Bh
CCPR2H	1Ch	CMCON	9Ch		11Ch		19Ch
CCP2CON	1Dh	CVRCON	9Dh		11Dh		19Dh
ADRESH	1Eh	ADRESL	9Eh		11Eh		19Eh
ADCON0	1Fh	ADCON1	9Fh		11Fh		19Fh
General Purpose Register 96 Bytes	20h	General Purpose Register 80 Bytes	A0h	General Purpose Register 80 Bytes	120h	General Purpose Register 80 Bytes	1A0h
			EFh		16Fh		1EFh
		accesses 70h-7Fh	F0h	accesses 70h-7Fh	170h	accesses 70h - 7Fh	1F0h
	7Fh		FFh		17Fh		1FFh
Bank 0		Bank 1		Bank 2		Bank 3	

☐ Unimplemented data memory locations, read as '0'.

* Not a physical register.

Note 1: These registers are not implemented on the PIC16F876A.

2: These registers are reserved; maintain these registers clear.

FIGURE 2-4: PIC16F873A/874A REGISTER FILE MAP

Bank 0	File Address	Bank 1	File Address	Bank 2	File Address	Bank 3	File Address
Indirect addr.(*)	00h	Indirect addr.(*)	80h	Indirect addr.(*)	100h	Indirect addr.(*)	180h
TMR0	01h	OPTION_REG	81h	TMR0	101h	OPTION_REG	181h
PCL	02h	PCL	82h	PCL	102h	PCL	182h
STATUS	03h	STATUS	83h	STATUS	103h	STATUS	183h
FSR	04h	FSR	84h	FSR	104h	FSR	184h
PORTA	05h	TRISA	85h		105h		185h
PORTB	06h	TRISB	86h	PORTB	106h	TRISB	186h
PORTC	07h	TRISC	87h		107h		187h
PORTD(1)	08h	TRISD(1)	88h		108h		188h
PORTE(1)	09h	TRISE(1)	89h		109h		189h
PCLATH	0Ah	PCLATH	8Ah	PCLATH	10Ah	PCLATH	18Ah
INTCON	0Bh	INTCON	8Bh	INTCON	10Bh	INTCON	18Bh
PIR1	0Ch	PIE1	8Ch	EEDATA	10Ch	EECON1	18Ch
PIR2	0Dh	PIE2	8Dh	EEADR	10Dh	EECON2	18Dh
TMR1L	0Eh	PCON	8Eh	EEDATH	10Eh	Reserved(2)	18Eh
TMR1H	0Fh		8Fh	EEADRH	10Fh	Reserved(2)	18Fh
T1CON	10h		90h		110h		190h
TMR2	11h	SSPCON2	91h				
T2CON	12h	PR2	92h				
SSPBUF	13h	SSPADD	93h				
SSPCON	14h	SSPSTAT	94h				
CCPR1L	15h		95h				
CCPR1H	16h		96h				
CCP1CON	17h		97h				
RCSTA	18h	TXSTA	98h				
TXREG	19h	SPBRG	99h				
RCREG	1Ah		9Ah				
CCPR2L	1Bh		9Bh				
CCPR2H	1Ch	CMCON	9Ch				
CCP2CON	1Dh	CVRCON	9Dh				
ADRESH	1Eh	ADRESL	9Eh				
ADCON0	1Fh	ADCON1	9Fh				
General Purpose Register 96 Bytes	20h 7Fh	General Purpose Register 96 Bytes	A0h FFh	accesses 20h-7Fh	120h 16Fh 170h 17Fh	accesses A0h - FFh	1A0h 1EFh 1F0h 1FFh

Bank 0 | Bank 1 | Bank 2 | Bank 3

▢ Unimplemented data memory locations, read as '0'.
* Not a physical register.

Note 1: These registers are not implemented on the PIC16F873A.
2: These registers are reserved; maintain these registers clear.

2.2.2 SPECIAL FUNCTION REGISTERS

The Special Function Registers are registers used by the CPU and peripheral modules for controlling the desired operation of the device. These registers are implemented as static RAM. A list of these registers is given in Table 2-1.

The Special Function Registers can be classified into two sets: core (CPU) and peripheral. Those registers associated with the core functions are described in detail in this section. Those related to the operation of the peripheral features are described in detail in the peripheral features section.

TABLE 2-1: SPECIAL FUNCTION REGISTER SUMMARY

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on: POR, BOR	Details on page:
Bank 0											
00h[3]	INDF	Addressing this location uses contents of FSR to address data memory (not a physical register)								0000 0000	31, 150
01h	TMR0	Timer0 Module Register								xxxx xxxx	55, 150
02h[3]	PCL	Program Counter (PC) Least Significant Byte								0000 0000	30, 150
03h[3]	STATUS	IRP	RP1	RP0	$\overline{TO}$	$\overline{PD}$	Z	DC	C	0001 1xxx	22, 150
04h[3]	FSR	Indirect Data Memory Address Pointer								xxxx xxxx	31, 150
05h	PORTA	—	—	PORTA Data Latch when written: PORTA pins when read						--0x 0000	43, 150
06h	PORTB	PORTB Data Latch when written: PORTB pins when read								xxxx xxxx	45, 150
07h	PORTC	PORTC Data Latch when written: PORTC pins when read								xxxx xxxx	47, 150
08h[4]	PORTD	PORTD Data Latch when written: PORTD pins when read								xxxx xxxx	48, 150
09h[4]	PORTE	—	—	—	—	—	RE2	RE1	RE0	---- -xxx	49, 150
0Ah[1,3]	PCLATH	—	—	—	Write Buffer for the upper 5 bits of the Program Counter					---0 0000	30, 150
0Bh[3]	INTCON	GIE	PEIE	TMR0IE	INTE	RBIE	TMR0IF	INTF	RBIF	0000 000x	24, 150
0Ch	PIR1	PSPIF[3]	ADIF	RCIF	TXIF	SSPIF	CCP1IF	TMR2IF	TMR1IF	0000 0000	26, 150
0Dh	PIR2	—	CMIF	—	EEIF	BCLIF	—	—	CCP2IF	-0-0 0--0	28, 150
0Eh	TMR1L	Holding Register for the Least Significant Byte of the 16-bit TMR1 Register								xxxx xxxx	60, 150
0Fh	TMR1H	Holding Register for the Most Significant Byte of the 16-bit TMR1 Register								xxxx xxxx	60, 150
10h	T1CON	—	—	T1CKPS1	T1CKPS0	T1OSCEN	$\overline{T1SYNC}$	TMR1CS	TMR1ON	--00 0000	57, 150
11h	TMR2	Timer2 Module Register								0000 0000	62, 150
12h	T2CON	—	TOUTPS3	TOUTPS2	TOUTPS1	TOUTPS0	TMR2ON	T2CKPS1	T2CKPS0	-000 0000	61, 150
13h	SSPBUF	Synchronous Serial Port Receive Buffer/Transmit Register								xxxx xxxx	79, 150
14h	SSPCON	WCOL	SSPOV	SSPEN	CKP	SSPM3	SSPM2	SSPM1	SSPM0	0000 0000	82, 82, 150
15h	CCPR1L	Capture/Compare/PWM Register 1 (LSB)								xxxx xxxx	63, 150
16h	CCPR1H	Capture/Compare/PWM Register 1 (MSB)								xxxx xxxx	63, 150
17h	CCP1CON	—	—	CCP1X	CCP1Y	CCP1M3	CCP1M2	CCP1M1	CCP1M0	--00 0000	64, 150
18h	RCSTA	SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D	0000 000x	112, 150
19h	TXREG	USART Transmit Data Register								0000 0000	118, 150
1Ah	RCREG	USART Receive Data Register								0000 0000	116, 150
1Bh	CCPR2L	Capture/Compare/PWM Register 2 (LSB)								xxxx xxxx	63, 150
1Ch	CCPR2H	Capture/Compare/PWM Register 2 (MSB)								xxxx xxxx	63, 150
1Dh	CCP2CON	—	—	CCP2X	CCP2Y	CCP2M3	CCP2M2	CCP2M1	CCP2M0	--00 0000	64, 150
1Eh	ADRESH	A/D Result Register High Byte								xxxx xxxx	133, 150
1Fh	ADCON0	ADCS1	ADCS0	CHS2	CHS1	CHS0	GO/$\overline{DONE}$	—	ADON	0000 00-0	127, 150

Legend: x = unknown, u = unchanged, q = value depends on condition, - = unimplemented, read as '0', r = reserved. Shaded locations are unimplemented, read as '0'.

Note 1: The upper byte of the program counter is not directly accessible. PCLATH is a holding register for the PC<12:8>, whose contents are transferred to the upper byte of the program counter.

2: Bits PSPIE and PSPIF are reserved on PIC16F873A/876A devices; always maintain these bits clear.

3: These registers can be addressed from any bank.

4: PORTD, PORTE, TRISD and TRISE are not implemented on PIC16F873A/876A devices, read as '0'.

5: Bit 4 of EEADRH implemented only on the PIC16F876A/877A devices.

TABLE 2-1: SPECIAL FUNCTION REGISTER SUMMARY (CONTINUED)

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on: POR, BOR	Details on page:
Bank 1											
80h[3]	INDF	Addressing this location uses contents of FSR to address data memory (not a physical register)								0000 0000	31, 150
81h	OPTION_REG	$\overline{\text{RBPU}}$	INTEDG	T0CS	T0SE	PSA	PS2	PS1	PS0	1111 1111	23, 150
82h[3]	PCL	Program Counter (PC) Least Significant Byte								0000 0000	30, 150
83h[3]	STATUS	IRP	RP1	RP0	$\overline{\text{TO}}$	$\overline{\text{PD}}$	Z	DC	C	0001 1xxx	22, 150
84h[3]	FSR	Indirect Data Memory Address Pointer								xxxx xxxx	31, 150
85h	TRISA	—	—	PORTA Data Direction Register						--11 1111	43, 150
86h	TRISB	PORTB Data Direction Register								1111 1111	45, 150
87h	TRISC	PORTC Data Direction Register								1111 1111	47, 150
88h[4]	TRISD	PORTD Data Direction Register								1111 1111	48, 151
89h[4]	TRISE	IBF	OBF	IBOV	PSPMODE	—	PORTE Data Direction bits			0000 -111	50, 151
8Ah[1,3]	PCLATH	—	—	—	Write Buffer for the upper 5 bits of the Program Counter					---0 0000	30, 150
8Bh[3]	INTCON	GIE	PEIE	TMR0IE	INTE	RBIE	TMR0IF	INTF	RBIF	0000 000x	24, 150
8Ch	PIE1	PSPIE[2]	ADIE	RCIE	TXIE	SSPIE	CCP1IE	TMR2IE	TMR1IE	0000 0000	25, 151
8Dh	PIE2	—	CMIE	—	EEIE	BCLIE	—	—	CCP2IE	-0-0 0--0	27, 151
8Eh	PCON	—	—	—	—	—	—	$\overline{\text{POR}}$	$\overline{\text{BOR}}$	qq	29, 151
8Fh	—	Unimplemented								—	—
90h	—	Unimplemented								—	—
91h	SSPCON2	GCEN	ACKSTAT	ACKDT	ACKEN	RCEN	PEN	RSEN	SEN	0000 0000	83, 151
92h	PR2	Timer2 Period Register								1111 1111	62, 151
93h	SSPADD	Synchronous Serial Port (I²C mode) Address Register								0000 0000	79, 151
94h	SSPSTAT	SMP	CKE	D/$\overline{\text{A}}$	P	S	R/$\overline{\text{W}}$	UA	BF	0000 0000	79, 151
95h	—	Unimplemented								—	—
96h	—	Unimplemented								—	—
97h	—	Unimplemented								—	—
98h	TXSTA	CSRC	TX9	TXEN	SYNC	—	BRGH	TRMT	TX9D	0000 -010	111, 151
99h	SPBRG	Baud Rate Generator Register								0000 0000	113, 151
9Ah	—	Unimplemented								—	—
9Bh	—	Unimplemented								—	—
9Ch	CMCON	C2OUT	C1OUT	C2INV	C1INV	CIS	CM2	CM1	CM0	0000 0111	135, 151
9Dh	CVRCON	CVREN	CVROE	CVRR	—	CVR3	CVR2	CVR1	CVR0	000- 0000	141, 151
9Eh	ADRESL	A/D Result Register Low Byte								xxxx xxxx	133, 151
9Fh	ADCON1	ADFM	ADCS2	—	—	PCFG3	PCFG2	PCFG1	PCFG0	00-- 0000	128, 151

Legend: x = unknown, u = unchanged, q = value depends on condition, - = unimplemented, read as '0', r = reserved. Shaded locations are unimplemented, read as '0'.

Note 1: The upper byte of the program counter is not directly accessible. PCLATH is a holding register for the PC<12:8>, whose contents are transferred to the upper byte of the program counter.

2: Bits PSPIE and PSPIF are reserved on PIC16F873A/876A devices; always maintain these bits clear.

3: These registers can be addressed from any bank.

4: PORTD, PORTE, TRISD and TRISE are not implemented on PIC16F873A/876A devices, read as '0'.

5: Bit 4 of EEADRH implemented only on the PIC16F876A/877A devices.

TABLE 2-1: SPECIAL FUNCTION REGISTER SUMMARY (CONTINUED)

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on: POR, BOR	Details on page:
Bank 2											
100h[3]	INDF	Addressing this location uses contents of FSR to address data memory (not a physical register)								0000 0000	31, 150
101h	TMR0	Timer0 Module Register								xxxx xxxx	55, 150
102h[3]	PCL	Program Counter's (PC) Least Significant Byte								0000 0000	30, 150
103h[3]	STATUS	IRP	RP1	RP0	$\overline{TO}$	$\overline{PD}$	Z	DC	C	0001 1xxx	22, 150
104h[3]	FSR	Indirect Data Memory Address Pointer								xxxx xxxx	31, 150
105h	—	Unimplemented								—	—
106h	PORTB	PORTB Data Latch when written: PORTB pins when read								xxxx xxxx	45, 150
107h	—	Unimplemented								—	—
108h	—	Unimplemented								—	—
109h	—	Unimplemented								—	—
10Ah[1,3]	PCLATH	—	—	—	Write Buffer for the upper 5 bits of the Program Counter					---0 0000	30, 150
10Bh[3]	INTCON	GIE	PEIE	TMR0IE	INTE	RBIE	TMR0IF	INTF	RBIF	0000 000x	24, 150
10Ch	EEDATA	EEPROM Data Register Low Byte								xxxx xxxx	39, 151
10Dh	EEADR	EEPROM Address Register Low Byte								xxxx xxxx	39, 151
10Eh	EEDATH	—	—	EEPROM Data Register High Byte						--xx xxxx	39, 151
10Fh	EEADRH	—	—	—	—[5]	EEPROM Address Register High Byte				---- xxxx	39, 151
Bank 3											
180h[3]	INDF	Addressing this location uses contents of FSR to address data memory (not a physical register)								0000 0000	31, 150
181h	OPTION_REG	$\overline{RBPU}$	INTEDG	T0CS	T0SE	PSA	PS2	PS1	PS0	1111 1111	23, 150
182h[3]	PCL	Program Counter (PC) Least Significant Byte								0000 0000	30, 150
183h[3]	STATUS	IRP	RP1	RP0	$\overline{TO}$	$\overline{PD}$	Z	DC	C	0001 1xxx	22, 150
184h[3]	FSR	Indirect Data Memory Address Pointer								xxxx xxxx	31, 150
185h	—	Unimplemented								—	—
186h	TRISB	PORTB Data Direction Register								1111 1111	45, 150
187h	—	Unimplemented								—	—
188h	—	Unimplemented								—	—
189h	—	Unimplemented								—	—
18Ah[1,3]	PCLATH	—	—	—	Write Buffer for the upper 5 bits of the Program Counter					---0 0000	30, 150
18Bh[3]	INTCON	GIE	PEIE	TMR0IE	INTE	RBIE	TMR0IF	INTF	RBIF	0000 000x	24, 150
18Ch	EECON1	EEPGD	—	—	—	WRERR	WREN	WR	RD	x--- x000	34, 151
18Dh	EECON2	EEPROM Control Register 2 (not a physical register)								---- ----	39, 151
18Eh	—	Reserved; maintain clear								0000 0000	—
18Fh	—	Reserved; maintain clear								0000 0000	—

Legend: x = unknown, u = unchanged, q = value depends on condition, - = unimplemented, read as '0', r = reserved. Shaded locations are unimplemented, read as '0'.

Note 1: The upper byte of the program counter is not directly accessible. PCLATH is a holding register for the PC<12:8>, whose contents are transferred to the upper byte of the program counter.

2: Bits PSPIE and PSPIF are reserved on PIC16F873A/876A devices; always maintain these bits clear.

3: These registers can be addressed from any bank.

4: PORTD, PORTE, TRISD and TRISE are not implemented on PIC16F873A/876A devices, read as '0'.

5: Bit 4 of EEADRH implemented only on the PIC16F876A/877A devices.

2.2.2.1 Status Register

The Status register contains the arithmetic status of the ALU, the Reset status and the bank select bits for data memory.

The Status register can be the destination for any instruction, as with any other register. If the Status register is the destination for an instruction that affects the Z, DC or C bits, then the write to these three bits is disabled. These bits are set or cleared according to the device logic. Furthermore, the $\overline{TO}$ and $\overline{PD}$ bits are not writable, therefore, the result of an instruction with the Status register as destination may be different than intended.

For example, `CLRF STATUS`, will clear the upper three bits and set the Z bit. This leaves the Status register as `000u u1uu` (where u = unchanged).

It is recommended, therefore, that only `BCF`, `BSF`, `SWAPF` and `MOVWF` instructions are used to alter the Status register because these instructions do not affect the Z, C or DC bits from the Status register. For other instructions not affecting any status bits, see **Section 15.0 "Instruction Set Summary"**.

Note:	The C and DC bits operate as a $\overline{borrow}$ and digit $\overline{borrow}$ bit, respectively, in subtraction. See the `SUBLW` and `SUBWF` instructions for examples.

REGISTER 2-1: STATUS REGISTER (ADDRESS 03h, 83h, 103h, 183h)

R/W-0	R/W-0	R/W-0	R-1	R-1	R/W-x	R/W-x	R/W-x
IRP	RP1	RP0	$\overline{TO}$	$\overline{PD}$	Z	DC	C
bit 7							bit 0

bit 7 **IRP**: Register Bank Select bit (used for indirect addressing)
1 = Bank 2, 3 (100h-1FFh)
0 = Bank 0, 1 (00h-FFh)

bit 6-5 **RP1:RP0**: Register Bank Select bits (used for direct addressing)
11 = Bank 3 (180h-1FFh)
10 = Bank 2 (100h-17Fh)
01 = Bank 1 (80h-FFh)
00 = Bank 0 (00h-7Fh)
Each bank is 128 bytes.

bit 4 **$\overline{TO}$**: Time-out bit
1 = After power-up, `CLRWDT` instruction or `SLEEP` instruction
0 = A WDT time-out occurred

bit 3 **$\overline{PD}$**: Power-down bit
1 = After power-up or by the `CLRWDT` instruction
0 = By execution of the `SLEEP` instruction

bit 2 **Z**: Zero bit
1 = The result of an arithmetic or logic operation is zero
0 = The result of an arithmetic or logic operation is not zero

bit 1 **DC**: Digit carry/$\overline{borrow}$ bit (`ADDWF`, `ADDLW`, `SUBLW`, `SUBWF` instructions)
(for $\overline{borrow}$, the polarity is reversed)
1 = A carry-out from the 4th low order bit of the result occurred
0 = No carry-out from the 4th low order bit of the result

bit 0 **C**: Carry/$\overline{borrow}$ bit (`ADDWF`, `ADDLW`, `SUBLW`, `SUBWF` instructions)
1 = A carry-out from the Most Significant bit of the result occurred
0 = No carry-out from the Most Significant bit of the result occurred

Note: For $\overline{borrow}$, the polarity is reversed. A subtraction is executed by adding the two's complement of the second operand. For rotate (`RRF`, `RLF`) instructions, this bit is loaded with either the high, or low order bit of the source register.

Legend:		
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'
- n = Value at POR	'1' = Bit is set	'0' = Bit is cleared x = Bit is unknown

2.2.2.2 OPTION_REG Register

The OPTION_REG Register is a readable and writable register, which contains various control bits to configure the TMR0 prescaler/WDT postscaler (single assignable register known also as the prescaler), the external INT interrupt, TMR0 and the weak pull-ups on PORTB.

Note:	To achieve a 1:1 prescaler assignment for the TMR0 register, assign the prescaler to the Watchdog Timer.

REGISTER 2-2: OPTION_REG REGISTER (ADDRESS 81h, 181h)

R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1
$\overline{RBPU}$	INTEDG	T0CS	T0SE	PSA	PS2	PS1	PS0
bit 7							bit 0

bit 7 **$\overline{RBPU}$**: PORTB Pull-up Enable bit
1 = PORTB pull-ups are disabled
0 = PORTB pull-ups are enabled by individual port latch values

bit 6 **INTEDG**: Interrupt Edge Select bit
1 = Interrupt on rising edge of RB0/INT pin
0 = Interrupt on falling edge of RB0/INT pin

bit 5 **T0CS**: TMR0 Clock Source Select bit
1 = Transition on RA4/T0CKI pin
0 = Internal instruction cycle clock (CLKO)

bit 4 **T0SE**: TMR0 Source Edge Select bit
1 = Increment on high-to-low transition on RA4/T0CKI pin
0 = Increment on low-to-high transition on RA4/T0CKI pin

bit 3 **PSA**: Prescaler Assignment bit
1 = Prescaler is assigned to the WDT
0 = Prescaler is assigned to the Timer0 module

bit 2-0 **PS2:PS0**: Prescaler Rate Select bits

Bit Value	TMR0 Rate	WDT Rate
000	1 : 2	1 : 1
001	1 : 4	1 : 2
010	1 : 8	1 : 4
011	1 : 16	1 : 8
100	1 : 32	1 : 16
101	1 : 64	1 : 32
110	1 : 128	1 : 64
111	1 : 256	1 : 128

Legend:		
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'
- n = Value at POR	'1' = Bit is set	'0' = Bit is cleared x = Bit is unknown

Note:	When using Low-Voltage ICSP Programming (LVP) and the pull-ups on PORTB are enabled, bit 3 in the TRISB register must be cleared to disable the pull-up on RB3 and ensure the proper operation of the device

2.2.2.3 INTCON Register

The INTCON register is a readable and writable register, which contains various enable and flag bits for the TMR0 register overflow, RB port change and external RB0/INT pin interrupts.

Note:	Interrupt flag bits are set when an interrupt condition occurs regardless of the state of its corresponding enable bit or the global enable bit, GIE (INTCON<7>). User software should ensure the appropriate interrupt flag bits are clear prior to enabling an interrupt.

REGISTER 2-3: INTCON REGISTER (ADDRESS 0Bh, 8Bh, 10Bh, 18Bh)

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-x
GIE	PEIE	TMR0IE	INTE	RBIE	TMR0IF	INTF	RBIF
bit 7							bit 0

bit 7 **GIE**: Global Interrupt Enable bit
1 = Enables all unmasked interrupts
0 = Disables all interrupts

bit 6 **PEIE**: Peripheral Interrupt Enable bit
1 = Enables all unmasked peripheral interrupts
0 = Disables all peripheral interrupts

bit 5 **TMR0IE**: TMR0 Overflow Interrupt Enable bit
1 = Enables the TMR0 interrupt
0 = Disables the TMR0 interrupt

bit 4 **INTE**: RB0/INT External Interrupt Enable bit
1 = Enables the RB0/INT external interrupt
0 = Disables the RB0/INT external interrupt

bit 3 **RBIE**: RB Port Change Interrupt Enable bit
1 = Enables the RB port change interrupt
0 = Disables the RB port change interrupt

bit 2 **TMR0IF**: TMR0 Overflow Interrupt Flag bit
1 = TMR0 register has overflowed (must be cleared in software)
0 = TMR0 register did not overflow

bit 1 **INTF**: RB0/INT External Interrupt Flag bit
1 = The RB0/INT external interrupt occurred (must be cleared in software)
0 = The RB0/INT external interrupt did not occur

bit 0 **RBIF**: RB Port Change Interrupt Flag bit
1 = At least one of the RB7:RB4 pins changed state; a mismatch condition will continue to set the bit. Reading PORTB will end the mismatch condition and allow the bit to be cleared (must be cleared in software).
0 = None of the RB7:RB4 pins have changed state

Legend:			
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
- n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

2.2.2.4 PIE1 Register

The PIE1 register contains the individual enable bits for the peripheral interrupts.

> **Note:** Bit PEIE (INTCON<6>) must be set to enable any peripheral interrupt.

REGISTER 2-4: PIE1 REGISTER (ADDRESS 8Ch)

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
PSPIE[1]	ADIE	RCIE	TXIE	SSPIE	CCP1IE	TMR2IE	TMR1IE
bit 7							bit 0

bit 7 **PSPIE:** Parallel Slave Port Read/Write Interrupt Enable bit[1]
1 = Enables the PSP read/write interrupt
0 = Disables the PSP read/write interrupt

Note 1: PSPIE is reserved on PIC16F873A/876A devices; always maintain this bit clear.

bit 6 **ADIE**: A/D Converter Interrupt Enable bit
1 = Enables the A/D converter interrupt
0 = Disables the A/D converter interrupt

bit 5 **RCIE**: USART Receive Interrupt Enable bit
1 = Enables the USART receive interrupt
0 = Disables the USART receive interrupt

bit 4 **TXIE**: USART Transmit Interrupt Enable bit
1 = Enables the USART transmit interrupt
0 = Disables the USART transmit interrupt

bit 3 **SSPIE**: Synchronous Serial Port Interrupt Enable bit
1 = Enables the SSP interrupt
0 = Disables the SSP interrupt

bit 2 **CCP1IE**: CCP1 Interrupt Enable bit
1 = Enables the CCP1 interrupt
0 = Disables the CCP1 interrupt

bit 1 **TMR2IE**: TMR2 to PR2 Match Interrupt Enable bit
1 = Enables the TMR2 to PR2 match interrupt
0 = Disables the TMR2 to PR2 match interrupt

bit 0 **TMR1IE**: TMR1 Overflow Interrupt Enable bit
1 = Enables the TMR1 overflow interrupt
0 = Disables the TMR1 overflow interrupt

Legend:			
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
- n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

2.2.2.5 PIR1 Register

The PIR1 register contains the individual flag bits for the peripheral interrupts.

Note:	Interrupt flag bits are set when an interrupt condition occurs regardless of the state of its corresponding enable bit or the global enable bit, GIE (INTCON<7>). User software should ensure the appropriate interrupt bits are clear prior to enabling an interrupt.

REGISTER 2-5: PIR1 REGISTER (ADDRESS 0Ch)

R/W-0	R/W-0	R-0	R-0	R/W-0	R/W-0	R/W-0	R/W-0
PSPIF(1)	ADIF	RCIF	TXIF	SSPIF	CCP1IF	TMR2IF	TMR1IF
bit 7							bit 0

bit 7 **PSPIF**: Parallel Slave Port Read/Write Interrupt Flag bit(1)
1 = A read or a write operation has taken place (must be cleared in software)
0 = No read or write has occurred

Note 1: PSPIF is reserved on PIC16F873A/876A devices; always maintain this bit clear.

bit 6 **ADIF**: A/D Converter Interrupt Flag bit
1 = An A/D conversion completed
0 = The A/D conversion is not complete

bit 5 **RCIF**: USART Receive Interrupt Flag bit
1 = The USART receive buffer is full
0 = The USART receive buffer is empty

bit 4 **TXIF**: USART Transmit Interrupt Flag bit
1 = The USART transmit buffer is empty
0 = The USART transmit buffer is full

bit 3 **SSPIF**: Synchronous Serial Port (SSP) Interrupt Flag bit
1 = The SSP interrupt condition has occurred and must be cleared in software before returning from the Interrupt Service Routine. The conditions that will set this bit are:
- SPI – A transmission/reception has taken place.
- I^2C Slave – A transmission/reception has taken place.
- I^2C Master
  - A transmission/reception has taken place.
  - The initiated Start condition was completed by the SSP module.
  - The initiated Stop condition was completed by the SSP module.
  - The initiated Restart condition was completed by the SSP module.
  - The initiated Acknowledge condition was completed by the SSP module.
  - A Start condition occurred while the SSP module was Idle (multi-master system).
  - A Stop condition occurred while the SSP module was Idle (multi-master system).

0 = No SSP interrupt condition has occurred

bit 2 **CCP1IF**: CCP1 Interrupt Flag bit
<u>Capture mode:</u>
1 = A TMR1 register capture occurred (must be cleared in software)
0 = No TMR1 register capture occurred
<u>Compare mode:</u>
1 = A TMR1 register compare match occurred (must be cleared in software)
0 = No TMR1 register compare match occurred
<u>PWM mode:</u>
Unused in this mode.

bit 1 **TMR2IF**: TMR2 to PR2 Match Interrupt Flag bit
1 = TMR2 to PR2 match occurred (must be cleared in software)
0 = No TMR2 to PR2 match occurred

bit 0 **TMR1IF**: TMR1 Overflow Interrupt Flag bit
1 = TMR1 register overflowed (must be cleared in software)
0 = TMR1 register did not overflow

Legend:			
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
- n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

2.2.2.6 PIE2 Register

The PIE2 register contains the individual enable bits for the CCP2 peripheral interrupt, the SSP bus collision interrupt, EEPROM write operation interrupt and the comparator interrupt.

Note:	Bit PEIE (INTCON<6>) must be set to enable any peripheral interrupt.

REGISTER 2-6: PIE2 REGISTER (ADDRESS 8Dh)

U-0	R/W-0	U-0	R/W-0	R/W-0	U-0	U-0	R/W-0
—	CMIE	—	EEIE	BCLIE	—	—	CCP2IE
bit 7							bit 0

bit 7 **Unimplemented:** Read as '0'

bit 6 **CMIE**: Comparator Interrupt Enable bit
1 = Enables the comparator interrupt
0 = Disable the comparator interrupt

bit 5 **Unimplemented:** Read as '0'

bit 4 **EEIE**: EEPROM Write Operation Interrupt Enable bit
1 = Enable EEPROM write interrupt
0 = Disable EEPROM write interrupt

bit 3 **BCLIE**: Bus Collision Interrupt Enable bit
1 = Enable bus collision interrupt
0 = Disable bus collision interrupt

bit 2-1 **Unimplemented:** Read as '0'

bit 0 **CCP2IE**: CCP2 Interrupt Enable bit
1 = Enables the CCP2 interrupt
0 = Disables the CCP2 interrupt

Legend:			
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
- n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

2.2.2.7 PIR2 Register

The PIR2 register contains the flag bits for the CCP2 interrupt, the SSP bus collision interrupt, EEPROM write operation interrupt and the comparator interrupt.

Note:	Interrupt flag bits are set when an interrupt condition occurs regardless of the state of its corresponding enable bit or the global enable bit, GIE (INTCON<7>). User software should ensure the appropriate interrupt flag bits are clear prior to enabling an interrupt.

REGISTER 2-7: PIR2 REGISTER (ADDRESS 0Dh)

U-0	R/W-0	U-0	R/W-0	R/W-0	U-0	U-0	R/W-0
—	CMIF	—	EEIF	BCLIF	—	—	CCP2IF
bit 7							bit 0

bit 7 **Unimplemented:** Read as '0'

bit 6 **CMIF:** Comparator Interrupt Flag bit
1 = The comparator input has changed (must be cleared in software)
0 = The comparator input has not changed

bit 5 **Unimplemented:** Read as '0'

bit 4 **EEIF:** EEPROM Write Operation Interrupt Flag bit
1 = The write operation completed (must be cleared in software)
0 = The write operation is not complete or has not been started

bit 3 **BCLIF:** Bus Collision Interrupt Flag bit
1 = A bus collision has occurred in the SSP when configured for I^2C Master mode
0 = No bus collision has occurred

bit 2-1 **Unimplemented:** Read as '0'

bit 0 **CCP2IF:** CCP2 Interrupt Flag bit
Capture mode:
1 = A TMR1 register capture occurred (must be cleared in software)
0 = No TMR1 register capture occurred
Compare mode:
1 = A TMR1 register compare match occurred (must be cleared in software)
0 = No TMR1 register compare match occurred
PWM mode:
Unused.

Legend:			
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
- n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

2.2.2.6 PCON Register

The Power Control (PCON) register contains flag bits to allow differentiation between a Power-on Reset (POR), a Brown-out Reset (BOR), a Watchdog Reset (WDT) and an external $\overline{\text{MCLR}}$ Reset.

Note:	$\overline{\text{BOR}}$ is unknown on Power-on Reset. It must be set by the user and checked on subsequent Resets to see if BOR is clear, indicating a brown-out has occurred. The BOR status bit is a "don't care" and is not predictable if the brown-out circuit is disabled (by clearing the BODEN bit in the configuration word).

REGISTER 2-8: PCON REGISTER (ADDRESS 8Eh)

U-0	U-0	U-0	U-0	U-0	U-0	R/W-0	R/W-1
—	—	—	—	—	—	$\overline{\text{POR}}$	$\overline{\text{BOR}}$
bit 7							bit 0

bit 7-2 **Unimplemented:** Read as '0'

bit 1 **$\overline{\text{POR}}$**: Power-on Reset Status bit
1 = No Power-on Reset occurred
0 = A Power-on Reset occurred (must be set in software after a Power-on Reset occurs)

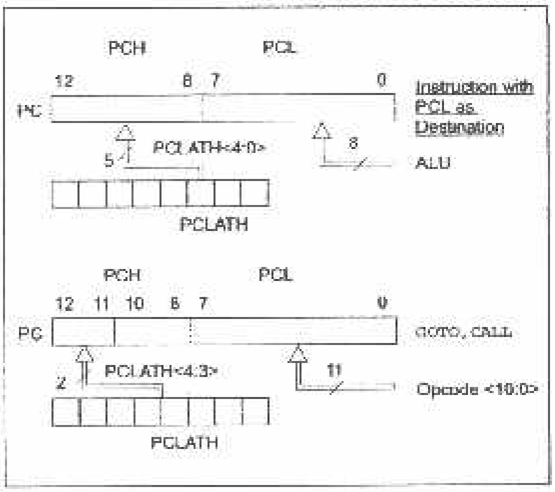
bit 0 **$\overline{\text{BOR}}$**: Brown-out Reset Status bit
1 = No Brown-out Reset occurred
0 = A Brown-out Reset occurred (must be set in software after a Brown-out Reset occurs)

Legend:			
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
- n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

2.3 PCL and PCLATH

The Program Counter (PC) is 13 bits wide. The low byte comes from the PCL register which is a readable and writable register. The upper bits (PC<12:8>) are not readable, but are indirectly writable through the PCLATH register. On any Reset, the upper bits of the PC will be cleared. Figure 2-5 shows the two situations for the loading of the PC. The upper example in the figure shows how the PC is loaded on a write to PCL (PCLATH<4:0> → PCH). The lower example in the figure shows how the PC is loaded during a `CALL` or `GOTO` instruction (PCLATH<4:3> → PCH).

FIGURE 2-5: LOADING OF PC IN DIFFERENT SITUATIONS



2.3.1 COMPUTED GOTO

A computed `GOTO` is accomplished by adding an offset to the program counter (`ADDWF PCL`). When doing a table read using a computed `GOTO` method, care should be exercised if the table location crosses a PCL memory boundary (each 256-byte block). Refer to the application note, *AN556, "Implementing a Table Read"* (DS00556).

2.3.2 STACK

The PIC16F87XA family has an 8-level deep x 13-bit wide hardware stack. The stack space is not part of either program or data space and the stack pointer is not readable or writable. The PC is PUSHed onto the stack when a `CALL` instruction is executed, or an interrupt causes a branch. The stack is POP'ed in the event of a `RETURN`, `RETLW` or a `RETFIE` instruction execution. PCLATH is not affected by a PUSH or POP operation.

The stack operates as a circular buffer. This means that after the stack has been PUSHed eight times, the ninth push overwrites the value that was stored from the first push. The tenth push overwrites the second push (and so on).

Note 1:	There are no status bits to indicate stack overflow or stack underflow conditions.
2:	There are no instructions/mnemonics called PUSH or POP. These are actions that occur from the execution of the `CALL`, `RETURN`, `RETLW` and `RETFIE` instructions or the vectoring to an interrupt address.

2.4 Program Memory Paging

All PIC16F87XA devices are capable of addressing a continuous 8K word block of program memory. The `CALL` and `GOTO` instructions provide only 11 bits of address to allow branching within any 2K program memory page. When doing a `CALL` or `GOTO` instruction, the upper 2 bits of the address are provided by PCLATH<4:3>. When doing a `CALL` or `GOTO` instruction, the user must ensure that the page select bits are programmed so that the desired program memory page is addressed. If a return from a `CALL` instruction (or interrupt) is executed, the entire 13-bit PC is popped off the stack. Therefore, manipulation of the PCLATH<4:3> bits is not required for the `RETURN` instructions (which POPs the address from the stack).

Note:	The contents of the PCLATH register are unchanged after a `RETURN` or `RETFIE` instruction is executed. The user must rewrite the contents of the PCLATH register for any subsequent subroutine calls or `GOTO` instructions.

Example 2-1 shows the calling of a subroutine in page 1 of the program memory. This example assumes that PCLATH is saved and restored by the Interrupt Service Routine (if interrupts are used).

EXAMPLE 2-1: CALL OF A SUBROUTINE IN PAGE 1 FROM PAGE 0

```
        ORG 0x500
        BCF PCLATH,4
        BSF PCLATH,3    ;Select page 1
                        ;(800h-FFFh)
        CALL SUB1_P1    ;Call subroutine in
        :               ;page 1 (800h-FFFh)
        :
        ORG 0x900       ;page 1 (800h-FFFh)
SUB1_P1
        :               ;called subroutine
                        ;page 1 (800h-FFFh)
        :
        RETURN          ;return to
                        ;Call subroutine
                        ;in page 0
                        ;(000h-7FFh)
```


2.5 Indirect Addressing, INDF and FSR Registers

The INDF register is not a physical register. Addressing the INDF register will cause indirect addressing.

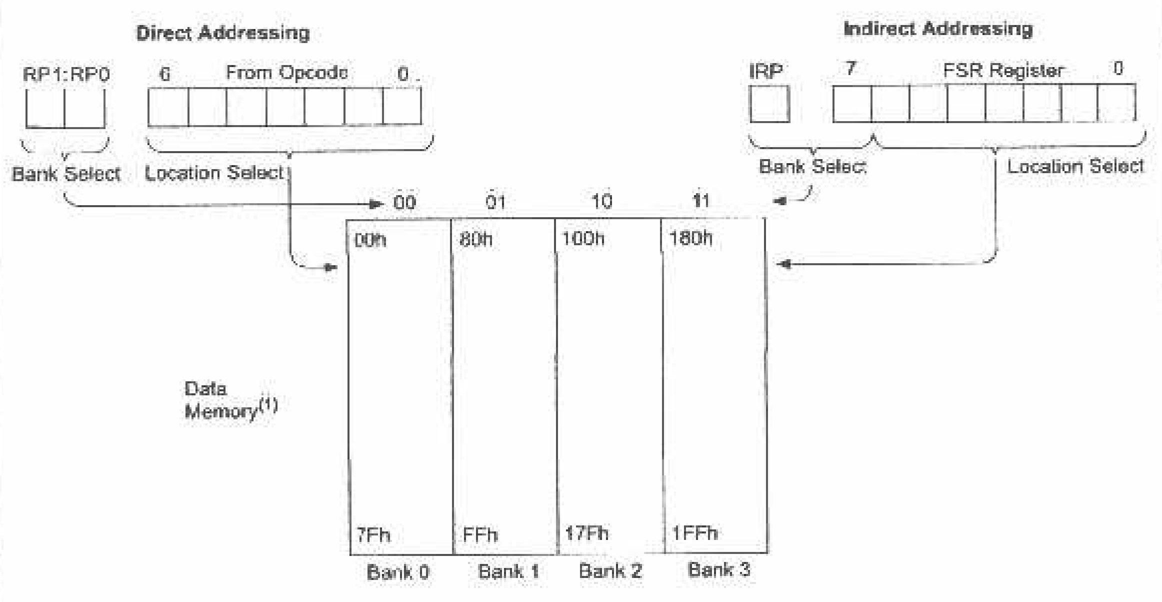
Indirect addressing is possible by using the INDF register. Any instruction using the INDF register actually accesses the register pointed to by the File Select Register, FSR. Reading the INDF register itself, indirectly (FSR = 0) will read 00h. Writing to the INDF register indirectly results in a no operation (although status bits may be affected). An effective 9-bit address is obtained by concatenating the 8-bit FSR register and the IRP bit (Status<7>) as shown in Figure 2-6.

A simple program to clear RAM locations 20h-2Fh using indirect addressing is shown in Example 2-2.

EXAMPLE 2-2: INDIRECT ADDRESSING

```
         MOVLW  0x20    ;initialize pointer
         MOVWF  FSR     ;to RAM
NEXT     CLRF   INDF    ;clear INDF register
         INCF   FSR,F   ;inc pointer
         BTFSS  FSR,4   ;all done?
         GOTO   NEXT    ;no clear next
CONTINUE
         :              ;yes continue
```

FIGURE 2-6: DIRECT/INDIRECT ADDRESSING



Note 1: For register file map detail, see Figure 2-3.

3.0 DATA EEPROM AND FLASH PROGRAM MEMORY

The data EEPROM and Flash program memory is readable and writable during normal operation (over the full VDD range). This memory is not directly mapped in the register file space. Instead, it is indirectly addressed through the Special Function Registers. There are six SFRs used to read and write this memory:

- EECON1
- EECON2
- EEDATA
- EEDATH
- EEADR
- EEADRH

When interfacing to the data memory block, EEDATA holds the 8-bit data for read/write and EEADR holds the address of the EEPROM location being accessed. These devices have 128 or 256 bytes of data EEPROM (depending on the device), with an address range from 00h to FFh. On devices with 128 bytes, addresses from 80h to FFh are unimplemented and will wraparound to the beginning of data EEPROM memory. When writing to unimplemented locations, the on-chip charge pump will be turned off.

When interfacing the program memory block, the EEDATA and EEDATH registers form a two-byte word that holds the 14-bit data for read/write and the EEADR and EEADRH registers form a two-byte word that holds the 13-bit address of the program memory location being accessed. These devices have 4 or 8K words of program Flash, with an address range from 0000h to 0FFFh for the PIC16F873A/874A and 0000h to 1FFFh for the PIC16F876A/877A. Addresses above the range of the respective device will wraparound to the beginning of program memory.

The EEPROM data memory allows single-byte read and write. The Flash program memory allows single-word reads and four-word block writes. Program memory write operations automatically perform an erase-before-write on blocks of four words. A byte write in data EEPROM memory automatically erases the location and writes the new data (erase-before-write).

The write time is controlled by an on-chip timer. The write/erase voltages are generated by an on-chip charge pump, rated to operate over the voltage range of the device for byte or word operations.

When the device is code-protected, the CPU may continue to read and write the data EEPROM memory. Depending on the settings of the write-protect bits, the device may or may not be able to write certain blocks of the program memory; however, reads of the program memory are allowed. When code-protected, the device programmer can no longer access data or program memory; this does NOT inhibit internal reads or writes.

3.1 EEADR and EEADRH

The EEADRH:EEADR register pair can address up to a maximum of 256 bytes of data EEPROM or up to a maximum of 8K words of program EEPROM. When selecting a data address value, only the LSByte of the address is written to the EEADR register. When selecting a program address value, the MSByte of the address is written to the EEADRH register and the LSByte is written to the EEADR register.

If the device contains less memory than the full address reach of the address register pair, the Most Significant bits of the registers are not implemented. For example, if the device has 128 bytes of data EEPROM, the Most Significant bit of EEADR is not implemented or access to data EEPROM.

3.2 EECON1 and EECON2 Registers

EECON1 is the control register for memory accesses.

Control bit, EEPGD, determines if the access will be a program or data memory access. When clear, as it is when reset, any subsequent operations will operate on the data memory. When set, any subsequent operations will operate on the program memory.

Control bits, RD and WR, initiate read and write or erase, respectively. These bits cannot be cleared, only set, in software. They are cleared in hardware at completion of the read or write operation. The inability to clear the WR bit in software prevents the accidental, premature termination of a write operation.

The WREN bit, when set, will allow a write or erase operation. On power-up, the WREN bit is clear. The WRERR bit is set when a write (or erase) operation is interrupted by a $\overline{MCLR}$ or a WDT Time-out Reset during normal operation. In these situations, following Reset, the user can check the WRERR bit and rewrite the location. The data and address will be unchanged in the EEDATA and EEADR registers.

Interrupt flag bit, EEIF in the PIR2 register, is set when the write is complete. It must be cleared in software.

EECON2 is not a physical register. Reading EECON2 will read all '0's. The EECON2 register is used exclusively in the EEPROM write sequence.

Note:	The self-programming mechanism for Flash program memory has been changed. On previous PIC16F87X devices, Flash programming was done in single-word erase/write cycles. The newer PIC18F87XA devices use a four-word erase/write cycle. See **Section 3.6 "Writing to Flash Program Memory"** for more information.

REGISTER 3-1: EECON1 REGISTER (ADDRESS 18Ch)

R/W-x	U-0	U-0	U-0	R/W-x	R/W-0	R/S-0	R/S-0
EEPGD	—	—	—	WRERR	WREN	WR	RD
bit 7							bit 0

bit 7 **EEPGD**: Program/Data EEPROM Select bit
1 = Accesses program memory
0 = Accesses data memory
Reads '0' after a POR; this bit cannot be changed while a write operation is in progress.

bit 6-4 **Unimplemented:** Read as '0'

bit 3 **WRERR:** EEPROM Error Flag bit
1 = A write operation is prematurely terminated (any $\overline{MCLR}$ or any WDT Reset during normal operation)
0 = The write operation completed

bit 2 **WREN:** EEPROM Write Enable bit
1 = Allows write cycles
0 = Inhibits write to the EEPROM

bit 1 **WR:** Write Control bit
1 = Initiates a write cycle. The bit is cleared by hardware once write is complete. The WR bit can only be set (not cleared) in software.
0 = Write cycle to the EEPROM is complete

bit 0 **RD:** Read Control bit
1 = Initiates an EEPROM read; RD is cleared in hardware. The RD bit can only be set (not cleared) in software.
0 = Does not initiate an EEPROM read

Legend:			
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
- n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

3.3 Reading Data EEPROM Memory

To read a data memory location, the user must write the address to the EEADR register, clear the EEPGD control bit (EECON1<7>) and then set control bit RD (EECON1<0>). The data is available in the very next cycle in the EEDATA register; therefore, it can be read in the next instruction (see Example 3-1). EEDATA will hold this value until another read or until it is written to by the user (during a write operation).

The steps to reading the EEPROM data memory are:

1. Write the address to EEADR. Make sure that the address is not larger than the memory size of the device.
2. Clear the EEPGD bit to point to EEPROM data memory.
3. Set the RD bit to start the read operation.
4. Read the data from the EEDATA register.

EXAMPLE 3-1: DATA EEPROM READ

```
BSF     STATUS,RP1         ;
BCF     STATUS,RP0         ; Bank 2
MOVF    DATA_EE_ADDR,W     ; Data Memory
MOVWF   EEADR              ; Address to read
BSF     STATUS,RP0         ; Bank 3
BCF     EECON1,EEPGD       ; Point to Data
                           ; memory
BSF     EECON1,RD          ; EE Read
BCF     STATUS,RP0         ; Bank 2
MOVF    EEDATA,W           ; W = EEDATA
```

3.4 Writing to Data EEPROM Memory

To write an EEPROM data location, the user must first write the address to the EEADR register and the data to the EEDATA register. Then the user must follow a specific write sequence to initiate the write for each byte.

The write will not initiate if the write sequence is not exactly followed (write 55h to EECON2, write AAh to EECON2, then set WR bit) for each byte. We strongly recommend that interrupts be disabled during this code segment (see Example 3-2).

Additionally, the WREN bit in EECON1 must be set to enable write. This mechanism prevents accidental writes to data EEPROM due to errant (unexpected) code execution (i.e., lost programs). The user should keep the WREN bit clear at all times, except when updating EEPROM. The WREN bit is not cleared by hardware

After a write sequence has been initiated, clearing the WREN bit will not affect this write cycle. The WR bit will be inhibited from being set unless the WREN bit is set. At the completion of the write cycle, the WR bit is cleared in hardware and the EE Write Complete Interrupt Flag bit (EEIF) is set. The user can either enable this interrupt or poll this bit. EEIF must be cleared by software.

The steps to write to EEPROM data memory are:

1. If step 10 is not implemented, check the WR bit to see if a write is in progress.
2. Write the address to EEADR. Make sure that the address is not larger than the memory size of the device.
3. Write the 8-bit data value to be programmed in the EEDATA register.
4. Clear the EEPGD bit to point to EEPROM data memory.
5. Set the WREN bit to enable program operations.
6. Disable interrupts (if enabled).
7. Execute the special five instruction sequence:
   - Write 55h to EECON2 in two steps (first to W, then to EECON2)
   - Write AAh to EECON2 in two steps (first to W, then to EECON2)
   - Set the WR bit
8. Enable interrupts (if using interrupts).
9. Clear the WREN bit to disable program operations.
10. At the completion of the write cycle, the WR bit is cleared and the EEIF interrupt flag bit is set. (EEIF must be cleared by firmware.) If step 1 is not implemented, then firmware should check for EEIF to be set, or WR to clear, to indicate the end of the program cycle.

EXAMPLE 3-2: DATA EEPROM WRITE

```
          BSF     STATUS,RP1         ;
          BSF     STATUS,RP0
          BTFSC   EECON1,WR          ;Wait for write
          GOTO    $-1                ;to complete
          BCF     STATUS, RP0        ;Bank 2
          MOVF    DATA_EE_ADDR,W     ;Data Memory
          MOVWF   EEADR              ;Address to write
          MOVF    DATA_EE_DATA,W     ;Data Memory Value
          MOVWF   EEDATA             ;to write
          BSF     STATUS,RP0         ;Bank 3
          BCF     EECON1,EEPGD       ;Point to DATA
                                     ;memory
          BSF     EECON1,WREN        ;Enable writes

          BCF     INTCON,GIE         ;Disable INTs.
Required  MOVLW   55h                ;
Sequence  MOVWF   EECON2             ;Write 55h
          MOVLW   AAh                ;
          MOVWF   EECON2             ;Write AAh
          BSF     EECON1,WR          ;Set WR bit to
                                     ;begin write
          BSF     INTCON,GIE         ;Enable INTs.
          BCF     EECON1,WREN        ;Disable writes
```

3.5 Reading Flash Program Memory

To read a program memory location, the user must write two bytes of the address to the EEADR and EEADRH registers, set the EEPGD control bit (EECON1<7>) and then set control bit RD (EECON1<0>). Once the read control bit is set, the program memory Flash controller will use the next two instruction cycles to read the data. This causes these two instructions immediately following the "BSF EECON1,RD" instruction to be ignored. The data is available in the very next cycle in the EEDATA and EEDATH registers; therefore, it can be read as two bytes in the following instructions. EEDATA and EEDATH registers will hold this value until another read or until it is written to by the user (during a write operation).

EXAMPLE 3-3: FLASH PROGRAM READ

```
         BSF     STATUS, RP1        ;
         BCF     STATUS, RP0        ; Bank 2
         MOVLW   MS_PROG_EE_ADDR    ;
         MOVWF   EEADRH             ; MS Byte of Program Address to read
         MOVLW   LS_PROG_EE_ADDR    ;
         MOVWF   EEADR              ; LS Byte of Program Address to read
         BSF     STATUS, RP0        ; Bank 3
         BSF     EECON1, EEPGD      ; Point to PROGRAM memory
         BSF     EECON1, RD         ; EE Read
Required ;
Sequence NOP
         NOP                        ; Any instructions here are ignored as program
                                    ; memory is read in second cycle after BSF EECON1,RD
         ;
         BCF     STATUS, RP0        ; Bank 2
         MOVF    EEDATA, W          ; W = LS Byte of Program EEDATA
         MOVWF   DATAL              ;
         MOVF    EEDATH, W          ; W = MS Byte of Program EEDATA
         MOVWF   DATAH              ;
```

3.6 Writing to Flash Program Memory

Flash program memory may only be written to if the destination address is in a segment of memory that is not write-protected, as defined in bits WRT1:WRT0 of the device configuration word (Register 14-1). Flash program memory must be written in four-word blocks. A block consists of four words with sequential addresses, with a lower boundary defined by an address, where EEADR<1:0> = 00. At the same time, all block writes to program memory are done as erase and write operations. The write operation is edge-aligned and cannot occur across boundaries.

To write program data, it must first be loaded into the buffer registers (see Figure 3-1). This is accomplished by first writing the destination address to EEADR and EEADRH and then writing the data to EEDATA and EEDATH. After the address and data have been set up, then the following sequence of events must be executed:

1. Set the EEPGD control bit (EECON1<7>).
2. Write 55h, then AAh, to EECON2 (Flash programming sequence).
3. Set the WR control bit (EECON1<1>).

All four buffer register locations **MUST** be written to with correct data. If only one, two or three words are being written to in the block of four words, then a read from the program memory location(s) not being written to must be performed. This takes the data from the program location(s) not being written and loads it into the EEDATA and EEDATH registers. Then the sequence of events to transfer data to the buffer registers must be executed.

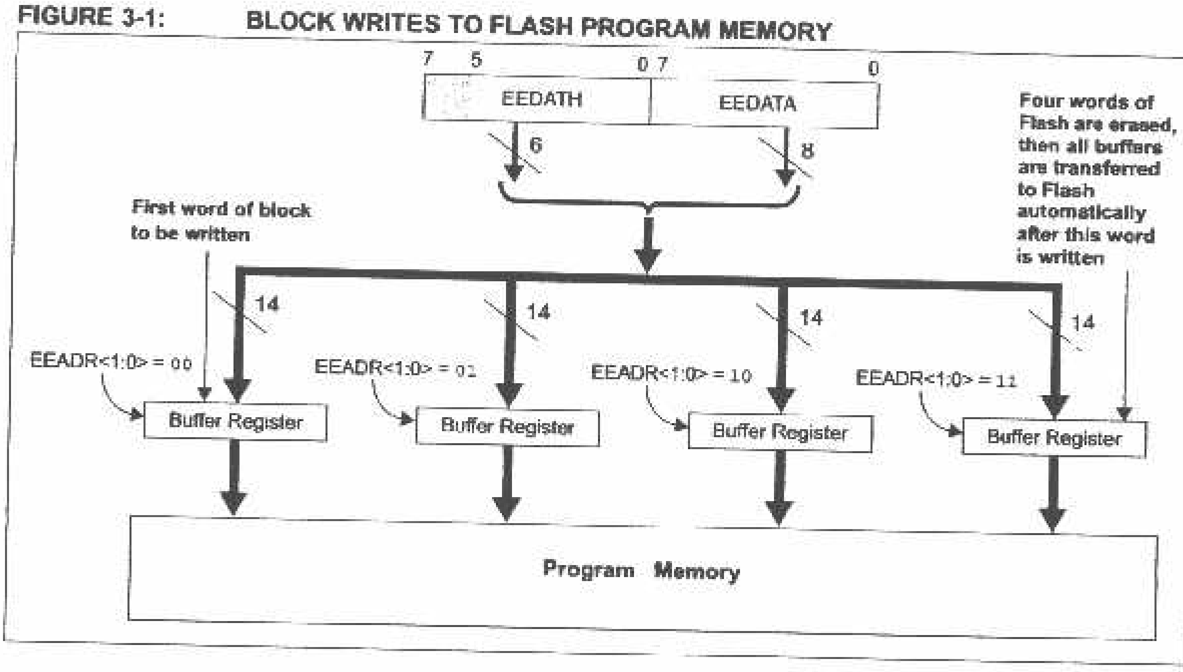
To transfer data from the buffer registers to the program memory, the EEADR and EEADRH must point to the last location in the four-word block (EEADR<1:0> = 11). Then the following sequence of events must be executed:

1. Set the EEPGD control bit (EECON1<7>).
2. Write 55h, then AAh, to EECON2 (Flash programming sequence).
3. Set control bit WR (EECON1<1>) to begin the write operation.

The user must follow the same specific sequence to initiate the write for each word in the program block, writing each program word in sequence (00, 01, 10, 11). When the write is performed on the last word (EEADR<1:0> = 11), the block of four words are automatically erased and the contents of the buffer registers are written into the program memory.

After the "BSF EECON1, WR" instruction, the processor requires two cycles to set up the erase/write operation. The user must place two NOP instructions after the WR bit is set. Since data is being written to buffer registers, the writing of the first three words of the block appears to occur immediately. The processor will halt internal operations for the typical 4 ms, only during the cycle in which the erase takes place (i.e., the last word of the four-word block). This is not Sleep mode as the clocks and peripherals will continue to run. After the write cycle, the processor will resume operation with the third instruction after the EECON1 write instruction. If the sequence is performed to any other location, the action is ignored.

FIGURE 3-1: BLOCK WRITES TO FLASH PROGRAM MEMORY



DATASHEET

MAX232

Table of Contents

5 Revision History

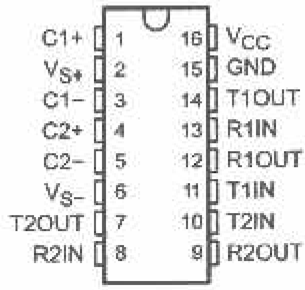
Changes from Revision L (March 2004) to Revision M | **Page**

- Removed Ordering Information table. 1
- Added Handling Rating table, Feature Description section, Device Functional Modes, Application and Implementation section, Power Supply Recommendations section, Layout section, Device and Documentation Support section, and Mechanical, Packaging, and Orderable Information section. 1
- Moved T_{stg} to Handling Ratings table. 4

6 Pin Configuration and Functions

Top View

MAX232 . . . D, DW, N, OR NS PACKAGE
MAX232I . . . D, DW, OR N PACKAGE
(TOP VIEW)



Pin Functions

PIN		TYPE	DESCRIPTION
NAME	NO.		
C1+	1	—	Positive lead of C1 capacitor
VS+	2	O	Positive charge pump output for storage capacitor only
C1-	3	—	Negative lead of C1 capacitor
C2+	4	—	Positive lead of C2 capacitor
C2-	5	—	Negative lead of C2 capacitor
VS-	6	O	Negative charge pump output for storage capacitor only
T2OUT, T1OUT	7, 14	O	RS232 line data output (to remote RS232 system)
R2IN, R1IN	8, 13	I	RS232 line data input (from remote RS232 system)
R2OUT, R1OUT	9, 12	O	Logic data output (to UART)
T2IN, T1IN	10, 11	I	Logic data input (from UART)
GND	15	—	Ground
V_{CC}	16	—	Supply Voltage, Connect to external 5V power supply

7 Specifications

7.1 Absolute Maximum Ratings[1]

over operating free-air temperature range (unless otherwise noted)

			MIN	MAX	UNIT
V_{CC}	Input Supply voltage range[2]		–0.3	6	V
V_{S+}	Positive output supply voltage range		V_{CC} – 0.3	15	V
V_{S-}	Negative output supply voltage range		–0.3	–15	V
V_I	Input voltage range	T1IN, T2IN	–0.3	V_{CC} + 0.3	V
		R1IN, R2IN		±30	
V_O	Output voltage range	T1OUT, T2OUT	V_{S-} – 0.3	V_{S+} + 0.3	V
		R1OUT, R2OUT	–0.3	V_{CC} + 0.3	
	Short-circuit duration	T1OUT, T2OUT	Unlimited		
T_J	Operating virtual junction temperature			150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) All voltages are with respect to network GND.

7.2 Handling Ratings

			MIN	MAX	UNIT
T_{stg}	Storage temperature range		-65	150	°C
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins[1]	0	2000	V
		Charged device model (CDM), per JEDEC specification JESD22-C101, all pins[2]	0	1000	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

7.3 Recommended Operating Conditions

			MIN	NOM	MAX	UNIT
V_{CC}	Supply voltage		4.5	5	5.5	V
V_{IH}	High-level input voltage (T1IN,T2IN)		2			V
V_{IL}	Low-level input voltage (T1IN, T2IN)				0.8	V
R1IN, R2IN	Receiver input voltage				±30	V
T_A	Operating free-air temperature	MAX232	0		70	°C
		MAX232I	–40		85	

7.4 Thermal Information

THERMAL METRIC[1]		MAX232xD	MAX232xDW	MAX232xN	MAX232xNS	UNIT
		SOIC	SOIC wide	PDIP	SOP	
		16 PINS	16 PINS	16 PINS	16 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	73	57	67	64	°C/W

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report (SPRA953).

7.5 Electrical Characteristics — Device

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted) (see Figure 6)

PARAMETER		TEST CONDITIONS[1]	MIN	TYP[2]	MAX	UNIT
I_{CC}	Supply current	V_{CC} = 5.5V, all outputs open, T_A = 25°C		8	10	mA

(1) Test conditions are C1–C4 = 1 µF at V_{CC} = 5 V ± 0.5 V
(2) All typical values are at V_{CC} = 5 V, and T_A = 25°C.

7.6 Electrical Characteristics — Driver

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

PARAMETER			TEST CONDITIONS(1)	MIN	TYP(2)	MAX	UNIT
V_{OH}	High-level output voltage	T1OUT, T2OUT	R_L = 3 kΩ to GND	5	7		V
V_{OL}	Low-level output voltage(3)	T1OUT, T2OUT	R_L = 3 kΩ to GND		–7	–5	V
r_O	Output resistance	T1OUT, T2OUT	$V_{S+} = V_{S-} = 0$, $V_O = \pm 2$ V	300			Ω
I_{OS}(4)	Short-circuit output current	T1OUT, T2OUT	V_{CC} = 5.5 V, V_O = 0 V		±10		mA
I_{IS}	Short-circuit input current	T1IN, T2IN	V_I = 0			200	μA

(1) Test conditions are C1–C4 = 1 μF at V_{CC} = 5 V ± 0.5 V
(2) All typical values are at V_{CC} = 5 V, T_A = 25°C.
(3) The algebraic convention, in which the least-positive (most negative) value is designated minimum, is used in this data sheet for logic voltage levels only.
(4) Not more than one output should be shorted at a time.

7.7 Electrical Characteristics — Receiver

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

PARAMETER			TEST CONDITIONS(1)	MIN	TYP(2)	MAX	UNIT
V_{OH}	High-level output voltage	R1OUT, R2OUT	I_{OH} = –1 mA	3.5			V
V_{OL}	Low-level output voltage(3)	R1OUT, R2OUT	I_{OL} = 3.2 mA			0.4	V
V_{IT+}	Receiver positive-going input threshold voltage	R1IN, R2IN	V_{CC} = 5 V, T_A = 25°C		1.7	2.4	V
V_{IT-}	Receiver negative-going input threshold voltage	R1IN, R2IN	V_{CC} = 5 V, T_A = 25°C	0.8	1.2		V
V_{hys}	Input hysteresis voltage	R1IN, R2IN	V_{CC} = 5 V	0.2	0.5	1	V
r_i	Receiver input resistance	R1IN, R2IN	V_{CC} = 5 V, T_A = 25°C	3	5	7	kΩ

(1) Test conditions are C1–C4 = 1 μF at V_{CC} = 5 V ± 0.5 V.
(2) All typical values are at V_{CC} = 5 V, T_A = 25°C.
(3) The algebraic convention, in which the least-positive (most negative) value is designated minimum, is used in this data sheet for logic voltage levels only.

7.8 Switching Characteristics

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS(1)	MIN	TYP(1)	MAX	UNIT
SR	Driver slew rate	RL = 3 kΩ to 7 kΩ, see Figure 4			30	V/μs
SR(t)	Driver transition region slew rate	see Figure 5		3		V/μs
	Data rate	One TOUT switching		120		kbit/s
$t_{PLH(R)}$	Receiver propagation delay time, low- to high-level output	TTL load, see Figure 3		500		ns
$t_{PHL(R)}$	Receiver propagation delay time, high- to low-level output	TTL load, see Figure 3		500		ns

(1) Test conditions are C1–C4 = 1 μF at V_{CC} = 5 V ± 0.5 V.

7.9 Typical Characteristics

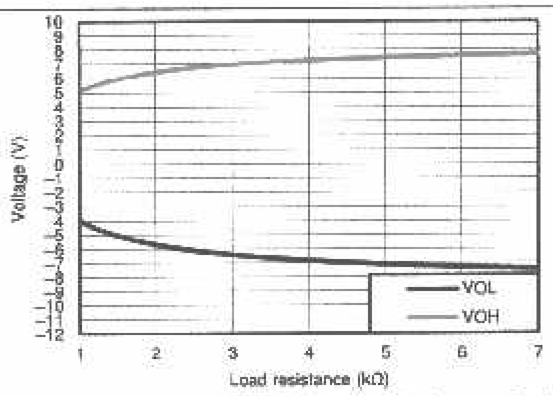


Figure 1. TOUT VOH & VOL vs Load Resistance, Both Drivers Loaded

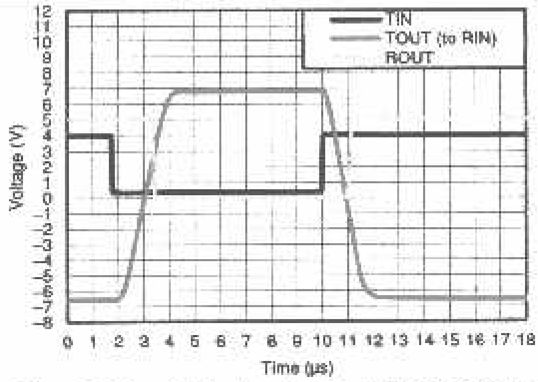
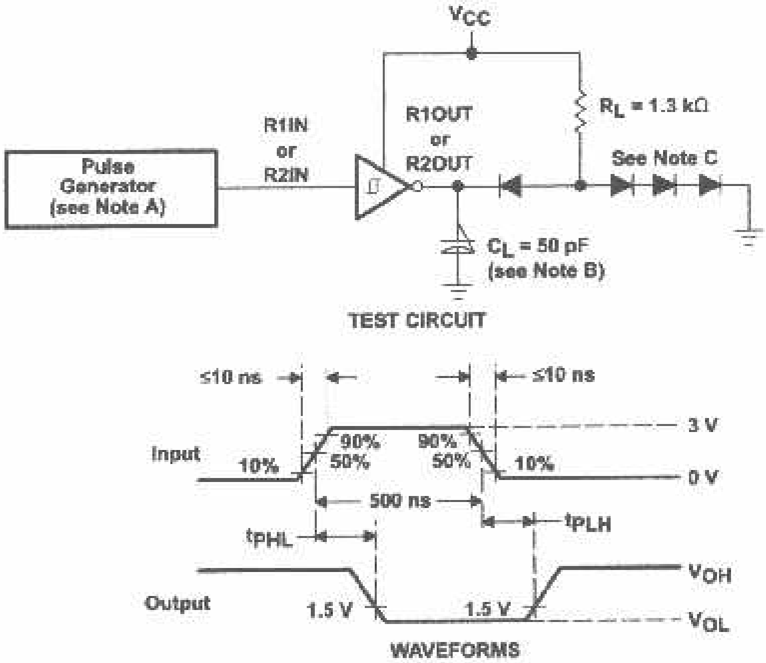


Figure 2. Driver to Receiver Loopback Timing Waveform

8 Parameter Measurement Information



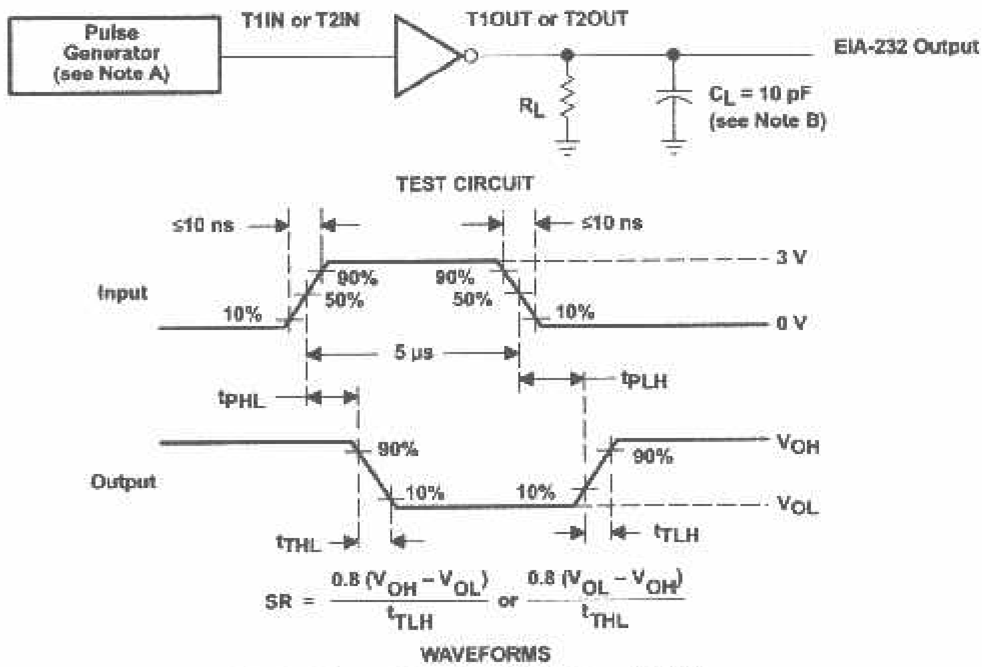
A. The pulse generator has the following characteristics: Z_O = 50 Ω, duty cycle ≤ 50%.

B. C_L includes probe and jig capacitance.

C. All diodes are 1N3064 or equivalent.

Figure 3. Receiver Test Circuit and Waveforms for t_{PHL} and t_{PLH} Measurements

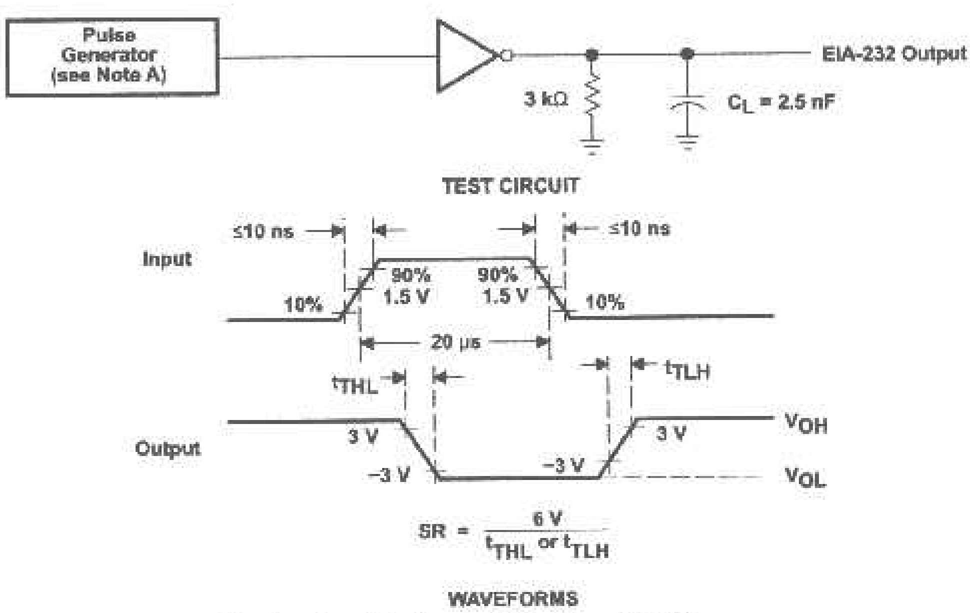
Parameter Measurement Information (continued)



A. The pulse generator has the following characteristics: Z_O = 50 Ω, duty cycle ≤ 50%.

B. C_L includes probe and jig capacitance.

Figure 4. Driver Test Circuit and Waveforms for t_{PHL} and t_{PLH} Measurements (5-µs Input)



A. The pulse generator has the following characteristics: Z_O = 50 Ω, duty cycle ≤ 50%.

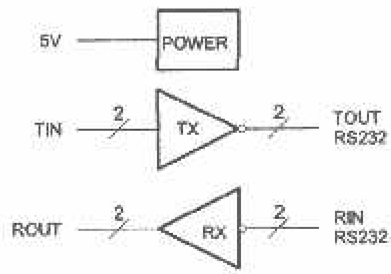
Figure 5. Test Circuit and Waveforms for t_{THL} and t_{TLH} Measurements (20-µs Input)

9 Detailed Description

9.1 Overview

The MAX232 device is a dual driver/receiver that includes a capacitive voltage generator using four capacitors to supply TIA/EIA-232-F voltage levels from a single 5-V supply. Each receiver converts TIA/EIA-232-F inputs to 5-V TTL/CMOS levels. These receivers have a typical threshold of 1.3 V, a typical hysteresis of 0.5 V, and can accept ±30-V inputs. Each driver converts TTL/CMOS input levels into TIA/EIA-232-F levels. The driver, receiver, and voltage-generator functions are available as cells in the Texas Instruments LinASIC™ library. Outputs are protected against shorts to ground.

9.2 Functional Block Diagram



9.3 Feature Description

9.3.1 Power

The power block increases and inverts the 5V supply for the RS232 driver using a charge pump that requires four 1-µF external capacitors.

9.3.2 RS232 Driver

Two drivers interface standard logic level to RS232 levels. Internal pull up resistors on TIN inputs ensures a high input when the line is high impedance.

9.3.3 RS232 Receiver

Two receivers interface RS232 levels to standard logic levels. An open input will result in a high output on ROUT.

9.4 Device Functional Modes

9.4.1 V_{CC} powered by 5V

The device will be in normal operation.

9.4.2 V_{CC} unpowered

When MAX232 is unpowered, it can be safely connected to an active remote RS232 device.

Table 1. Function Table Each Driver(1)

INPUT TIN	OUTPUT TOUT
L	H
H	L

(1) H = high level, L = low level, X = irrelevant, Z = high impedance

Table 2. Function Table Each Receiver[1]

INPUTS RIN	OUTPUT ROUT
L	H
H	L
Open	H

(1) H = high level, L = low level, X = irrelevant, Z = high impedance (off), Open = disconnected input or connected driver off

10 Application and Implementation

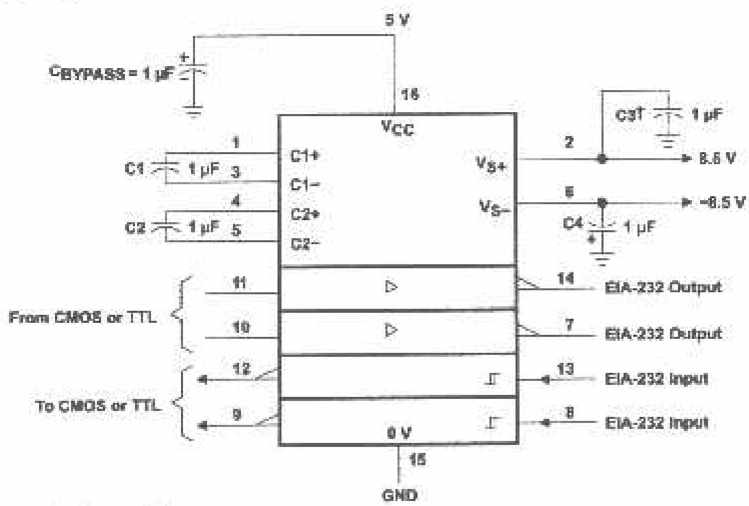
NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

10.1 Application Information

For proper operation add capacitors as shown in Figure 6. Pins 9 through 12 connect to UART or general purpose logic lines. EIA-232 lines will connect to a connector or cable.

10.2 Typical Application



† C3 can be connected to V_{CC} or GND.

NOTES: A. Resistor values shown are nominal.

B. Nonpolarized ceramic capacitors are acceptable. If polarized tantalum or electrolytic capacitors are used, they should be connected as shown. In addition to the 1-µF capacitors shown, the MAX202 can operate with 0.1-µF capacitors.

Figure 6. Typical Operating Circuit

10.2.1 Design Requirements

- V_{CC} minimum is 4.5 V and maximum is 5.5 V.
- Maximum recommended bit rate is 120 kbps.

10.2.2 Detailed Design Procedure

Use 1 uF tantalum or ceramic capacitors.

Typical Application (continued)

10.2.3 Application Curves

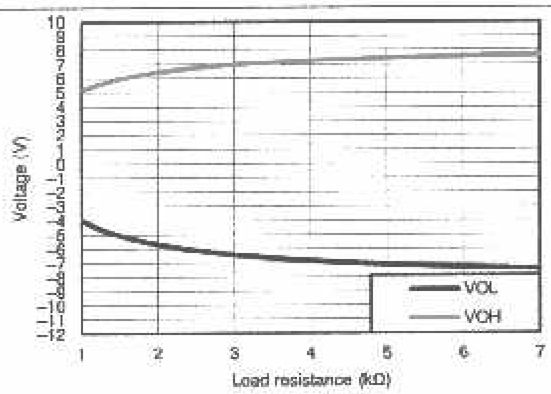


Figure 7. TOUT VOH & VOL vs Load Resistance, Both Drivers Loaded

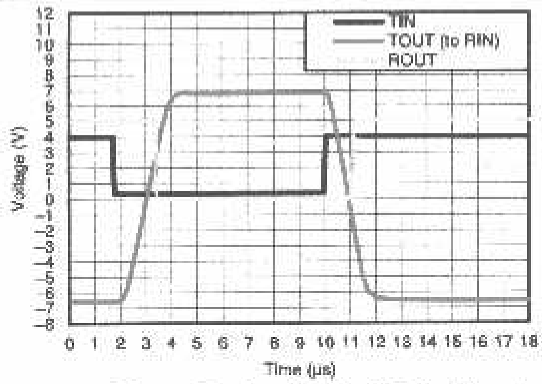


Figure 8. Driver to Receiver Loopback Timing Waveform

11 Power Supply Recommendations

The V_{CC} voltage should be connected to the same power source used for logic device connected to TIN pins. V_{CC} should be between 4.5V and 5.5V.

12 Layout

12.1 Layout Guidelines

Keep the external capacitor traces short. This is more important on C1 and C2 nodes that have the fastest rise and fall times.

12.2 Layout Example

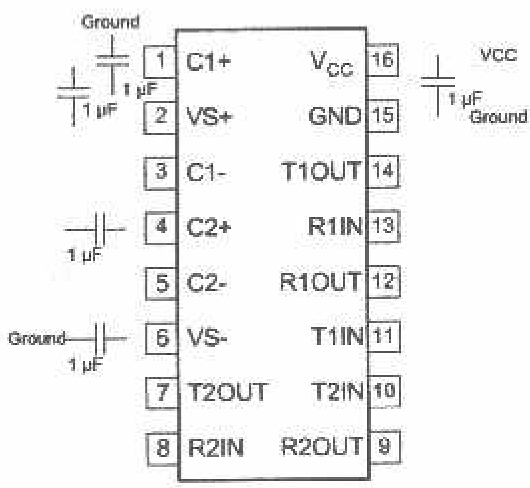


Figure 9. Layout Schematic

13 Device and Documentation Support

13.1 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

Table 3. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
MAX232	Click here	Click here	Click here	Click here	Click here
MAX232I	Click here	Click here	Click here	Click here	Click here

13.2 Trademarks

All trademarks are the property of their respective owners.

13.3 Electrostatic Discharge Caution

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

13.4 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms and definitions.

14 Mechanical, Packaging, and Orderable Information

The following pages include mechanical packaging and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser based versions of this data sheet, refer to the left hand navigation.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
MAX232D	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	MAX232	Samples
MAX232DE4	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	MAX232	Samples
MAX232DG4	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	MAX232	Samples
MAX232DR	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU | CU SN	Level-1-260C-UNLIM	0 to 70	MAX232	Samples
MAX232DRE4	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	MAX232	Samples
MAX232DRG4	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	MAX232	Samples
MAX232DW	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	MAX232	Samples
MAX232DWE4	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	MAX232	Samples
MAX232DWG4	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	MAX232	Samples
MAX232DWR	ACTIVE	SOIC	DW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU | CU SN	Level-1-260C-UNLIM	0 to 70	MAX232	Samples
MAX232DWRE4	ACTIVE	SOIC	DW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	MAX232	Samples
MAX232DWRG4	ACTIVE	SOIC	DW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	MAX232	Samples
MAX232ID	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	MAX232I	Samples
MAX232IDE4	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	MAX232I	Samples
MAX232IDG4	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	MAX232I	Samples
MAX232IDR	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	MAX232I	Samples
MAX232IDRG4	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	MAX232I	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
MAX232IDW	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	MAX232I	Samples
MAX232IDWG4	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	MAX232I	Samples
MAX232IDWR	ACTIVE	SOIC	DW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU | CU SN	Level-1-260C-UNLIM	-40 to 85	MAX232I	Samples
MAX232IDWRE4	ACTIVE	SOIC	DW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	MAX232I	Samples
MAX232IDWRG4	ACTIVE	SOIC	DW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	MAX232I	Samples
MAX232IN	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	-40 to 85	MAX232IN	Samples
MAX232INE4	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	-40 to 85	MAX232IN	Samples
MAX232N	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	0 to 70	MAX232N	Samples
MAX232NE4	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	0 to 70	MAX232N	Samples
MAX232NSR	ACTIVE	SO	NS	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	MAX232	Samples

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

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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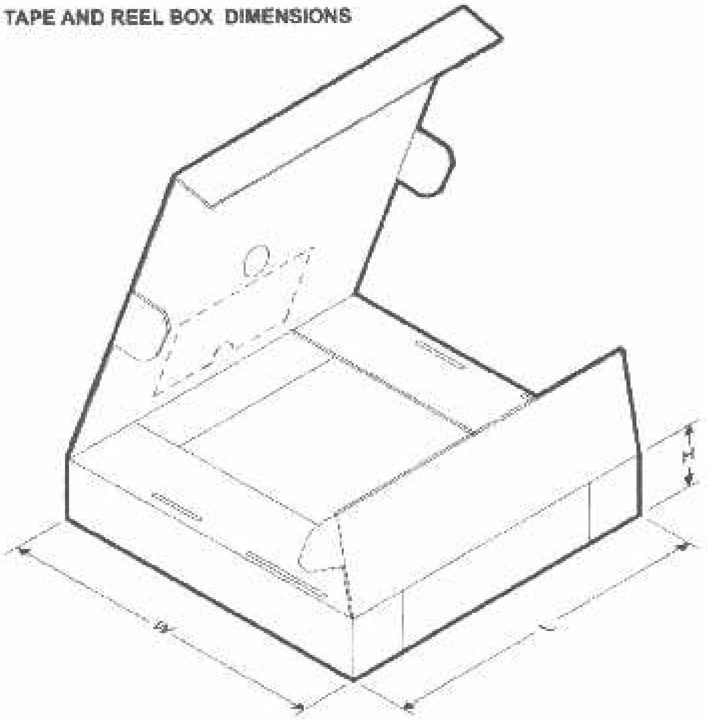
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

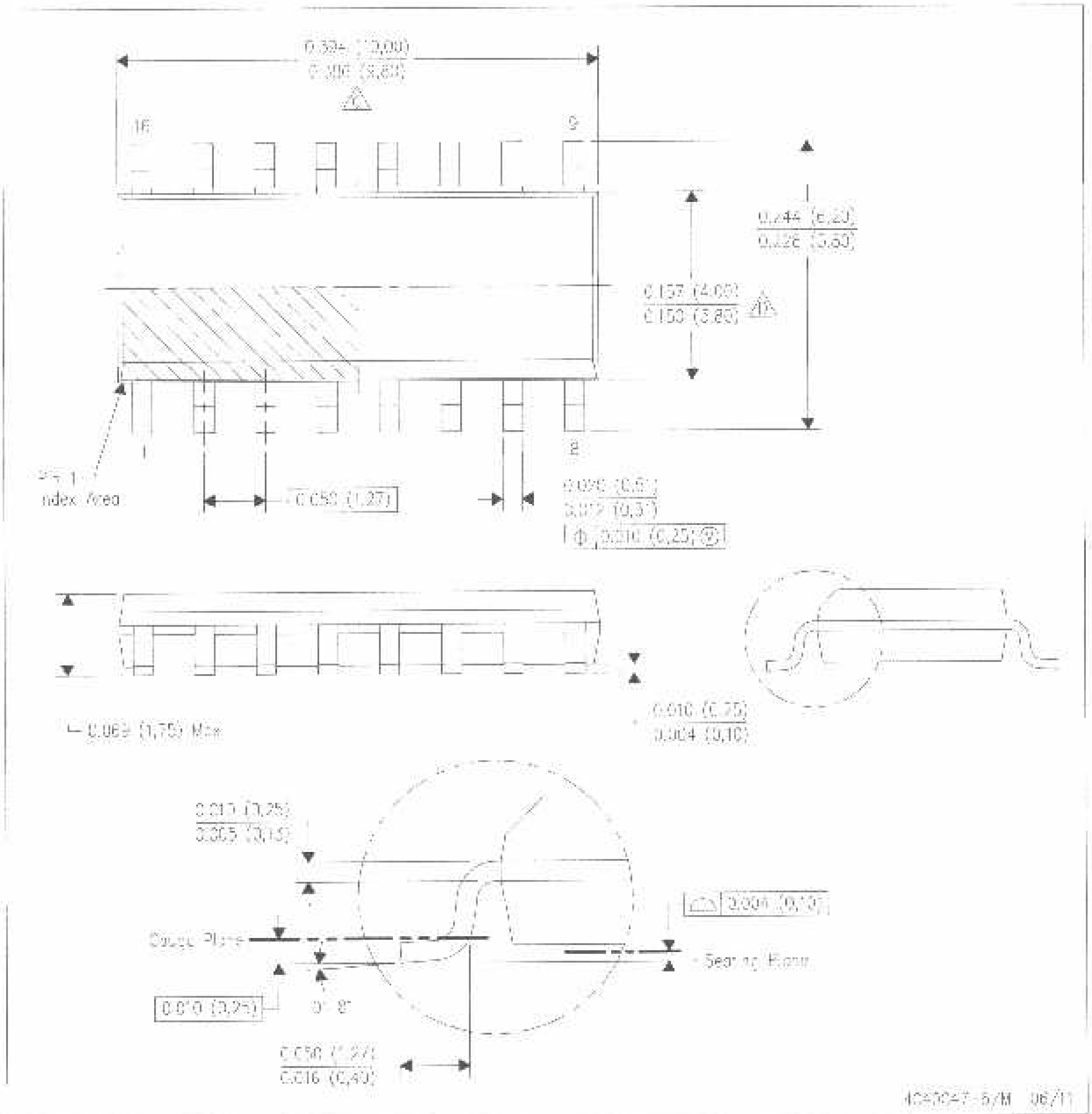
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

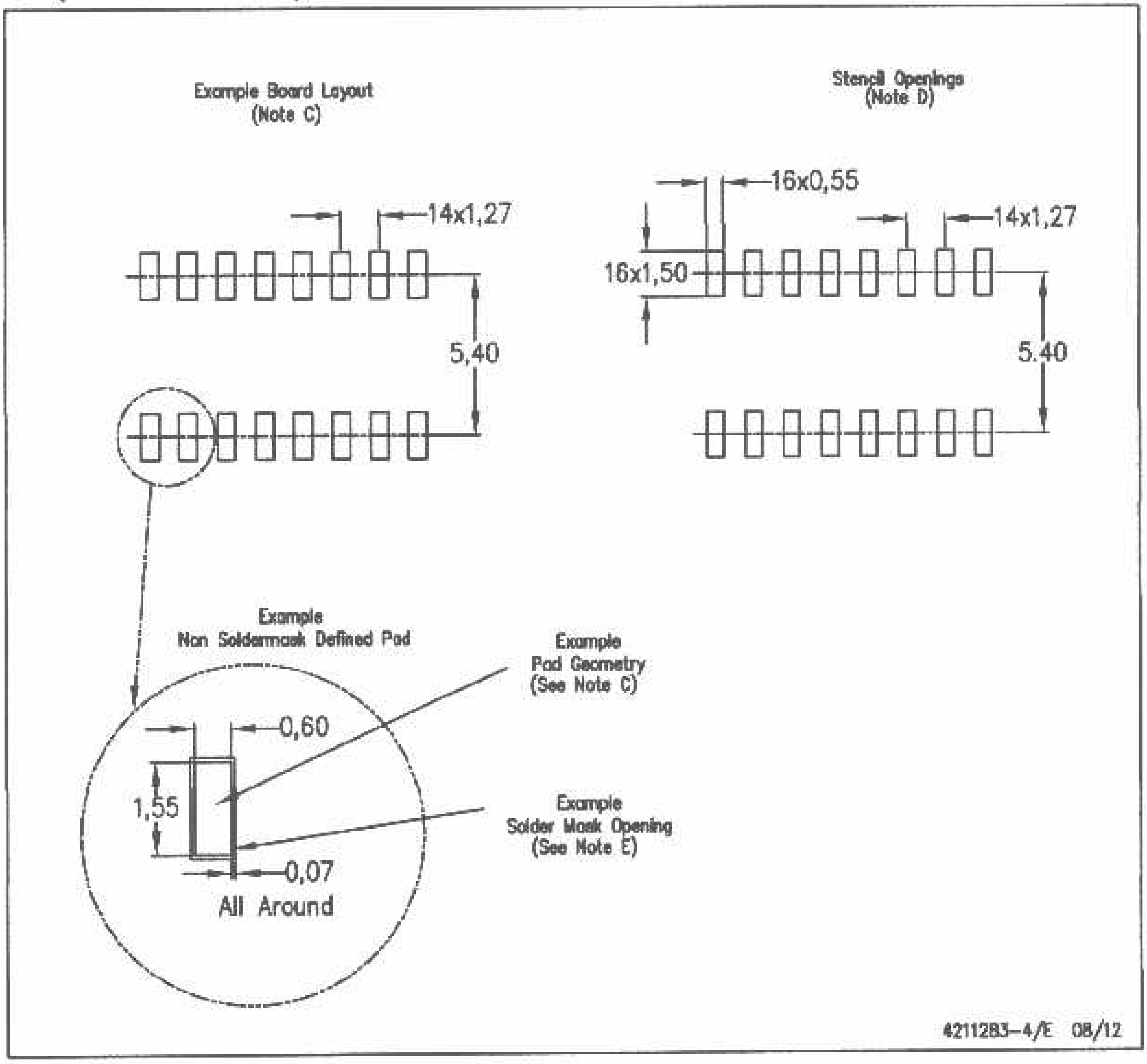
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
MAX232DR	SOIC	D	16	2500	333.2	345.9	28.6
MAX232DR	SOIC	D	16	2500	367.0	367.0	38.0
MAX232DRG4	SOIC	D	16	2500	333.2	345.9	28.6
MAX232DRG4	SOIC	D	16	2500	367.0	367.0	38.0
MAX232DWR	SOIC	DW	16	2000	367.0	367.0	38.0
MAX232DWRG4	SOIC	DW	16	2000	367.0	367.0	38.0
MAX232IDR	SOIC	D	16	2500	333.2	345.9	28.6
MAX232IDWR	SOIC	DW	16	2000	367.0	367.0	38.0
MAX232IDWRG4	SOIC	DW	16	2000	367.0	367.0	38.0

D (R-PDSO-G16) PLASTIC SMALL OUTLINE



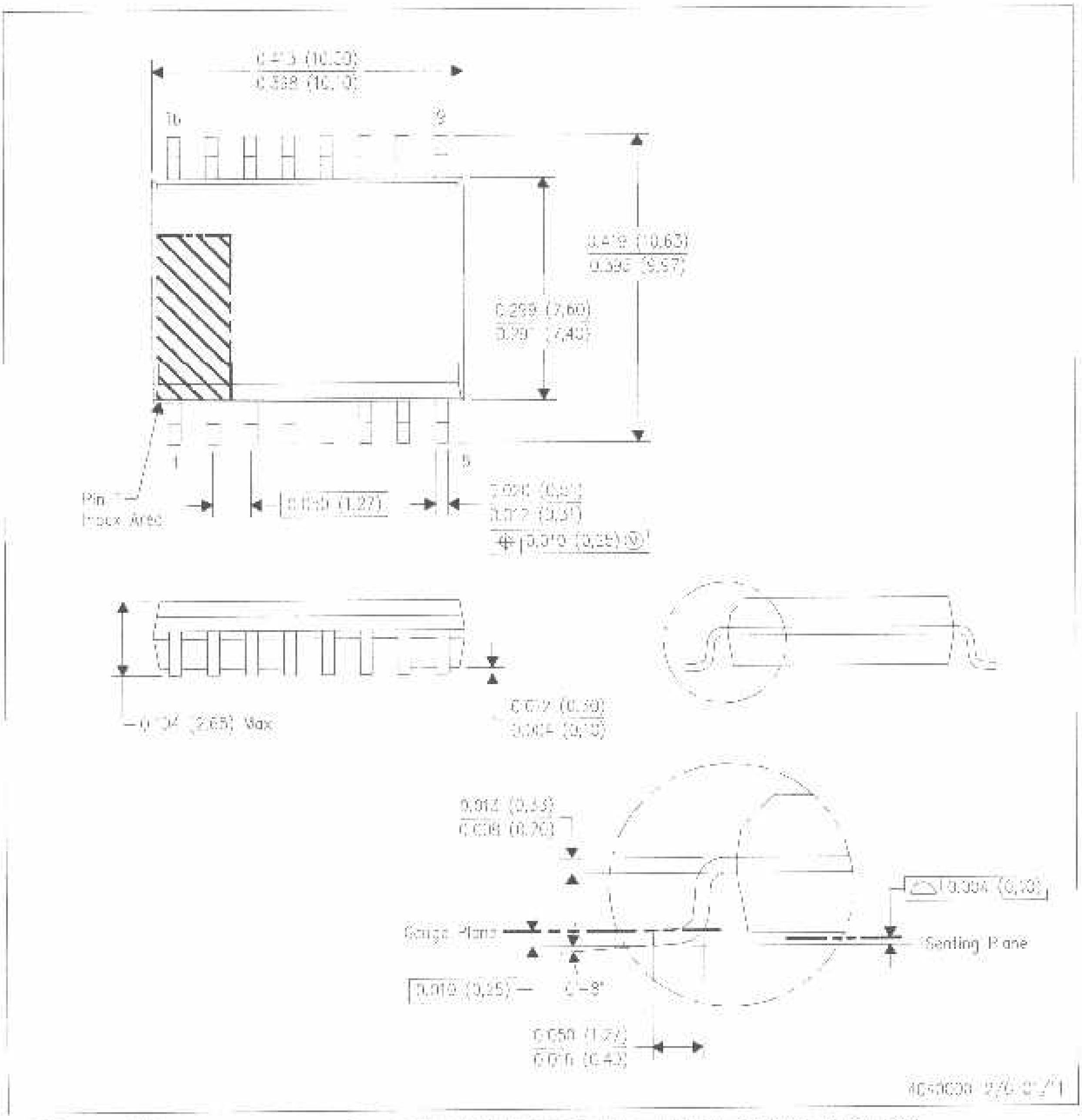
NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
D. Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
E. Reference JEDEC MS-012 variation AC.

D (R-PDSO-G16) PLASTIC SMALL OUTLINE



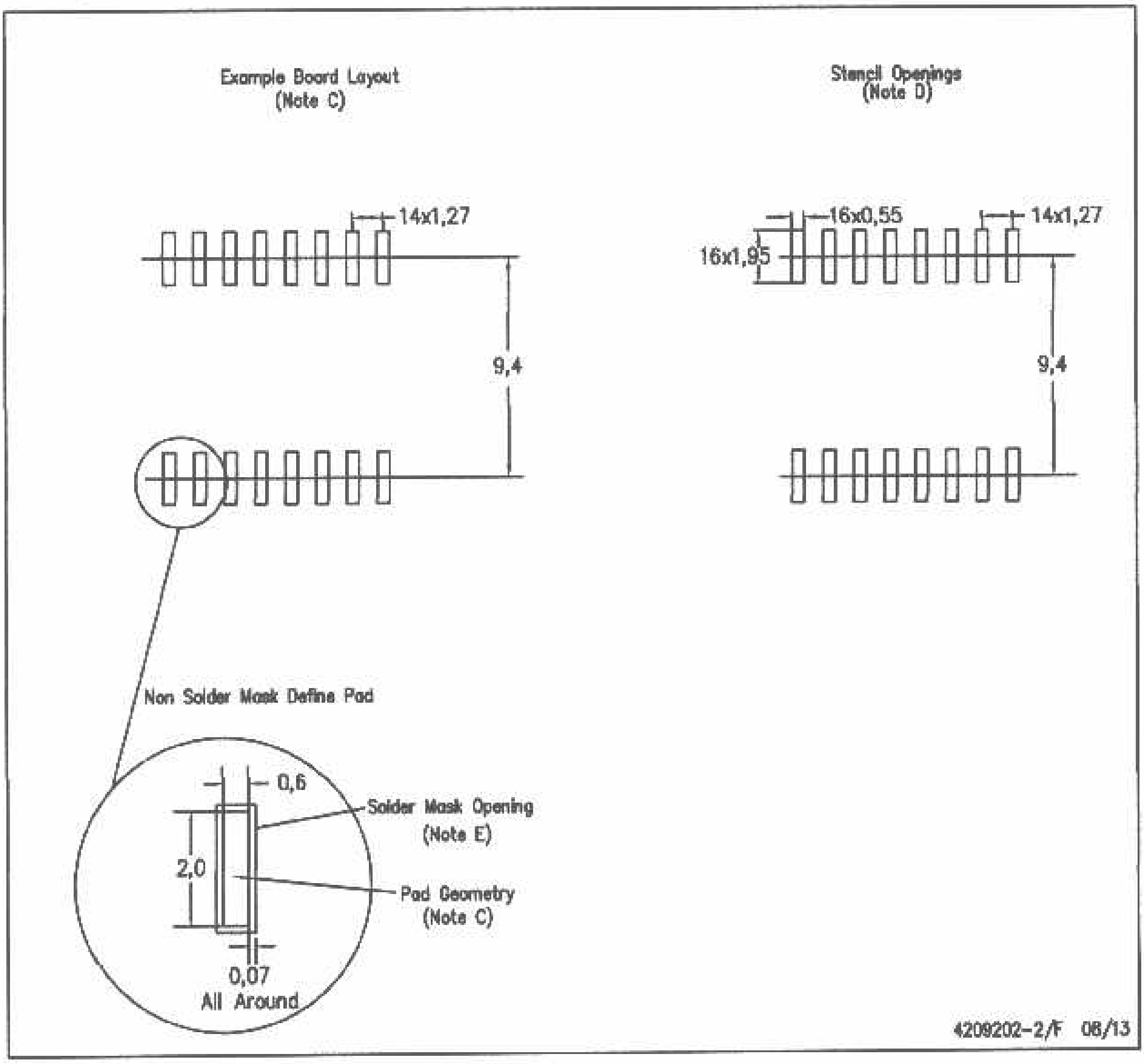
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC-7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

DW (R-PDSO-G16) PLASTIC SMALL-OUTLINE



NOTES:
A. All linear dimensions are in inches (millimeters). Dimensioning and tolerancing per ASME Y14.5M–1994.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).
D. Falls within JEDEC MS-013 variation AA.

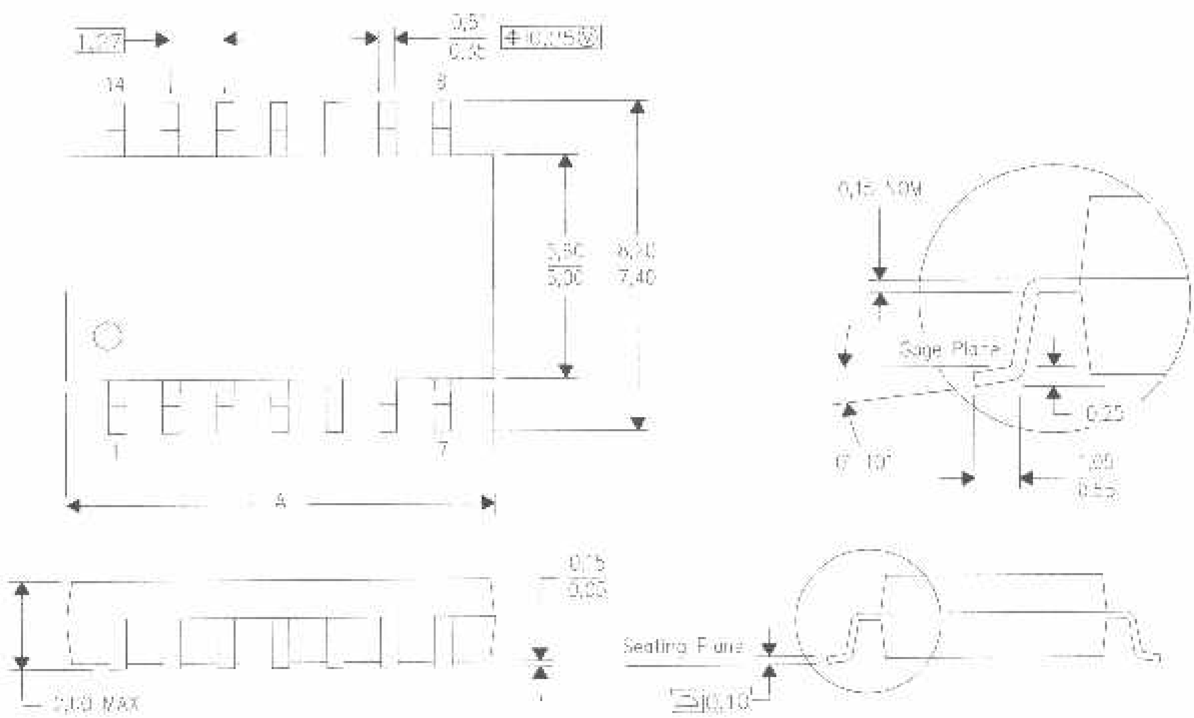
DW (R-PDSO-G16) PLASTIC SMALL OUTLINE



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Refer to IPC7351 for alternate board design.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

NS (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14-PINS SHOWN



PINS ** / DIM	14	16	20	24
A MAX	10,50	10,50	12,90	15,30
A MIN	9,90	9,90	12,30	14,70

4040062/C 03/03

NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0,15.

IMPORTANT NOTICE

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

LM258, LM358, LM358A, LM358E, LM2904, LM2904A, LM2904E, LM2904V, NCV2904, NCV2904V

Single Supply Dual Operational Amplifiers

Utilizing the circuit designs perfected for Quad Operational Amplifiers, these dual operational amplifiers feature low power drain, a common mode input voltage range extending to ground/V_{EE}, and single supply or split supply operation. The LM358 series is equivalent to one–half of an LM324.

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

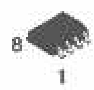
Features

- 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
- ESD Clamps on the Inputs Increase Ruggedness of the Device without Affecting Operation
- NCV Prefix for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC–Q100 Qualified and PPAP Capable
- These Devices are Pb–Free, Halogen Free/BFR Free and are RoHS Compliant

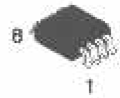
ON Semiconductor®

www.onsemi.com

PDIP–8
N, AN, VN SUFFIX
CASE 626

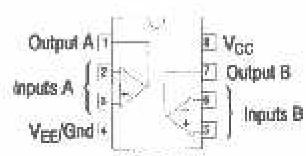


SOIC–8
D, VD SUFFIX
CASE 751



Micro8™
DMR2 SUFFIX
CASE 846A

PIN CONNECTIONS



(Top View)

ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 10 of this data sheet.

DEVICE MARKING INFORMATION

See general marking information in the device marking section on page 11 of this data sheet.

Figure 1.

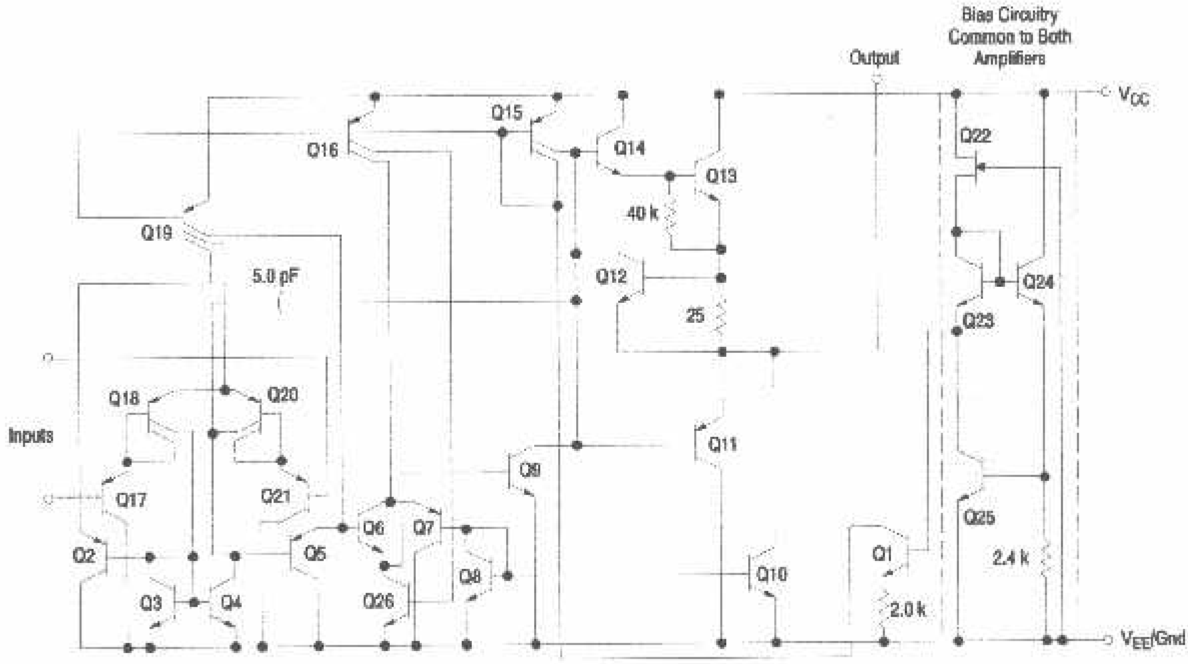


Figure 2. Representative Schematic Diagram
(One–Half of Circuit Shown)

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

Rating	Symbol	Value	Unit
Power Supply Voltages Single Supply Split Supplies	 V_{CC} V_{CC}, V_{EE}	 32 ±16	Vdc
Input Differential Voltage Range (Note 1)	V_{IDR}	±32	Vdc
Input Common Mode Voltage Range	V_{ICR}	−0.3 to 32	Vdc
Output Short Circuit Duration	t_{SC}	Continuous	
Junction Temperature	T_J	150	°C
Thermal Resistance, Junction−to−Air (Note 2) Case 846A Case 751 Case 626	$R_{\theta JA}$	238 212 161	°C/W
Storage Temperature Range	T_{stg}	−65 to +150	°C
ESD Protection at any Pin Human Body Model Machine Model	V_{esd}	 2000 200	V
Operating Ambient Temperature Range LM258 LM358, LM358A, LM358E LM2904, LM2904A, LM2904E LM2904V, NCV2904 (Note 3) NCV2904V (Note 3)	T_A	 −25 to +85 0 to +70 −40 to +105 −40 to +125 −40 to +150	°C

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1. Split Power Supplies.
2. All $R_{\theta JA}$ measurements made on evaluation board with 1 oz. copper traces of minimum pad size. All device outputs were active.
3. *NCV2904 and NCV2904V are qualified for automotive use.*

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

Characteristic	Symbol	LM258			LM358, LM358E			LM358A			Unit
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage V_{CC} = 5.0 V to 30 V, V_{IC} = 0 V to V_{CC} −1.7 V, V_O = 1.4 V, R_S = 0 Ω	V_{IO}										mV
T_A = 25°C		–	2.0	5.0	–	2.0	7.0	–	2.0	3.0	
T_A = T_{high} (Note 4)		–	–	7.0	–	–	9.0	–	–	5.0	
T_A = T_{low} (Note 4)		–	–	7.0	–	–	9.0	–	–	5.0	
Average Temperature Coefficient of Input Offset Voltage T_A = T_{high} to T_{low} (Note 4)	$\Delta V_{IO}/\Delta T$	–	7.0	–	–	7.0	–	–	7.0	–	µV/°C
Input Offset Current	I_{IO}	–	3.0	30	–	5.0	50	–	5.0	30	nA
T_A = T_{high} to T_{low} (Note 4)		–	–	100	–	–	150	–	–	75	
Input Bias Current	I_{IB}	–	−45	−150	–	−45	−250	–	−45	−100	
T_A = T_{high} to T_{low} (Note 4)		–	−50	−300	–	−50	−500	–	−50	−200	
Average Temperature Coefficient of Input Offset Current T_A = T_{high} to T_{low} (Note 4)	$\Delta I_{IO}/\Delta T$	–	10	–	–	10	–	–	10	–	pA/°C
Input Common Mode Voltage Range (Note 5), V_{CC} = 30 V	V_{ICR}	0	–	28.3	0	–	28.3	0	–	28.5	V
V_{CC} = 30 V, T_A = T_{high} to T_{low}		0	–	28	0	–	28	0	–	28	
Differential Input Voltage Range	V_{IDR}	–	–	V_{CC}	–	–	V_{CC}	–	–	V_{CC}	V
Large Signal Open Loop Voltage Gain R_L = 2.0 kΩ, V_{CC} = 15 V, For Large V_O Swing,	A_{VOL}	50	100	–	25	100	–	25	100	–	V/mV
T_A = T_{high} to T_{low} (Note 4)		25	–	–	15	–	–	15	–	–	
Channel Separation 1.0 kHz ≤ f ≤ 20 kHz, Input Referenced	CS	–	−120	–	–	−120	–	–	−120	–	dB
Common Mode Rejection R_S ≤ 10 kΩ	CMR	70	85	–	65	70	–	65	70	–	dB
Power Supply Rejection	PSR	65	100	–	65	100	–	65	100	–	dB
Output Voltage–High Limit T_A = T_{high} to T_{low} (Note 4)	V_{OH}										V
V_{CC} = 5.0 V, R_L = 2.0 kΩ, T_A = 25°C		3.3	3.5	–	3.3	3.5	–	3.3	3.5	–	
V_{CC} = 30 V, R_L = 2.0 kΩ		26	–	–	26	–	–	26	–	–	
V_{CC} = 30 V, R_L = 10 kΩ		27	28	–	27	28	–	27	28	–	
Output Voltage–Low Limit V_{CC} = 5.0 V, R_L = 10 kΩ, T_A = T_{high} to T_{low} (Note 4)	V_{OL}	–	5.0	20	–	5.0	20	–	5.0	20	mV
Output Source Current V_{ID} = +1.0 V, V_{CC} = 15 V	I_{O+}	20	40	–	20	40	–	20	40	–	mA
T_A = T_{high} to T_{low} (LM358A Only)								10	–	–	
Output Sink Current V_{ID} = −1.0 V, V_{CC} = 15 V	I_{O-}	10	20	–	10	20	–	10	20	–	mA
T_A = T_{high} to T_{low} (LM358A Only)								5.0	–	–	mA
V_{ID} = −1.0 V, V_O = 200 mV		12	50	–	12	50	–	12	50	–	µA
Output Short Circuit to Ground (Note 6)	I_{SC}	–	40	60	–	40	60	–	40	60	mA
Power Supply Current (Total Device) T_A = T_{high} to T_{low} (Note 4)	I_{CC}										mA
V_{CC} = 30 V, V_O = 0 V, R_L = ∞		–	1.5	3.0	–	1.5	3.0	–	1.5	2.0	
V_{CC} = 5 V, V_O = 0 V, R_L = ∞		–	0.7	1.2	–	0.7	1.2	–	0.7	1.2	

4. LM258: T_{low} = −25°C, T_{high} = +85°C
   LM2904/A/E: T_{low} = −40°C, T_{high} = +105°C
   NCV2904 and NCV2904V are qualified for automotive use.
   LM358, LM358A, LM358E: T_{low} = 0°C, T_{high} = +70°C
   LM2904V & NCV2904: T_{low} = −40°C, T_{high} = +125°C
   NCV2904V: T_{low} = −40°C, T_{high} = +150°C
5. 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.
6. 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.

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

Characteristic	Symbol	LM2904/LM2904E			LM2904A			LM2904V, NCV2904 NCV2904V			Unit
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage V_{CC} = 5.0 V to 30 V, V_{IC} = 0 V to V_{CC} −1.7 V, V_O = 1.4 V, R_S = 0 Ω T_A = 25°C $T_A = T_{high}$ (Note 7) $T_A = T_{low}$ (Note 7)	V_{IO}	 – – –	 2.0 – –	 7.0 10 10	 – – –	 2.0 – –	 7.0 10 10	 – – –	 – – –	 7.0 13 10	mV
Average Temperature Coefficient of Input Offset Voltage $T_A = T_{high}$ to T_{low} (Note 7)	$\Delta V_{IO}/\Delta T$	–	7.0	–	–	7.0	–	–	7.0	–	μV/°C
Input Offset Current $T_A = T_{high}$ to T_{low} (Note 7) Input Bias Current $T_A = T_{high}$ to T_{low} (Note 7)	I_{IO} I_{IB}	– – – –	5.0 45 −45 −50	50 200 −250 −500	– – – –	5.0 45 −45 −50	50 200 −100 −250	– – – –	5.0 45 −45 −50	50 200 −250 −500	nA
Average Temperature Coefficient of Input Offset Current $T_A = T_{high}$ to T_{low} (Note 7)	$\Delta I_{IO}/\Delta T$	–	10	–	–	10	–	–	10	–	pA/°C
Input Common Mode Voltage Range (Note 8), V_{CC} = 30 V V_{CC} = 30 V, $T_A = T_{high}$ to T_{low}	V_{ICR}	0 0	– –	28.3 28	0 0	– –	28.3 28	0 0	– –	28.3 28	V
Differential Input Voltage Range	V_{IDR}	–	–	V_{CC}	–	–	V_{CC}	–	–	V_{CC}	V
Large 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 7)	A_{VOL}	25 15	100 –	– –	25 15	100 –	– –	25 15	100 –	– –	V/mV
Channel Separation 1.0 kHz ≤ f ≤ 20 kHz, Input Referenced	CS	–	−120	–	–	−120	–	–	−120	–	dB
Common Mode Rejection R_S ≤ 10 kΩ	CMR	50	70	–	50	70	–	50	70	–	dB
Power Supply Rejection	PSR	50	100	–	50	100	–	50	100	–	dB
Output Voltage–High Limit $T_A = T_{high}$ to T_{low} (Note 7) V_{CC} = 5.0 V, R_L = 2.0 kΩ, T_A = 25°C V_{CC} = 30 V, R_L = 2.0 kΩ V_{CC} = 30 V, R_L = 10 kΩ	V_{OH}	 3.3 26 27	 3.5 – 28	 – – –	 3.3 26 27	 3.5 – 28	 – – –	 3.3 26 27	 3.5 – 28	 – – –	V
Output Voltage–Low Limit V_{CC} = 5.0 V, R_L = 10 kΩ, $T_A = T_{high}$ to T_{low} (Note 7)	V_{OL}	–	5.0	20	–	5.0	20	–	5.0	20	mV
Output Source Current V_{ID} = +1.0 V, V_{CC} = 15 V	I_{O+}	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 –	20 –	– –	10 –	20 –	– –	10 –	20 –	– –	mA μA
Output Short Circuit to Ground (Note 9)	I_{SC}	–	40	60	–	40	60	–	40	60	mA
Power Supply Current (Total Device) $T_A = T_{high}$ to T_{low} (Note 7) V_{CC} = 30 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	mA

7. LM258: T_{low} = −25°C, T_{high} = +85°C
   LM358, LM358A, LM358E: T_{low} = 0°C, T_{high} = +70°C
   LM2904/A/E: T_{low} = −40°C, T_{high} = +105°C
   LM2904V & NCV2904: T_{low} = −40°C, T_{high} = +125°C
   NCV2904 and NCV2904V are qualified for automotive use.
   NCV2904V: T_{low} = −40°C, T_{high} = +150°C
8. 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.
9. 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.

CIRCUIT DESCRIPTION

The LM358 series is made using two internally compensated, two–stage operational amplifiers. The first stage of each consists of differential input devices Q20 and Q18 with input buffer transistors Q21 and Q17 and the differential to single ended converter Q3 and Q4. The first stage performs not only the first stage gain function but also performs the level shifting and transconductance reduction functions. By reducing the transconductance, a smaller compensation capacitor (only 5.0 pF) can be employed, thus saving chip area. The transconductance reduction is accomplished by splitting the collectors of Q20 and Q18. Another feature of this input stage is that the input common mode range can include the negative supply or ground, in single supply operation, without saturating either the input devices or the differential to single–ended converter. The second stage consists of a standard current source load amplifier stage.

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

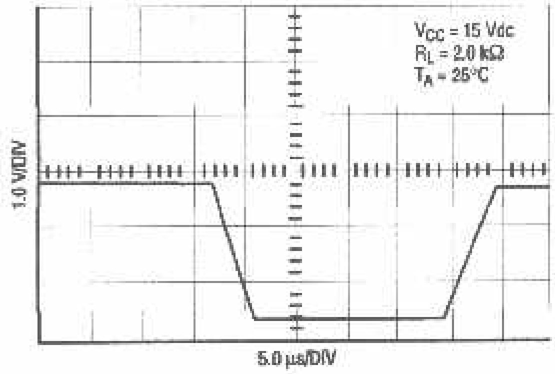


Figure 3. Large Signal Voltage Follower Response

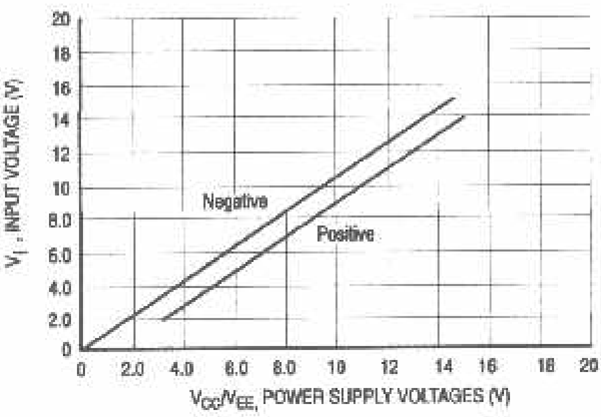


Figure 4. Input Voltage Range

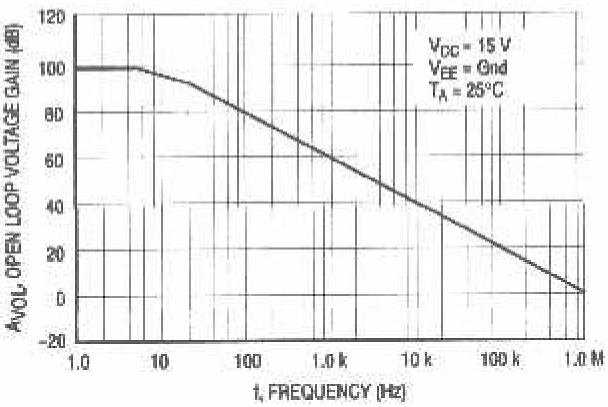


Figure 5. Large–Signal Open Loop Voltage Gain

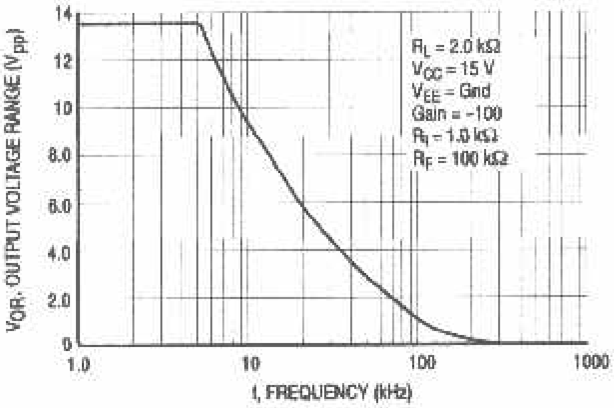


Figure 6. Large−Signal Frequency Response

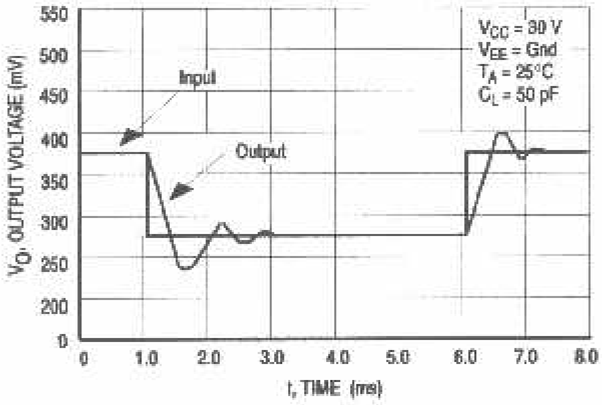


Figure 7. Small Signal Voltage Follower Pulse Response (Noninverting)

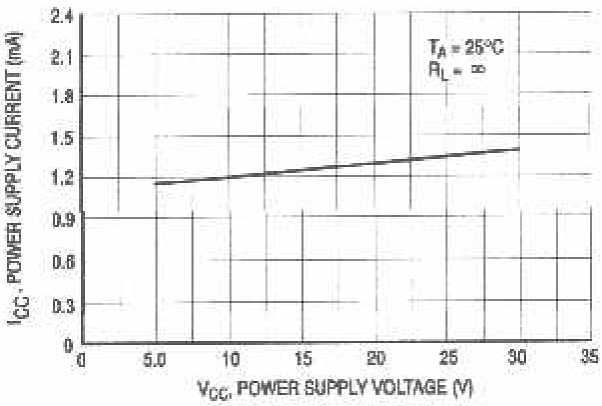


Figure 8. Power Supply Current versus Power Supply Voltage

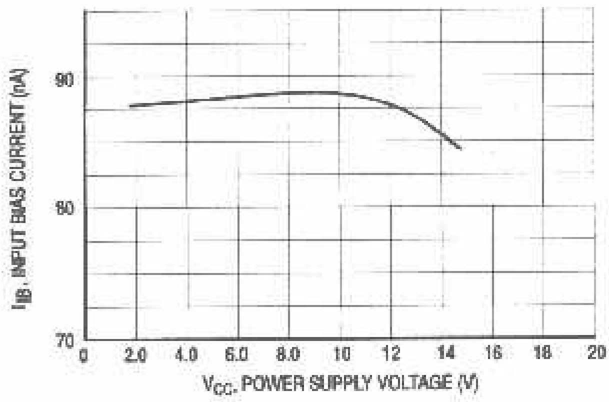


Figure 9. Input Bias Current versus Supply Voltage

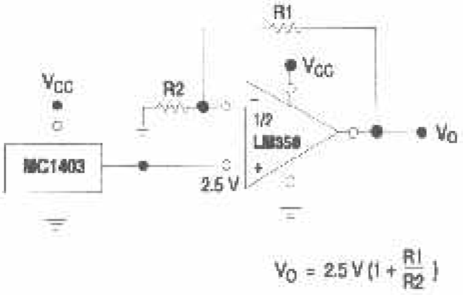


Figure 10. Voltage Reference

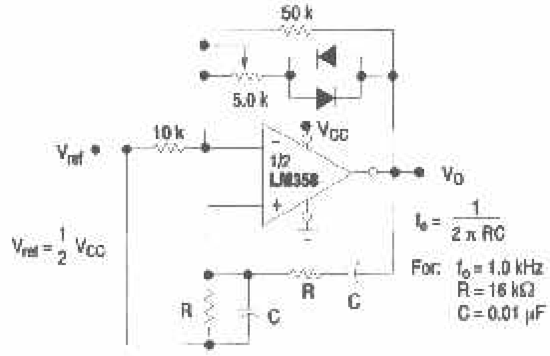


Figure 11. Wien Bridge Oscillator

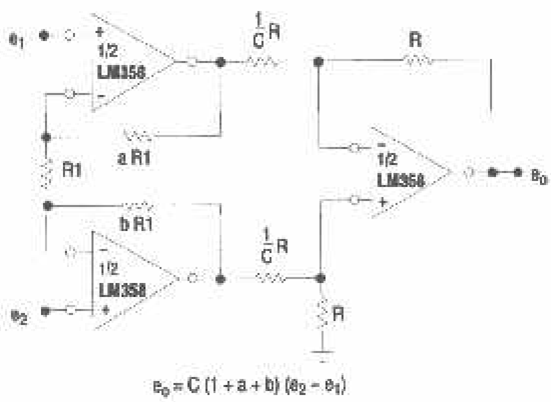


Figure 12. High Impedance Differential Amplifier

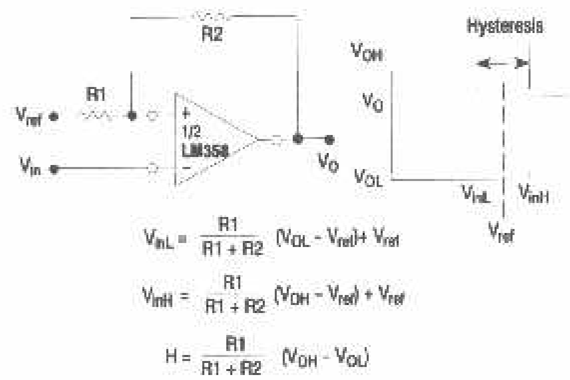


Figure 13. Comparator with Hysteresis

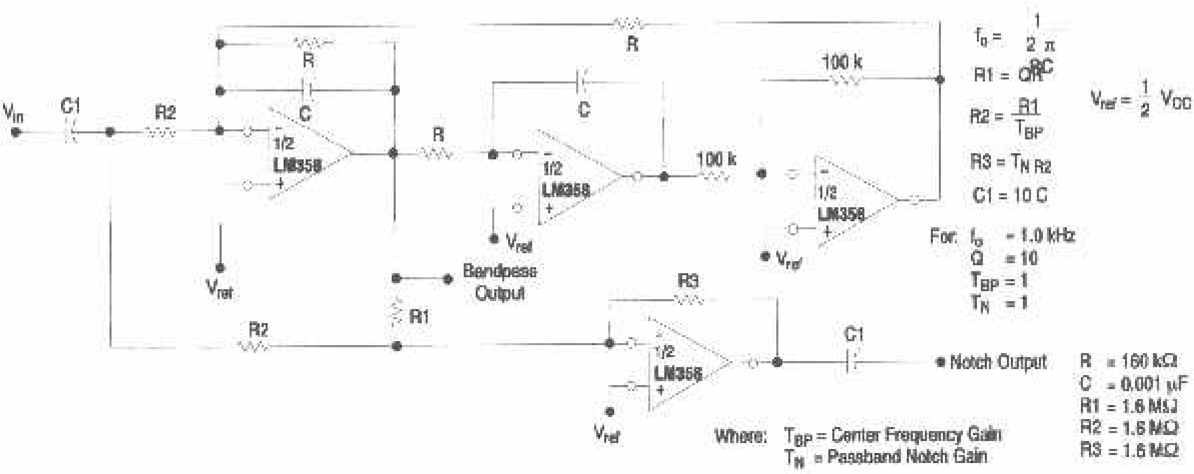
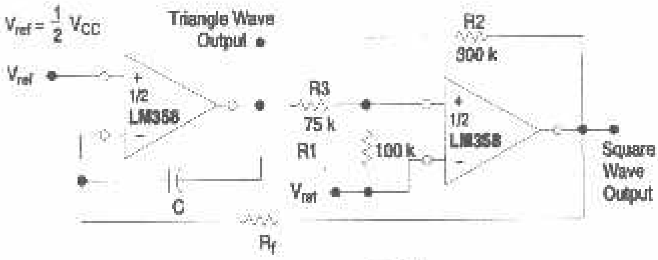
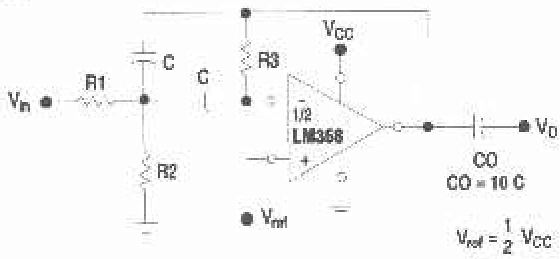


Figure 14. Bi-Quad Filter



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

Figure 15. Function Generator



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.

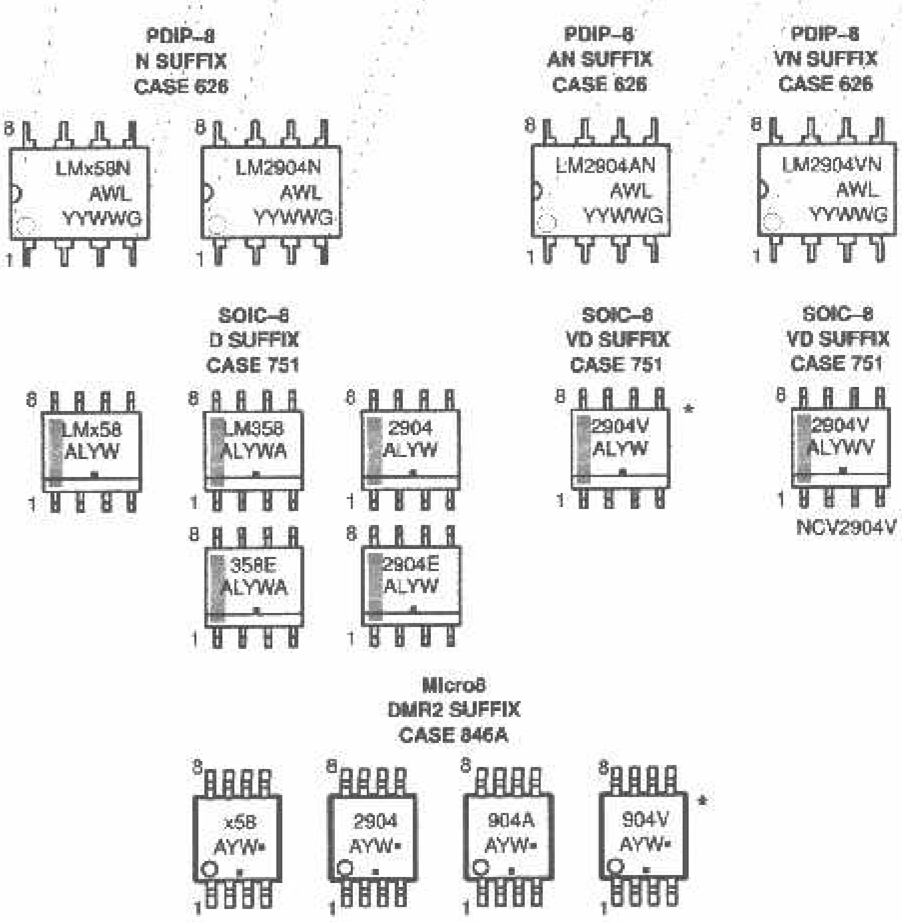
Figure 16. Multiple Feedback Bandpass Filter

ORDERING INFORMATION

Device	Operating Temperature Range	Package	Shipping†
LM358ADR2G	0°C to +70°C	SOIC−8 (Pb−Free)	2500 / Tape & Reel
LM358DG			98 Units / Rail
LM358DR2G			2500 / Tape & Reel
LM358EDR2G		SOIC−8 (Pb−Free)	2500 / Tape & Reel
LM358DMR2G		Micro8 (Pb−Free)	4000 / Tape & Reel
LM358NG		PDIP−8 (Pb−Free)	50 Units / Rail
LM258DG	−25°C to +85°C	SOIC−8 (Pb−Free)	98 Units / Rail
LM258DR2G			2500 / Tape & Reel
LM258DMR2G		Micro8 (Pb−Free)	4000 / Tape & Reel
LM258NG		PDIP−8 (Pb−Free)	50 Units / Rail
LM2904DG	−40°C to +105°C	SOIC−8 (Pb−Free)	98 Units / Rail
LM2904DR2G			2500 / Tape & Reel
LM2904EDR2G		SOIC−8 (Pb−Free)	2500 / Tape & Reel
LM2904DMR2G		Micro8 (Pb−Free)	2500 / Tape & Reel
LM2904NG		PDIP−8 (Pb−Free)	50 Units / Rail
LM2904ADMG		Micro8 (Pb−Free)	4000 / Tape & Reel
LM2904ADMR2G			4000 / Tape & Reel
LM2904ANG		PDIP−8 (Pb−Free)	50 Units / Rail
LM2904VDG	−40°C to +125°C	SOIC−8 (Pb−Free)	98 Units / Rail
LM2904VDR2G			2500 / Tape & Reel
LM2904VDMR2G		Micro8 (Pb−Free)	4000 / Tape & Reel
LM2904VNG		PDIP−8 (Pb−Free)	50 Units / Rail
NCV2904DR2G*		SOIC−8 (Pb−Free)	2500 / Tape & Reel
NCV2904DMR2G*		Micro8 (Pb−Free)	4000 / Tape & Reel
NCV2904VDR2G*	−40°C to +150°C	SOIC−8 (Pb−Free)	2500 / Tape & Reel

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.
*NCV Prefix for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC−Q100 Qualified and PPAP Capable.

MARKING DIAGRAMS

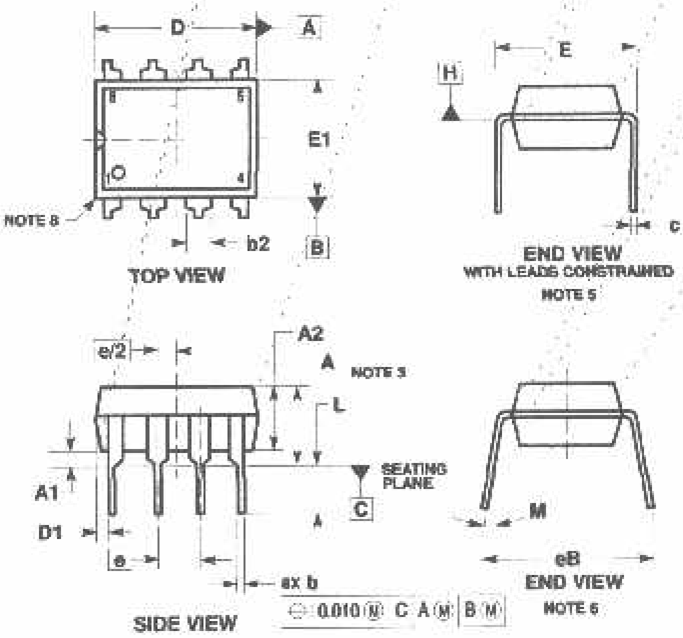


x	= 2 or 3
A	= Assembly Location
WL, L	= Wafer Lot
YY, Y	= Year
WW, W	= Work Week
G	= Pb−Free Package
▪	= Pb−Free Package − (Note: Microdot may be in either location)

*This diagram also applies to NCV2904

PACKAGE DIMENSIONS

PDIP–8
N, AN, VN SUFFIX
CASE 626–05
ISSUE P

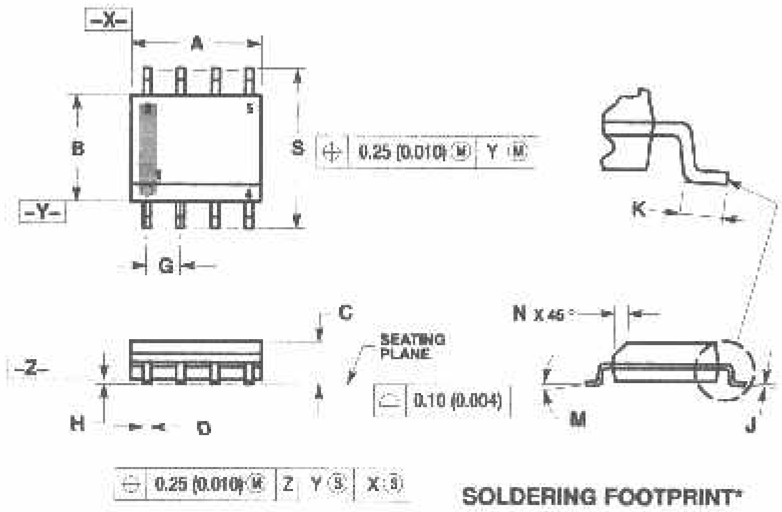


NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: INCHES.
3. DIMENSIONS A, A1 AND L ARE MEASURED WITH THE PACKAGE SEATED IN JEDEC SEATING PLANE GAUGE GS–3.
4. DIMENSIONS D, D1 AND E1 DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS ARE NOT TO EXCEED 0.10 INCH.
5. DIMENSION E IS MEASURED AT A POINT 0.015 BELOW DATUM PLANE H WITH THE LEADS CONSTRAINED PERPENDICULAR TO DATUM C.
6. DIMENSION eB IS MEASURED AT THE LEAD TIPS WITH THE LEADS UNCONSTRAINED.
7. DATUM PLANE H IS COINCIDENT WITH THE BOTTOM OF THE LEADS, WHERE THE LEADS EXIT THE BODY.
8. PACKAGE CONTOUR IS OPTIONAL (ROUNDED OR SQUARE CORNERS).

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	----	0.210	---	5.33
A1	0.015	----	0.38	---
A2	0.115	0.195	2.92	4.95
b	0.014	0.022	0.35	0.56
b2	0.060 TYP		1.52 TYP	
C	0.008	0.014	0.20	0.36
D	0.355	0.400	9.02	10.16
D1	0.005	----	0.13	---
E	0.300	0.325	7.62	8.26
E1	0.240	0.280	6.10	7.11
e	0.100 BSC		2.54 BSC	
eB	----	0.430	---	10.92
L	0.115	0.150	2.92	3.81
M	----	10°	---	10°

PACKAGE DIMENSIONS

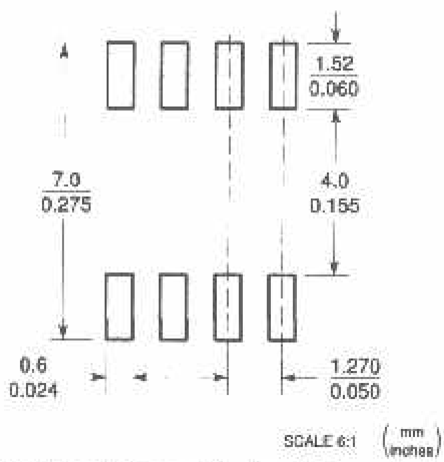
SOIC–8 NB
CASE 751–07
ISSUE AK



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION 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.
6. 751–01 THRU 751–06 ARE OBSOLETE. NEW STANDARD IS 751–07.

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.80	5.00	0.189	0.197
B	3.80	4.00	0.150	0.157
C	1.35	1.75	0.053	0.069
D	0.33	0.51	0.013	0.020
G	1.27 BSC		0.050 BSC	
H	0.10	0.25	0.004	0.010
J	0.19	0.25	0.007	0.010
K	0.40	1.27	0.016	0.050
M	0 °	8 °	0 °	8 °
N	0.25	0.50	0.010	0.020
S	5.80	6.20	0.228	0.244

SOLDERING FOOTPRINT*



*For additional information on our Pb–Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.