SKRIPSI

PERANCANGAN DAN PEMBUATAN ALAT UKUR VOLUME UDARA DALAM PARU-PARU (*SPIROMETRY*) DENGAN MENGGUNAKAN RENESAS R8C13 TINY

Disusun Oleh :

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

2009

LEMBAR PERSETUJUAN

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SKRIPSI

Disusun dan diajukan sebagai salah satu syarat untuk memperoleh gelar Sarjana Teknik Elektronika Strata Satu (S-1)

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Abstrak

Tujuan pembuatan skripsi ini adalah untuk membantu rumah sakit atau instansi medis memperoleh atau mendapatkan alat ukur volume udara dalam paru- paru dengan harga yang relatif lebih terjangkau (murah) dan untuk mengetahui volume paru-paru. Hal ini disebabkan oleh banyak rumah sakit yang mengalami keterbatasan dalam hal biaya untuk membeli alat ukur kapasitas (volume) paru-paru menyebabkan rumah sakit akan mengalami kesulitan dalam mendiagnosa penyakit pernapasan. Untuk merealisasikan alat ukur volume paru-paru diperlukan beberapa alat dan rangkaian penunjang, untuk mengukur volume digunakan sensor ultrasonik ping sebagai pembaca kenaikan air yang nantinya hasil dari pengukuran akan ditampilkan pada LCD dan PC berupa angka dan grafik, serta sebagai pengontrol seluruh sistem digunakan mikrokontroller Renesas R8C13 tiny.

Kata kunci : Spirometry, Ultrasonik, Renesas R8C13 tiny.

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Malang, Maret 2009

Penyusun

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BAB I

PENDAHULUAN

1.1 Latar Belakang

Topik tentang *Global Warming* akhir-akhir ini sering menjadi perdebatan, baik tentang penyebabnya maupun efek yang ditimbulkan. Pemanasan global disebabkan oleh kegiatan manusia yang menghasilkan emisi gas rumah kaca dari kendaraan bermotor, pembangkit listrik bahkan menggunakan listrik berlebihan. Dampak dari pemanasan global juga telah dirasakan oleh seluruh kalangan masyarakat. Hal ini dibuktikan dengan meningkatnya kasus penyakit tropis yang dapat menganggu kesehatan.

Kesehatan adalah salah satu bagian terpenting dalam hidup. Banyak orang menginginkan agar tubuhnya sehat. Untuk mengetahui tingkat kesehatan dalam tubuh kita dapat ditinjau dari beberapa aspek, salah satunya dapat ditinjau dari kinerja alat pernafasan. Bernafas adalah proses pengambilan udara masuk ke dalam paru-paru dan pengeluarannya. Semua sel akan mati bila tidak mendapat oksigen tiga sampai empat menit saja.

Di bidang kedokteran, teknologi sangat berguna bagi para medis, baik skala kecil maupun besar peran teknologi dalam hal ini telah memberikan kemudahan dan kepastian dalam hal ilmu pengobatan dan peralatan medis, karena sangat fleksibel dan mempunyai kemampuan untuk diprogram serta dapat melakukan bermacam – macam fungsi sesuai dengan kebutuhan. misalnya ditemukannya alat untuk mendiagnosa penyakit yang diderita oleh pasien. Alat medis yang digunakan dalam ilmu kedokteran salah satunya adalah alat ukur kapasitas paru-paru atau lebih dikenal dengan spirometry.

Spirometry adalah metode yang digunakan dalam diagnosa fungsi paru-paru, yang mengukur kapasitas yang dihirup dan dihembuskan. Spirometry, bagaimanapun juag, tidak dapat mengetahui besarnya volume absolute dari paru-paru, karena tidak dapat mengukur besarnya volume udara dalam paru-paru tetapi hanya besarnya volume udara yang masuk dan keluar paru-paru. (Johns Hopkins University; 1995).

Alat ukur kapasitas paru-paru ini masih jarang dipakai secara luas pada instansi medis. Keterbatasan rumah sakit dalam hal biaya untuk membeli alat ukur kapasitas paru-paru ini menyebabkan rumah sakit atau klinik akan mengalami kesulitan dalam mendiagnosa volume paru-paru. hanya rumah sakit kelas satu yang saja yang mungkin dapat membeli alat ukur ini.

Kapasitas atau volume paru-paru adalah volume udara yang secara normal tetap berada dalam paru-paru. Udara ini penting untuk fungsi kerja paru-paru. Fungsi paru-paru akan terganggu bila nilai kapasitasnya akan berubah nyata apabila paru-paru terserang beberapa jenis penyakit paru-paru, karena itulah seringkali kapasitas paru-paru ini harus diukur. Kapasitas atau volume paru-paru kondisi normal adalah antara range 1500-3500 ml (Guyton & Hall,1997:hal 605)

Dalam hal ini pengukuran fungsi kerja paru-paru sangat penting untuk mengetahui perkembangan kesehatan seseorang. oleh karna itu pemeriksaan secara berkala terhadap keadaan paru-paru amat penting guna mengetahui kondisi/kinerja dari alat pernapasan atau paru paru.

Berdasarkan permasalahan tersebut, penulis berinisiatif membuat alat yang mempunyai fungsi sebagai alat pengukur volume paru-paru (spirometry). Perbedaan alat ini dengan yang sudah ada adalah harga alat ini terjangkau oleh instansi medis. Selain bekerja mengukur kapasitas paru-paru manusia dan juga membantu kesulitan setiap orang untuk mengetahui keadaan kesehatan sendiri, yang mana hasil dari pengukuran dapat dilihat secara langsung yang ditampilkan lewat fungsi kerja *LCD* dalam proses pengukuran yang menunjukkan kapasitas atau volume paru-paru tersebut. Dengan demikian tidak hanya rumah sakit kelas satu, yang berada di kota-kota besar saja yang dapat memiliki alat ukur ini. Rumah sakit kelas dua,klinik,puskesmas bahkan dokter pun tidak akan mengalami kesulitan untuk dapat memiliki alat ukur kapasitas/volume paru-paru.

1.2 Rumusan Masalah

Berdasarkan pada latar belakang di atas, maka dalam perencanaan dan pembuatan alat ini diutamakan pada hal-hal sebagai berikut :

a. Bagaimana cara mengukur kapasitas paru-paru?
b. Bagaimana merancang *hardware* dan *software* alat ukur kapasitas dalam paru-paru?
c. Bagaimana cara menampilkan hasil pengukuran ke dalam LCD?

1.3 Batasan Masalah

Dalam laporan akhir "Perancangan Dan Pembuatan Alat Ukur Kapasitas paru-Paru (Spirometry) Menggunakan Renesas R8C/TINY", penulis akan memberikan batasan-batasan masalah agar tidak terjadi penyimpangan maksud dan tujuan utama penyusunan skripsi ini.

1. Alat pengukur volume paru-paru yang dirancang memiliki kemampuan pada range volume maksimal 2500 ml.
2. Alat ini tidak untuk mendeteksi atau mendiagnosa adanya penyakit pernapasan.
3. Tidak membahas organ atau bagian bagian dari paru paru.
4. Menggunakan Sensor Ultrasonic Ping))).
5. Bahasa pemrograman menggunakan bahasa C++.
6. Menggunakan Mikrokontroller Renesas R8C/TINY

1.4 Tujuan Penulisan

Berdasarkan rumusan masalah yang ada, maka tujuan yang akan dicapai dalam penulisan skripsi ini adalah sebagai berikut :

1. Untuk mengetahui cara mengukur kapasitas atau volume dalam paru-paru
2. Untuk menampilkan hasil pengukuran ke LCD.
3. Untuk merancang *hardware* dan *software* pada alat ukur kapasitas paru-paru.
4. Agar diperoleh alat ukur kapasitas atau volume dalam paru-paru dengan harga yang lebih terjangkau (murah).

1.5 Sistematika Penulisan

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

BAB I PENDAHULUAN

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

BAB II TEORI

Membahas teori-teori dasar penunjang, Mikrokontroller Renesas R8C/Tiny,LCD

Sensor Ultrasonic PING))).

BAB III PERANCANGAN DAN PEMBUATAN ALAT

Membahas tentang perancangan alat baik perangkat keras maupun perangkat lunak, serta cara kerja blok diagram.

BAB IV PENGUJIAN ALAT

Mencakup pembahasan tentang proses pengujian alat yang terdiri dari peralatan yang digunakan, langkah kerja dan analisa hasil pengujian.

BAB V PENUTUP

Memuat kesimpulan yang diperoleh dari pembuatan dan pengujian alat, serta saran – saran untuk pengembangan lebih lanjut.

BAB II

LANDASAN TEORI

Bab ini membahas tentang teori-teori dasar yang akan dipergunakan dalam "Alat Ukur Kapasitas Paru-Paru", serta membahas komponen dan teori penunjang sistem.

2.1 Proses Pernafasan manusia

Paru-paru manusia berada di dalam rongga dada. Rongga dada dipisahkan dari rongga perut oleh sekat diafragma. Rongga dada dilindungi oleh tulang rusuk dan tulang dada. Pada dasarnya proses pernafasan terdiri dari dua kegiatan, yaitu menghirup udara dan menghembuskan udara. Menghirup udara disebut inspirasi dan menghembuskan udara disebut ekspirasi. Berdasarkan bagian tubuh yang mengatur kembang-kempisnya paru-paru, pernafasan dapat dibedakan menjadi dua yaitu:

a. Pernafasan Dada

Pernafasan dada terjadi karena gerakan otot-otot antar tulang rusuk. Bila otot tulang rusuk berkontraksi, tulang rusuk akan terangkat naik. Akibatnya volume rongga dada membesar sehingga tekanan rongga dada turun dan paru-paru mengembang. Pada saat paru-paru mengembang, tekanan udara di dalam paru-paru akan mengembang juga. Pada saat paru-paru mengembang, tekanan udara di dalam paru-paru lebih rendah daripada tekanan udara di atmosfer. Akibatnya udara mengalir dari luar ke dalam paru-paru (inspirasi). Sebaliknya ketika otot-otot antar tulang rusuk relaksasi, tulang rusuk turun. Akibatnya rongga dada menyempit dan tekanan udara di dalamnya naik. Keadaan ini membuat paru-

paru mengempis. Karena paru-paru mengempis tekanan udara di dalam paru-paru lebih tinggi daripada tekanan atmosfer sehingga udara keluar (ekspirasi).

b. Pernafasan Perut

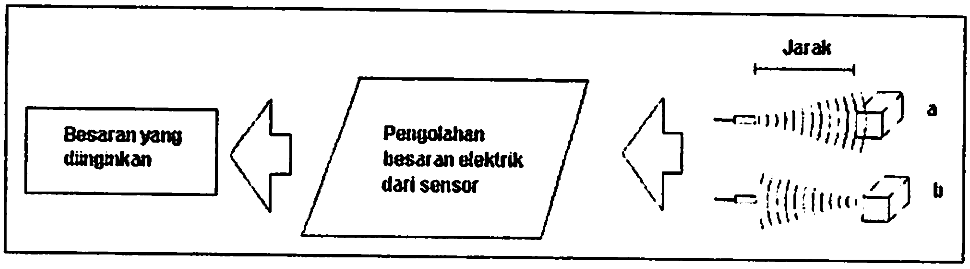
Pernafasan perut terjadi akibat gerakan diafragma. Jika otot diafragma berkontraksi, maka diafragma yang semula cembung ke atas bergerak turun menjadi agak rata. Akibatnya rongga dada membesar dan paru-paru mengembang sehingga perut mengembang, tekanan udara di dalam paru-paru turun dan udara dari luar masuk ke dalam paru-paru (inspirasi). Ketika otot diafragma kembali ke keadaaan semula (cembung), akibatnya rongga dada menyempit. Pada saat demikian, paru-paru mengempis dan mendorong udara keluar dari paru-paru (ekspirasi). Pernafasan perut terjadi terutama pada saat tidur.

2.2 Volume dan Kapasitas Paru-paru

Kemampuan paru-paru untuk menghirup dan menghembuskan udara secara minimum dinamakan kapasitas vital paru-paru. Hal itu bergantung pada besar kecilnya tubuh dan gerakan rongga dada manusia. Volume dan kapasitas seluruh paru pada wanita kira-kira 20 sampai 25 persen lebih kecil daripada pria.

2.3 Sensor Ultrasonik

Sensor ultrasonik bekerja berdasarkan prinsip pantulan gelombang suara, dimana sensor ini menghasilkan gelombang suara yang kemudian menangkapnya kembali dengan perbedaan waktu sebagai dasar penginderaannya. Perbedaan waktu antara gelombang suara dipancarkan dengan ditangkapnya kembali gelombang suara tersebut adalah berbanding lurus dengan jarak atau tinggi objek yang memantulkannya.



Gambar 2.1. Kerja sensor ultrasonik
(www.electroniclab.com)

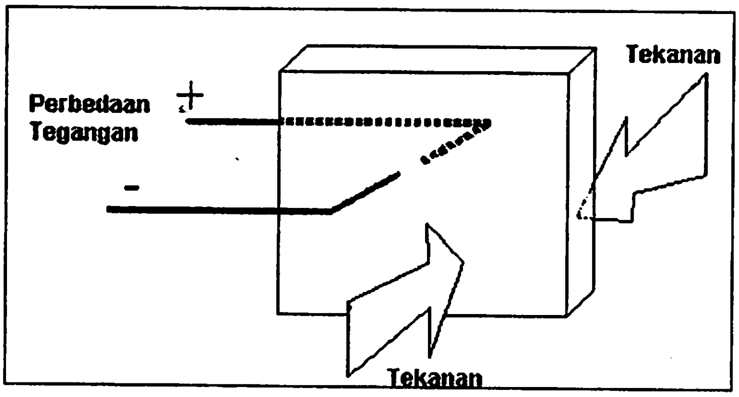
Pada gambar 2.1.a, sebuah tranduser merubah besaran listrik menjadi suatu sinyal ultrasonik yang dipancarkan ke suatu benda pada jarak tertentu. Gambar 2.1.b gelombang ultrasonik yang dipancarkan tadi akan dipantulkan kembali menuju tranduser yang akan merubah besaran gelombang menjadi besaran elektrik. Tranduser ini biasanya terbuat dari bahan piezoelektrik. Sifat dari piezoelektrik adalah sebagai berikut :

a. Sifat piezoelektrik langsung

1. Bila pelat piezoelektrik diberi tekanan, maka akan timbul muatan listrik pada kedua permukaannya.
2. Pelat juga merupakan kapasitor dengan konstanta dielektrik tertentu, timbul beda tegangan.

b. Sifat piezoelektrik balik

1. Bila pelat piezoelektrik diberi tegangan listrik, maka kedua permukaannya mendapat tekanan.
2. Pelat juga merupakan bahan elastik dengan konstanta elastik tertentu, tebalnya akan berubah.



Gambar 2.2. Pelat piezoelectrik
(www.electroniclab.com)

Dengan sifat tersebut piezoelektrik dapat berperan sebagai tranduser dan sensor. Waktu yang dihabiskan antara pengiriman sinyal ultrasonik dengan penerimaan sinyal ultrasonik pantulan disebut *Time of Flight* (TOF). TOF merupakan besaran yang kita gunakan untuk menghitung jarak dari tranduser ke benda objek. Dengan mengetahui TOF, dan mengetahui kecepatan gelombang ultrasonik di udara maka kita dapat menghitung jarak yang telah ditempuh oleh gelombang ultrasonik, sehingga jarak antara tranduser terhadap benda adalah setengahnya. Tentunya pengukuran ini akan dipengaruhi banyak hal seperti kemiringan permukaan benda, kerefleksian permukaan, perubahan suhu dan lain-lain.

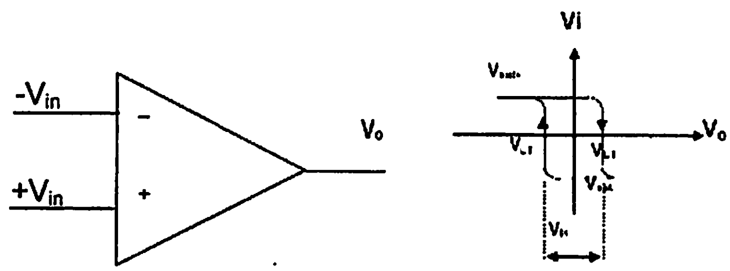
2.4 Rangkaian Komparator

Op-amp adalah salah satu rangkaian terintegrasi *(Integrated Circuit)* yang banyak digunakan pada sistem instrumentasi, khususnya untuk pembuat pengkondisi sinyal. Salah satu aplikasi dari Op-amp yang sangat luas penggunaanya dalam instrumentasi adalah komparator.

Komparator berfungsi untuk membandingkan amplitudo dua buah sinyal, jika $+V_{in}$ dan $-V_{in}$ masing-masing menyatakan amplitudo sinyal masukan tak membalik dan masukan membalik, V_O dan V_{sat} masing-masing menyatakan tegangan keluaran dan tegangan saturasi, maka prinsip dari komparator adalah :

1. Jika $+V_{in} \geq -V_{in}$ maka $V_O = V_{sat+}$
2. Jika $+V_{in} < -V_{in}$ maka $V_O = V_{sat-}$

Gambar 2.3 merupakan simbol dari komparator yang mempunyai dua masukan sebagai pembanding dan grafik respon dari komparator

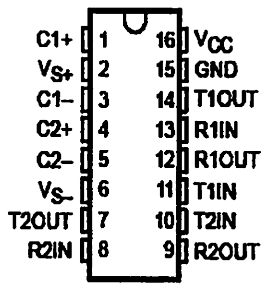


Gambar 2.3 Simbol Komparator dan Grafik Respon dari Komparator
Sumber: Wibawanto, 2007:9

2.5 Komunikasi Data Serial (RS 232 dan IC Max 232)

IC Serial RS 232 yang berada pada kabel data digunakan sebagai *interface* (antar muka) dari PC ke perangkat luar (level TTL) atau sebaliknya dari perangkat luar ke PC. Tegangan pada RS 232 berbeda dengan level tegangan digital. Tegangan yang digunakan oleh RS 232 atau TC 232 tersebut adalah +3 V s/d +25 V untuk logika " 0 " dan -3 s/d -25 untuk level logika "1". Tegangan yang cukup tinggi ini mengakibatkan data dapat ditransmisikan cukup jauh. Ada dua macam sistem transmisi dalam komunikasi serial, yaitu asinkron dan sinkron. Pada komunikasi data serial sinkron, *clock* dikirimkan bersama-sama dengan data serial, sedangkan komunikasi data asinkron *clock* tidak dikirimkan bersama data serial, melainkan dibangkitkan secara sendiri-sendiri baik pada sisi pengirim (*transmitter*) maupun pada sisi penerima (*receiver*).

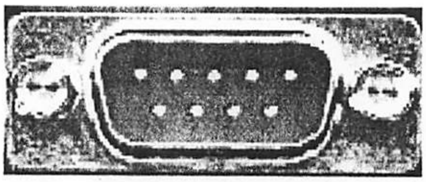
Konsep dasar pengiriman seri adalah pada saat data paralel internal dimasukkan ke pengubah paralel ke seri. Pengubah paralel ke seri ini biasanya dengan IC yang juga melakukan sejumlah fungsi yang lain yang dikenal sebagai UART, VART, ACIA, PIA, dsb. Kanal seri mengirimkan setiap karakter per elemen sehingga hanya diperlukan 2 penghantar, yaitu kirim data (TXD), dan terima data (RXD). Untuk komunikasi dengan komputer *server* secara serial menggunakan RS 232, untuk itu mikrokontroler memerlukan sebuah piranti yang berfungsi sebagai pengubah level tegangan. Adapun piranti tambahan yang dibutuhkan adalah IC MAX 232. Gambar pin IC MAX 232 ditunjukkan pada Gambar 2.4.



Gambar 2. 4 Pin MAX 232
Sumber :www.datasheetcatalog.com

Pada dasarnya IC ini hanya digunakan sebagai pengubah level tegangan ke level *Transistor Transistor Logic (TTL),* tidak berfungsi sebagai pengkodean sinyal yang melewati RS 232, dan juga tidak mengonversikan data serial ke paralel. RS 232 yang bekerja pada level tegangan +3 s/d +25 Volt untuk *space (logic 0)* dan -3 s/d -25 Volt untuk *mark (logic 1)*. Sedangkan TTL bekerja pada level tegangan -5 s/d +5 Volt.

RS 232 yang dihubungkan ke sensor akan melakukan komunikasi serial dengan mikrokontroler menggunakan salah satu konektor serial yaitu DB9, seperti ditunjukkan pada Gambar 2.5.



Gambar 2. 5 DB 9 Male
Sumber: widodo, 2006 : 66

Keterangan pin-pin yang ada di DB9 adalah sebagai berikut:

a. pin 1 = Data *Carrier Detect* (DCD).

b. pin 2 = *Received* Data (RxD).

c. pin 3 = *Transmitted* Data (TxD).

d. pin 4 = Data *Terminal Ready* (DTR).

e. pin 5 = *Signal Ground (common).*

f. pin 6 = Data *Set Ready* (DSR).

g. pin 7 = *Request To Send* (RTS).

h. pin 8 = *Clear To Send* (CTS).

i. pin 9 = *Ring Indicator* (RI).

2.6 *Display* LCD (*Liquid Cristal Display*)

LCD *Display Module* M1632 buatan *Seiko Instrument Inc.* terdiri dari dua bagian. Bagian yang pertama merupakan panel LCD sebagai media penampil informasi dalam bentuk huruf/angka dua baris, masing-masing baris bisa menampung 16 huruf/angka.

Bagian kedua merupakan sebuah sistem yang dibentuk dengan mikrokontroler yang ditempelkan dibalik panel LCD. Bagian kedua berfungsi untuk mengatur tampilan informasi serta berfungsi mengatur komunikasi M1632 dengan mikrokontroler yang memakai tampilan LCD itu. Dengan demikian pemakaian M1632 menjadi sederhana. Sistem lain yang menggunakan M1632 cukup mengirimkan kode-kode ASCII dari informasi yang ditampilkan seperti layaknya memakai sebuah printer.

Gambar 2.6 LCD M1632
(*Sumber : Datasheet Seiko M1632*)

Menurut *datasheet* Seiko Instruments (1987) modul penampil M1632 mempunyai berbagai fitur sebagai berikut:

1. LCD ini terdiri dari 32 karakter dengan masing-masing baris terdiri dari 16 karakter dengan display dot matrik 5 X 7.
2. ROM dengan 192 tipe karakter.
3. RAM dengan 8 tipe karakter.
4. Catu daya +5 volt.
5. Dilengkapi fungsi tambahan: *display clear, cursor home, display on/off, cursor on/off, display character blink, cursor shift dan display shift.*

Fungsi terminal pada LCD ditunjukkan pada Tabel 2.1 sebagai berikut:

Tabel 2.1 Fungsi Terminal Pada LCD

Nama Sinyal	Jumlah Terminal	I/O	Tujuan	Fungsi
DB0 – DB1	4	I/O	MPU	Sebagai lalu lintas data dan instruksi ke atau dari MPU *lower Byte*
DB4 – DB7	4	I/O	MPU	Sebagai lalu lintas data/instruksi 2 arah, *upper byte* DB7 juga sebagai *busy flag*
E	1	*Input*	MPU	Sinyal *start (Read/Write)*
R/W	1	*Input*	MPU	Seleksi sinyal
RS	1	*Input*	MPU	0: *Write* 1: *Read* Seleksi register 0: Instruksi register (*write) busy flag address counter (read)* 1: data register (*Write dan read)* Untuk mengatur tampilan
VLC	1	-	PS	LCD +5 volt DC
VDD	1	-	PS	*Ground*

(Sumber: Seiko Instruments Inc, 1987: 7)

Konfigurasi pin pada LCD ditujukkan dalam Tabel 2.2 sebagai berikut

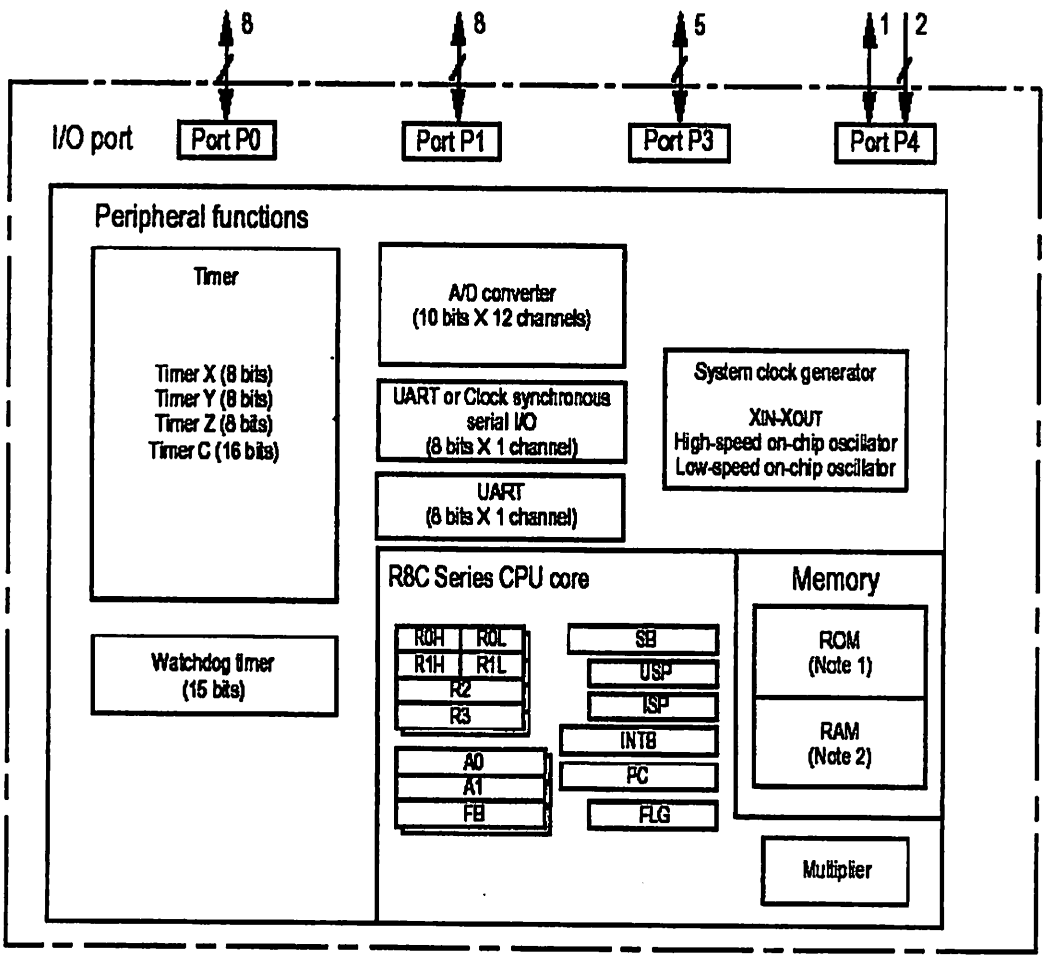
Tabel 2.2 Konfigurasi Pin LCD

NO	SYMBOL	LEVEL	FUNGSI
1	Vss	-	0, Ground
2	Vcc	-	5V +10%
3	Vee	-	LCD driver
4	RS	H/L	H: Data Input L: Instruksi Input
5	R/W	H/L	H: read, L: write
6	E	H/L	Enable Signal
7	DB0 – DB7	H/L	Data Bus
8	V+ BL	-	Menyalakan Lampu LCD, max 4,2 V; 50 – 200mA
9	V- BL	-	Ground

(sumber: Seiko Instruments Inc, 1987: 2)

2.7 Mikrokontroler RENESAS R8C / Tiny

Mikrokontroler RENESAS dibangun menggunakan proses gerbang silicon CMOS dengan kemampuan tinggi menggunakan CPU seri R8C/Tiny dan dikemas dalam modul plastic dengan jumlah pin sebanyak 32. Mikrokontroler ini beroperasi menggunakan perintah canggih khususnya efisiensi perintah dengan level tinggi. Mikrokontroler ini mempunyai 1 Mbytes kapasitas alamat, yang bisa digunakan untuk mengeksekusi perintah dengan kecepatan tinggi. Data flash ROM sebesar 2 KB x 2 blocks.

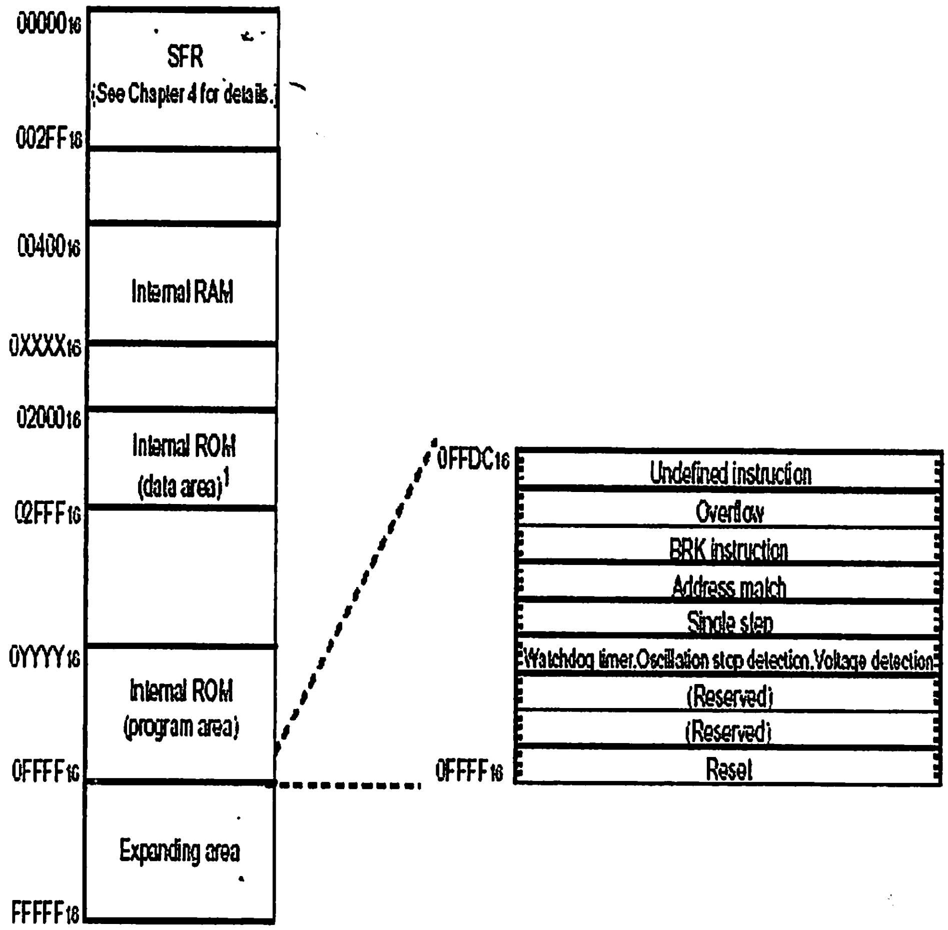


Gambar 2.7 Blok Diagram MCU Renesas

(Sumber : Datasheet Renesas)

Mikrokontroler Renesas R8C/Tiny mempunyai struktur memori yang terdiri atas:

- Space alamat hingga 1 Mbytes dari alamat 00000_{16} sampai $FFFFF_{16}$.
- ROM internal (*program area*) dialokasikan pada alamat terendah dimulai dari alamat $0FFFF_{16}$. Misalnya, 16 Kbyte ROM internal dialokasikan pada alamat yang dimulai dari $0C000_{16}$ sampai $0FFFF_{16}$.
- ROM internal untuk *data area* dialokasikan pada alamat 02000_{16} sampai $02FFF_{16}$.
- Sedangkan RAM internal dialokasikan pada arah alamat yang lebih tinggi dimulai dari alamat 00400_{16}.
- *Special Function Register* (SFR) dialokasikan pada alamat mulai dari 00000_{16} sampai $002FF_{16}$. Fungsi register control peripheral digunakan untuk fungsi tertentu yang dispesifikasikan oleh pembuat IC. Misalnya, untuk mengaktifkan mode-mode dan untuk komunikasi serial baud rate diinisialisasi pada alamat.



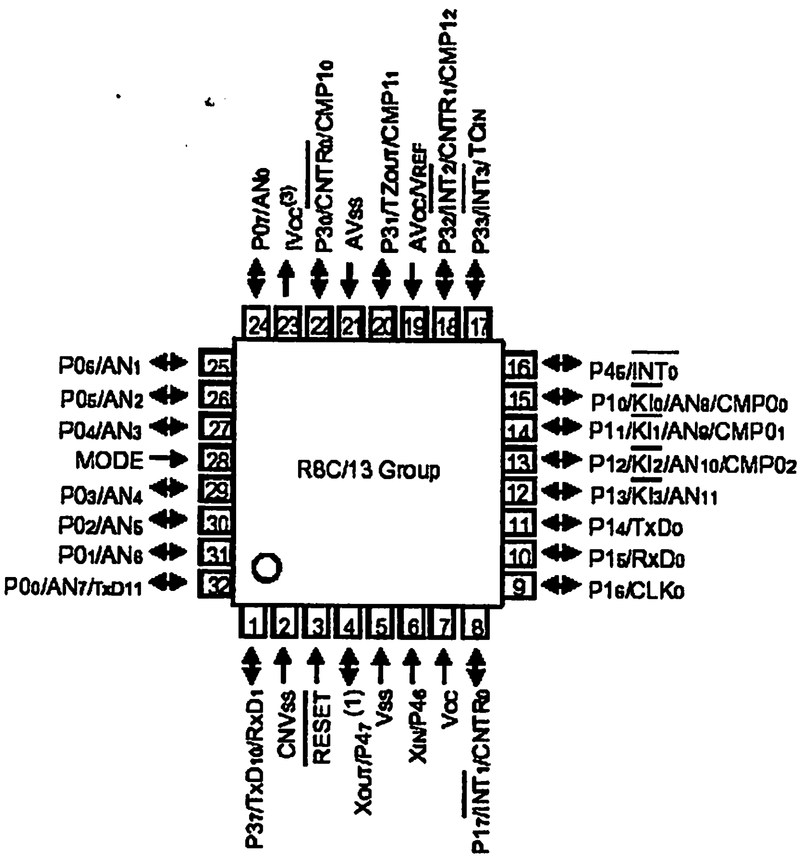
NOTES:

1. The data flash ROM block A (2K bytes) and block B (2K bytes) are shown.
2. Blank spaces are reserved. No access is allowed.

Type name	Internal ROM		Internal RAM	
	Size	Address $0YYYY_{16}$	Size	Address $0XXXX_{16}$
R5F21134FP, R5F21134DFP	16K bytes	$0C000_{16}$	1K bytes	$007FF_{16}$
R5F21133FP, R5F21133DFP	12K bytes	$0D000_{16}$	768 bytes	$006FF_{16}$
R5F21132FP, R5F21132DFP	8K bytes	$0E000_{16}$	512 bytes	$005FF_{16}$

Gambar 2.8 Memory Map

(Sumber : Datasheet Renesas)



Gambar 2.9 Konfigurasi Pin R8C/Tiny

(Sumber : Datasheet Renesas)

Keterangan fungsi masing-masing pin :

1. V_{CC}

   Digunakan untuk sumber tegangan dengan range nilai antara 2,7 – 5,5 Volt.

2. V_{SS}

   Range tegangan 0 Volt

3. IV_{CC}

   Pin ini digunakan untuk menyetabilkan sumber tegangan internal. Pin ini dihubungkan ke V_{SS} melalui kapasitor 0,1 μF.

4. AV_{CC}, AV_{SS}

   Pin ini merupakan input power supply untuk A/D Converter. Pin ini dihubungkan ke pin V_{CC}, sedangkan AV_{SS} dihubungkan ke V_{SS}. Hubungkan pin AV_{SS} dan AV_{CC} dengan kapasitor.

5. Reset

   Merupakan input reset pada MCU.

6. CNV_{SS}

   Pin ini dihubungkan ke V_{SS} melalui resistor.

7. Mode

   Pin ini dihubungkan ke V_{CC} melalui resistor.

8. X_{IN}, X_{OUT}

   Pin ini disediakan untuk pembangkitan rangkaian I/O pada clock utama. Hubungkan resonator keramik atau osilator kristal antara X_{IN} dan X_{OUT}. Untuk menggunakan clock derived external, masukkan ke pin X_{IN} dan pin X_{OUT} dibiarkan terbuka.

9. $INT_0 - INT_3$

   Merupakan pin input interupt

10. $KI_0 - KI_3$

    Merupakan pin Key Input interrupt.

11. $CNTR_0$ (I/O)

    Merupakan timer pin X I/O

12. $CNTR_0$ (O)

    Merupakan timer pin X output.

13. $CNTR_1$

Merupakan timer pin Y I/O

14. TZ_{OUT}

Merupakan timer pin Z output.

15. TC_{IN}

Merupakan timer pin C input.

16. $CMPO_0 - CMPO_3$ dan $CMPO_{10} - CMPO_{13}$

Merupakan timer pin C output.

17. CLK_0

Merupakan transfer clock untuk pin I/O.

18. RxD_0 dan RxD_1

Pin serial data input.

19. TxD_0, TxD_{10} dan TxD_{11}

Pin serial data output.

20. V_{REF}

Referensi pin input tegangan untuk A/D Converter. Hubungkan V_{REF} ke V_{CC}.

21. $AN_0 - AN_{11}$

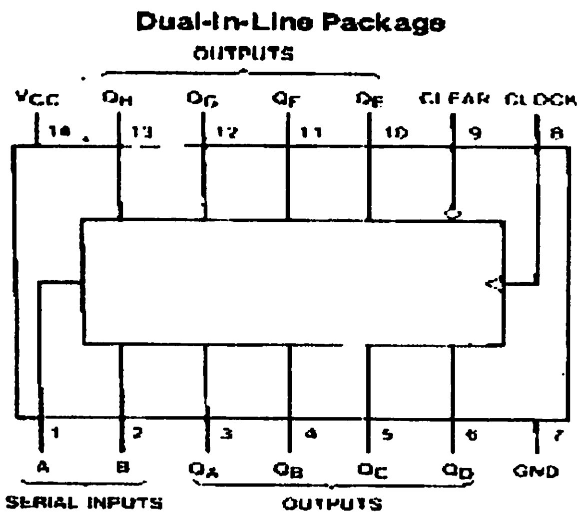
Pin input analog untuk A/D Converter.

22. $P0_0 - P0_1$, $P1_0 - P1_7$, $P3_0 - P3_3$, $P3_7$ dan $P4_5$

Merupakan port 8 bit CMOS I/O. $P1_0 - P1_7$ juga berfungsi sebagai port LED driver.

2.8 DM 74LS164

DM 74LS164 merupakan sebuah IC yang berfungsi sebagai *shift register* 8-bit. IC ini memiliki 2 *serial input, input clock, input reset* dan *output paralel.* Pada saaat logika *LOW,* kedua *input* menghalangi masukan data baru dan me*reset* flip-flop pertama menjadi *LOW* pada saat pulsa *clock* pulsa berikutnya, hal ini untuk mengendalikan data yang masuk. Sedangkan pada saat logika *HIGH,* kedua *input* memungkinkan adanya inputan yang lain, yang mana kemudian akan menentukan status flip-flop yang pertama, data pada *serial input* kemungkinan akan berubah pada saat *clock high* atau *low* akan tetapi informasinya saja yang akan masuk.



Gambar 2.10 Konfigurasi PIN IC DM 74LS164[6]

2.9 Bahasa Pemrograman

Bahasa C merupakan bahasa pemrograman yang digunakan dalam pengisian mikrokontroler Renesas R8C/Tiny. Bahasa C digunakan untuk mengembangkan berbagai jenis permasalahan pemrograman, dari *level operating system* (Unix, Linux, MS DOS, dan sebagainya), aplikasi perkantoran (*Text Editor, Word Processor, Spreadsheet,* dan sebagainya), bahkan sampai pengembangan sistem pakar (*expert system*). Kompiler C tersedia di semua jenis *platform* komputer, mulai dari Macintosh, UNIX, PC, Micro PC, sampai super komputer. Bahasa C disebut bahasa pemrograman tingkat menengah (*middle level programming language*) yaitu bahasa pemrograman yang mempunyai kemampuan mengakses fungsi dan perintah dasar bahasa mesin/ *hardware* (*machine basic instruction set*). Semakin tinggi tingkat bahasa pemrograman semakin mudah bahasa pemrograman dipahami manusia. Demikian sebaliknya dengan bahasa pemrograman tingkat rendah, semakin sulit dipahami manusia dan hanya berisi perintah untuk mengakses bahasa mesin. Bahasa C digolongkan dalam bahasa tingkat tinggi, tetapi Bahasa C menyediakan kemampuan yang ada pada bahasa tingkat rendah, misalnya operasi bit, operasi byte, pengaksesan memori, dan sebagainya.

Beberapa alasan mengapa memakai bahasa C antara lain:

1. Bahasa C adalah bahasa pemrograman yang paling populer saat ini sehingga mempermudah dalam menemukan pemecahan masalah ketika menulis program.
2. Bahasa C adalah bahasa pemrograman yang memiliki portabilitas tinggi. Bahasa C yang ditulis untuk satu jenis *platform* dapat di kompiler dan

jalankan di *platform* lain dengan sedikit perubahan karena ada standarisasi ANSI untuk C.

3. Bahasa C adalah bahasa pemrograman dengan sedikit kata kunci (*keyword*) sehingga memudahkan dalam penulisan pemrograman dan mempercepat eksekusi program. Bahasa C menyediakan 32 kata kunci yaitu: *auto, break, case, char, const, continue, default, do, double, else, enum, extern, float, for, goto, if, int, long, register, return, short, signed, sizeof, static, struct, switch, typedef, union, unsigned, void, volatile, while.*
4. Bahasa C adalah bahasa pemrograman yang fleksibel. Karena dapat menulis dan mengembangkan berbagai jenis program mulai dari *operating system, word processor, graphic processor, spreadsheets*, atau kompiler untuk suatu bahasa pemrograman.
5. Bahasa C adalah bahasa pemrograman yang bersifat modular karena ditulis dalam *routine* yang bisa dipanggil dengan fungsi. Fungsi yang telah dibuat, dapat digunakan kembali (*reuse*) dalam program maupun aplikasi lain.

Tabel 2.3 Tabel Tipe Data

No	Tipe Data	Ukuran	*Range* (jangkauan)	keterangan
1	*char*	1 *byte*	-128 s/ d127	Karakter/ *string*
2	*int*	2 *byte*	-32768 s/d 32767	*Integer*/ bilangan bulat
3	*float*	4 *byte*	$-3,4.10^{-38}$ s/d $3,4.10^{+38}$	*float* /bilangan pecahan
4	*double*	8 *byte*	$-1,7.10^{-308}$ s/d $1,7.10^{+308}$	pecahan presisi ganda
5	*void*	0 *byte*	-	tidak bertipe

(sumber:http://www.Ilmukomputer.com)

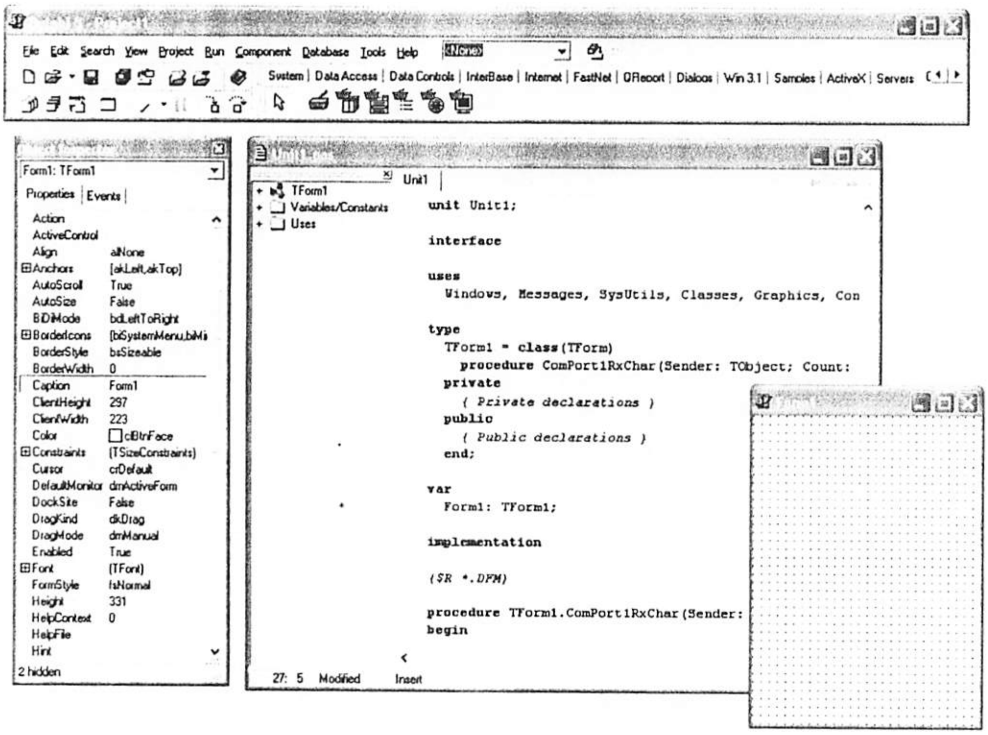
Tipe data dapat ditambahkan awalan *signed* untuk bilangan bertanda dan *unsigned* untuk bilangan tidak bertanda.

Bahasa C adalah suatu program terdiri dari satu atau lebih fungsi. Fungsi utama dan harus ada pada program adalah fungsi main ( ). Fungsi main ( ) adalah fungsi pertama yang akan diproses pada saat program di kompile dan dijalankan (fungsi yang mengontrol fungsi-fungsi lain). Karena struktur bahasa C terdiri dari fungsi-fungsi lain sebagai program bagian (*subroutine*), maka bahasa C disebut sebagai bahasa pemrograman terstruktur.

Statement adalah pernyataan yang menyebabkan suatu tindakan akan akan dilakukan oleh komputer (Jogianto, 1993:14). Tindakan tersebut misalnya adalah tindakan untuk menghitung, menampilkan hasil, menerima *input* data, mengendalikan proses program dan lain sebagainya. Suatu *statement* di bahasa C ditulis dengan diakhiri oleh titik koma (';'). *Statement* dapat berupa *statement* kosong, *statement* ungkapan, *statement* kendali atau *statement* jamak.

2.10. Borlan Delphi

Dalam pembuatan program database sistem pada skripsi ini menggunakan program *Borland Delphi* yang merupakan suatu bahasa pemograman yang memberikan berbagai fasilitas pembuatan aplikasi visual. Keunggulan bahasa pemograman ini terletak pada produktifitas, kualitas, pengembangan perangkat lunak, kecepatan kompilasi, pola desain yang menarik serta diperkuat dengan program yang terstruktur. Keunggulan lain dari *Delphi* ini adalah dapat digunakan untuk merancang program aplikasi yang memiliki tampilan seperti program aplikasi lain yang berbasis *Windows*. Khusus untuk pemrograman *database, Borland Delphi* menyediakan fasilitas objek yang kuat dan lengkap yang memudahkan *programmer* dalam membuat program.Lingkungan pengembangan terpadu atau *Integrated Development Environment* (IDE) dalam program *Delphi* terbagi menjadi delapan bagian utama, yaitu *Main Window, ToolBar, Component palette, Form Designer,Code Editor, Object Inspector, Exploring dan Object TreeView.* Untuk lebih jelasnya perhatikan gambar dibawah ini:

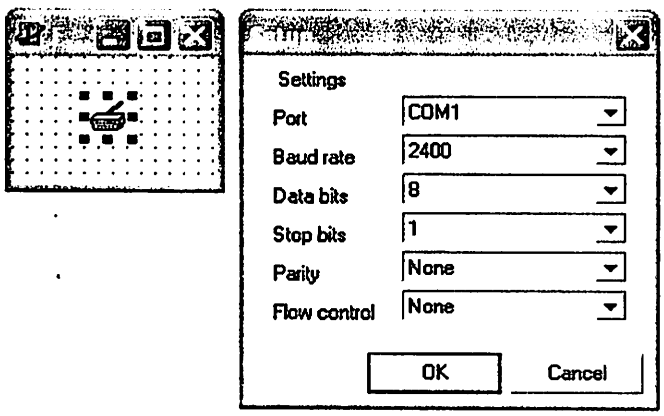


Gambar 2.11. Lembar Kerja Delphi

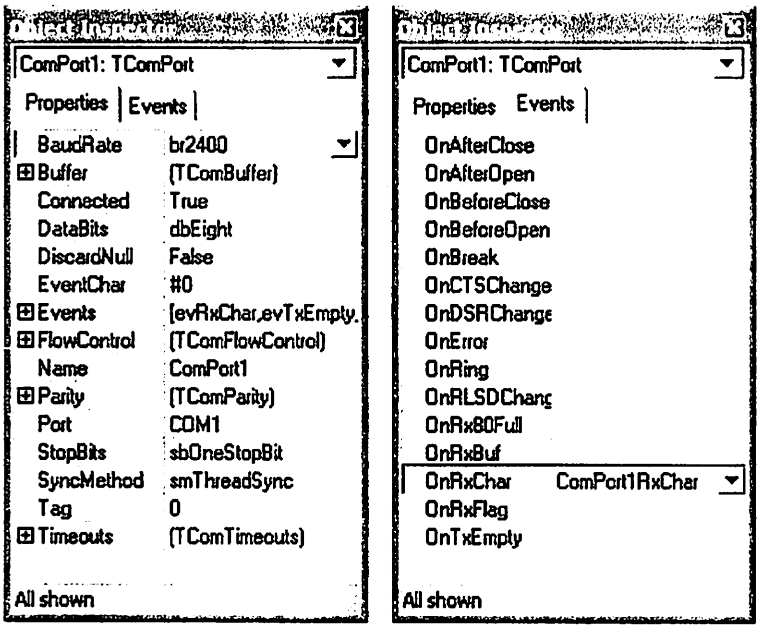
IDE merupakan sebuah lingkungan dimana semua tombol perintah yang diperlukan untuk mendesain aplikasi, menjalankan dan menguji sebuah aplikasi disajikan dengan baik untuk memudahkan pegembangan program.

2.10.1 Interaksi Delphi dengan Port Serial

Untuk membaca port serial PC digunakan komponen ComPort pada Delphi, jika komponen ini belum tersedia di menu maka perlu dilakukan instalasi terlebih dahulu, atau dipergunakan komponen lain yang fungsinya sama. Untuk mengatur komponen ini perlu dilakukan pengaturan pada *object inspector*–nya seperti ditunjukkan dalam Gambar 2.14 serta pada setup komponen ComPortnya sendiri seperti ditunjukkan dalam Gambar 2.15 berikut ini:



Gambar 2.12 Komponen ComPort dan *setup*-nya



Gambar 2.13 Pengaturan pada Object Properties komponen ComPort

BAB III

PERENCANAAN DAN PEMBUATAN ALAT

Dalam bab ini membahas mengenai metode perancangan sistem, perancangan perangkat keras dan perancangan perangkat lunak. Perancangan sistem meliputi blok diagram sistem dan cara kerja sistem. Perancangan perangkat keras meliputi perancangan rangkaian sensor ultrasonik, rangkaian LCD sebagai tampilan hasil pengukuran, rangkaian max 232 sebagai penghubung antara mikrokontroler dan PC, dimana PC adalah sebagai tampilan hasil pengukuran berupa grafik, dan rangkaian mikrokontroler Renesas R8C/13 sebagai kontrol utama semua sistem. Perancangan perangkat lunak meliputi perancangan *flowchart* program dari sistem ini.

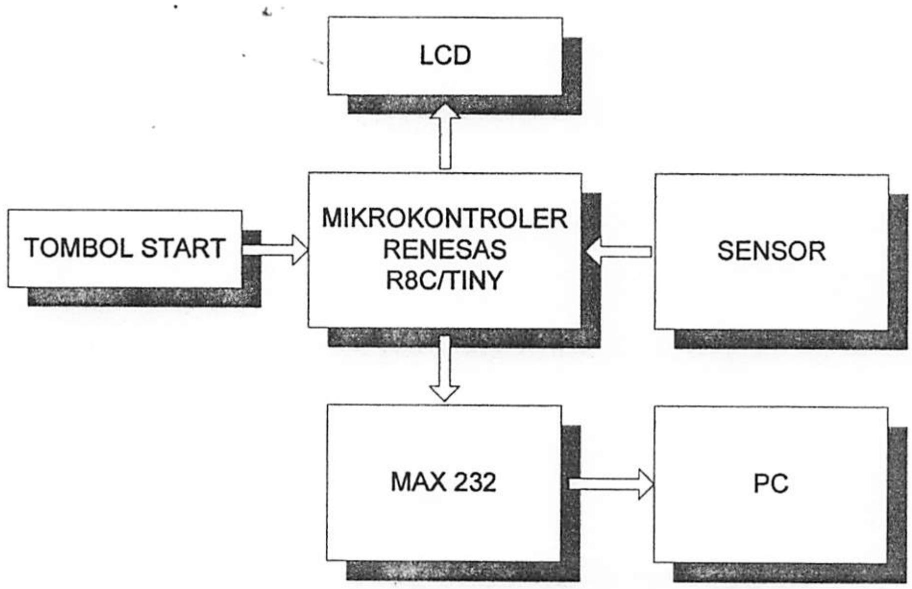
3.1 Perancangan dan Pembuatan Alat

3.1.1 Cara kerja alat

Rancangan mekanik dari alat ukur kapasitas paru-paru ini adalah dengan menggunakan dua buah tabung yang dihubungkan dengan pipa. Tabung pertama berdiameter 2 inchi dengan tinggi 50 cm, sedangkan balok kaca dengan tinggi 50 cm diasumsikan sebagai tabung kedua.

Pada saat tabung pertama diberi hembusan nafas (ekspirasi), maka sensor ultrasonik yang dipasang pada tabung kedua akan mendeteksi ketinggian permukaan air pada tabung kedua. Hasil yang diperoleh dari sensor ultrasonik akan diolah oleh mikrokontroler dan ditampilkan ke LCD. Dari ketinggian permukaan air tersebut akan dikonversikan ke volume, dan dapat diperoleh berapa nilai kapasitas paru-paru.

3.1.2 Blok diagram sistem



Gambar 3.1 Blok Diagram Alat Ukur Kapasitas Paru-Paru

3.1.3 Cara Kerja Sistem

Perancangan sistem ini terdiri dari beberapa blok yang masing-masing memiliki fungsi dalam proses informasi. Gambar 3.1 merupakan blok diagram alat ukur kapasitas paru-paru dengan menggunakan sensor ultrasonik. Fungsi dari masing-masing blok dalam Gambar 3.1 dijelaskan sebagai berikut:

a. Tombol start adalah tombol yang digunakan untuk pengaktifan alat ukur kapasitas paru-paru, perintah untuk mengontrol alat dilakukan dengan menekan tombol on / off.

b. Ultrasonik berfungsi sebagai sensor yang akan memancarkan dan menerima gelombang ultrasonik, yang dibangkitkan oleh mikrokontroler dengan frekuensi 40 kHz. Sensor yang berupa modul siap pakai ini akan mengukur ketinggian permukaan air.

c. Mikrokontroler Renesas R8C13 Tiny, sebagai kontrol utama dari seluruh sistem.

d. LCD M1632 berfungsi untuk menampilkan setiap intruksi, yaitu menampilkan ketinggian level air yang telah dikonversikan menjadi volume dari data yang dibaca oleh sensor.

e. Max 232 berfungsi sebagai penghubung antar mikro dan PC, atau penyeimbang tegangan pada mikro.

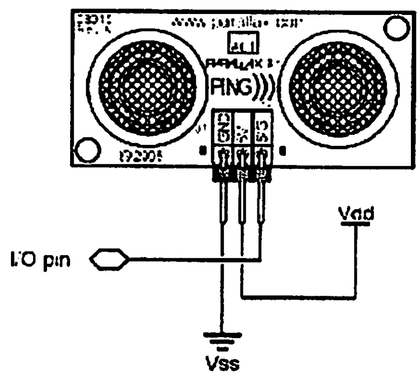
f. PC berfungsi untuk menampilkan tampilan dari hasil pengukuran berupa grafik.

3.2 Perancangan Perangkat Keras

Perangkat keras yang digunakan dalam sistem ini adalah perangkat keras yang mendukung proses keseluruhan. Perangkat keras yang dibutuhkan adalah sensor ultrasonik dan pengondisi sinyal, Mikrokontroller Renesas R8C/Tiny, LCD,Max 232, dan PC.

3.2.1 Rangkaian Sensor Ultrasonik

Sensor ultrasonik yang dipakai dalam tugas akhir ini adalah sensor ping yang berupa modul siap pakai lengkap dengan pengirim dan penerima. Sensor ultrasonik ini dipilih karena dapat mendeteksi jarak antara 3 cm sampai 3 m dengan frekuensi 40 kHz. Pada tugas akhir ini jarak yang akan diukur dari sensor menuju obyek adalah sekitar 40 cm. Sinyal data sensor ping ini akan masuk ke kaki mikrokontroler.

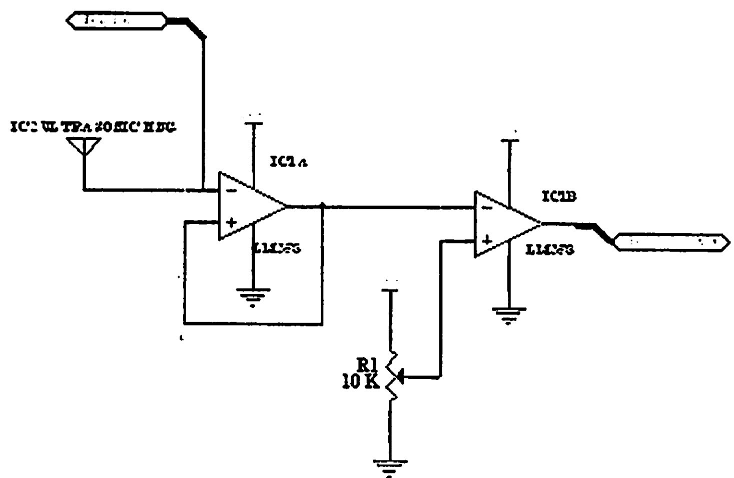


Gambar 3.2 Sensor ultrasonik PING

Sumber: www.parallax.com

Untuk mengaktifkan sensor ping diperlukan trigger sebesar 5 us, setelah itu dari keluaran sensor ultrasonik didapat level tegangan 0,7 V. Pada saat level tegangan 0,7 V maka keluarannya adalah aktif 1. Dalam perancangan ini diperlukan rangkaian komparator yang fungsinya untuk mendeteksi level tegangan yang keluar, yaitu 0,7 V.

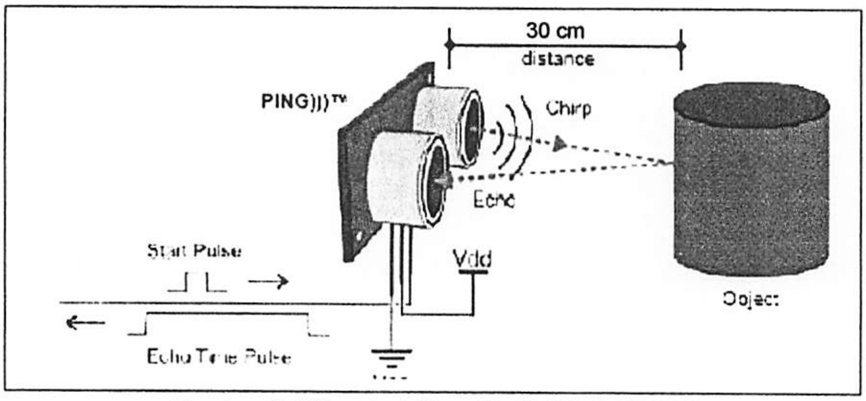
Dalam perancangan ini rangkaian pembanding tegangan (komparator) menggunakan op-amp LM358 dengan catu daya tunggal +5V DC. Tegangan acuan V_{ref} diterapkan ke masukan (+) op-amp, dan tegangan masukan dari sensor ping (-) op-amp. Bila tegangan masukan dari ping lebih besar atau sama dengan V_{ref}, maka tegangan keluaran op-amp, Vo = 0 Volt. Bila tegangan masukan dari ping lebih kecil V_{ref}, maka tegangan keluaran op-amp, Vo = 5 Volt.



Gambar 3.3 Rangkaian Sensor Ultrasonik Dengan pengkondisi sinyal

3.2.2 Perhitungan Jarak

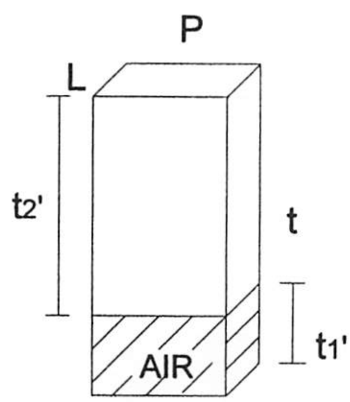
Modul Ping mengukur jarak objek dengan cara memancarkan gelombang ultrasonik sebesar 40 kHz kemudian menunggu pantulannya. Modul Ping memancarkan gelombang ultrasonik sesuai dengan input kontrol dari pin I/O. Gelombang ultrasonik tersebut melalui udara dengan kecepatan 34399,22 cm/ detik, mengenai objek dan memantul kembali ke modul Ping. Modul Ping akan mengeluarkan pulsa high pada pin I/O setelah memancarkan gelombang ultrasonik. Setelah pantulan gelombang terdeteksi, modul PING akan membuat pin I/O low. Lebar pulsa high (t_{IN}) sesuai dengan lama waktu tempuh gelombang ultrasonik untuk 2 kali jarak objek, sehingga jarak objek yang terukur adalah [(t_{IN} s X 34399,22 cm/s) / 2] cm. Pin I/O adalah pin yang digunakan untuk mengirim data ke mikrokontroler. Ilustrasi cara kerja modul Ping ditunjukkan dalam Gambar 3.4



Gambar 3.4 Ilustrasi Cara Kerja Modul PING

Sumber: www.parallax.com

3.2.3 Menghitung Volume



Untuk mencari volume dapat digunakan rumus:

Volume =luas alas x tinggi

Jadi jumlah volume:

V = luas penampang x t_1'

A = panjang x lebar x tinggi

Dimana:

t_1'= t - t_2'

$t = 50cm$.

$t1' = 10cm$

$t2' = 40cm$

$p = 10cm$

$L = 10cm$

$A = 10 \times 10cm = 100cm^2$

Keterangan gambar:

P = panjang

L = lebar

t = tinggi balok kaca

t1' = tinggi air dalam tabung

t2' = jarak antara air dengan sensor

Dalam alat ini digunakan balok yang diasumsikan sebagai tabung kedua. Balok ini mempunyai tinggi 50 cm dan luas penampang 100 cm^2.

Volume = luas penampang x t (1 cm)

$=100 \, cm^2 \times 1 \, cm$

$=100 \, cm^3$

$=100 \, ml$

$1 \, dm^3 = 1$ liter

$100 \, cm^3 = 0,1 \, dm^3$

$= 0,1$ liter

Jadi setiap 1 cm dari tinggi tabung kedua, mewakili 0,1 liter dari volume atau kapasitas paru-paru yang di ukur.

Besarnya perubahan volume atau udara pada tabung pertama berbanding lurus dengan perubahan ketinggian permukaan air pada tabung kedua. Waktu tempuh gelombang ultrasonik berbanding terbalik dengan besarnya volume udara pada tabung pertama. Semakin besar volume udara pada tabung pertama maka semakin cepat waktu tempuh gelombang ultrasonik yang terdapat pada tabung kedua.

3.2.4 Rangkaian Kontrol Mikrokontroller Renesas R8C / Tiny

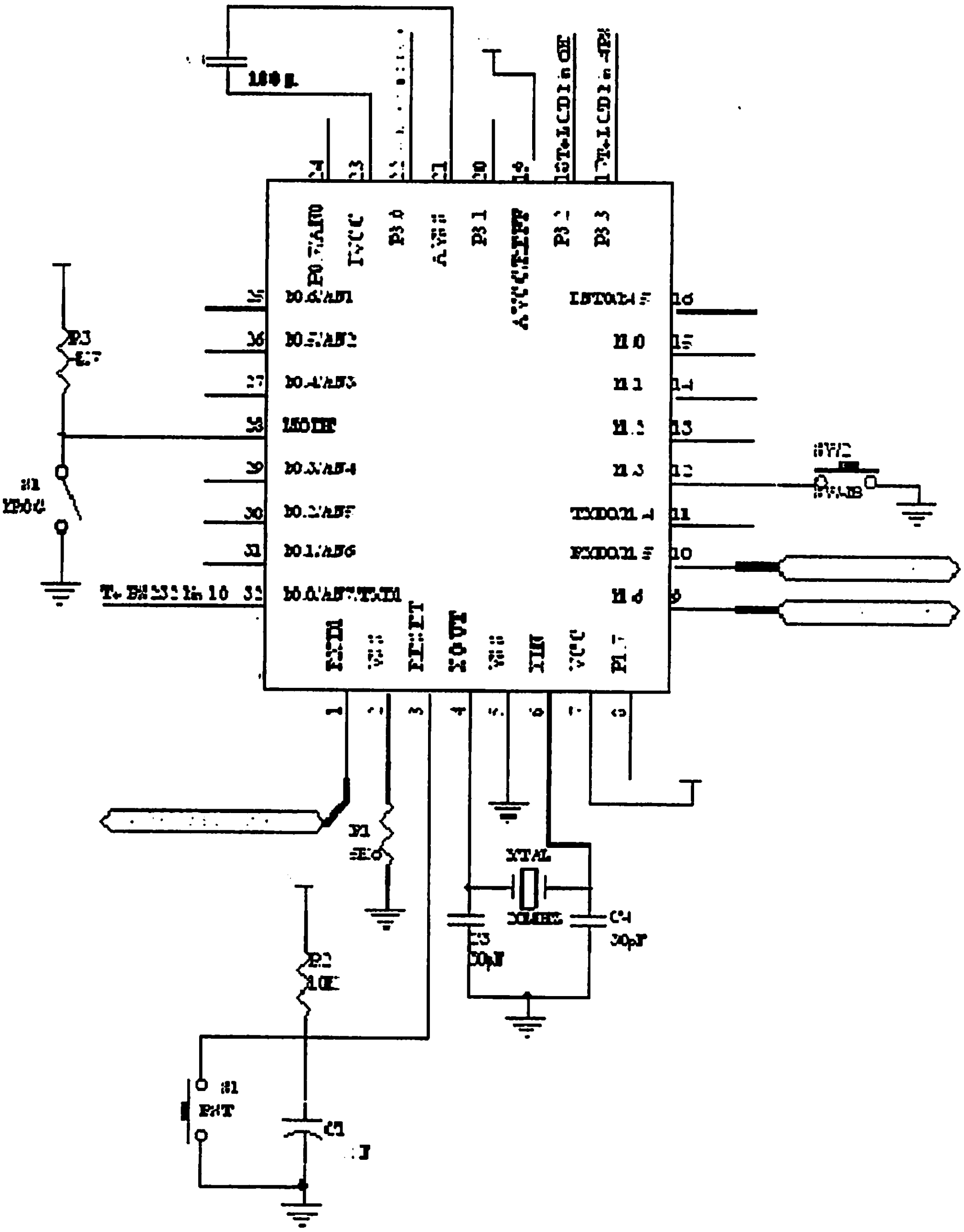
Dalam perancangan tugas akhir ini menggunakan mikrokontroller Renesas R8C/Tiny yang merupakan keluarga keluarga M16C. Mikrokontroler pada alat ini digunakan sebagai pengendali utama dari seluruh sistem. Mikrokontroler Renesas R8C/Tiny ini dipilih karena pada mikrokontroler ini memiliki 16 kbyte Flash *ROM* (Flash Read Only Memory) dan 1 kbytes *SRAM* serta 2x2 kbytes Data *Flash*, *RAM* sampai 1 kbyte, 22 bit port I/O (4 buah port I/O bit) yang mana tiap pin tersebut dapat di program secara paralel dan sendiri, mempunyai ADC (Analog to Digital Converter) mempunyai tiga buah timer/counter 8 bit (Timer X, Y, Z) dan satu buah timer/counter 16 bit (Timer C), mempunyai *watchdog timer*, mempunyai *power on reset*, mempunyai serial I/F (A/Sync), mempunyai on-Chip Debug, serta *Oscilator Circuit.*

Mikrokontroller Renesas R8C13 digunakan untuk membangkitkan sensor ultrasonik dan mengolah data yang merupakan masukan dari sensor ultrasonik tersebut. Mikrokontroller ini memiliki 4 port, yaitu *port* P0, *Port* P1, *port* P3, dan *Port* *P* 4. Masing-masing port difungsikan sebagai berikut:

- Port 0 memiliki fungsi sebagai berikut :
  - Port 0.0 digunakan sebagai ouput ke Max 232 (Tx)
- Port 1 memiliki fungsi sebagai berikut :
  - Port 1.3 digunakan sebagai inputan data.
  - Port 1.5 digunakan sebagai input data dari sensor.
  - Port 1.6 digunakan sebagai output data ke sensor.
- Port 3 memiliki fungsi sebagai berikut :
  - Port 3.0 digunakan sebagai inputan data dari IC 74LS164.
  - Port 3.1 digunakan sebagai clock.
  - Port 3.2 *Enable.*
  - Port 3.3 digunakan sebagai *Register select.*
  - Port 3.7 digunakan sebagai intput dari Max 232 (Rx)

❖ Port 4 memilki fungsi sebagai berikut :

➢ Port 4.7 dengan port 4.6 disambungkan dengan rangkaian osilator.



Gambar 3.5 Rangkaian Mikrokontroller

3.2.5 Rangkaian LCD

Pada Proyek akhir ini *Display* yang digunakan adalah LCD TM16x2, karena mempunyai tampilan sebanyak 16 karakter 2 baris. Untuk mengirim data ke LCD program harus mengeset EN ke kondisi high (1). Dalam kondisi ini RS dan R/W mengirimkan data ke jalur data bus. Dalam perancangan alat ini pada pin nomor 3 dari LCD dihubungkan dengan VR 1kΩ yang berguna untuk mengatur tampilan *contrast*. *Backlight* memerlukan tegangan sebesar 4.3V sehingga untuk menurunkan tegangan yang sebesar 5V dari *supply* perlu ditambahkan dioda IN4007 sebelum tegangan dihubungkan ke pin.

LCD ini berfungsi untuk menampilkan data perubahan ketinggian air dalam gelas ukur, selain itu LCD ini berfungsi sebagai alat komunikasi antara alat dengan pemakai. Sedangkan keuntungannya adalah tingkat kesederhanaan dalam rangkaian dan perangkat lunak serta kemudahan dalam pengoperasian dan tersedianya register-register dalam modul. Rangkaian unit LCD dapat dilihat pada gambar 3.6 yang mempunyai 16 pin masukan untuk mengendalikan modul dalam bentuk bus data dan sinyal kontrol. Gambar 3.6 menunjukkan rangkaian LCD yang dihubungkan pada mikrokontroller. Konfigurasi rangkaian LCD dengan komponen lain dapat dijelaskan sebagai berikut:

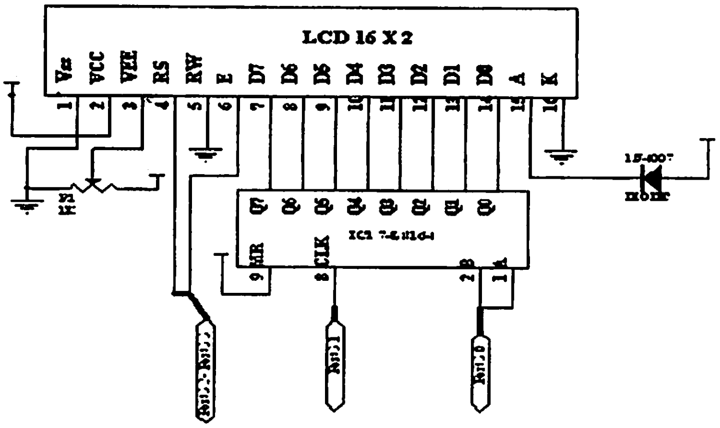
a. Pin 1(Vss), Pin 5(R/W) dan Pin 3(Vee) dihubungkan dengan resistor variabel 1KΩ, fungsinya adalah untuk mengatur kontras pada LCD.

b. Pin 2 dihubungkan dengan Vcc.

c. Pin 4(RS) dihubungkan dengan *port* P3.3 pada mikrokontroller Renesas R8C/TINY sebagai pemilih register.

d. Pin 6(E) dihubungkan dengan *port* P3.2 sebagai sinyal untuk seleksi baca atau tulis.

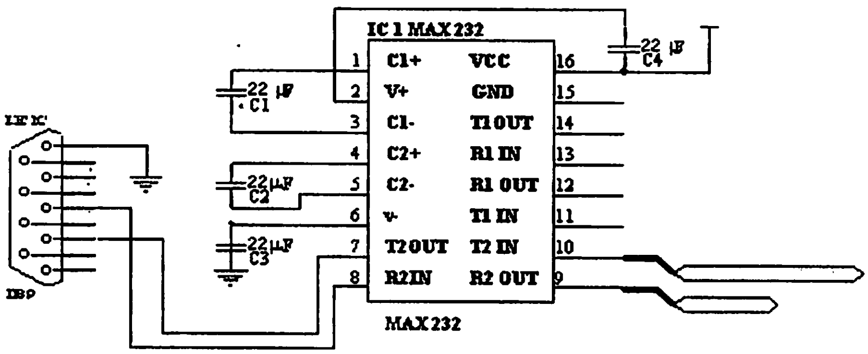
e. Pin 7-14(D0-D7) dihubungkan dengan output IC register 74LS164 yang berfungsi sebagai register geser 8-bit memiliki 4 jalan masuk dan 8 jalan keluar.



Gambar 3.6 Rangkaian LCD

3.2.6 Rangkaian *Interface*

Untuk dapat berkomunikasi antara MCU dengan PC, maka perlu disesuaikan *signal* yang dipakai yaitu dengan menggunakan *interface* RS 232. Dengan IC yang dipakai adalah MAX 232. Berikut ini adalah rangkaian *interface* dari MCU PC.



Gambar 3.7 Rangkaian RS 232

(Sumber : Perencanaan)

Pada MAX232, port yang digunakan :

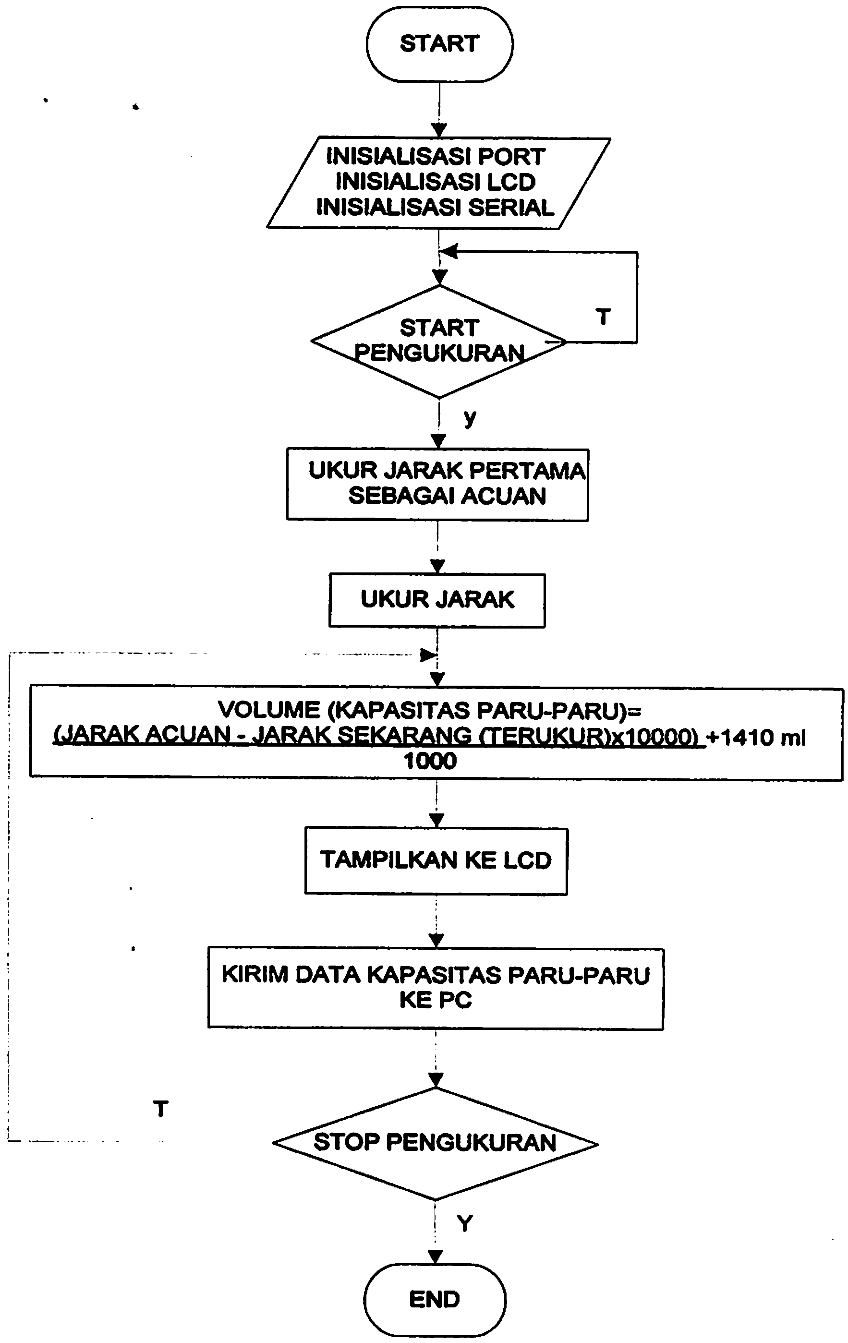
- Pin1 (C1+) dengan pin 3 (C1-) disambungkan dengan capasitor 22µF.
- Pin 2 (V+) dengan pin 16 (Vcc) disambungkan dengan capasitor 22µF.
- Pin 4 (C2+) dengan pin 5 (C2-) disambungkan dengan capasitor 22µF.
- Pin 6 (V-) dengan GND (ground) disambungkan dengan capasitor 22µF.
- Pin 7 (T2 OUT) disambungkan ke DB 9 port 2 (Rx).

- ➢ Pin 8 (R2 IN) disambungkan ke DB 9 port 3 (Tx).
- ➢ Pin 9 (R2 OUT) disambungkan ke Rx1 (MCU Renesas R8C/Tiny).
- ➢ Pin 10 (T2 IN) disambungkan ke Tx1 (MCU Renesas R8C/Tiny).

3.3 Perancangan Perangkat Lunak (*Software*)

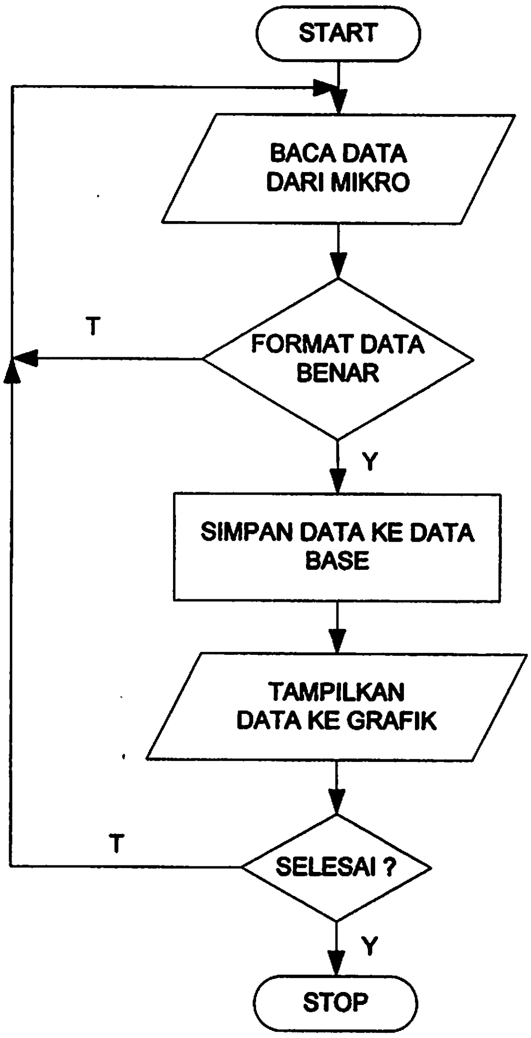
3.3.1 Flowchart Program Pada Mikrokontroler

Pemakaian mikrokontroler dalam suatu sistem perlu direncanakan perangkat lunak. Perangkat lunak merupakan susunan perintah-perintah program di dalam memori yang harus dilaksanakan mikrokontroler. Diagram alir program utama kerja alat ditunjukkan dalam Gambar 3.8.



Gambar 3.8 Gambar flowchart pada Mikrokontroller.

3.3.2 Flowchart Program Pada PC



Gambar 3.9 Gambar flowchart pada PC.

BAB IV

PENGUJIAN ALAT

Dalam bab ini akan dibahas tentang pengujian berdasarkan perencanaan dari sistem yang dibuat. Pengujian ini dilaksanakan untuk mengetahui kehandalan dari sistem dan untuk mengetahui apakah sudah sesuai dengan perencanaan atau belum. Pengujian pertama-tama dilakukan secara terpisah, dan kemudian dilakukan kedalam sistem yang telah diintegrasi.

4.1 Pengujian *Hardware*, *Software* dan Pengujian Keseluruhan

Pengujian bertujuan untuk mengetahui apakah sistem yang telah direalisasikan dapat bekerja sesuai dengan perencanaan yang telah ditetapkan. Pengujian sistem dilakukan pada perangkat *harware* dan *software*, pada masing-masing blok rangkaian penyusun sistem, antara lain: Pengujian LCD, Pengujian Sensor ultrasonik, Max 232, PC dan Pengujian secara keseluruhan.

4.1.1 Pengujian LCD

1. Tujuan

Tujuan pengujian rangkaian LCD adalah untuk mengetahui bahwa LCD dapat menampilkan karakter sesuai dengan program yang telah diisikan.

2. Alat yang digunakan

Alat yang digunakan dalam pengujian antara lain:

a. Rangkaian LCD.

b. Rangkaian minimum sistem mikrokontroler.

c. Catu daya 12 V.

3. Metode Pengujian

Langkah-langkah pengujian rangkaian ini adalah sebagai berikut:

a. Rangkaian disusun seperti pada Gambar 4.1.

b. Mikrokontroler diisi dengan program inisialisasi LCD.

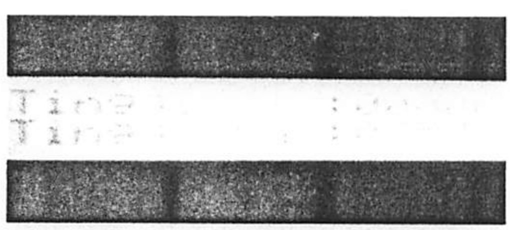
c. Pasang mikrokontroler pada soket di minimum sistem.

d. Menghubungkan catu daya.

e. Amati tampilan pada LCD.

4. Hasil dan Analisa Pengujian *LCD*

Dari pengujian LCD menggunakan Mikrokontroler Renesas R8C13 Tiny didapat hasil seperti pada Gambar 4.2.



Gambar 4.1
Hasil pengujian LCD

Dari hasil pengujian LCD dalam Gambar 4.2, maka dapat diambil kesimpulan bahwa LCD dapat menampilkan karakter dengan baik, yaitu tampilan huruf yang dituliskan pada LCD.

4.1.2 Pengujian Sensor ultrasonik

1. **Tujuan**

   Tujuan pengujian adalah untuk mengetahui sinyal keluaran dari sensor ultrasonik.

2. **Alat yang digunakan**

   Alat yang digunakan dalam pengujian antara lain:

   a. Transduser ultrasonok.

   b. osciloscop.

3. **Metode Pengujian**

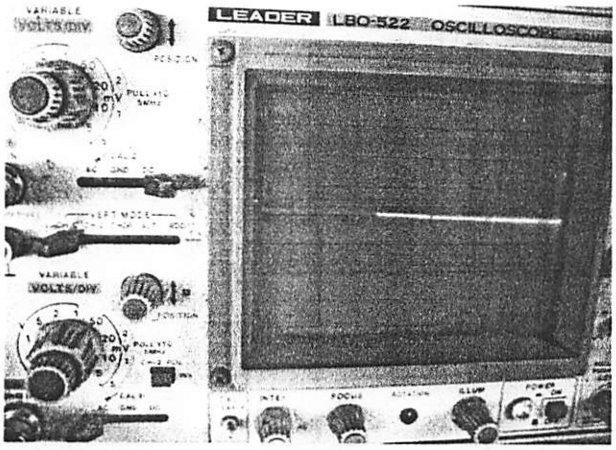
   Langkah-langkah pengujian adalah sebagai berikut:

   a. Rangkaian diberi catu daya 5 volt.

   b. Letakkan penyidik osciloskap pada rangkaian sensor ultrasonoik.

4. **Hasil dan Analisa Pengujian Sensor Ultrasonik**

Frequensi yang dipancarkan 40 KHz.



Gambar 4. 2
Hasil pengujian sensor ultrasonik

Tabel 4.1
Penyempurnaan pengujian sensor ultrasonik

Tinggi air dalam tabung yang sebenarnya (cm)	Tampilan *LCD*	Selisih tinggi air (cm)	*Error* (%)
0	0	0	0
1	1	0	0
5	4,8	0,2	0,8
10	9,7	0,3	1,8
15	14,8	0,2	1,3
20	19,7	0,3	2,1
25	24,8	0,2	0,5
30	29,7	0,3	0,9
35	34,9	0,1	0,2
40	39,8	0,2	0,5
Eror rata-rata		0,19	0,81

Tabel 4.1 bisa dilihat bahwa *error* dari hasil pengujian terhadap nilai yang di inginkan dalam perancangan bisa dihitung dengan:

$$Error = \frac{|\text{tinggi sebenarnya - tampilan LCD}|}{\text{tinggi sebenarnya}} \times 100\%$$

$$Error \text{ rata-rata} = \frac{\sum error}{\sum pengukuran}$$

$$= \frac{8{,}1}{10}$$

$$= 0.81\ \%$$

Kesimpulan hasil pengujian rangkaian ultrasonik sekaligus menggunakan *software* menunjukkan bahwa tinggi permukaan air yang ditampilkan pada LCD terdapat penyimpangan data (*error*) rata-rata sebesar 0.81 % dikarenakan pembacaan sensor yang tidak tepat.

4.1.3 Pengujian Rangkaian Komparator

1. **Tujuan**

Tujuan pengujian adalah untuk mengetahui sinyal keluaran dari rangkaian komparator.

2. **Alat yang digunakan**

Alat yang digunakan dalam pengujian antara lain:

c. Rangkaian komparator.

d. osciloscop.

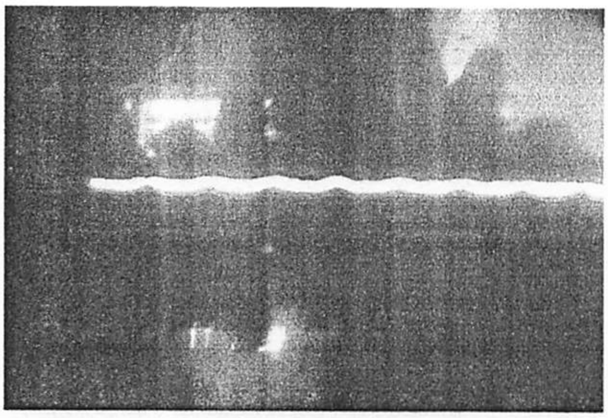
3. **Metode Pengujian**

Langkah-langkah pengujian adalah sebagai berikut:

a. Rangkaian diberi catu daya 5 volt.

b.Letakkan penyidik osciloskap pada rangkaian komparator.

4. **Hasil dan Analisa Pengujian rangklaian koparator**



Gambar 4.3
Hasil pengujian Rangkaian Komparator

Kesimpulan hasil pengujian rangkaian rangkaian komparator menggunakan osciloskap menunjukkan sinyakl keluaran pada rangkaian komparator.

4.1.4 Pengujian Shift Register (IC 74LS164)

1. **Tujuan**

Tujuan pengujian adalah untuk mengetahui sinyal keluaran dari IC 74LS164.

2. **Alat yang digunakan**

Alat yang digunakan dalam pengujian antara lain:

a. rangkaian shift register (IC 74LS164).

b.osciloscop.

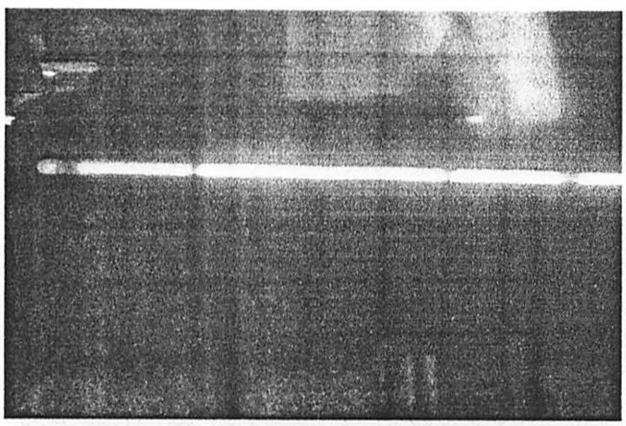
3. Metode Pengujian

Langkah-langkah pengujian adalah sebagai berikut:

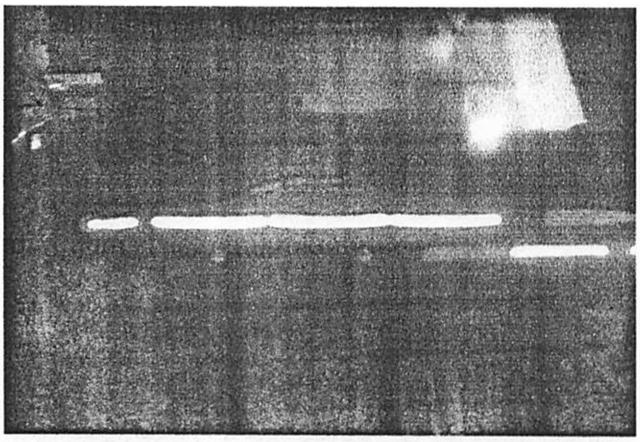
a. Rangkaian diberi catu daya 5 volt.

b.Letakkan penyidik osciloskap pada rangkaian shift register.

4. Hasil dan Analisa Pengujian Shift Register (IC 74LS164).



Gambar 4. 4
Hasil pengujian shift register seri



Gambar 4. 5
Hasil pengujian shift register paralel

4.1.5 Pengujian RS 232

1. Tujuan

Tujuan pengujian RS 232 ini dilakukan untuk melihat atau mengetahui apakah RS 232 dapat bekerja dengan baik, dengan adanya sinyal pada transmitter RS 232, maka akan terlihat bentuk gelombang RS 232 pada osiloskop.

2. Alat yang digunakan

Alat yang digunakan dalam pengujian antara lain:

a.Osiloskop.

b.RS 232.

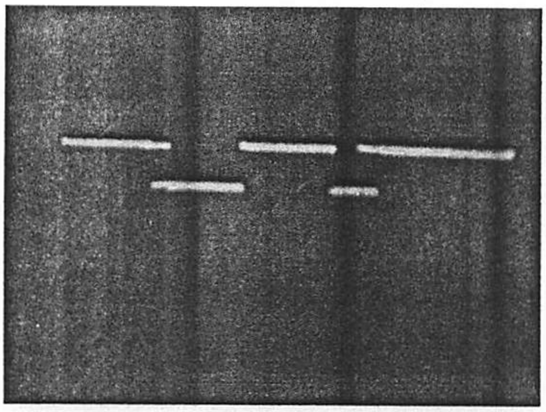
c.Rangkaian minimum sistem mikrokontroler.

d.Catu daya 12 V.

3. Metode pengujiannya adalah sebagai berikut :

Pin Tx mikrokontroler dihubungkan ke Max232, keluaran Max232 dihubungkan ke osiloskop.

4. Hasil Pengujian :



Gambar 4.6
Gambar Hasil Pengujian Max 232
Sumber : Pengujian

5. Analisa Hasil Pengujian

Dari pengujian max 232 menggunakan Mikrokontroler Renesas R8C13 Tiny dan osiloskop, Max 232 yg dihubungkan ke osiloskop diperoleh hasil pengujian seperti pada Gambar 4.6

5.1.6 Pengujian Komunikasi serial

1. Tujuan

Untuk mengetahui apakah komunikasi data serial PC dengan mikrokontroler dapat berjalan dengan baik.

2. Alat yang digunakan

Alat yang digunakan dalam pengujian antara lain :

a. Rangkaian minimum sistem mikrokontroler.

b. Rangkaian Max 232.

c. PC

d. Catu daya 12 V.

e. Kabel serial .

3. Metode Pengujian

Langkah-langkah pengujian rangkaian adalah sebagai berikut:

a. Hubungkan kabel serial pada konektor pada rangkaian serial dengan konektor serial pada komputer.

b. Mikrokontroler diisi dengan program.

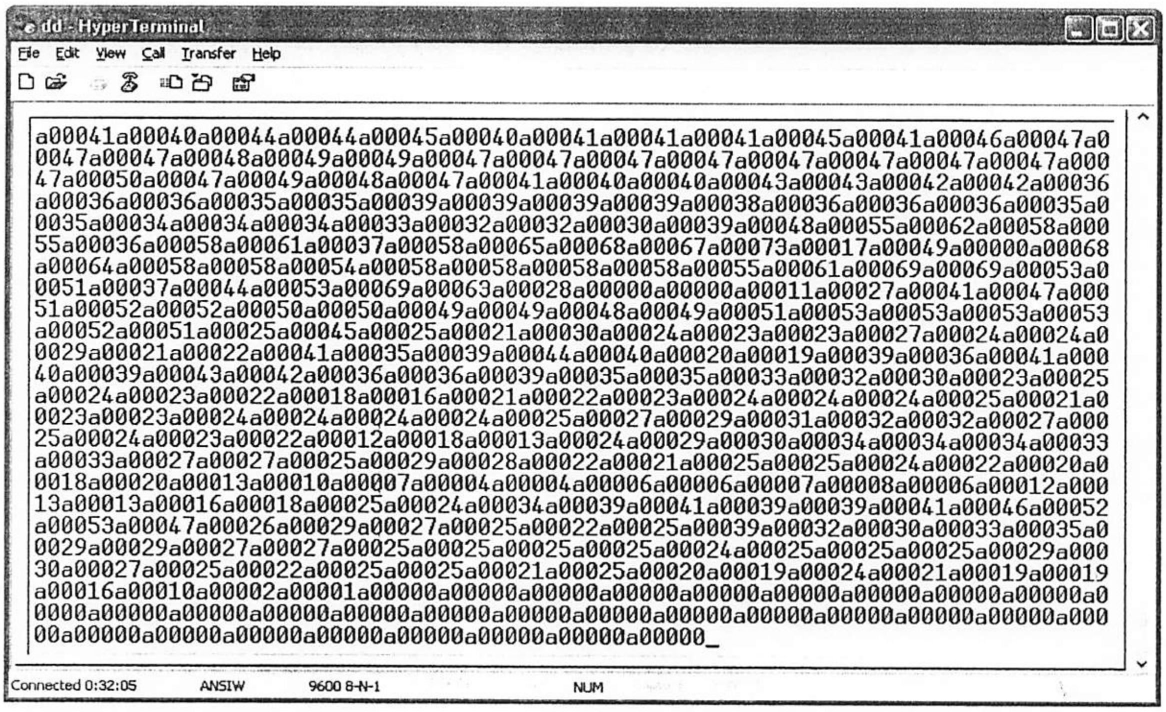
c. Pasang mikrokontroler pada soket di minimum sistem.

d. Menghubungkan catu daya.

e. Amati tampilan pada PC.

4. **Hasil dan Analisa Pengujian pada Komunikasi Data Serial RS-232**

Dari pengujian pengiriman data serial RS232 menggunakan Mikrokontroler Renesas R8C13 Tiny dan Max 232 yg dihubungkan ke *Personal Komputer* diperoleh hasil pengujian seperti pada Gambar 4.9.



Gambar 4.7
Hasil pengujian pengiriman data komunikasi serial RS232

4.1.7 Pengujian Keseluruhan Sistem

1. Tujuan

Tujuan pengujian keseluruhan sistem adalah untuk mengetahui prinsip kerja sistem secara lebih jelas. Untuk menguji keseluruhan sistem maka diintegrasikan antara *software* dan *hardware* secara bersama-sama. Pengujian dilakukan dengan langkah-langkah sesuai dengan rancangan per-blok yang telah dibuat.

2. **Alat yang digunakan**

Alat yang digunakan dalam pengujian antara lain:

a. Catu daya 12 V.

b. Perangkat keras dengan semua masukan dan keluaran.

c. *Software* yang telah dimasukkan ke dalam mikrokontroler.

3. **Metodologi Pengujian**

Pada pengujian rangkaian ini dilakukan antara lain:

a. Susun rangkaian seperti gambar 3.1.

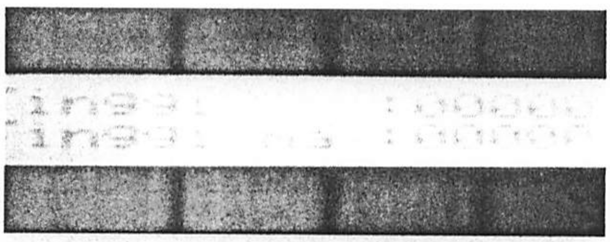
b. Aktifkan sistem

c. Ukur ketinggian maksimal permukaan level air pada tabung kedua.

d. Amati perubahan volume paru-paru yang diukur.

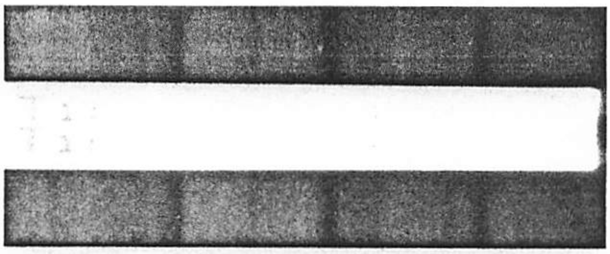
4. **Hasil dan Analisa Sistem Keseluruhan**

Hasil pengujian secara keseluruhan menunjukkan bahwa sistem dapat bekerja sesuai dengan rancangan yang telah dibuat. Pengujian pertama, dilakukan dengan cara mengaktifkan alat. Tampilan awal LCD dapat ditunjukkan Gambar 4.10 yang menampilkan volume paru-paru maksimal.

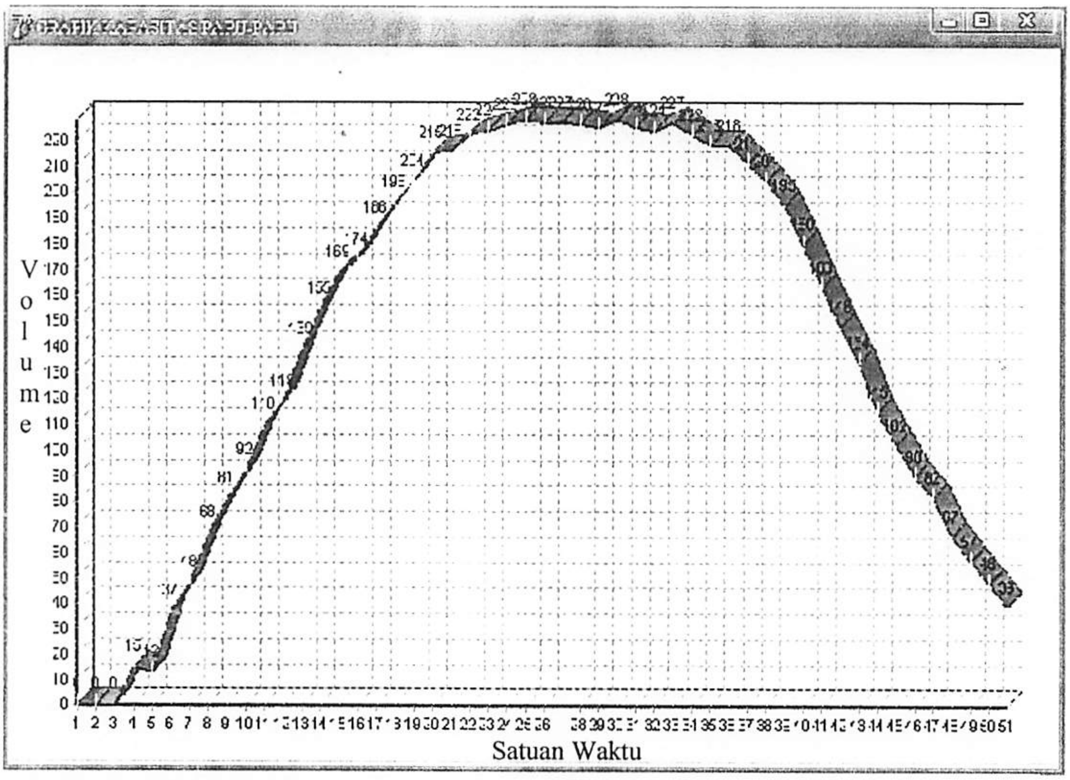


Gambar 4.8
Tampilan Awal LCD

Pengujian kedua, dengan memberi input pada tabung kedua yang berupa hembusan nafas (ekspirasi). Apabila hembusan nafas sudah maksimum maka LCD akan menampilkan berapa kapasitas paru-paru yang telah diukur, dan pada PC akan muncul tampilan berupa grafik. Tampilan proses pada saat kapasitas paru-paru telah terukur dapat ditunjukkan pada Gambar 4.11 sampai Gambar 4.12.



Gambar 4.9
Volume Paru-paru 3570 ml



Gambar 4.10
Gambar tampailan grafik pada PC

Tabel 4.2
Tabel Data Pengukuran Kapasitas Paru-paru

NO	NAMA	UMUR	Alat ukur volume paru-paru yang di buat	Alat ukur acuan di RS batu	Error (%)
1	Zul	27	3.92	3.95	1.54
2	Hery	27	3.59	3.64	1.93
3	Hendra	24	3.59	3.64	1.39
4	Randi	21	3.78	3.82	1.86
5	Irfan	19	3.86	3.89	1.04
Rata-rata					1.55

Dari data hasil pengukuran pada tabel 4.2 bisa dilihat bahwa *error* dari hasil pengukuran volume udara pada paru-paru (kapasitas udara pada paru-paru) yang di peroleh nilai *erro*r yang cukup besar, maka besarnya nilai *error* yang di dapat bisa dihitung dengan rumus:

$$\textit{Error} = \frac{|\text{Hasil pengukuran alat - Hasil dari alat sampel RS}|}{\text{Hasil pengukuran alat}} \times 100\%$$

$$\textit{Error}\text{ rata-rata} = \frac{\sum error}{\sum pengukuran}$$

$$= \frac{7.76}{5}$$

$$= 1.55\ \%$$

Kesimpulan hasil pengujian rangkaian keseluruhan yang meliputi *hardware* dan *software* dapat bekerja sesuai dengan yang direncanakan. Sensor dapat mendeteksi ketinggian air sehingga dapat diketahui nilai kapasitas paru-paru yang telah diukur menunjukkan bahwa tinggi permukaan air yang ditampilkan pada LCD terdapat penyimpangan data (*error*) rata-rata sebesar 1.55 % dikarenakan pembacaan sensor yang tidak tepat dan adanya beban berupa air yang sangat berpengaruh terhadap kinerja dari lat pernapasan dan alat atu sendiri..

Hasil pengujian sistem secara keseluruhan yang meliputi *hardware* dan *software* dapat bekerja sesuai dengan yang direncanakan. Rangkaian mikrokontroler dapat bekerja dengan baik sehingga pengiriman dan penerimaan data dari sensor ke mikrokontroler dapat diterima dan diproses dengan baik pula.

BAB V

PENUTUP

Kesimpulan dan saran yang dapat disajikan berdasarkan perancangan, pembuatan dan pengujian alat "Alat Ukur Kapasitas Paru-paru" adalah sebagai berikut:

5.1 Kesimpulan

Berdasarkan hasil pengujian pada masing-masing blok, maka dapat diperoleh beberapa kesimpulan sebagai berikut:

1. terjadi error antara alat yang di buat dengan alat pada rumah sakit yang disebabkan oleh perbesaan beban. Adanya beban berupa air pada alat yang di buat menyebabkan dadnya error di bandingkan dengan alat pada rumah sakit yang tidak memiliki beban.
2. Error terjadi karena :
   a. pada alat ukur volume udara pada paru-paru terdaoat beban berupa air, sedangkan pada lat rumah sakit tidak terdapat beban samasekali.
   b. kondisi fisik sangat berpengaruh terhaap kinerja alat pernapasan, kondisi lelah dan fit dapat menimbulkan perbedaan pada hasil pengukuran.
3. Hasil pengujian rangkaian ultrasonik menggunakan *software* menunjukan bahwa tinggi air yang ditampilkan pada LCD terdapat penyimpangan *(error)* rata-rata sebesar 1.55 % dikarenakan pembacaan sensor yang tidak tepat.

5.2 Saran

Dalam pengembangan selanjutnya dapat dilakukan beberapa hal untuk kesempurnaan alat yang berkaitan dengan sistem alat ukur volume udara dalam paru-paru , yaitu:

1. error dapat di minimalisasi dengan mengganti beban atau dengan merubah ukuran tabung yang di pakai menjadi lebih kecil, agar hasil pembacaan dari sensor lebih presisi..
2. kondisi fisik pasien sebelum dan sesudah mmmenguji volume paru- paru perlu di perhatina kembali.
3. Untuk menghasilkan hasil bacaan sensor yang presisi sebaiknya bentuk dan ukuran tabung pengukuran di ubah menjadi lebih kecil agar hasil pembacaan sensor lebih presisi.
4. Hasil pembacaan dari sensor dapat disimpan ke PC *(Personal Computer)*, sehingga tidak perlu diadakan pencatatan.

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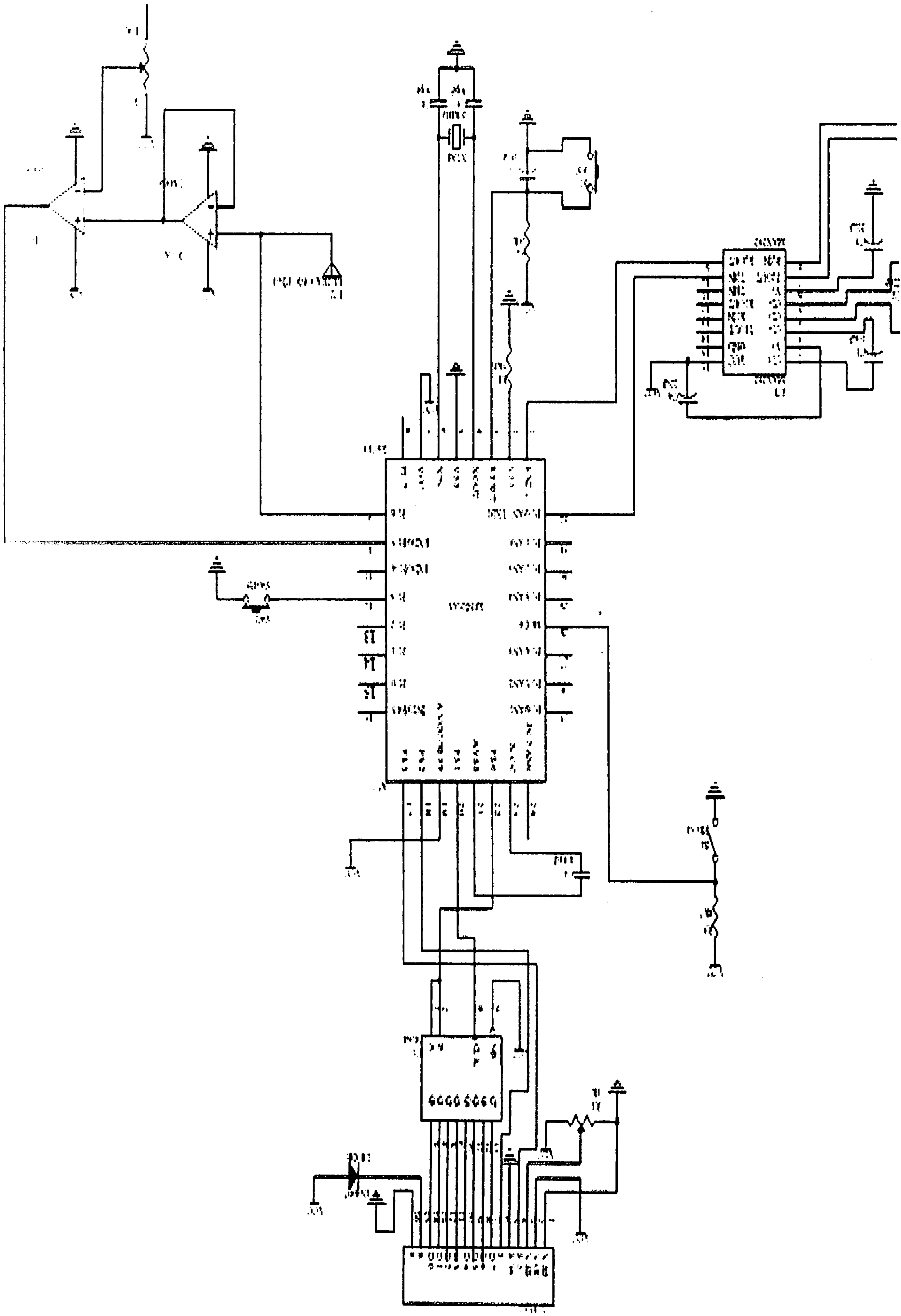

```
/***************************************************************************/
/*                                                                         */
/*  FILE        :tes.c                                                     */
/*  DATE        :Thu, Sep 28, 2006                                         */
/*  DESCRIPTION :Main Program                                              */
/*  CPU TYPE    :Other                                                     */
/*                                                                         */
/*  This file is generated by Renesas Project Generator (Ver.4.0).        */
/*                                                                         */
/***************************************************************************/

//#include <stdio.h>
#include "sfr_r813.h"
#include "timer.h"
#include "lcdku.h"
#include "adda.h"
//#include "keypad.h"
#include "serial.h"
/*
interup0 p45
sensor gaya adc0 vertikal
                        adc1 horisontal
*/


#define ping            p1_6
#define pong            p1_7
#define tombol          p1_1

unsigned char hit,c,step;
unsigned int a,ai,i,b,s;
unsigned long it,it1,k,kb,kh,kmax;
unsigned int k1;


void initport()
{
prc2=1;
pd0_5=1;
pd1=0b11110000;
prc2=1;pd0_6=0;
prc2=1;pd0_7=0;
pd3=0b11111111;//0xff;
pd3_7=0;
pd1_6=1;pd1_7=0;

}

void initADC(void)                                        //rutin inisialisasi adc
{
adcon0 = 0x01;  //prescaler fAD/2 (invalid), A/D conv disabled, P0 group
selected, oneshot mode, pin AN1 selected
adcon1 = 0x38; //0x38;  //Vref  connected, freq select at fAD valid, 10 bit mode
adcon2 = 0x00;  //0;//without sample and hold
//adst = 1;             //start conversion
}
void initint0()
{
        /* interupt terjadi saat rising edge */
        /* level interupt = 3 */
        int0ic=0x1;

        /* filter tidak digunakan */
        int0f=0x00;

        /* Global interupt dan int0 input diaktifkan */
        inten=0x01;
        asm("FSET I");
```

```
}
unsigned int bacasuhu(unsigned char nn)
{
        s=0;
        for(ai=0;ai<100;ai++)
        {
        adcon0 &= 0xF8 ;
        adcon0 |= nn;//0x06;
        asm("nop");
        adst = 1;
        while(adst) ;
        s=ad+s;
        }
        ai=s/200;
        return ai;
}


#pragma INTERRUPT i0
void i0(void)
{


        }
#pragma INTERRUPT tmx
void tmx(void)
{
        txund=0;
        prex=9;tx=1;txs=1;
        it++;
        }
void tampilcounter()
{
hit=hit*48/4;
b=((hit/100)%10)+48;dataout(b);
b=((hit/10)%10)+48;dataout(b);dataout(',');
b=(hit%10)+48;dataout(b);
hit=hit/10;
}
void tampilsuhu(unsigned int cc)
{
unsigned char bb;
bb=((cc/100)%10)+48;dataout(bb);
dataout(',');
bb=((cc/10)%10)+48;dataout(bb);
bb=(cc%10)+48;dataout(bb);
}
void tampil(unsigned int cc)
{
unsigned char bb;
bb=((cc/10000))+48;dataout(bb);
bb=((cc/1000)%10)+48;dataout(bb);
bb=((cc/100)%10)+48;dataout(bb);
bb=((cc/10)%10)+48;dataout(bb);
bb=(cc%10)+48;dataout(bb);
}
void kirimdata(unsigned int cc)
{
unsigned char bb;
kirim_serial('a');
bb=((cc/10000))+48;kirim_serial(bb);
bb=((cc/1000)%10)+48;kirim_serial(bb);
bb=((cc/100)%10)+48;kirim_serial(bb);
bb=((cc/10)%10)+48;kirim_serial(bb);
bb=(cc%10)+48;kirim_serial(bb);
}
void ukur()
{
ping=1;ping=1;
```

```
        asm("nop");
        asm("nop");
        asm("nop");
        asm("nop");
        asm("nop");
        asm("nop");
        asm("nop");
        asm("nop");
        asm("nop");
        asm("nop");
        asm("nop");
        asm("nop");
  ping=0;
  k1=0;delay(1);
 while(pong==1)   ;
 while(pong==0) k1++;
        k=k1/4.9;
}

void main(void)
{
/* Inisialisasi Variable*/
        //unsigned char data;
        /* Inisialisasi Awal MK */
        asm("FCLR I");  // Interrupt disable
        prcr = 1;                   // Protect off
        cm13 = 1;                   // X-in X-out = Clock External
        cm15 = 1;                   // XCIN-XCOUT drivecapacity select bit : HIGH
        cm05 = 0;                   // X-in on
        cm16 = 0;                   // Main clock = No division mode
        cm17 = 0;
        cm06 = 0;                   // CM16 and CM17 enable
        asm("nop");
        asm("nop");
        asm("nop");
        asm("nop");
        ocd2 = 0;                   // Main clock change (x-tal)
        prcr = 0;                   // Protect on
        //s1ric=3;s0ric=0;
        txic=2;
        /* p1 sebagai keluaran dan p0 sebagai masukan */
        //pd1=0xff;
        //asm("FSET I");
        initport();
        initlcd();
        delay(500);
        //initint0();
        initADC();
        initSerial();
        init_timer_X();//txs = 1;
        busek();
        //Send_Text("hfdsk");
        //cetak(1,1,"Jancuk");
        delay(1000);

        while (1) /////////////////////////////////////////////////////
        {
        busek();
        cetak(1,1,"Tekan tombol");
        cetak(2,1,"untuk memulai");
        while(tombol==1)
        {
        ukur();
        delay(100);
        }
        kb=k;
        kmax=0;
        busek();delay(500);
```

```
        cetak(1,1,"Tinggi    :");
        cetak(2,1,"Tinggi max:");
        while(tombol==1)
        {
        ukur();
        if(k<kb)kh=(kb-k)*10+1410;
        else kh=0;
        if(kh>kmax)kmax=kh;
        else ;
        pos(1,12);
        tampil(kh);
        kirimdata(kh);
        pos(2,12);
        tampil(kmax);
        delay(100);
        }

        }
}
```

```
/*#define e            p1_1
#define rs             p1_0
#define con_lcd        p1_2
#define data_lcd  p1_3*/

#define e              p3_2
#define rs             p3_3
#define con_lcd        p3_1
#define data_lcd  p3_0

unsigned char usa;
unsigned int jl,il;


void delay(unsigned int usa1)
{
for(il=0;il<usa1;il++)
{
for(jl=0;jl<625;jl++) ;
}
}

void delayx(int ni)
{
//int i;
for (il=0; il< ni ; il++)
;
}
void geser(unsigned char asul)
{
            con_lcd=0;

for(il=0;il<8;il++)
{
        data_lcd=(asul & 0x1)==0x1 ? 1 : 0;
        asm("nop");
            asm("nop");
            asm("nop");
            asm("nop");
            con_lcd=1;
        asm("nop");
            asm("nop");
            asm("nop");
            asm("nop");
            con_lcd=0;
            usa1=usa1>>1;
}
}

void callout(unsigned char usa1)
{
      rs=0;
      e=1;
      geser(usa1);
      delayx(10000);
      e=0;
}
void dataout(unsigned char usa1)
{
      rs=1;
      e=1;
      geser(usa1);
      delayx(5000);
      e=0;
}
void initlcd()
```

```
{
	callout(0x1);
	callout(0x38);
	callout(0x6);
	callout(0xc);
}
void pos(int i,int n)
{
if(i==1)
	usa=0x80+n-1;
else
	usa=0xc0+n-1;
	callout(usa);
}
void cetak(int i,int n,unsigned char *text)

{
	pos(i,n);
while(*text)
	{

	//usa=(*text++);
	dataout(*text++);
	}
}
void busek()
{
cetak(1,1,"                ");
cetak(2,1,"                ");
pos(1,1);
}
```

```
void initSerial(void)
{
      /* parity disable, 1 stop bit */
      /* internal clock, UART mode 8 bits data length */
      u1mr = 0x05;u0mr=0x05;
      /* data dikirim LSB dulu,TxD is CMOS output, /*
      /* tidak ada data, prescaler dibagi 1 */
      u1c0 = 0x08;u0c0=0x08;
      /* baud rate 9600 at 20 MHz   */
      u1brg = 129;
      u0brg = 129;
      /* re = 1;  enable reception */
      u1c1 |= 0x05; u0c1 |= 0x05;
      /* interupt at transmit completed, TXd11 activated */
      ucon |= 0x26;
}


void kirim_serial(char data)
{
      u1tb=data;
      while(txept_u1c0 == 0);
      //txept_u1c0 = 0;
      u1rb = data;
      u1c1 |= 1;
      delay(1);
      //delayx(20);
}
void kirimenter(char data)
{
      u1tb=data;
      while(txept_u1c0 == 0);
      //txept_u1c0 = 0;
      u1rb = data;
      u1c1 |= 1;
      //delay(1);
      delayx(11);
}
unsigned char GetChar()
{
while(ri_u0c1 == 0);
      ri_u0c1 =0;
      //dataout(u0rb);
      //asu1=u0rb;
      u0c1 |= 1;
      return u0rb;
}
unsigned char terimaser()
{
while(ri_u1c1 == 0);
      ri_u1c1 =0;
      //dataout(u0rb);
      //asu1=u0rb;
      u1c1 |= 1;
      return u1rb;
}

void kirimgps(unsigned char *text)
{
      while( *text!=',' )          // while not end of text
      {
```

```
            kirim_serial(*text++);  // Write character and increment
position
        }
return;
}

void kirimasli(unsigned char *text)
{
        while( *text!='?' )           // while not end of text
        {
            kirim_serial(*text++);  // Write character and increment
position
        }
return;
}

void enter()
{
        kirimenter(0x0D);
        // kirimenter(0x0A);

}
void Send_Text(unsigned char *text)
{
        while( *text )          // while not end of text
        {
        kirim_serial(*text++);  // Write character and increment position
        //delay(100);
        }
return;
}
void atcmg(unsigned char *CommandSMS)
{
        //send command SMS
        Send_Text(CommandSMS);
        delay(20)           ;
        enter()                         ;
        //delay(100)            ;
        return;
}
void del()
{
atcmg("at+cmgd=1");delay(200);
atcmg("at+cmgd=2");delay(200);
atcmg("at+cmgd=3");delay(200);
atcmg("at+cmgd=4");delay(200);
atcmg("at+cmgd=5");delay(200);
atcmg("at+cmgd=6");delay(200);
atcmg("at+cmgd=7");delay(200);
atcmg("at+cmgd=8");delay(200);
atcmg("at+cmgd=9");delay(200);
atcmg("at+cmgd=10");delay(200);
}
```

```
nit Unit1;

nterface

ses
 Windows, Messages, SysUtils, Variants, Classes, Graphics, Controls, Forms,
 Dialogs, StdCtrls, CPort, ExtCtrls, TeEngine, Series, TeeProcs, Chart,
 DbChart, DB, DBTables;

pe
 TForm1 = class(TForm)
   ComPort1: TComPort;
   Memo1: TMemo;
   Memo2: TMemo;
   Table1: TTable;
   DataSource1: TDataSource;
   DBChart1: TDBChart;
   Series1: TLineSeries;
   Timer1: TTimer;
   procedure ComPort1RxChar(Sender: TObject; Count: Integer);
   procedure Timer1Timer(Sender: TObject);
   procedure FormShow(Sender: TObject);
 private
   { Private declarations }
 public
   { Public declarations }
 end;

r
 Form1: TForm1;
 data_lkp:string;

plementation

R *.dfm}

ocedure TForm1.ComPort1RxChar(Sender: TObject; Count: Integer);
r data:string;
gin
mPort1.ReadStr(data,count);
ta_lkp:=data_lkp+data;
mo1.Text:=Memo1.Text+data;
mer1.Enabled:=false;
mer1.Enabled:=true;
 (copy(data_lkp,1,1)='a') and (length(data_lkp)-pos('a',data_lkp)>=6) then
 begin
 Memo2.Lines.Add(copy(data_lkp,pos('a',data_lkp)+1,5));
 data_lkp:='';
 end
se if length(data_lkp)>10 then  data_lkp:='';
d;

ocedure TForm1.Timer1Timer(Sender: TObject);
r i:integer;
gin
ile Table1.RecordCount<>0 do Table1.Delete;
=0;
peat
c(i);
ble1.Append;
ble1.FieldByName('no').AsInteger:=i;
ble1.FieldByName('data').AsInteger:=StrToInt(Memo2.Lines.Strings[i]);
ble1.Post;
```

```
ShowMessage(Memo2.Lines.Strings[i]);
til i>=Memo2.Lines.Count-1;

ShowMessage(IntToStr(Memo2.Lines.Count));
mer1.Enabled:=false;
mo2.Clear;
d;

ocedure TForm1.FormShow(Sender: TObject);
gin
mo1.Clear;
mo2.Clear;
d;

d.
```

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

FORMULIR PERBAIKAN SKRIPSI

NAMA : HENDRA MARIADI
N.I.M : 02.17.116
JURUSAN : TEKNIK ELEKTRO S-1
JUDUL SKRIPSI : PERANCANGAN DAN PEMBUATAN ALAT UKUR VOLUME UDARA PARU-PARU *(SPIROMETRY)* DENGAN MENGGUNAKAN RENESAS R8C/TINY

No.	TANGGAL	MATERI PERBAIKAN	PARAF
1.	23 MARET 2009	Hasil pengujian komparator	
2.	23 MARET 2009	Tambahkan metode penelitian	
3.	23 MARET 2009	Hitung penguatan OP-Amp	

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PING)))™ Ultrasonic Range Finder (#28015)

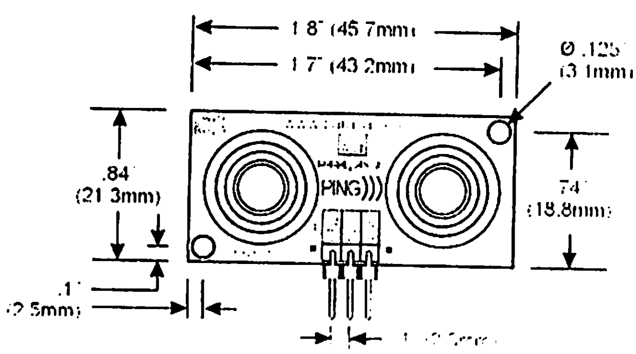
The Parallax PING))) ultrasonic range finder provides precise, non-contact distance measurements from about 3 cm (1.2 inches) to 3 meters (3.3 yards). It is very easy to connect to BASIC Stamp or Javelin Stamp microcontrollers, requiring only one I/O pin.

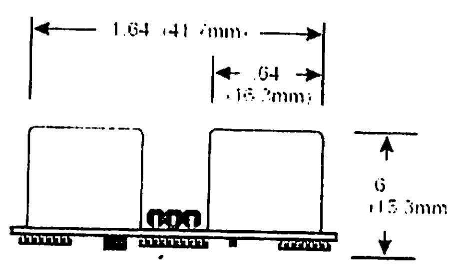
The Ping sensor works by transmitting an ultrasonic (well above human hearing range) burst and providing an output pulse that corresponds to the time required for the burst echo to return to the sensor. By measuring the echo pulse width the distance to target can easily be calculated.

Features

- Supply Voltage – 5 vdc
- Supply Current – 30 mA typ; 35 mA max
- Range – 3 cm to 3 m (1.2 in to 3.3 yrds)
- Input Trigger – positive TTL pulse, 2 uS min, 5 uS typ.
- Echo Pulse – positive TTL pulse, 115 uS to 18.5 mS
- Echo Hold-off – 750 uS from fall of Trigger pulse
- Burst Frequency – 40 kHz for 200 uS
- Burst Indicator LED shows sensor activity
- Delay before next measurement – 200 uS
- Size – 22 mm H x 46 mm W x 16 mm D (0.84 in x 1.8 in x 0.6 in)

Dimensions





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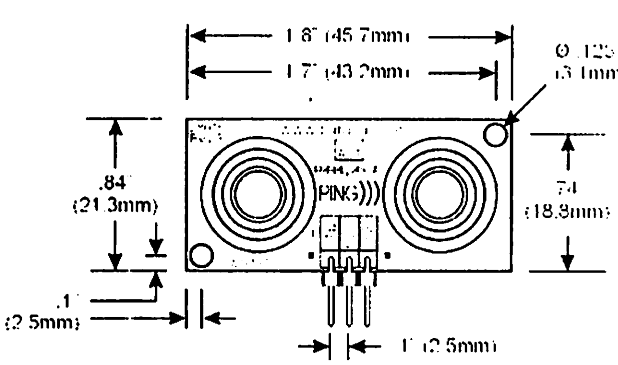
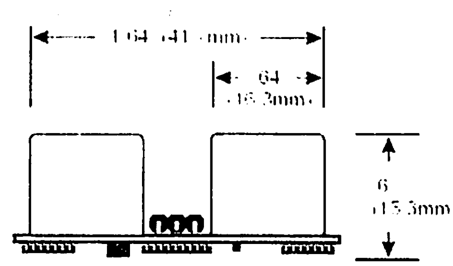
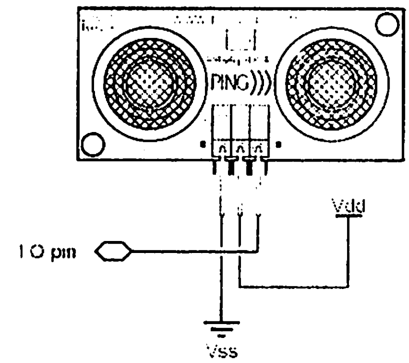




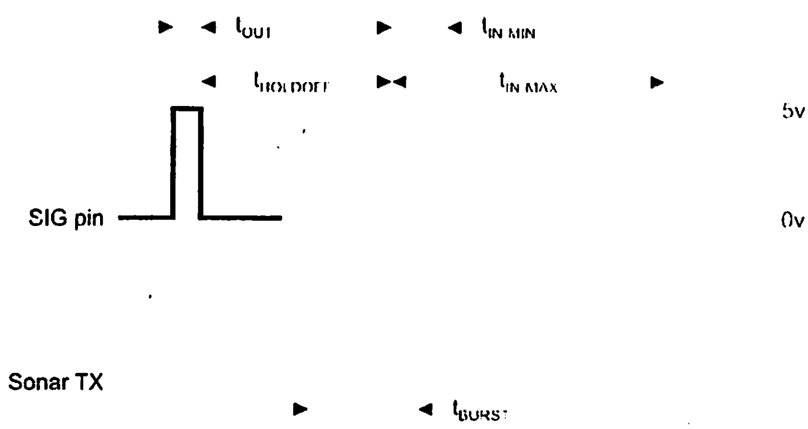
Connection to a Microcontroller

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



Theory of Operation

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



HOST

PING

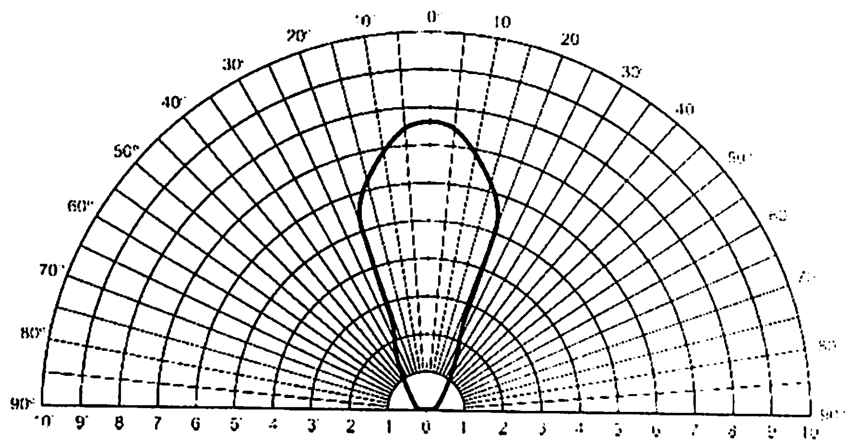
t_{OUT}	2 uS (min), 5 uS typical
$t_{HOLDOFF}$	750 uS
t_{BURST}	200 uS @ 40 kHz
$t_{IN\ MIN}$	115 uS
$t_{IN\ MAX}$	18.5 mS

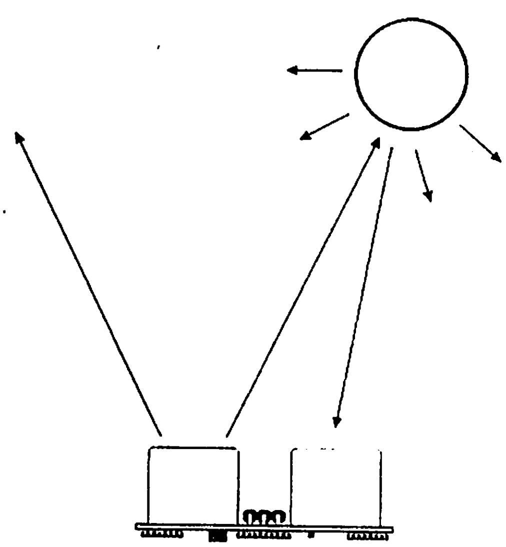
Test Data

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

Test 1

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

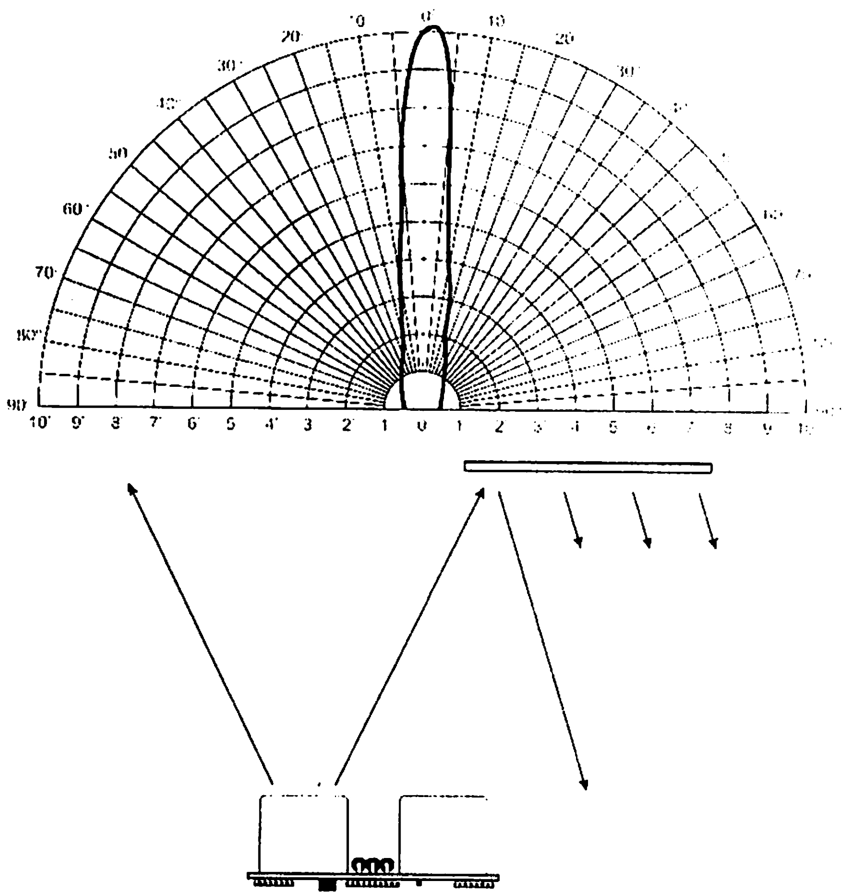




Test 2

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

- target positioned parallel to backplane of sensor



Program Example: BASIC Stamp 2 Microcontroller

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

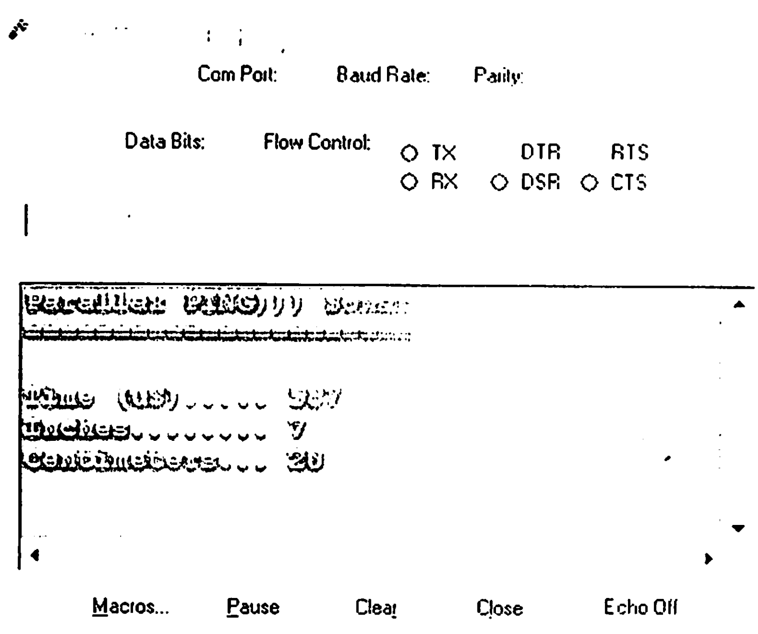
The heart of the program is the **Get_Sonar** subroutine. This routine starts by making the output bit of the selected IO pin zero – this will cause the successive **PULSOUT** to be low-high-low as required for triggering the PING))) sensor. After the trigger pulse falls the sensor will wait about 200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

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

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

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

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



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


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


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

Ping            PIN     15


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

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

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

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

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

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


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

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


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

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

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

    PAUSE 100
  LOOP
  END


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

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

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

Program Example: BASIC Stamp 1 Microcontroller

```
' =========================================================================
'
'   File....... Ping_Demo.BS1
'   Purpose.... Demo Code for Parallax Ping Sonar Sensor
'   Author..... Parallax, Inc.
'   E-mail..... support@parallax.com
'   Started....
'   Updated.... 03 FEB 2005
'
'   {$STAMP BS1}
'   {$PBASIC 1.0}
'
' =========================================================================


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


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

SYMBOL  Ping            = 7


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

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

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

SYMBOL  IsHigh          = 1                     ' for PULSOUT
SYMBOL  IsLow           = 0


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

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

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

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

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

  PAUSE 500
  GOTO Main

  END

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

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

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

Program Example: Javelin Stamp Microcontroller

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

```
package stamp.peripheral.sensor;

import stamp.core.*;


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

  private int ioPin;

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


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

    int echoRaw = 0;

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

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

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

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


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


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

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


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

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

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


public class testPing {

  public static final char HOME = 0x01;

  public static void main() {

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

    int distance;

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

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

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

19-0175; Rev 3; 5/96

MAXIM

±15kV ESD-Protected, +5V RS-232 Transceivers

General Description

The MAX202E–MAX213E, MAX232E/MAX241E line drivers/receivers are designed for RS-232 and V.28 communications in harsh environments. Each transmitter output and receiver input is protected against ±15kV electrostatic discharge (ESD) shocks, without latchup. The various combinations of features are outlined in the *Selection Guide*. The drivers and receivers for all ten devices meet all EIA/TIA-232E and CCITT V.28 specifications at data rates up to 120kbps, when loaded in accordance with the EIA/TIA-232E specification.

The MAX211E/MAX213E/MAX241E are available in 28-pin SO packages, as well as a 28-pin SSOP that uses 60% less board space. The MAX202E/MAX232E come in 16-pin narrow SO, wide SO, and DIP packages. The MAX203E comes in a 20-pin DIP/SO package, and needs no external charge-pump capacitors. The MAX205E comes in a 24-pin wide DIP package, and also eliminates external charge-pump capacitors. The MAX206E/MAX207E/MAX208E come in 24-pin SO, SSOP, and narrow DIP packages. The MAX232E/MAX241E operate with four 1µF capacitors, while the MAX202E/MAX206E/MAX207E/MAX208E/MAX211E/MAX213E operate with four 0.1µF capacitors, further reducing cost and board space.

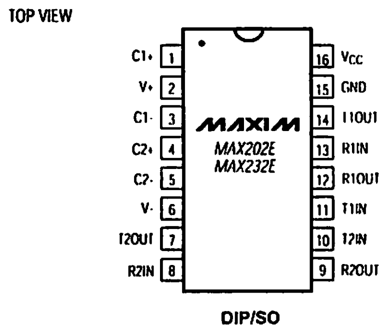
Applications

Notebook, Subnotebook, and Palmtop Computers
Battery-Powered Equipment
Hand-Held Equipment

Features

- ESD Protection for RS-232 I/O Pins:
  - ±15kV—Human Body Model
  - ±8kV—IEC1000-4-2, Contact Discharge
  - ±15kV—IEC1000-4-2, Air-Gap Discharge
- Latchup Free (unlike bipolar equivalents)
- Guaranteed 120kbps Data Rate—LapLink™ Compatible
- Guaranteed 3V/µs Min Slew Rate
- Operate from a Single +5V Power Supply

Pin Configurations



Pin Configurations and Typical Operating Circuits continued at end of data sheet.

Ordering Information appears at end of data sheet.

Selection Guide

PART	No. of RS-232 DRIVERS	No. of RS-232 RECEIVERS	RECEIVERS ACTIVE IN SHUTDOWN	No. of EXTERNAL CAPACITORS	LOW-POWER SHUTDOWN	TTL THREE-STATE
MAX202E	2	2	0	4 (0.1µF)	No	No
MAX203E	2	2	0	None	No	No
MAX205E	5	5	0	None	Yes	Yes
MAX206E	4	3	0	4 (0.1µF)	Yes	Yes
MAX207E	5	3	0	4 (0.1µF)	No	No
MAX208E	4	4	0	4 (0.1µF)	No	No
MAX211E	4	5	0	4 (0.1µF)	Yes	Yes
MAX213E	4	5	2	4 (0.1µF)	Yes	Yes
MAX232E	2	2	0	4 (1µF)	No	No
MAX241E	4	5	0	4 (1µF)	Yes	Yes

LapLink is a registered trademark of Traveling Software, Inc.

±15kV ESD-Protected, +5V RS-232 Transceivers

ABSOLUTE MAXIMUM RATINGS

V_{CC} ....-0.3V to +6V
V+ ....(V_{CC} - 0.3V) to +14V
V- ....-14V to +0.3V
Input Voltages
  T_IN ....-0.3V to (V+ + 0.3V)
  R_IN ....±30V
Output Voltages
  T_OUT ....(V- - 0.3V) to (V+ + 0.3V)
  R_OUT ....-0.3V to (V_{CC} + 0.3V)
Short-Circuit Duration, T_OUT ....Continuous
Continuous Power Dissipation (T_A = +70°C)
  16-Pin Plastic DIP (derate 10.53mW/°C above +70°C)....842mW
  16-Pin Narrow SO (derate 8.70mW/°C above +70°C) 696mW
  16-Pin Wide SO (derate 9.52mW/°C above +70°C) 762mW
  20-Pin Plastic DIP (derate 11.11mW/°C above +70°C)...889mW
  20-Pin SO (derate 10.00mW/°C above +70°C)............800mW
  24-Pin Narrow Plastic DIP
  (derate 13.33mW/°C above +70°C) 1.07W
  24-Pin Wide Plastic DIP
  (derate 14.29mW/°C above +70°C) 1.14W
  24-Pin SO (derate 11.76mW/°C above +70°C)............941mW
  24-Pin SSOP (derate 8.00mW/°C above +70°C) 640mW
  28-Pin SO (derate 12.50mW/°C above +70°C)....................1W
  28-Pin SSOP (derate 9.52mW/°C above +70°C) 762mW
Operating Temperature Ranges
  MAX2_ _EC_ _ ....0°C to +70°C
  MAX2_ _EE_ _ ....-40°C to +85°C
Storage Temperature Range ....-65°C to +165°C
Lead Temperature (soldering, 10sec) ....+300°C

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 in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

(V_{CC} = +5V ±10% for MAX202E/206E/208E/211E/213E/232E/241E; V_{CC} = +5V ±5% for MAX203E/205E/207E; C1–C4 = 0.1µF for MAX202E/206E/207E/208E/211E/213E; C1–C4 = 1µF for MAX232E/241E; T_A = T_{MIN} to T_{MAX}; unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
DC CHARACTERISTICS							
V_{CC} Supply Current	I_{CC}	No load, T_A = +25°C	MAX202E/203E		8	15	mA
			MAX205E–208E		11	20	
			MAX211E/213E		14	20	
			MAX232E		5	10	
			MAX241E		7	15	
Shutdown Supply Current		T_A = +25°C, Figure 1	MAX205E/206E		1	10	µA
			MAX211E/241E		1	10	
			MAX213E		15	50	
LOGIC							
Input Pull-Up Current		T_IN = 0V (MAX205E–208E/211E/213E/241E)			15	200	µA
Input Leakage Current		T_IN = 0V to V_{CC} (MAX202E/203E/232E)				±10	µA
Input Threshold Low	V_{IL}	T_IN; EN, $\overline{SHDN}$ (MAX213E) or $\overline{EN}$, SHDN (MAX205E–208E/211E/241E)				0.8	V
Input Threshold High	V_{IH}	T_IN		2.0			V
		EN, $\overline{SHDN}$ (MAX213E) or $\overline{EN}$, SHDN (MAX205E–208E/211E/241E)		2.4			
Output Voltage Low	V_{OL}	R_OUT; I_{OUT} = 3.2mA (MAX202E/203E/232E) or I_{OUT} = 1.6mA (MAX205E/208E/211E/213E/241E)				0.4	V
Output Voltage High	V_{OH}	R_OUT; I_{OUT} = -1.0mA		3.5	V_{CC} - 0.4		V
Output Leakage Current		$\overline{EN}$ = V_{CC}, EN = 0V, 0V ≤ R_{OUT} ≤ V_{CC}, MAX205E–208E/211E/213E/241E outputs disabled			±0.05	±10	µA

ELECTRICAL CHARACTERISTICS (continued)

(V_{CC} = +5V ±10% for MAX202E/206E/208E/211E/213E/232E/241E; V_{CC} = +5V ±5% for MAX203E/205E/207E; C1–C4 = 0.1µF for MAX202E/206E/207E/208E/211E/213E; C1–C4 = 1µF for MAX232E/241E; T_A = T_{MIN} to T_{MAX}; unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
EIA/TIA-232E RECEIVER INPUTS							
Input Voltage Range				-30		30	V
Input Threshold Low		T_A = +25°C, V_{CC} = 5V	All parts, normal operation	0.8	1.2		V
			MAX213E, $\overline{SHDN}$ = 0V, EN = V_{CC}	0.6	1.5		
Input Threshold High		T_A = +25°C, V_{CC} = 5V	All parts, normal operation		1.7	2.4	V
			MAX213E (R4, R5), $\overline{SHDN}$ = 0V, EN = V_{CC}		1.5	2.4	
Input Hysteresis		V_{CC} = 5V, no hysteresis in shutdown		0.2	0.5	1.0	V
Input Resistance		T_A = +25°C, V_{CC} = 5V		3	5	7	kΩ
EIA/TIA-232E TRANSMITTER OUTPUTS							
Output Voltage Swing		All drivers loaded with 3kΩ to ground (Note 1)		±5	±9		V
Output Resistance		V_{CC} = V+ = V- = 0V, V_{OUT} = ±2V		300			Ω
Output Short-Circuit Current					±10	±60	mA
TIMING CHARACTERISTICS							
Maximum Data Rate		R_L = 3kΩ to 7kΩ, C_L = 50pF to 1000pF, one transmitter switching		120			kbps
Receiver Propagation Delay	t_{PLHR}, t_{PHLR}	C_L = 150pF	All parts, normal operation		0.5	10	µs
			MAX213E (R4, R5), $\overline{SHDN}$ = 0V, EN = V_{CC}		4	40	
Receiver Output Enable Time		MAX205E/206E/211E/213E/241E normal operation, Figure 2			600		ns
Receiver Output Disable Time		MAX205E/206E/211E/213E/241E normal operation, Figure 2			200		ns
Transmitter Propagation Delay	t_{PLHT}, t_{PHLT}	R_L = 3kΩ, C_L = 2500pF, all transmitters loaded			2		µs
Transition-Region Slew Rate		T_A = +25°C, V_{CC} = 5V, R_L = 3kΩ to 7kΩ, C_L = 50pF to 1000pF, measured from -3V to +3V or +3V to -3V, Figure 3		3	6	30	V/µs
ESD PERFORMANCE: TRANSMITTER OUTPUTS, RECEIVER INPUTS							
ESD-Protection Voltage		Human Body Model			±15		kV
		IEC1000-4-2, Contact Discharge			±8		
		IEC1000-4-2, Air-Gap Discharge			±15		

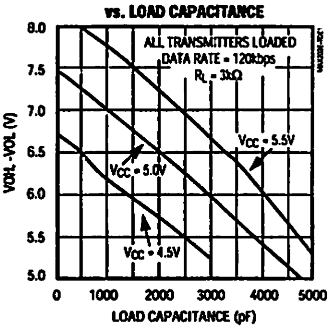
Note 1: MAX211EE_ _ tested with V_{CC} = +5V ±5%.

±15kV ESD-Protected, +5V RS-232 Transceivers

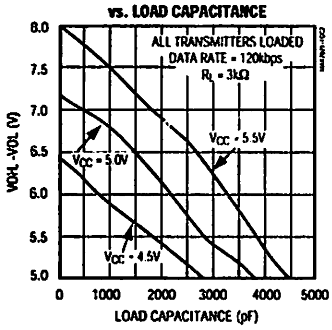
Typical Operating Characteristics

(Typical Operating Circuits, V_{CC} = +5V, T_A = +25°C, unless otherwise noted.)

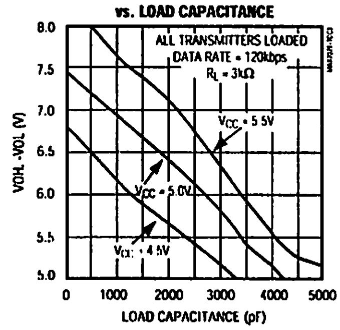
MAX232E
TRANSMITTER OUTPUT VOLTAGE
vs. LOAD CAPACITANCE



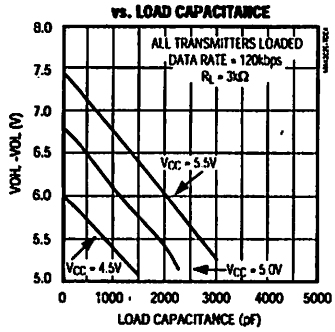
MAX202E/MAX203E
TRANSMITTER OUTPUT VOLTAGE
vs. LOAD CAPACITANCE



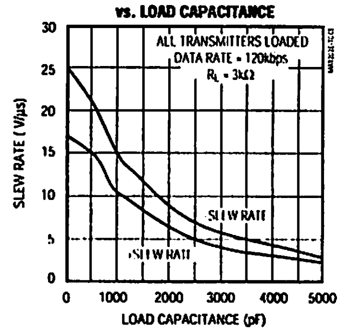
MAX241E
TRANSMITTER OUTPUT VOLTAGE
vs. LOAD CAPACITANCE



MAX211E/MAX213E
TRANSMITTER OUTPUT VOLTAGE
vs. LOAD CAPACITANCE



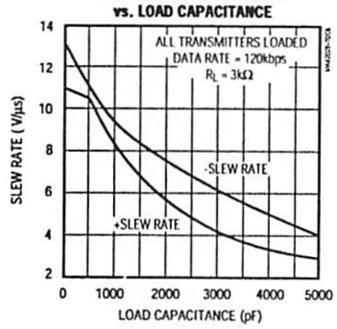
MAX211E/MAX213E/MAX241E
TRANSMITTER SLEW RATE
vs. LOAD CAPACITANCE



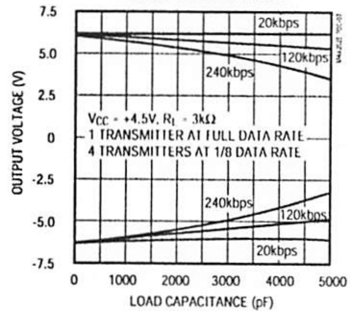
Typical Operating Characteristics (continued)

(Typical Operating Circuits, V_{CC} = +5V, T_A = +25°C, unless otherwise noted.)

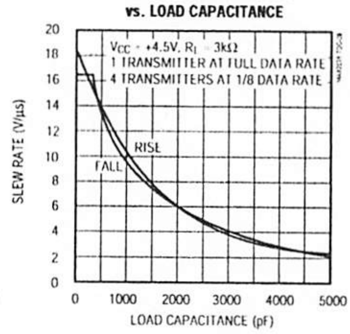
MAX202E/MAX203E/MAX232E TRANSMITTER SLEW RATE vs. LOAD CAPACITANCE



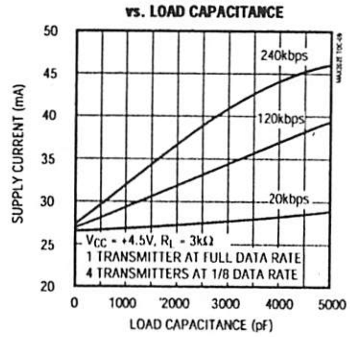
MAX205E–MAX208E TRANSMITTER OUTPUT VOLTAGE vs. LOAD CAPACITANCE



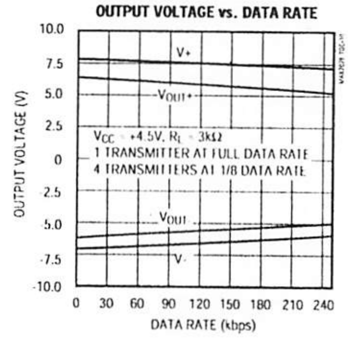
MAX205E–MAX208E TRANSMITTER SLEW RATE vs. LOAD CAPACITANCE



MAX205E–MAX208E SUPPLY CURRENT vs. LOAD CAPACITANCE



MAX205E–MAX208E OUTPUT VOLTAGE vs. DATA RATE



±15kV ESD-Protected, +5V RS-232 Transceivers

Pin Descriptions

MAX202E/MAX232E

PIN		NAME	FUNCTION
DIP/SO	LCC		
1, 3	2, 4	C1+, C1-	Terminals for positive charge-pump capacitor
2	3	V+	+2V_{CC} voltage generated by the charge pump
4, 5	5, 7	C2+, C2-	Terminals for negative charge-pump capacitor
6	8	V-	-2V_{CC} voltage generated by the charge pump
7, 14	9, 18	T_OUT	RS-232 Driver Outputs
8, 13	10, 17	R_IN	RS-232 Receiver Outputs
9, 12	12, 15	R_OUT	RS-232 Receiver Outputs
10, 11	13, 14	T_IN	RS-232 Driver Inputs
15	19	GND	Ground
16	20	V_{CC}	+4.5V to +5.5V Supply-Voltage Input
—	1, 6, 11, 16	N.C.	No Connect—not internally connected.

MAX203E

PIN		NAME	FUNCTION
DIP	SO		
1, 2	1, 2	T_IN	RS-232 Driver Inputs
3, 20	3, 20	R_OUT	RS-232 Receiver Outputs
4,19	4, 19	R_IN	RS-232 Receiver Inputs
5,18	5, 18	T_OUT	RS-232 Transmitter Outputs
6, 9	6, 9	GND	Ground
7	7	V_{CC}	+4.5V to +5.5V Supply-Voltage Input
8	13	C1+	Make no connection to this pin.
10, 16	11, 16	C2-	Connect pins together.
12, 17	10, 17	V-	-2V_{CC} voltage generated by the charge pump. Connect pins together.
13	14	C1-	Make no connection to this pin.
14	8	V+	+2V_{CC} voltage generated by the charge pump
11, 15	12, 15	C2+	Connect pins together.

MAX205E

PIN	NAME	FUNCTION
1-4, 19	T_OUT	RS-232 Driver Outputs
5, 10, 13, 18, 24	R_IN	RS-232 Receiver Inputs
6, 9, 14, 17, 23	R_OUT	TTL/CMOS Receiver Outputs. All receivers are inactive in shutdown.
7, 8, 15, 16, 22	T_IN	TTL/CMOS Driver Inputs. Internal pull-ups to V_{CC}.
11	GND	Ground
12	V_{CC}	+4.75V to +5.25V Supply Voltage
20	$\overline{EN}$	Receiver Enable—active low
21	SHDN	Shutdown Control—active high

Pin Descriptions (continued)

MAX206E

PIN	NAME	FUNCTION
1, 2, 3, 24	T_OUT	RS-232 Driver Outputs
4, 16, 23	R_IN	RS-232 Receiver Inputs
5, 17, 22	R_OUT	TTL/CMOS Receiver Outputs. All receivers are inactive in shutdown.
6, 7, 18, 19	T_IN	TTL/CMOS Driver Inputs. Internal pull-ups to V_{CC}.
8	GND	Ground
9	V_{CC}	+4.5V to +5.5V Supply Voltage
10, 12	C1+, C1-	Terminals for positive charge-pump capacitor
11	V+	+2V_{CC} generated by the charge pump
13, 14	C2+, C2-	Terminals for negative charge-pump capacitor
15	V-	-2V_{CC} generated by the charge pump
20	$\overline{EN}$	Receiver Enable—active low
21	SHDN	Shutdown Control—active high

MAX207E

PIN	NAME	FUNCTION
1, 2, 3, 20, 24	T_OUT	RS-232 Driver Outputs
4, 16, 23	R_IN	RS-232 Receiver Inputs
5, 17, 22	R_OUT	TTL/CMOS Receiver Outputs. All receivers are inactive in shutdown.
6, 7, 18, 19, 21	T_IN	TTL/CMOS Driver Inputs. Internal pull-ups to V_{CC}.
8	GND	Ground
9	V_{CC}	+4.75V to +5.25V Supply Voltage
10, 12	C1+, C1-	Terminals for positive charge-pump capacitor
11	V+	+2V_{CC} generated by the charge pump
13, 14	C2+, C2-	Terminals for negative charge-pump capacitor
15	V-	-2V_{CC} generated by the charge pump

MAX208E

PIN	NAME	FUNCTION
1, 2, 20, 24	T_OUT	RS-232 Driver Outputs
3, 7, 16, 23	R_IN	RS-232 Receiver Inputs
4, 6, 17, 22	R_OUT	TTL/CMOS Receiver Outputs. All receivers are inactive in shutdown.
5, 18, 19, 21	T_IN	TTL/CMOS Driver Inputs. Internal pull-ups to V_{CC}.
8	GND	Ground
9	V_{CC}	+4.5V to +5.5V Supply Voltage
10, 12	C1+, C1-	Terminals for positive charge-pump capacitor
11	V+	+2V_{CC} generated by the charge pump
13, 14	C2+, C2-	Terminals for negative charge-pump capacitor
15	V-	-2V_{CC} generated by the charge pump

Pin Descriptions (continued)

MAX211E/MAX213E/MAX241E

PIN	NAME	FUNCTION
1, 2, 3, 28	T_OUT	RS-232 Driver Outputs
4, 9, 18, 23, 27	R_IN	RS-232 Receiver Inputs
5, 8, 19, 22, 26	R_OUT	TTL/CMOS Receiver Outputs. For the MAX213E, receivers R4 and R5 are active in shutdown mode when EN = 1. For the MAX211E and MAX241E, all receivers are inactive in shutdown.
6, 7, 20, 21	T_IN	TTL/CMOS Driver Inputs. Only the MAX211E, MAX213E, and MAX241E have internal pull-ups to V_{CC}.
10	GND	Ground
11	V_{CC}	+4.5V to +5.5V Supply Voltage
12, 14	C1+, C1-	Terminals for positive charge-pump capacitor
13	V+	+2V_{CC} voltage generated by the charge pump
15, 16	C2+, C2-	Terminals for negative charge-pump capacitor
17	V-	-2V_{CC} voltage generated by the charge pump
24	$\overline{EN}$	Receiver Enable—active low (MAX211E, MAX241E)
	EN	Receiver Enable—active high (MAX213E)
25	SHDN	Shutdown Control—active high (MAX211E, MAX241E)
	$\overline{SHDN}$	Shutdown Control—active low (MAX213E)

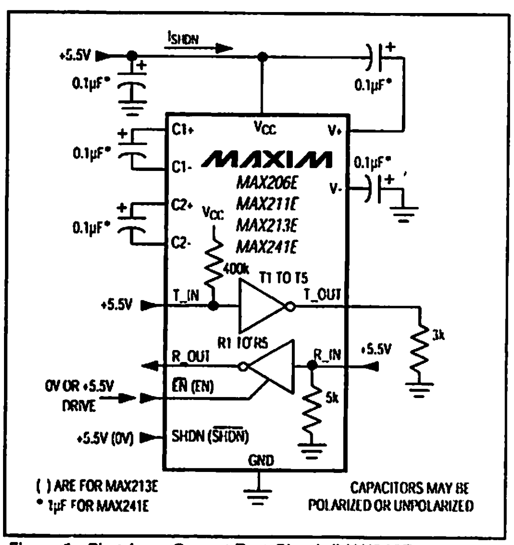


Figure 1. Shutdown-Current Test Circuit (MAX206E, MAX211E/MAX213E/MAX241E)

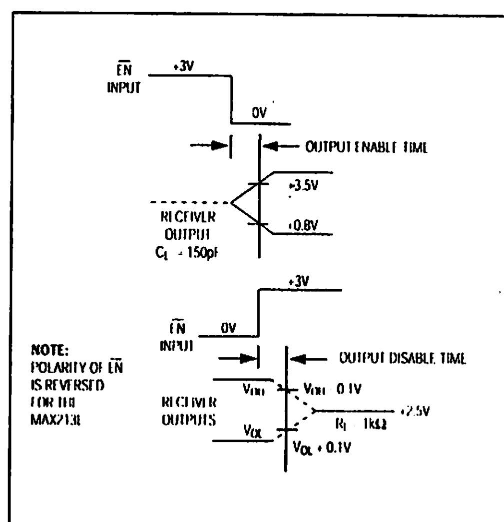


Figure 2. Receiver Output Enable and Disable Timing (MAX205E/MAX206E/MAX211E/MAX213E/MAX241E)

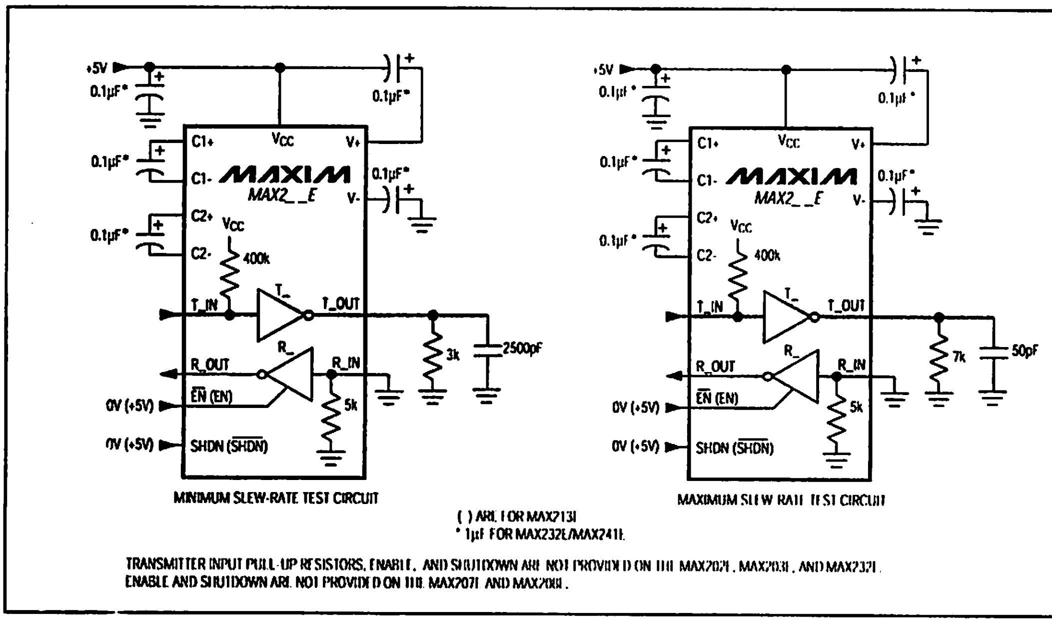


Figure 3. Transition Slew-Rate Circuit

Detailed Description

The MAX202E–MAX213E, MAX232E/MAX241E consist of three sections: charge-pump voltage converters, drivers (transmitters), and receivers. These E versions provide extra protection against ESD. They survive ±15kV discharges to the RS-232 inputs and outputs, tested using the Human Body Model. When tested according to IEC1000-4-2, they survive ±8kV contact-discharges and ±15kV air-gap discharges. The rugged E versions are intended for use in harsh environments or applications where the RS-232 connection is frequently changed (such as notebook computers). The standard (non-"E") MAX202, MAX203, MAX205–MAX208, MAX211, MAX213, MAX232, and MAX241 are recommended for applications where cost is critical.

+5V to ±10V Dual Charge-Pump Voltage Converter

The +5V to ±10V conversion is performed by dual charge-pump voltage converters (Figure 4). The first charge-pump converter uses capacitor C1 to double the +5V into +10V, storing the +10V on the output filter capacitor, C3. The second uses C2 to invert the +10V into -10V, storing the -10V on the V- output filter capacitor, C4.

In shutdown mode, V+ is internally connected to V_{CC} by a 1kΩ pull-down resistor, and V- is internally connected to ground by a 1kΩ pull-up resistor.

RS-232 Drivers

With V_{CC} = 5V, the typical driver output voltage swing is ±8V when loaded with a nominal 5kΩ RS-232 receiver. The output swing is guaranteed to meet EIA/TIA-232E and V.28 specifications that call for ±5V minimum output levels under worst-case conditions. These include a 3kΩ load, minimum V_{CC}, and maximum operating temperature. The open-circuit output voltage swings from (V+ - 0.6V) to V-.

Input thresholds are CMOS/TTL compatible. The unused drivers' inputs on the MAX205E–MAX208E, MAX211E, MAX213E, and MAX241E can be left unconnected because 400kΩ pull-up resistors to V_{CC} are included on-chip. Since all drivers invert, the pull-up resistors force the unused drivers' outputs low. The MAX202E, MAX203E, and MAX232E do not have pull-up resistors on the transmitter inputs.

±15kV ESD-Protected, +5V RS-232 Transceivers

When in low-power shutdown mode, the MAX205E/ MAX206E/MAX211E/MAX213E/MAX241E driver outputs are turned off and draw only leakage currents—even if they are back-driven with voltages between 0V and 12V. Below -0.5V in shutdown, the transmitter output is diode-clamped to ground with a 1kΩ series impedance.

RS-232 Receivers

The receivers convert the RS-232 signals to CMOS-logic output levels. The guaranteed 0.8V and 2.4V receiver input thresholds are significantly tighter than the ±3V thresholds required by the EIA/TIA-232E specification. This allows the receiver inputs to respond to TTL/CMOS-logic levels, as well as RS-232 levels.

The guaranteed 0.8V input low threshold ensures that receivers shorted to ground have a logic 1 output. The 5kΩ input resistance to ground ensures that a receiver with its input left open will also have a logic 1 output.

Receiver inputs have approximately 0.5V hysteresis. This provides clean output transitions, even with slow rise/fall-time signals with moderate amounts of noise and ringing.

In shutdown, the MAX213E's R4 and R5 receivers have no hysteresis.

Shutdown and Enable Control (MAX205E/MAX206E/MAX211E/ MAX213E/MAX241E)

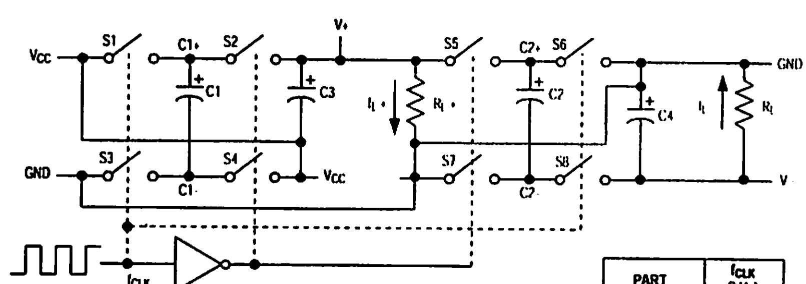
In shutdown mode, the charge pumps are turned off, V+ is pulled down to V_{CC}, V- is pulled to ground, and the transmitter outputs are disabled. This reduces supply current typically to 1μA (15μA for the MAX213E). The time required to exit shutdown is under 1ms, as shown in Figure 5.

Receivers

All MAX213E receivers, except R4 and R5, are put into a high-impedance state in shutdown mode (see Tables 1a and 1b). The MAX213E's R4 and R5 receivers still function in shutdown mode. These two awake-in-shutdown receivers can monitor external activity while maintaining minimal power consumption.

The enable control is used to put the receiver outputs into a high-impedance state, to allow wire-OR connection of two EIA/TIA-232E ports (or ports of different types) at the UART. It has no effect on the RS-232 drivers or the charge pumps.

Note: The enable control pin is active low for the MAX211E/MAX241E ($\overline{EN}$), but is active high for the MAX213E (EN). The shutdown control pin is active high for the MAX205E/MAX206E/MAX211E/MAX241E (SHDN), but is active low for the MAX213E ($\overline{SHDN}$).



PART	f_{CLK} (kHz)
MAX202E	230
MAX203E	230
MAX205E - 208E	200
MAX211E/213E	200
MAX232E	140
MAX241E	30

Figure 4. Charge-Pump Diagram

The MAX213E's receiver propagation delay is typically 0.5µs in normal operation. In shutdown mode, propagation delay increases to 4µs for both rising and falling transitions. The MAX213E's receiver inputs have approximately 0.5V hysteresis, except in shutdown, when receivers R4 and R5 have no hysteresis.

When entering shutdown with receivers active, R4 and R5 are not valid until 80µs after $\overline{SHDN}$ is driven low. When coming out of shutdown, all receiver outputs are invalid until the charge pumps reach nominal voltage levels (less than 2ms when using 0.1µF capacitors).

±15kV ESD Protection

As with all Maxim devices, ESD-protection structures are incorporated on all pins to protect against electrostatic discharges encountered during handling and assembly. The driver outputs and receiver inputs have extra protection against static electricity. Maxim's engineers developed state-of-the-art structures to protect these pins against ESD of ±15kV without damage. The ESD structures withstand high ESD in all states: normal operation, shutdown, and powered down. After an ESD event, Maxim's E versions keep working without latchup, whereas competing RS-232 products can latch and must be powered down to remove latchup.

ESD protection can be tested in various ways; the transmitter outputs and receiver inputs of this product family are characterized for protection to the following limits:

1) ±15kV using the Human Body Model
2) ±8kV using the contact-discharge method specified in IEC1000-4-2
3) ±15kV using IEC1000-4-2's air-gap method.

ESD Test Conditions

ESD performance depends on a variety of conditions. Contact Maxim for a reliability report that documents test set-up, test methodology, and test results.

Human Body Model

Figure 6a shows the Human Body Model, and Figure 6b shows the current waveform it generates when discharged into a low impedance. This model consists of a 100pF capacitor charged to the ESD voltage of interest, which is then discharged into the test device through a 1.5kΩ resistor.

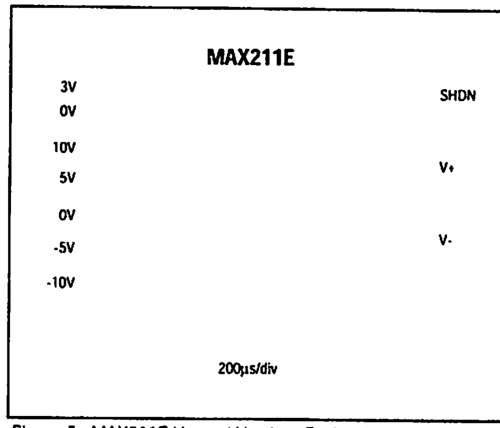


Figure 5. MAX211E V+ and V- when Exiting Shutdown (0.1µF capacitors)

Table 1a. MAX205E/MAX206E/MAX211E/MAX241E Control Pin Configurations

SHDN	$\overline{EN}$	OPERATION STATUS	Tx	Rx
0	0	Normal Operation	All Active	All Active
0	1	Normal Operation	All Active	All High-Z
1	X	Shutdown	All High-Z	All High-Z

X = Don't Care

Table 1b. MAX213E Control Pin Configurations

$\overline{SHDN}$	EN	OPERATION STATUS	Tx 1–4	Rx	
				1–3	4, 5
0	0	Shutdown	All High-Z	High-Z	High-Z
0	1	Shutdown	All High-Z	High-Z	Active*
1	0	Normal Operation	All Active	High-Z	High-Z
1	1	Normal Operation	All Active	Active	Active

*Active = active with reduced performance

±15kV ESD-Protected, +5V RS-232 Transceivers

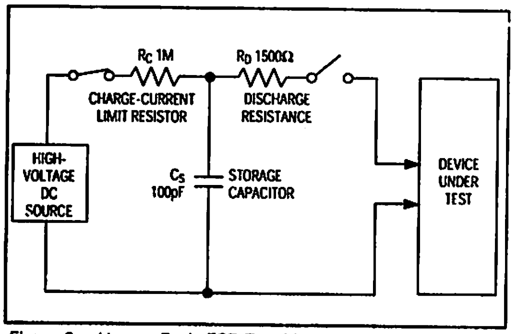


Figure 6a. Human Body ESD Test Model

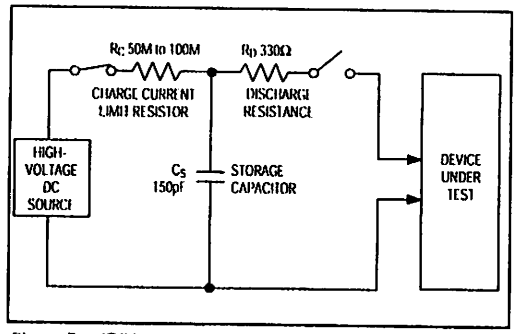


Figure 7a. IEC1000-4-2 ESD Test Model

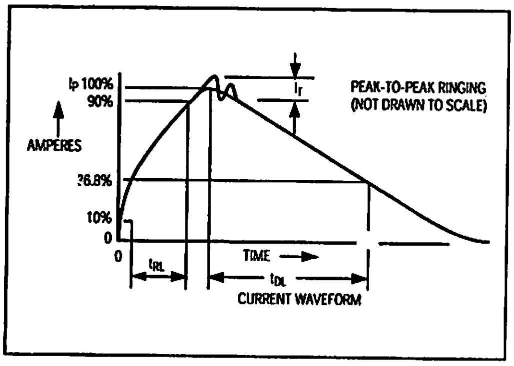


Figure 6b. Human Body Model Current Waveform

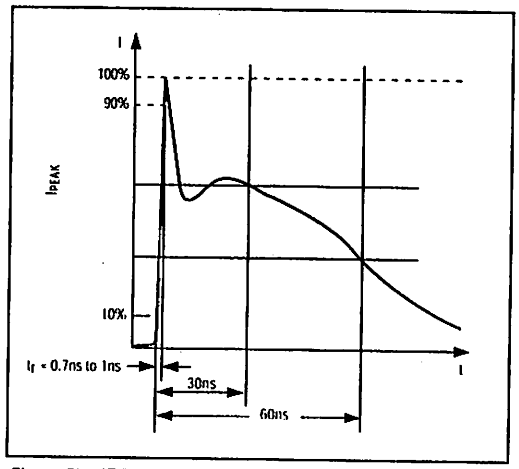


Figure 7b. IEC1000-4-2 ESD Generator Current Waveform

IEC1000-4-2

The IEC1000-4-2 standard covers ESD testing and performance of finished equipment; it does not specifically refer to integrated circuits. The MAX202E/MAX203E–MAX213E, MAX232E/MAX241E help you design equipment that meets level 4 (the highest level) of IEC1000-4-2, without the need for additional ESD-protection components.

The major difference between tests done using the Human Body Model and IEC1000-4-2 is higher peak current in IEC1000-4-2, because series resistance is lower in the IEC1000-4-2 model. Hence, the ESD withstand voltage measured to IEC1000-4-2 is generally lower than that measured using the Human Body Model. Figure 7b shows the current waveform for the 8kV IEC1000-4-2 level-four ESD contact-discharge test.

The air-gap test involves approaching the device with a charged probe. The contact-discharge method connects the probe to the device before the probe is energized.

Machine Model

The Machine Model for ESD tests all pins using a 200pF storage capacitor and zero discharge resistance. Its objective is to emulate the stress caused by contact that occurs with handling and assembly during manufacturing. Of course, all pins require this protection during manufacturing, not just RS-232 inputs and outputs. Therefore, after PC board assembly, the Machine Model is less relevant to I/O ports.

Applications Information

Capacitor Selection

The capacitor type used for C1–C4 is not critical for proper operation. The MAX202E, MAX206–MAX208E, MAX211E, and MAX213E require 0.1µF capacitors, and the MAX232E and MAX241E require 1µF capacitors, although in all cases capacitors up to 10µF can be used without harm. Ceramic, aluminum-electrolytic, or tantalum capacitors are suggested for the 1µF capacitors, and ceramic dielectrics are suggested for the 0.1µF capacitors. When using the minimum recommended capacitor values, make sure the capacitance value does not degrade excessively as the operating temperature varies. If in doubt, use capacitors with a larger (e.g., 2x) nominal value. The capacitors' effective series resistance (ESR), which usually rises at low temperatures, influences the amount of ripple on V+ and V-.

Use larger capacitors (up to 10µF) to reduce the output impedance at V+ and V-. This can be useful when "stealing" power from V+ or from V-. The MAX203E and MAX205E have internal charge-pump capacitors.

Bypass V_{CC} to ground with at least 0.1µF. In applications sensitive to power-supply noise generated by the charge pumps, decouple V_{CC} to ground with a capacitor the same size as (or larger than) the charge-pump capacitors (C1–C4).

V+ and V- as Power Supplies

A small amount of power can be drawn from V+ and V-, although this will reduce both driver output swing and noise margins. Increasing the value of the charge-pump capacitors (up to 10µF) helps maintain performance when power is drawn from V+ or V-.

Driving Multiple Receivers

Each transmitter is designed to drive a single receiver. Transmitters can be paralleled to drive multiple receivers.

Driver Outputs when Exiting Shutdown

The driver outputs display no ringing or undesirable transients as they come out of shutdown.

High Data Rates

These transceivers maintain the RS-232 ±5.0V minimum driver output voltages at data rates of over 120kbps. For data rates above 120kbps, refer to the Transmitter Output Voltage vs. Load Capacitance graphs in the *Typical Operating Characteristics*. Communication at these high rates is easier if the capacitive loads on the transmitters are small; i.e., short cables are best.

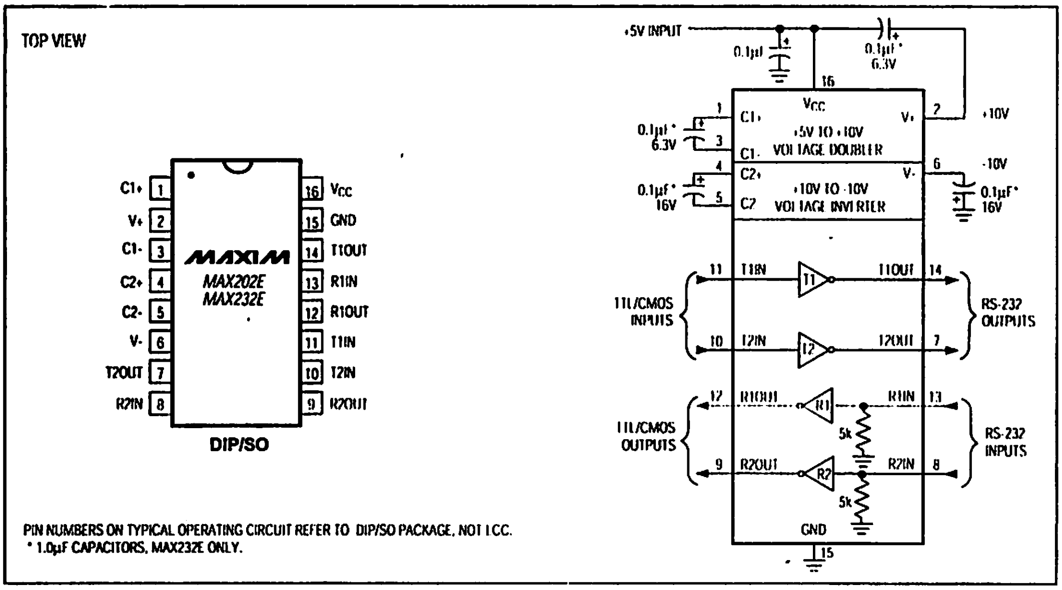
Table 2. Summary of EIA/TIA-232E, V.28 Specifications

PARAMETER		CONDITIONS	EIA/TIA-232E, V.28 SPECIFICATIONS
Driver Output Voltage	0 Level	3kΩ to 7kΩ load	+5V to +15V
	1 Level	3kΩ to 7kΩ load	-5V to -15V
Driver Output Level, Max		No load	±25V
Data Rate		3kΩ ≤ R_L ≤ 7kΩ, C_L ≤ 2500pF	Up to 20kbps
Receiver Input Voltage	0 Level		+3V to +15V
	1 Level		-3V to -15V
Receiver Input Level			±25V
Instantaneous Slew Rate, Max		3kΩ ≤ R_L ≤ 7kΩ, C_L ≤ 2500pF	30V/µs
Driver Output Short-Circuit Current, Max			100mA
Transition Rate on Driver Output		V.28	1ms or 3% of the period
		EIA/TIA-232E	4% of the period
Driver Output Resistance		-2V < V_{OUT} < +2V	300Ω

Table 3. DB9 Cable Connections Commonly Used for EIA/TIAE-232E and V.24 Asynchronous Interfaces

PIN	CONNECTION	
1	Received Line Signal Detector (sometimes called Carrier Detect, DCD)	Handshake from DCE
2	Receive Data (RD)	Data from DCE
3	Transmit Data (TD)	Data from DTE
4	Data Terminal Ready	Handshake from DTE
5	Signal Ground	Reference point for signals
6	Data Set Ready (DSR)	Handshake from DCE
7	Request to Send (RTS)	Handshake from DTE
8	Clear to Send (CTS)	Handshake from DCE
9	Ring Indicator	Handshake from DCE

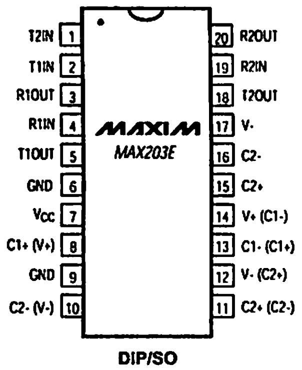
Pin Configurations and Typical Operating Circuits (continued)

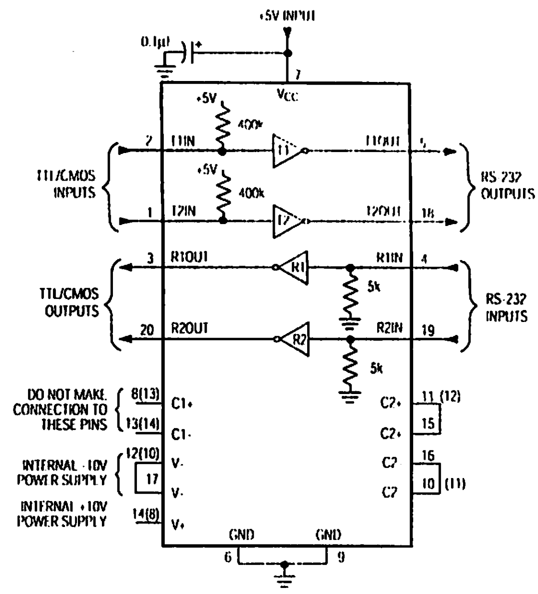


PIN NUMBERS ON TYPICAL OPERATING CIRCUIT REFER TO DIP/SO PACKAGE, NOT LCC.
* 1.0µF CAPACITORS, MAX232E ONLY.

Pin Configurations and Typical Operating Circuits (continued)

TOP VIEW

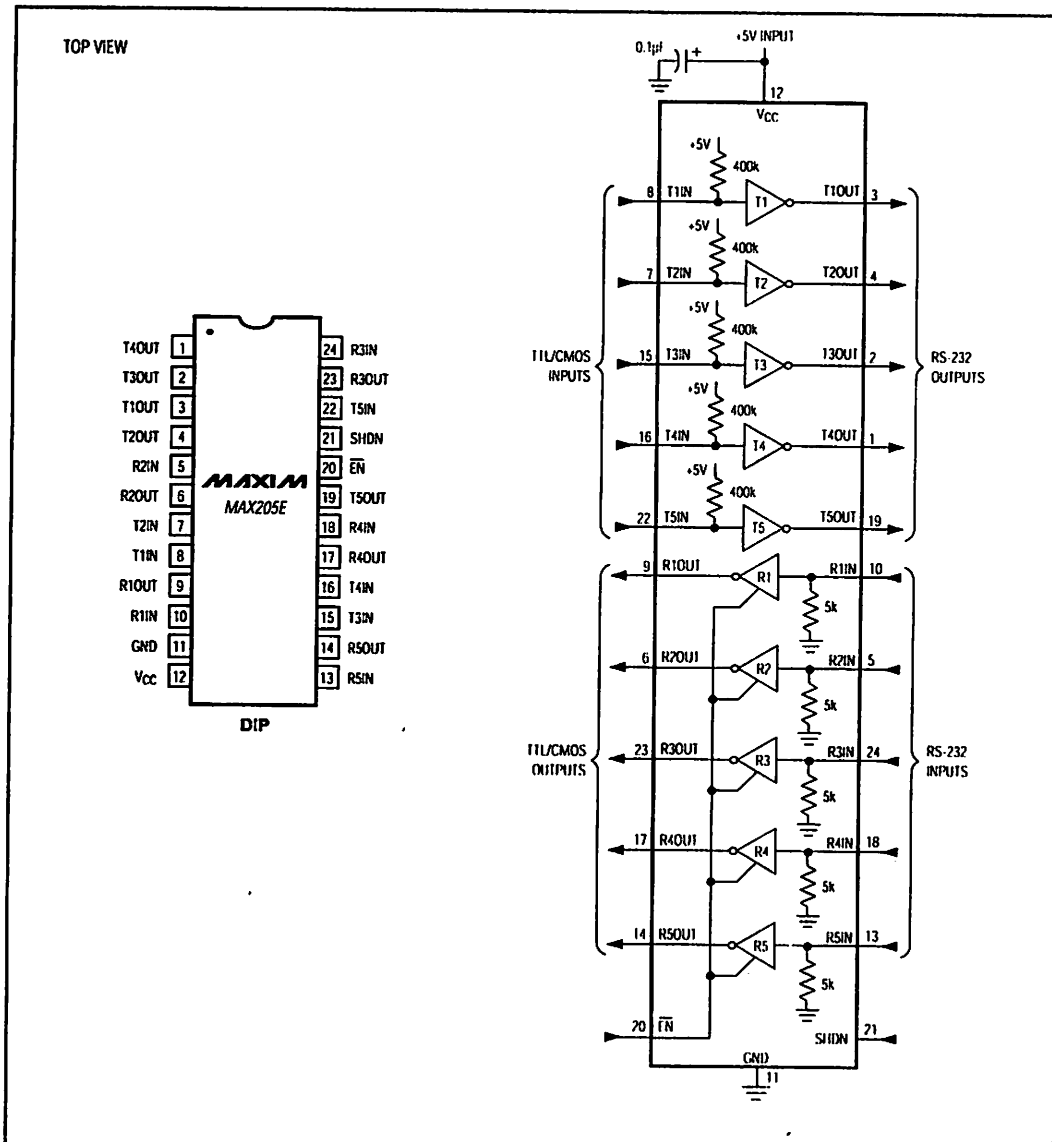




PIN NUMBERS IN ( ) ARE FOR SO PACKAGE.

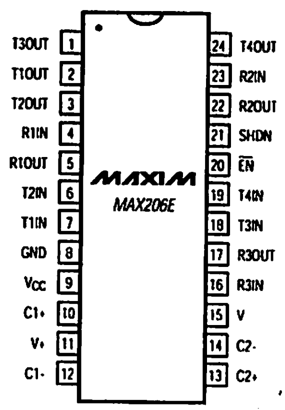
±15kV ESD-Protected, +5V RS-232 Transceivers

Pin Configurations and Typical Operating Circuits (continued)

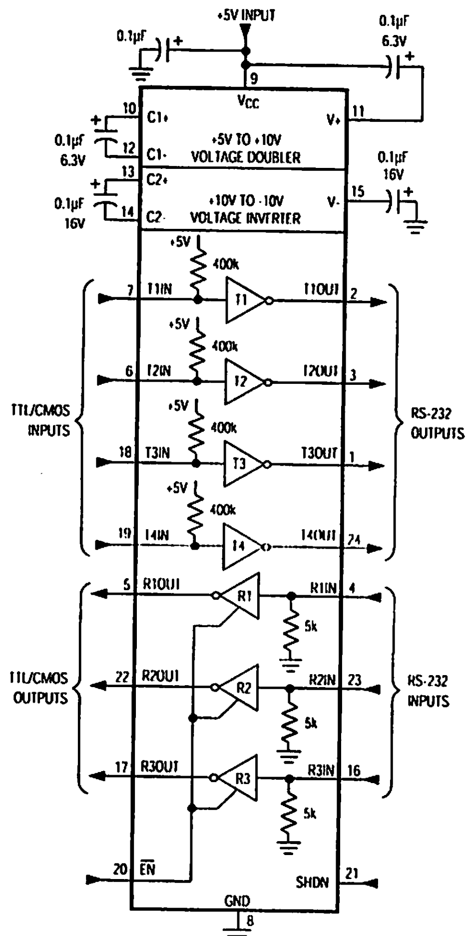


Pin Configurations and Typical Operating Circuits (continued)

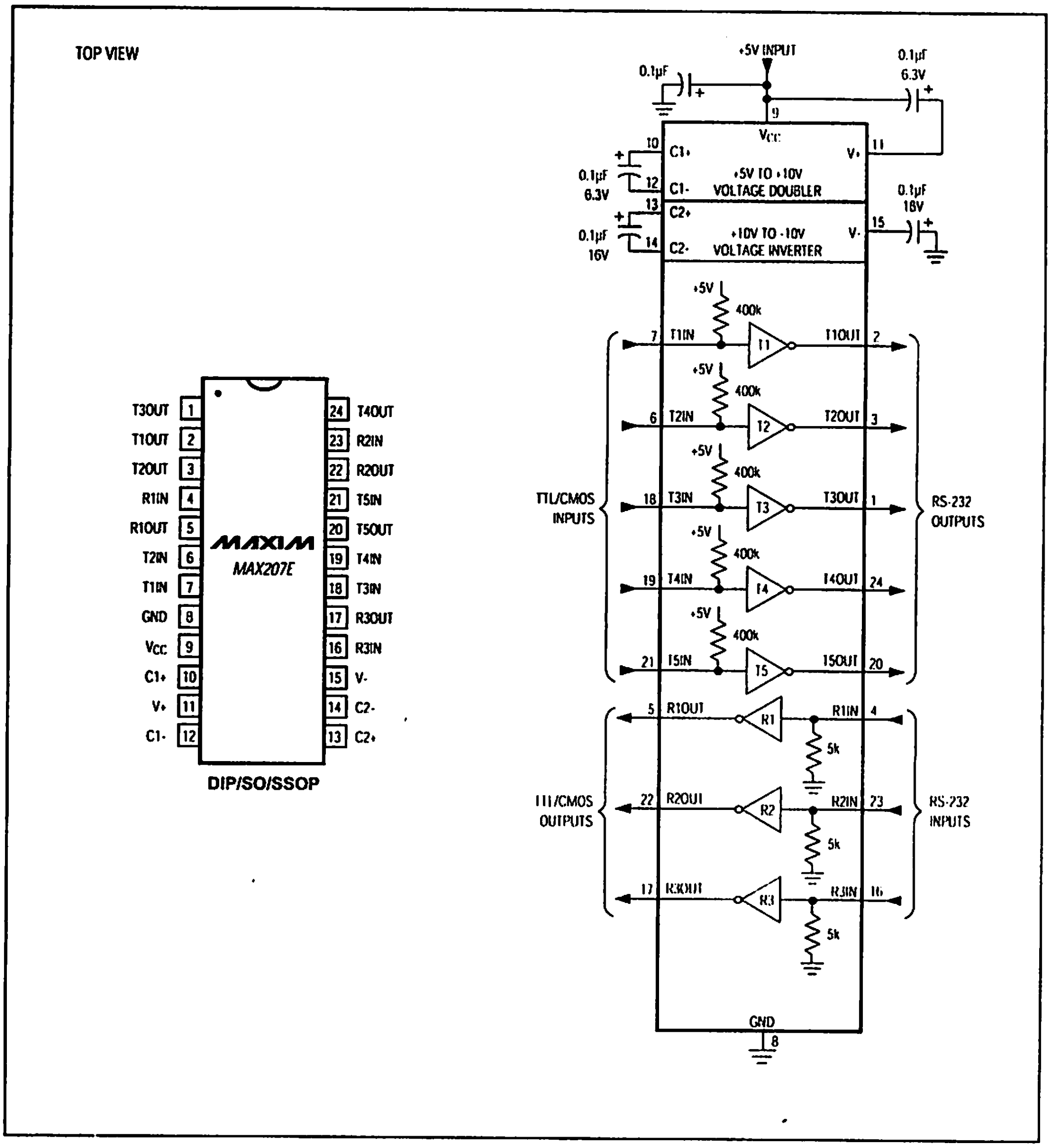
TOP VIEW



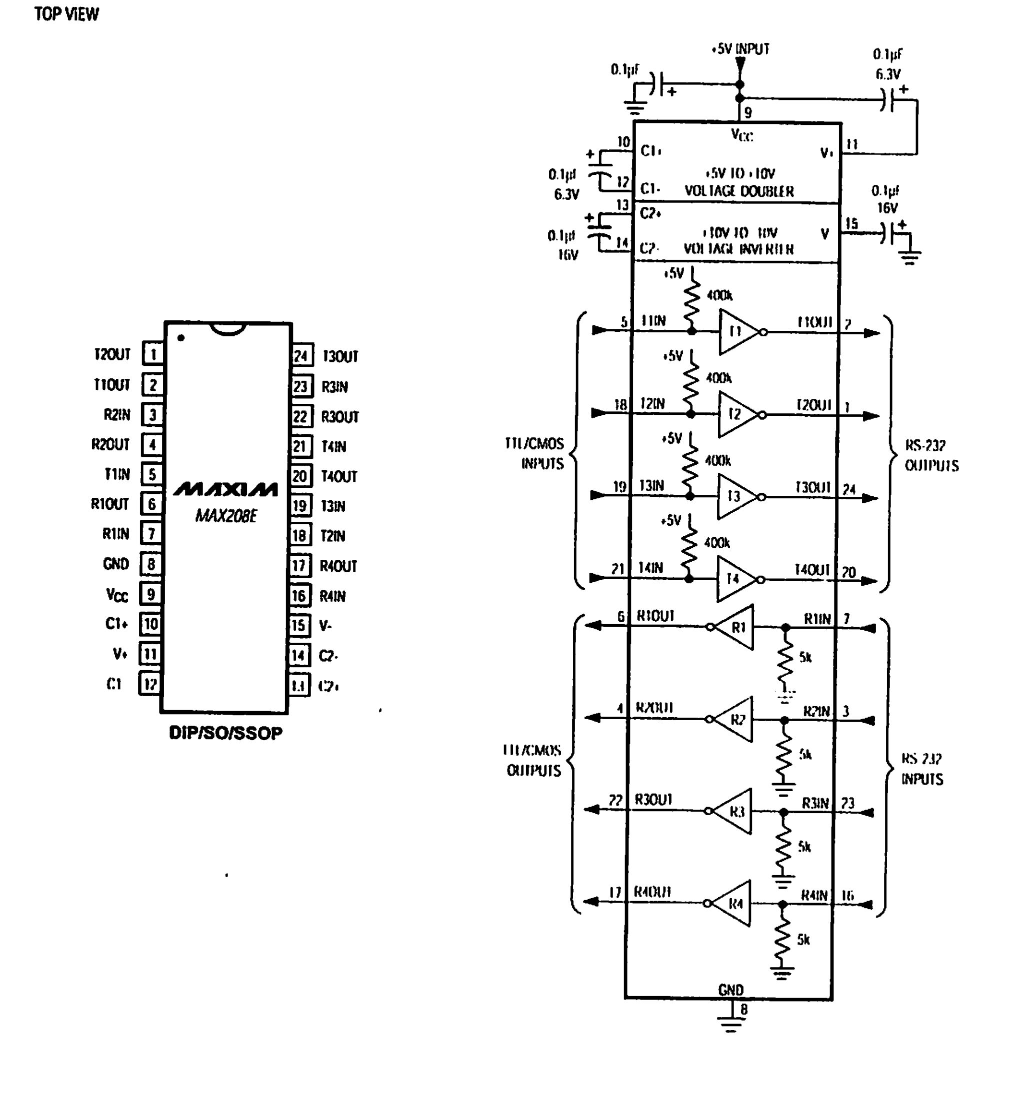
DIP/SO/SSOP



Pin Configurations and Typical Operating Circuits (continued)

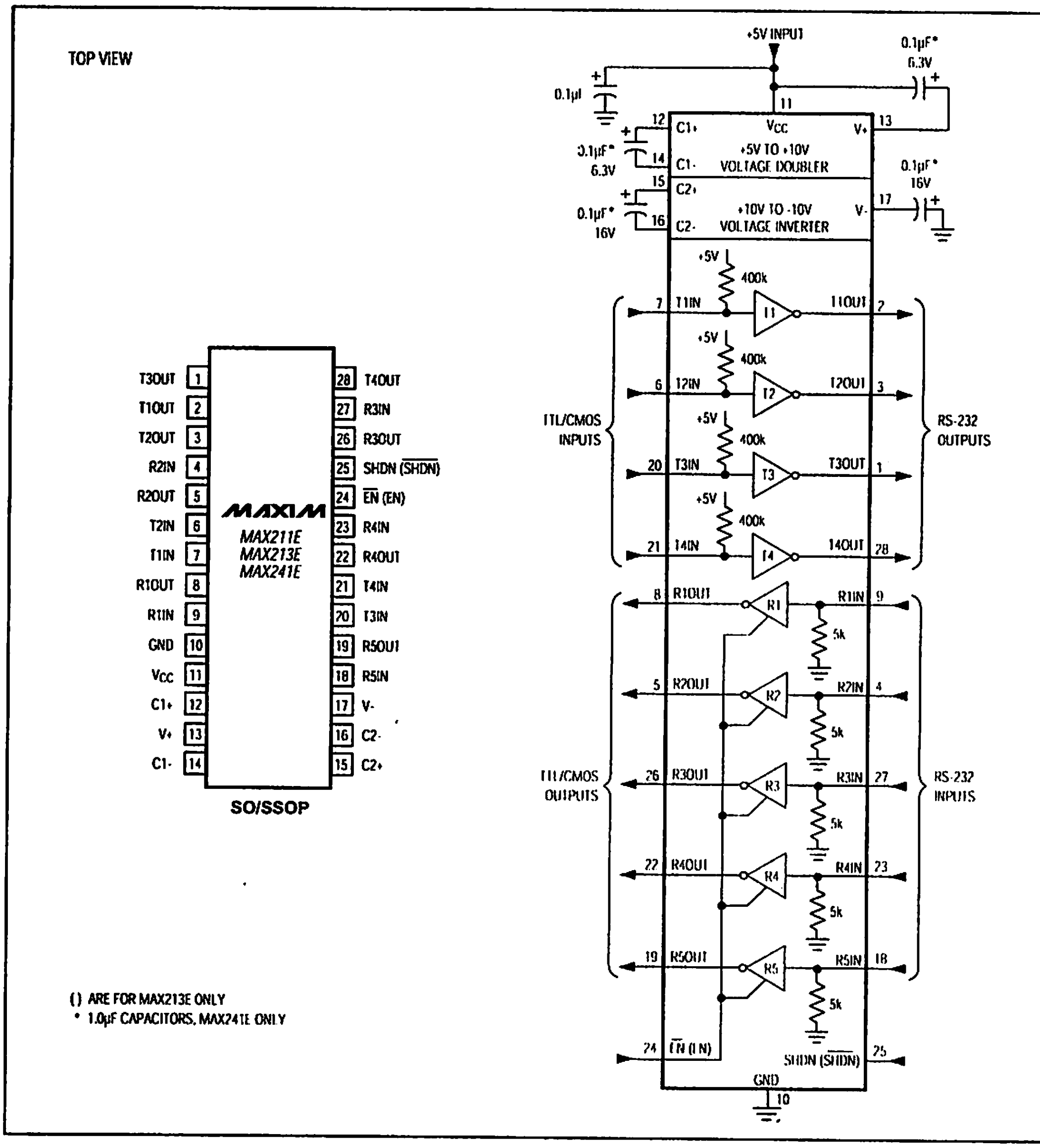


Pin Configurations and Typical Operating Circuits (continued)



±15kV ESD-Protected, +5V RS-232 Transceivers

Pin Configurations and Typical Operating Circuits (continued)



Ordering Information

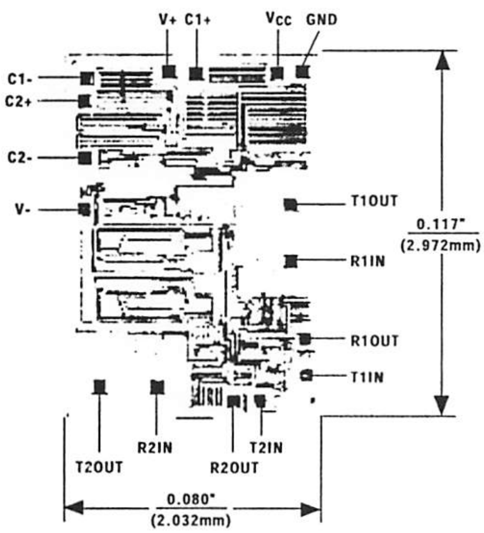
PART	TEMP. RANGE	PIN-PACKAGE
MAX202ECPE	0°C to +70°C	16 Plastic DIP
MAX202ECSE	0°C to +70°C	16 Narrow SO
MAX202ECWE	0°C to +70°C	16 Wide SO
MAX202EC/D	0°C to +70°C	Dice*
MAX202EEPE	-40°C to +85°C	16 Plastic DIP
MAX202EESE	-40°C to +85°C	16 Narrow SO
MAX202EEWE	-40°C to +85°C	16 Wide SO
MAX203ECPP	0°C to +70°C	20 Plastic DIP
MAX203ECWP	0°C to +70°C	20 SO
MAX203EEPP	-40°C to +85°C	20 Plastic DIP
MAX203EEWP	-40°C to +85°C	20 SO
MAX205ECPG	0°C to +70°C	24 Wide Plastic DIP
MAX205EEPG	-40°C to +85°C	24 Wide Plastic DIP
MAX206ECNG	0°C to +70°C	24 Narrow Plastic DIP
MAX206ECWG	0°C to +70°C	24 SO
MAX206ECAG	0°C to +70°C	24 SSOP
MAX206EENG	-40°C to +85°C	24 Narrow Plastic DIP
MAX206EEWG	-40°C to +85°C	24 SO
MAX206EEAG	-40°C to +85°C	24 SSOP
MAX207ECNG	0°C to +70°C	24 Narrow Plastic DIP
MAX207ECWG	0°C to +70°C	24 SO
MAX207ECAG	0°C to +70°C	24 SSOP
MAX207EENG	-40°C to +85°C	24 Narrow Plastic DIP
MAX207EEWG	-40°C to +85°C	24 SO
MAX207EEAG	-40°C to +85°C	24 SSOP

PART	TEMP. RANGE	PIN-PACKAGE
MAX208ECNG	0°C to +70°C	24 Narrow Plastic DIP
MAX208ECWG	0°C to +70°C	24 SO
MAX208ECAG	0°C to +70°C	24 SSOP
MAX208EENG	-40°C to +85°C	24 Narrow Plastic DIP
MAX208EEWG	-40°C to +85°C	24 SO
MAX208EEAG	-40°C to +85°C	24 SSOP
MAX211ECWI	0°C to +70°C	28 SO
MAX211ECAI	0°C to +70°C	28 SSOP
MAX211EEWI	-40°C to +85°C	28 SO
MAX211EEAI	-40°C to +85°C	28 SSOP
MAX213ECWI	0°C to +70°C	28 SO
MAX213ECAI	0°C to +70°C	28 SSOP
MAX213EEWI	-40°C to +85°C	28 SO
MAX213EEAI	-40°C to +85°C	28 SSOP
MAX232ECPE	0°C to +70°C	16 Plastic DIP
MAX232ECSE	0°C to +70°C	16 Narrow SO
MAX232ECWE	0°C to +70°C	16 Wide SO
MAX232EC/D	0°C to +70°C	Dice*
MAX232EEPE	-40°C to +85°C	16 Plastic DIP
MAX232EESE	-40°C to +85°C	16 Narrow SO
MAX232EEWE	-40°C to +85°C	16 Wide SO
MAX241ECWI	0°C to +70°C	28 SO
MAX241ECAI	0°C to +70°C	28 SSOP
MAX241EEWI	-40°C to +85°C	28 SO
MAX241EEAI	-40°C to +85°C	28 SSOP

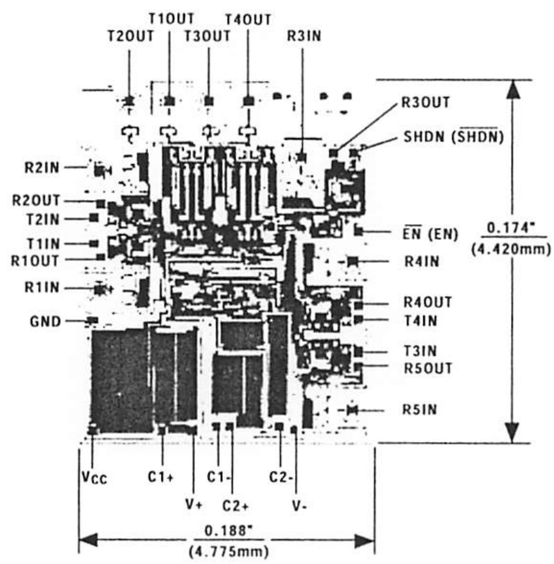
Dice are specified at $T_A = +25°C$.

Chip Topographies

MAX202E/MAX232E



MAX211E/MAX213E/MAX241E



( ) ARE FOR MAX213E ONLY

TRANSISTOR COUNT: 123
SUBSTRATE CONNECTED TO GND

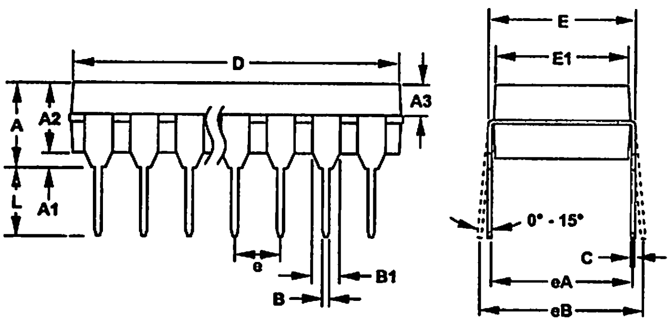
TRANSISTOR COUNT: 542
SUBSTRATE CONNECTED TO GND

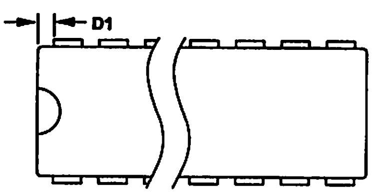
Chip Information

MAX205E/MAX206E/MAX207E/MAX208E

TRANSISTOR COUNT: 328
SUBSTRATE CONNECTED TO GND

Package Information



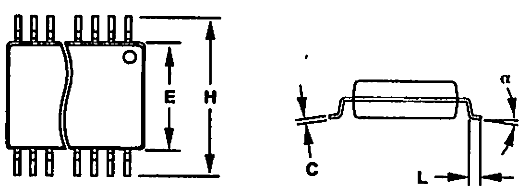


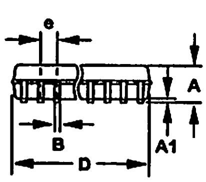
Plastic DIP
PLASTIC DUAL-IN-LINE PACKAGE (0.300 in.)

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	–	0.200	–	5.08
A1	0.015	–	0.38	–
A2	0.125	0.175	3.18	4.45
A3	0.055	0.080	1.40	2.03
B	0.016	0.022	0.41	0.56
B1	0.045	0.065	1.14	1.65
C	0.008	0.012	0.20	0.30
D1	0.005	0.080	0.13	2.03
E	0.300	0.325	7.62	8.26
E1	0.240	0.310	6.10	7.87
e	0.100	–	2.54	–
eA	0.300	–	7.62	–
eB	–	0.400	–	10.16
L	0.115	0.150	2.92	3.81

PKG.	DIM	PINS	INCHES		MILLIMETERS	
			MIN	MAX	MIN	MAX
P	D	8	0.348	0.390	8.84	9.91
P	D	14	0.735	0.765	18.67	19.43
P	D	16	0.745	0.765	18.92	19.43
P	D	18	0.885	0.915	22.48	23.24
P	D	20	1.015	1.045	25.78	26.54
N	D	24	1.14	1.265	28.96	32.13

21-0043A





SSOP
SHRINK SMALL-OUTLINE PACKAGE

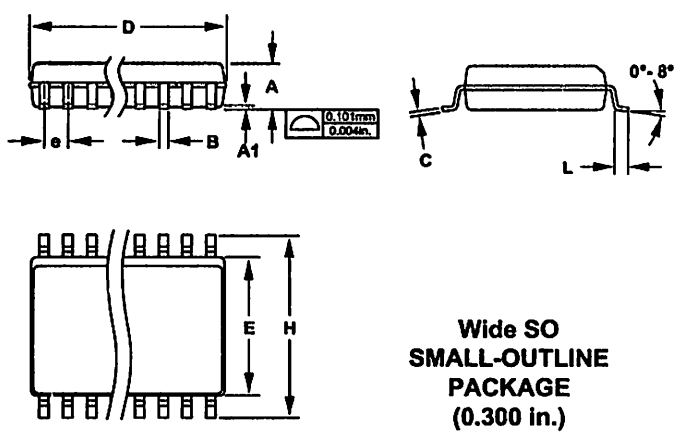
DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.068	0.078	1.73	1.99
A1	0.002	0.008	0.05	0.21
B	0.010	0.015	0.25	0.38
C	0.004	0.008	0.09	0.20
D	SEE VARIATIONS			
E	0.205	0.209	5.20	5.38
e	0.0256 BSC		0.65 BSC	
H	0.301	0.311	7.65	7.90
L	0.025	0.037	0.63	0.95
α	0°	8°	0°	8°

DIM	PINS	INCHES		MILLIMETERS	
		MIN	MAX	MIN	MAX
D	14	0.239	0.249	6.07	6.33
D	16	0.239	0.249	6.07	6.33
D	20	0.278	0.289	7.07	7.33
D	24	0.317	0.328	8.07	8.33
D	28	0.397	0.407	10.07	10.33

21-0056A

±15kV ESD-Protected, +5V RS-232 Transceivers

Package Information (continued)



Wide SO SMALL-OUTLINE PACKAGE (0.300 in.)

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.093	0.104	2.35	2.65
A1	0.004	0.012	0.10	0.30
B	0.014	0.019	0.35	0.49
C	0.009	0.013	0.23	0.32
E	0.291	0.299	7.40	7.60
e	0.050		1.27	
H	0.394	0.419	10.00	10.65
L	0.016	0.050	0.40	1.27

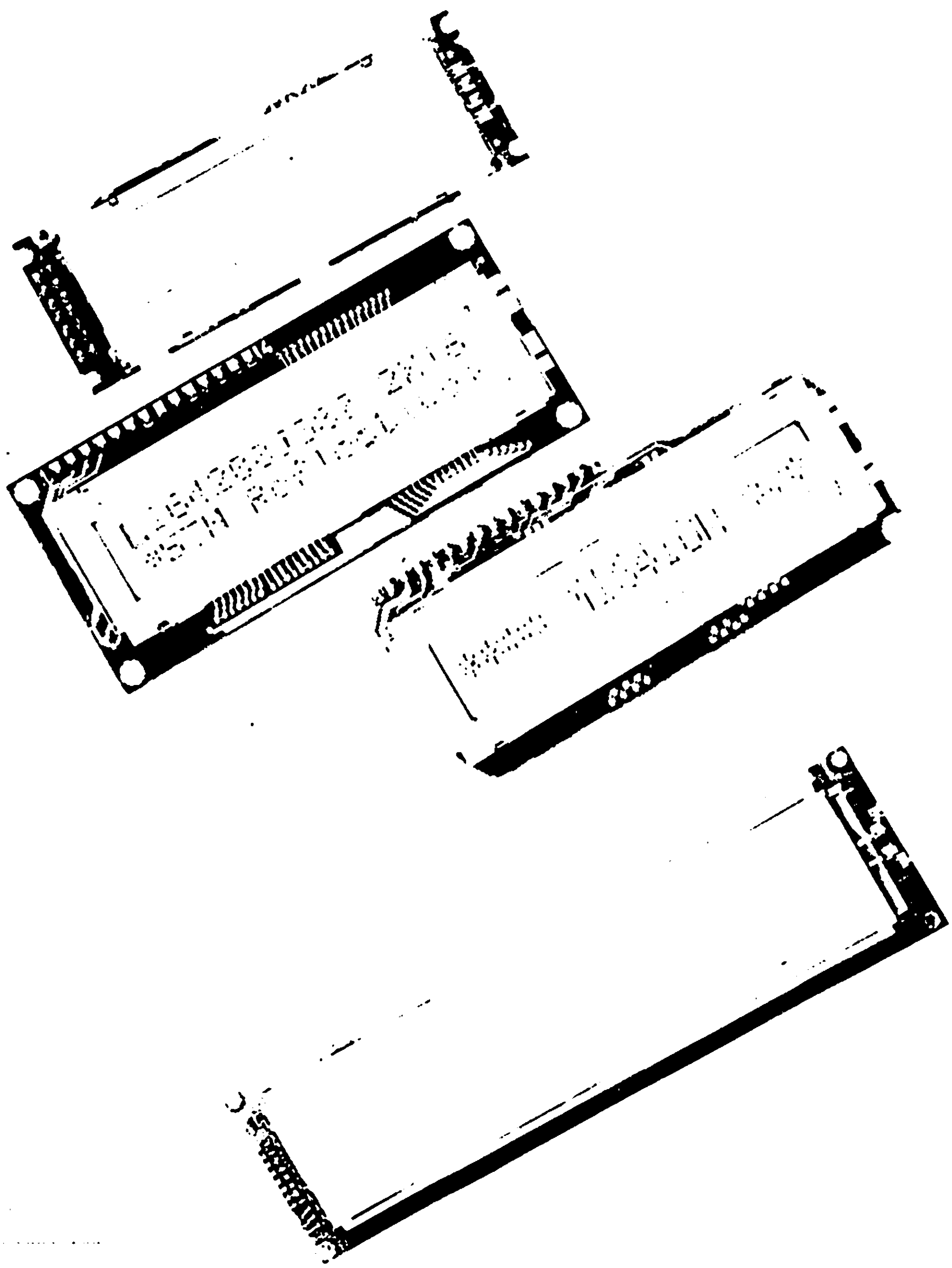
DIM	PINS	INCHES		MILLIMETERS	
		MIN	MAX	MIN	MAX
D	16	0.398	0.413	10.10	10.50
D	18	0.447	0.463	11.35	11.75
D	20	0.496	0.512	12.60	13.00
D	24	0.598	0.614	15.20	15.60
D	28	0.697	0.713	17.70	18.10

21-0042A

LCM

Liquid Crystal Display Modules

Seiko Instruments GmbH

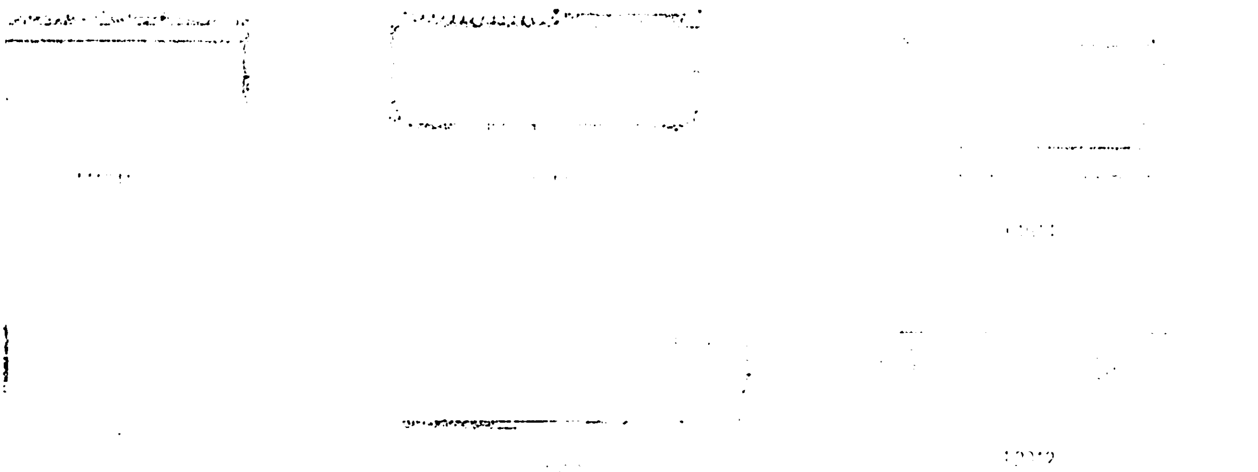


)ot Matrix Liquid Crystal Display Modules

HARACTER TYPE

• FEATURES :

- Slim, light weight and low power consumption
- High contrast and wide viewing angle
- Built-in controller for easy interfacing
- LCD modules with built in EL or LED backlight



• SPECIFICATIONS :

[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
...cklight ...		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
...der font		[illegible]	[illegible]	[illegible]	[illegible]	5x7 dots + cursor	5x7 dots + cursor
...	Reflective	80.0 x [illegible] x 11.5	85.0 x [illegible] x 10.[illegible]	80.0 x [illegible] x 11.3	122.0 x [illegible] x 11.3	87.0 x 60.5 x 11.6	116.0 x [illegible]
	EL backlight	80.0 x [illegible] x 11.3	85.0 x [illegible] x 10.1	80.0 x [illegible] x 11.3	122.0 x [illegible] x 11.3	87.0 x [illegible] x 11.6	116.0 x [illegible]
...	LED backlight	80.0 x [illegible] x 15.8	80.0 x [illegible] x 15.8	80.0 x [illegible] x 15.8	122.0 x [illegible] x 15.[illegible]	87.0 x [illegible] x 15.8	116.0 x [illegible]
...g area ... mm		61.5 x 13.8	[illegible] x 16.0	61.5 x 13.8	99.0 x 13.0	61.5 x 25.2	93.[illegible] x [illegible]
...ter size ...		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
...		0.55 x [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
...supply ...		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
...t consumption	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
...p)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
...g method ...		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
...n LSI		[illegible] or equivalent	[illegible] MSM[illegible] or equivalent	[illegible] MSM[illegible] or equivalent	[illegible] or equivalent	[illegible] or equivalent	[illegible] or equivalent
...ting temperature ...	normal temp	0 to + 50	0 to + 50	0 to + 50	0 to + 50	0 to + 50	0 to + 50
	wide temp *2	- 20 to + 70	20 to + 70	- 20 to + 70	- 20 to + 70	- 20 to + 70	- 20 to + 70
...e temperat...	normal temp	- 20 to + 60	- 20 to + 60	- 20 to + 60	- 20 to + 50	- 20 to + 60	- 20 to + [illegible]
	wide temp	- 30 to + 80	- 30 to + 80	- 30 to + 80	- 30 to + 80	- 30 to + 80	- 30 to + 80
...	Reflective	25	25	25	50	50	40
...)	EL backlight	30	30	30	55	55	45
	LED backlight	35	40	35	65	65	60
	Model	5S	5S	5S	5C	5A	5[illegible]
...ers	Power supply (V)	+ 5.0	+ 5.0	+ 5.0	+ 5.0	+ 5.0	+ 5.0
	current consumption (mA) *3	10	10	10	35	45	45
	Forward current consumption (mA)	100	112	100	240	200	154
...ght	Forward input voltage (V,typ.)	+ 4.1	+ 4.1	+ 4.1	+ 4.1	+ 4.1	+ 4.1

...luding cursor H : Horizontal V : Vertical T : Thickness (max)

...th external temperature compensation

...luding EL backlight

...sed on normal temperature range

...ur policy is one of continues improvements we reserve the right to change the specifications for the products in the catalogue without notice

L2022

L2432

L4042

L2014

M4024

• SPECIFICATIONS :

: Standard products — Products of optional specification

Character Format (character x line)		20 x 2	20 x 4	24 x 2	40 x 2	40 x 4
Model		L2022	L2014	L2432	L4042	M4024
Reflective		-	L201400J000S	L243200J000S	L404200J000S	M40240AS
EL backlight		-	L201421J000S	L243221J000S	L404221J000S	M40249DWS
LED backlight		-	L2014B1J000S	L2432B1J000S	L4042B1J000S	M40247DYS
Reflective (wide temp)		L202200P000S	L201400L000S	L243200L000S	L404200L000S	M40240CS
LED backlight (wide temp)		L2022B1P000S	L2014B1L000S	L2432B1L000S	L4042B1L000S	M40247JYS
Character font		5x7 dots + cursor	5x7 dots + cursor	5x7 dots + cursor	5x7 dots + cursor	5x7 dots + cursor
Module size (HxVxT) mm	Reflective	180,0 x 40,0 x 10,5	98,0 x 60,0 x 11,6	118.0 x 36.0 x 11.3	182.0 x 33.5 x 11.3	190.0 x 54.0 x 10.1
	EL backlight	180,0 x 40,0 x 10,5	98,0 x 60,0 x 11,6	118.0 x 36.0 x 11.3	182.0 x 33.5 x 11.3	190.0 x 54.0 x 10.1
	LED backlight	180,0 x 40,0 x 14,8	98,0 x 60,0 x 15,8	118.0 x 36.0 x 15.8	182.0 x 33.5 x 16.3	190.0 x 54.0 x 16.3
Viewing area (HxV) mm		149,0 x 23,0	76,0 x 25,2	94.5 x 17.8	154.4 x 15.8	147.0 x 29.5
Character size (HxV) mm *1		6,00 x 9,66	2,95 x 4,15	3.20 x 4.85	3.20 x 4.85	2.78 x 4.27
Dot size (HxV) mm		1,12 x 1,12	0,55 x 0,55	0.60 x 0.65	0.60 x 0.65	0.50 x 0.55
Power supply voltage (VDD-VSS) V		+ 5 V	+ 5 V	+ 5 V	+ 5 V	+ 5 V
Current consumption (mA,typ)	IDD	4,2	2,9	2.5	3.0	8.0
	ILC *4	2,6	1,2	0.5	1.0	3.0
Driving method (duty)		1/16	1/16	1/16	1/16	1/16
Built-in LSI		KS0066 KS0063 or equivalent	KS0066 MSM5839 or equivalent	KS0066 KS0063 or equivalent	KS0066 KS0063 or equivalent	KS0066 MSM5839 or equivalent
Operating temperature (°C)	normal temp.	-	0 to + 50	0 to + 50	0 to + 50	0 to + 50
	wide temp. *2	- 20 to + 70	- 20 to + 70	- 20 to + 70	- 20 to + 70	- 20 to + 70
Storage temperature (°C)	normal temp.	-	- 20 to + 60	- 20 to + 60	- 20 to + 60	- 20 to + 60
	wide temp	30 to + 80	30 to + 80	30 to + 80	30 to + 80	30 to + 80
Weight (g. typ.)	Reflective	80	55	40	70	90
	EL backlight	-	60	45	75	105
	LED backlight	110	70	60	95	140
Inverters for EL	Model	-	5A	5A	5C	5D
	Power supply (V)	+ 5.0	+ 5.0	+ 5.0	+ 5.0	+ 5.0
	current consumption (mA) *3	-	45	45	25	80
LED backlight	Forward current consumption (mA)	320	240	150	260	480
	Forward input voltage (V.typ.)	+ 4.1	+ 4.1	+ 4.1	+ 4.1	+ 4.1

*1 : Excluding cursor — H : Horizontal — V : Vertical — T : Thickness (max)

*2 : With external temperature compensation

*3 : Including EL backlight

*4 : Based on normal temperature range

)ot Matrix Liquid Crystal Display Modules

;RAPHIC TYPE

• FEATURES :

- •Wide viewing angle and high contrast
- •Full dot configuration fits any application
- •Slim, light weight and low power consumption
- •Available in STN and FSTN

• SPECIFICATIONS :

mat (HxV,dot)			97 x 32	128 x 32	128 x 64	128 x 64
			Y97031	G1213	G1216	G1226
pe	Reflective	built-in RAM	-	-	-	-
node)	Reflective wide temp.	built-in RAM	-	G121300N000S	G121600N000S	-
	LED backlight	built-in RAM	-	-	-	G1226B1J000S
	LED backlight wide temp	built-in RAM	-	G1213B1N000S	G1216B1N000S	-
type	Transmissive	-	-	-	-	-
node)	with CFL backlight	built-in controller	-	-	-	-
	Transflective	built-in RAM	Y97031LF60W	-	-	-
size	Reflective (no backlight)		47,5 x 65,4 x 2,1	75,0 x 41,5 x 6,8	75,0 x 52,7 x 6,8	-
x T)	LED backlight		-	75,0 x 41,5 x 8,9	75,0 x 52,7 x 8,9	93,0 x 70,0 x 11,4
	CFL backlight		-	-	-	-
g area (HxV) mm			43,5 x 23,9	60,0 x 21,3	60,0 x 32,5	70,7 x 38,8
e (H x V) mm			0,35 x 0,48	0,40 x 0,48	0,40 x 0,40	0,44 x 0,44
h (H x V) mm			0,39 x 0,52	0,43 x 0,51	0,43 x 0,43	0,48 x 0,48
supply voltage (V)		(VDD - VSS)	+5,0	+5,0	+5,0	+5,0
		(VLC - VSS)	-	- 8,0	- 8,1	-8,2
consumption		IDD	0,10	2,0	2,0	3,0
		IDD (built-in controller)	-	-	-	-
p.)		ILC	-	1,8	1,8	2,0
	Driving method (duty)		1/33	1/64	1/64	1/64
LSI		Driver	SED1530 or equivalent	HD61202 HD61203 or equivalent	HD61202 HD61203 or equivalent	KS0107 KS0108 or equivalent
		Controller	-	-	-	-
ng temperature range (°C)			- 20 to + 70	- 20 to + 70	- 20 to + 70	0 to + 50
temperature range (°C)			- 30 to + 80	- 30 to + 80	- 30 to + 80	- 20 to + 60
	Reflective (Transflective no backlight)		10	23	35	-
)	LED backlight		-	35	45	72
	CFL backlight		-	-	-	-
cklight	Forward current consumption (mA)		-	40	90	125
	Forward input voltage (V, typ.)		-	3,8	4,1	4,1
	Mode		-	-	-	-
for CFL	Power supply voltage (V)		-	-	-	-
	Current consumption (mA, typ.)		-	-	-	-

lt-in DC/DC converter (single power source)

: with external temperature compensation circuit

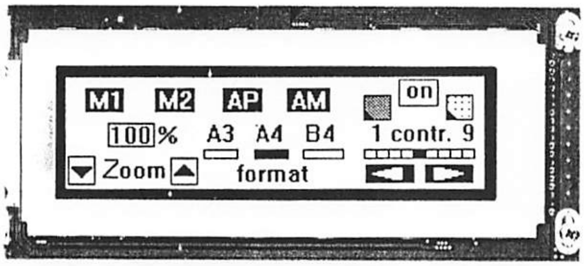
ur policy is one of continues improvements we reserve the right to change the specifications of the products in the catalogue without notice.

ɔt format (HxV,dot)			240 x 64	240 x 128	320 x 200	320 x 240	640 x 200
ɔdel			G2446	G242C	G321D	G324E	G649D
TN type	Reflective	built-in RAM	-	-	-	-	-
;ray mode)	Reflective wide temp.	built-in RAM	-	-	-	-	-
	LED backlight	built-in RAM	-	-	-	-	-
	LED backlight wide temp	built-in RAM	-	-	-	-	-
;TN type	Transmissive	-	G2446X5R1A0S	G242CX5R1ACS	G321DX5R1A0S	G324EX5R1A0S	G649DX5R010S
&W mode)	with CFL backlight	built-in controller	G2446X5R1ACS	G242CX5R1A0S	G321DX5R1ACS	G324EX5R1ACS	-
	Transflective	built-in RAM	-	-	-	-	-
ɔdule size	Reflective (no backlight)			-	-	-	-
I x V x T)	LED backlight			-	-	-	-
n	CFL backlight		191,0 x 79,0 x 15,1	180,0 x 110,0 x 15,1	166,0 x 134,0 x 15,1	166,0 x 134,0 x 15,1	260,0 x 122,0 x 15,7
ewing area (HxV) mm			134,0 x 41,0	134,0 x 76,0	128,0 x 110,0	128,0 x 110,0	216,0 x 83,0
ɔt size (H x V) mm			0,49 x 0,49	0,47 x 0,47	0,34 x 0,48	0,32 x 0,39	0,30 x 0,36
ɔt pitch (H x V) mm			0,53 x 0,53	0,51 x 0,51	0,38 x 0,52	0,36 x 0,43	0,33 x 0,39
ɔwer supply voltage (V)		(VDD - VSS)	+5,0	+5,0	+5,0	+5,0	+5,0
		(VLC - VSS)	*1	*1	-24,0	-24,0	-24,0
ırrent consumption		IDD	12	30	8	7,5	11
		IDD (built-in controller)	15	40	23	23	-
A, typ.)		ILC	-	-	6	6,5	9
	Driving method (duty)		1/64	1/128	1/200	1/240	1/200
ilt-in LSI		Driver	MSM5298 MSM5299 or equivalent	KS0103 KS0104 or equivalent	MSM5298 MSM5299 or equivalent	HD66204 HD66205 or equivalent	MSM5298 MSM5299 or equivalent
		Controller	SED1330FB	SED1330FB	SED1330FB	SED1330FB	-
ɔerating temperature range (°C)			0 to +50	0 to +50	0 to +50	0 to +50	0 to +50
ɔrage temperature range (°C)			- 20 to +60	- 20 to +60	- 20 to +60	- 20 to +60	- 20 to +60
ight	Reflective (Transflective no backlight)		-	-	-	-	-
typ.)	LED backlight		-	-	-	-	-
	CFL backlight		200	280	350	350	420
D backlight	Forward current consumption (mA)		-	-	-	-	-
	Forward input voltage (V, typ.)		-	-	-	-	-
	Mode		4800210	4800210	4800210	4800210	4800120
erter for CFL	Power supply voltage (V)		+5,0	+5,0	+5,0	+5.0	+12,0
	Current consumption (mA, typ.)		250	350	365	365	390

: built-in DC/DC converter (single power source)

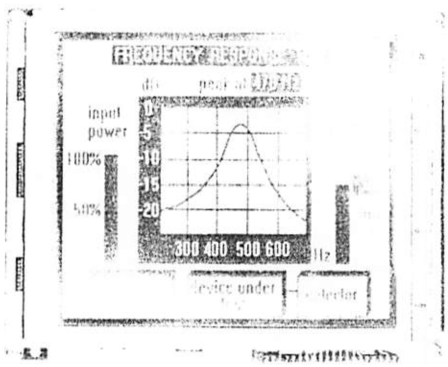
: Use with external temperature compensation

ıce our policy is one of continous improvemets, we reserve the right to change the specifications of the products in the catalogue without notice.



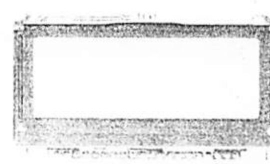
G2446

G1226

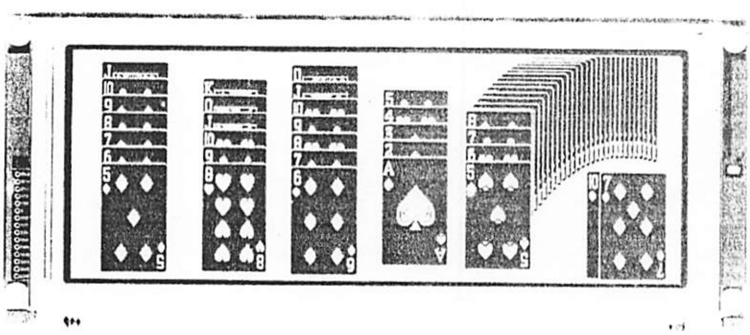


G321D

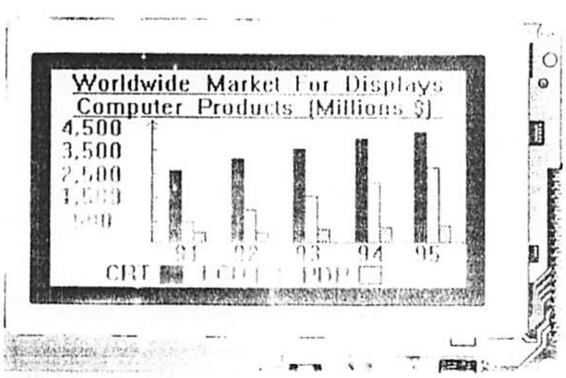
G1216



G1213



G649D



G242C

G324E

HECK LIST FOR CUSTOM DESIGNED LCD MODULE

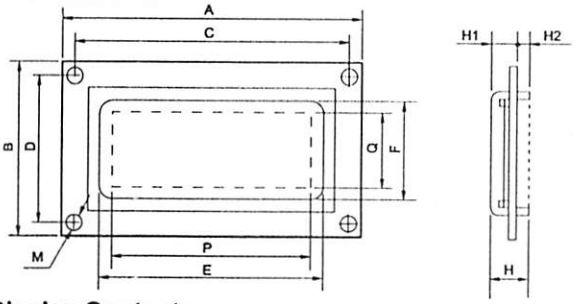
Company____________ 2. Application____________ 3. Customer Specified Part No.____________

Design

] New ☐ Modified : Manufacturer____________, Part No.____________, Remarks ____________

] Equivalent: Manufacturer____________, Part No.____________, Remarks ____________

.CM Dimensions



A x B : Module size ______ x ______ mm
E x F : Viewing area ______ x ______ mm
P x Q : Active display area ______ x ______ mm
C : Length between mounting holes ______ mm
D : Length between mounting holes ______ mm
M : Diameter of mounting hole ______ mm
H : Total thickness ______ mm
H1 : Upper thickness ______ mm
H2 : Lower thickness ______ mm

)isplay Contents

] Character type:______ characters______ lines
Character font ______ x ______ dots + cursor
Character pitch ______ x ______ mm
Dot pitch ______ x ______ mm
Dot size ______ x ______ mm
] Graphics (Full dot) type:______ x ______ dots
Dot pitch ______ x ______ mm
Dot size ______ x ______ mm
] Segment type:______ digits______ lines
] Others ____________

.CD Panel

iewing angle: ☐ 6 o'clock ☐ 12 o'clock ☐ ____ o'clock
/pe: ☐ TN ☐ FSTN (Black and white)
☐ STN (☐ Yellow green ☐ Gray ☐ Blue)
Chromaticity coordinates
(_____ ≦ x ≦ _____ , _____ ≦ y ≦ _____)
☐ Positive type ☐ Negative type
☐ Reflective ☐ Transflective ☐ Transmissive
☐ Others ____________
ray scale: ☐ Yes______ gray scale ☐ No
referential specifications:
☐ Response time t_{on} ____ ms (____ °C) t_{off} ____ ms (____ °C)
☐ Viewing angle ____ deg. (____ °C) ☐ Contrast ____ (____ °C)
☐ Others ____________
:D surface finishing:
☐ Normal ☐ Anti-glare ☐ ____________
ılarizer color: ☐ Normal (neutral gray) ☐ Red
☐ Green ☐ Blue ☐ ____________

)riving Method

ıltiplexing:1/______ duty, 1/______ bias
ame frequency: ______ Hz

;

:D driver: ☐ Specified ☐ Unspecified
Segment driver ______ (Manufacturer ______)
Common driver ______ (Manufacturer ______)
ontroller: ☐ Internal ☐ External
Type No.______ (Manufacturer ______)
PU: ☐ Internal ☐ External
Type No.______ (Manufacturer ______)
\M: ☐ Internal ☐ External
Type No. /Memory size______ (Kbit) (Manufacturer ______)

Power Supply

Single power supply: ☐ 5V ☐ ______ V
2 power supplies
For logic: (V_{DD}-V_{SS}) : ☐ 5V ☐ ______ V
For LC drive: (V_{LC}-V_{SS}) : ☐ ______ V

11. Temperature Compensation Circuit

☐ Internal ☐ External ☐ Unnecessary
Compensation range: ☐ 0°C to 50°C ☐ ____ °C to ____ °C

12. Current Consumption

For logic: typ.______ mA, max.______ mA
For LC drive: typ.______ mA, max.______ mA
Others (____) : typ.______ mA, max.______ mA

13. Contrast Adjustment

☐ Internal ☐ External ☐ Unnecessary
Method: ☐ Temp. compensation circuit ☐ Volume ☐ ______

14. Temperature Range

Operating temperature range: ☐ 0°C to 50°C ☐ ____ °C to ____ °C
Storage temperature range: ☐ - 20°C to 60°C ☐ ____ °C to ____ °C

15. Input/Output Terminals

Specifying allocation: ☐ Yes ☐ No
Specifying position: ☐ Yes ☐ No

16. Weight

typ.______ g, max.______ g

17. Connector

☐ Internal ☐ External ☐ Unnecessary
Type No.______ (Manufacturer ______)

18. Backlight

☐ Internal ☐ External ☐ Unnecessary
☐ EL: ☐ Green ☐ White ☐ ______
☐ LED: ☐ Yellow green ☐ Amber ☐ ______
☐ CFL: ☐ White ☐ ______
☐ Incandescent lamp ☐ Others ______
☐ Backlight type ☐ Edge backlight type
Brightness: ______ cd/m²
Inverter: ☐ Internal ☐ External ☐ Unnecessary
Power supply voltage______ V
Current consumption (backlight included)______ mA
Brightness control: ☐ Yes ☐ No

19. Others

____
____
____

20. Schedule

Estimate: ____________
Sample: Delivery______, Quantity:______ pcs
Mass production: Target price: ______
Delivery ______, Total quantity: ______ pcs
Quantity per month______ pcs

ECK LIST FOR CUSTOM DESIGNED LCD

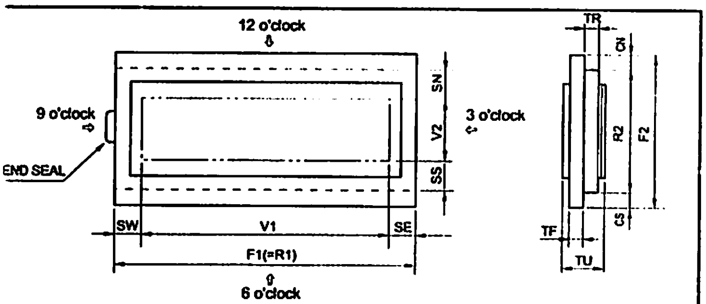
ompany__________ 2. Application__________ 3. Customer Specified Part No.__________

esign

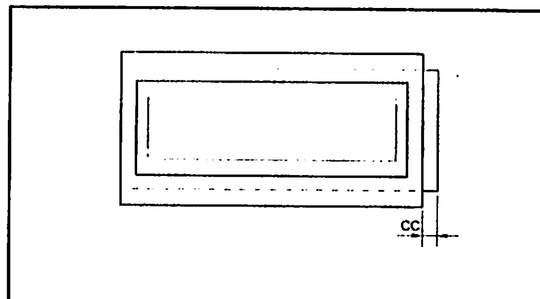
New ☐Modified: Manufacturer __________ , Part No.________ , Remarks__________

Equivalent: Manufacturer__________ , Part No.________ , Remarks__________

ınel Dimensions



- Type A (connection through conductive material) -



- Type B (direct common) -

ɩorizontal length of upper glass __________ mm

'ertical length of upper glass__________ mm

ɨorizontal length of lower glass_____ the same as F1

Vertical length of lower glass__________ mm

is generally longer than F2 when terminals are with pin.

R***: Thickness of glass__________ mm

ɩtandard type: 1.1 mm or 0.7 mm

'hickness of LCD__________ mm

ɜeal: ☐Right ☐Left ☐Right or Left

V1 :Horizontal length of viewing area __________ mm

V2 :Vertical length of viewing area __________ mm

CN**: Terminal length__________ mm

CS**:Terminal length__________ mm

**CN or CS=0 in case of one side terminal type.

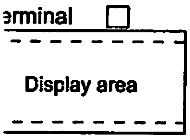
CC: Terminal length__________ mm

SE,SW,SN,SS : Seal width

(According to design or manufacturing condition: about 2.0 mm to 4.0 mm)

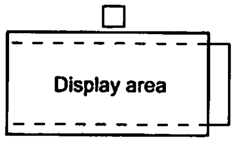
ınel Form

ɜrminal ☐

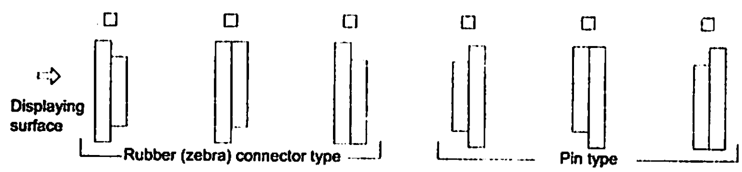


- Type A -

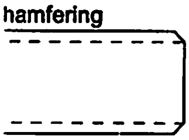
☐



- Type B -

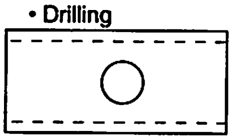


hamfering



☐Yes
☐No

• Drilling



☐Yes
☐No

splay Mode

wing angle : ☐6 o'clock ☐12 o'clock ☐______o'clock

ɘ: ☐TN ☐FSTN (Black and white)

]STN: (☐Yellow green ☐Gray ☐Blue)

Chromaticity coordinates (____≦ x ≦____ , ____≦ y ≦____)

]Positive type ☐Negative type

]Reflective ☐Transflective ☐Transmissive

ferential specifications:

]Response time t_{on} ___ms (___°C) t_{off} ___ms (___°C)

]Viewing angle ___deg. (___°C) ☐Contrast___ (___°C)

]Others__________

ılarizer

face finishing: ☐Normal ☐Anti-glare ☐__________

or: ☐Normal (neutral gray) ☐Red ☐Green

☐Blue ☐__________

nt polarizer : ☐Attached type ☐Separate type

ır polarizer : ☐Attached type ☐Separate type

iving Method

tatic ☐Multiplexing: (1/______duty, 1/______bias)

erating voltage (V_{opr}) :__________ V

ıme frequency:__________ Hz

ving IC:______ (Manufacturer__________)

rrent consumption:__________ µA

10. Temperature Range

Operating temperature range

☐With temperature compensation circuit (or volume)

(☐ 0°C to 50°C ☐________°C to________°C)

☐Without temperature compensation circuit

(☐ 0°C to 50°C ☐________°C to________°C)

Storage temperature range

(☐ - 20°C to 60°C ☐________°C to________°C)

11. Terminal Connecting Method

☐Rubber connector (Zebra rubber)

☐Pin: ☐DIL ☐SIL ☐__________

Pitch (☐2.54 ☐_______mm) Length (______mm)

☐Heat seal: ☐Equipped ☐Unnecessary

12. Others

Print (Characters, lines, masks etc.) : ☐Yes ☐No

Protective film:

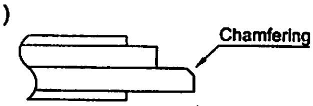
☐Yes (Color: ☐ Red ☐Translucent ☐Transparent) ☐No

Chamfering (for heat-seal connector) :

☐Yes (Position:_______)

(Quantity:_______)

☐No



13. Schedule

Estimate :__________

Sample : Delivery________ , Quantity :________ pcs

Mass production : Target price : __________

Delivery ________ , Total quantity:________ pcs

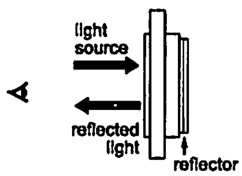
Quantity per month:__________ pcs

Liquid Crystal Display Modules

REFLECTIVE/TRANSFLECTIVE/TRANSMISSIVE LCD

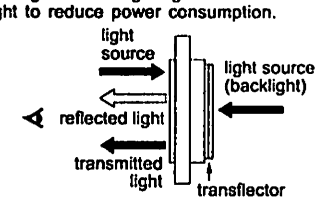
❶ Reflective LCD

Reflector bonded to the rear polarizer reflects the incoming ambient light. Low power consumption because no backlight is required.



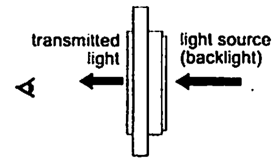
❷ Transflective LCD

Transflector bonded to the rear polarizer reflects light from the front as well as enabling lights to pass through the back. Used with backlight off in bright light and with it on in low light to reduce power consumption.



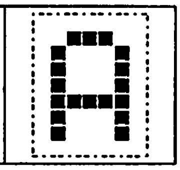
❸ Transmissive LCD

Without reflector or transflector bonded to the rear polarizer. Backlight required. Most common is transmissive negative image.

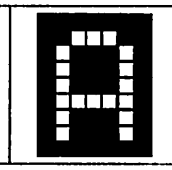


POSITIVE/NEGATIVE MODE

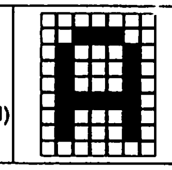
Positive type



Negative type



Negative type (inverse image) (when data is inverted)



TN TYPE/STN TYPE/FSTN TYPE

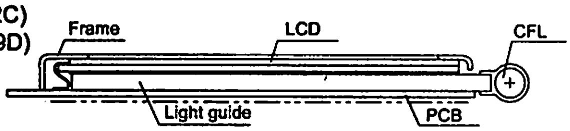
TN	(Background/dot color) Gray/Black	TN(Twisted Nematic) type is most conventional and economical. It is used for static drive LCD and low-duty drive LCD (watch,calculator, etc.)
STN	Yellowgreen/Dark blue Gray/Dark blue White/Blue	STN (Super Twisted Nematic) type has a higher twist angle, and thus provides clear visibility and wider viewing angle. This is suitable especially for high-duty drive LCD.
FSTN	White/Black	FSTN (Film Super Twisted Nematic) type utilizes RCF (Retardation Control Film) to remove the coloring of STN LCD. Thus FSTN type provides easy-to-read black-and-white display.

STRUCTURE AND FEATURE OF LCD MODULE WITH BACKLIGHT

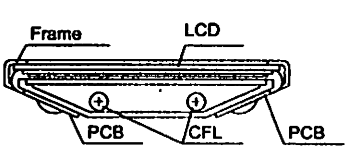
CFL (Cold Cathode Fluorescent Lamp) backlight

Features: high brightness, long service life, inverter required

- Edge backlight type
  (G2446,G242C)
  (G321D,G649D)

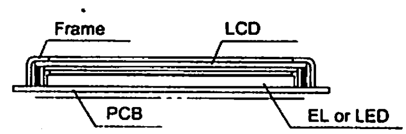


- Backlight type



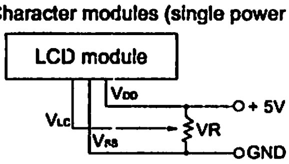
EL (Electroluminescent Lamp) backlight
LED (Light Emitting Diode) backlight

Features: EL: thin, inverter required
LED: long service life, low voltage driving, no inverter required

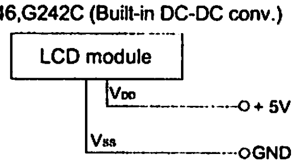


POWER SUPPLY

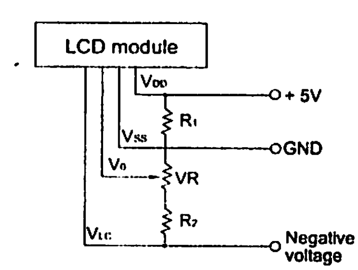
- Character modules (single power supply)



- G2446,G242C (Built-in DC-DC conv.)

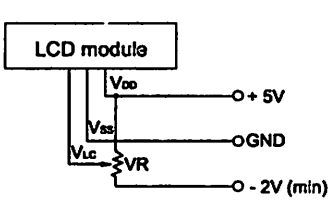


- G321D, G324E and G649D

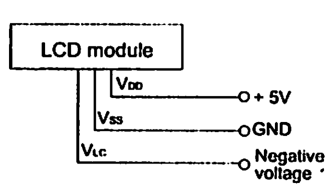


Note 1:Contrast can be adjusted by VR.
Note 2:For module with backlight, power supply for backlight is necessary.

- Character Modules(Dual power supply)



- Y1206 and G1226



·Negative voltage should be variable for contrast adjustment.

Precautions

Safety Instructions

- If the LCD panel is damaged, be careful not to get the liquid crystal in your mouth and not to be injured by crushed glasses.
- If you should swallow the liquid crystal, first, wash your mouth thoroughly with water, then, drink a lot of water and induce vomiting, and then, consult a physician.
- If the liquid crystal should get in your eye, flush your eye with running water for at least fifteen minutes.
- If the liquid crystal touches your skin or clothes, remove it and wash the affected part of your skin or clothes with soap and running water.
- EL or CFL backlight is driven by a high voltage with an inverter. Do not touch the connection part or the wiring pattern of the inverter.
- Do not use inverters without a load or in the short-circuit mode.
- Use the LCD module within the rated voltage to prevent overheating and/or damage. Also, take steps to ensure that the connector does not come off.

Handling Precautions

- Since the LCD panel has glass substrate, avoid applying mechanical shock or pressure on the module. Do not drop, bend, twist or press the module.
- Do not soil or damage LCD panel terminals.
- Since the polarizer is made of easily-scratched material, be careful not to touch or place objects on the display surface.
- Keep the display surface clean. Do not touch it with your skin.
- CMOS LSI is used in the LCD module. Be careful of static electricity.
- Do not disassemble the module or remove the liquid crystal panel or the panel frame.
- Do not damage the film surface of the EL lamp; otherwise the lamp will be damaged by humidity.
- To set an EL lamp in an LCD module, push the EL lamp with its emitting side up, without pushing the rubber connectors too hard. If you damage them, the LCD module may not work properly.

Mounting and Designing

- To protect the polarizer and the LCD panel, cover the display surface with a transparent plate (e.g., acrylic or glass) with a small gap between the transparent plate and the display surface.
- Keep the module dry. Avoid condensation to prevent the transparent electrodes from being damaged.
- Drive LCD panel with AC waveform in which DC element is not included to prevent deterioration in the LCD panel.
- Contrast of LCD varies depending on the ambient temperature. To offer the optimum contrast, LC drive voltage should be adjusted. LCD driven in a high duty ratio must be provided with drive voltage adjustment method.
- Mount a LCD module with the specified mounting part/holes.
- Design the equipment so that input signal is not applied to the LCD module while power supply voltage is not applied to it.
- Do not locate the CFL tube and the lamp lead wire close to a metal plate or a plated part inside the equipment. Otherwise stray capacity causes a drop in voltage, decreasing the brightness and the ability to start-up.

Cleaning

- Do not wipe the polarizer with a dry cloth, as it may scratch the surface.
- Wipe the LCD panel gently with a soft cloth soaked with a petroleum benzine.
- Do not use ketonic solvents (ketone and acetone)or aromatic solvents (toluene and xylene), as they may damage the polarizer.

Storing

- Store the LCD panel in a dark place, where the temperature is 25°C±10°C and the relative humidity below 65%. If possible, store the LCD panel in the packaging situation when it was delivered.
- Do not store the module near organic solvents or corrosive gases.
- Keep the module (including accessories) safe from vibration, shock and pressure.
- Use an LCD module with built-in EL backlight within six months of delivery.
- EL backlight is easily affected by environmental conditions such as temperature and humidity; the quality may deteriorate if stored for an extended period of time. Contact Seiko Instruments GmbH for details.
- Some parts of the backlight and the inverter generate heat. Take care so that the heat does not affect the liquid crystal or any other parts.
- Dust particles attached to the surface of the LCD or the surface of the backlight degrade the display quality. Be careful to keep dust out in designing the structure as well as in handling the module.
- Black or white air-bubbles may be produced if the LCD panel is stored for long time in the lower temperature or mechanical shocks are applied onto the LCD panel.

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- The colors of the products reproduced herein may be different from the actual colors. Check color on actual products before using the product.
- The information contained herein shall not be reproduced in whole or in part without the express written consent of Seiko Instruments GmbH
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Notes :

ꞅ8C/13 Group
ꞅINGLE-CHIP 16-BIT CMOS MICROCOMPUTER

REJ03B0069-0110
Rev.1.10
Apr 27, 2005

1. Overview

This MCU is built using the high-performance silicon gate CMOS process using a R8C/Tiny Series CPU core and is packaged in a 32-pin plastic molded LQFP. This MCU operates using sophisticated instructions featuring a high level of instruction efficiency. With 1M bytes of address space, it is capable of executing instructions at high speed.
The data flash ROM (2 KB X 2 blocks) is embedded.

1.1 Applications

Electric household appliance, office equipment, housing equipment (sensor, security), general industrial equipment, audio, etc.

1.2 Performance Outline

Table 1.1. lists the performance outline of this MCU.

Table 1.1 Performance outline

Item		Performance
CPU	Number of basic instructions	89 instructions
	Shortest instruction execution time	50 ns (f(XIN) = 20 MHz, VCC = 3.0 to 5.5 V) 100 ns (f(XIN) = 10 MHz, VCC = 2.7 to 5.5 V)
	Operating mode	Single-chip
	Address space	1M bytes
	Memory capacity	See Table 1.2.
Peripheral function	Interrupt	Internal: 11 factors, External: 5 factors, Software: 4 factors, Priority level: 7 levels
	Watchdog timer	15 bits x 1 (with prescaler) Reset start function selectable
	Timer	Timer X: 8 bits x 1 channel, Timer Y: 8 bits x 1 channel, Timer Z: 8 bits x 1 channel (Each timer equipped with 8-bit prescaler) Timer C: 16 bits x 1 channel Circuits of input capture and output compare.
	Serial interface	•1 channel Clock synchronous, UART •1 channel UART
	A/D converter	10-bit A/D converter: 1 circuit, 12 channels
	Clock generation circuit	2 circuits •Main clock generation circuit (Equipped with a built-in feedback resistor) •On-chip oscillator (high-speed, low-speed) On high-speed on-chip oscillator the frequency adjust-ment function is usable.
	Oscillation stop detection function	Stop detection of main clock oscillation
	Voltage detection circuit	Included
	Power on reset circuit	Included
	Port	Input/Output: 22 (including LED drive port), Input: 2 (LED drive I/O port: 8)
Electrical characteristics	Power supply voltage	VCC = 3.0 to 5.5V (f(XIN) = 20MHz) VCC = 2.7 to 5.5V (f(XIN) = 10MHz)
	Power consumption	Typ.9 mA (VCC = 5.0V, (f(XIN) = 20MHz,High-speed mode) Typ.5 mA (VCC = 3.0V, (f(XIN) = 10MHz,High-speed mode) Typ.35 µA (VCC = 3.0V, Wait mode, Peripheral clock stops) Typ.0.7 µA (VCC = 3.0V, Stop mode)
Flash memory	Program/erase voltage	VCC = 2.7 to 5.5 V
	Number of program/erase	10,000 times (Data area) 1,000 times (Program area)
Operating ambient temperature		-20 to 85°C -40 to 85°C (D-version)
Package		32-pin plastic mold LQFP

1.3 Block Diagram

Figure 1.1 shows this MCU block diagram.

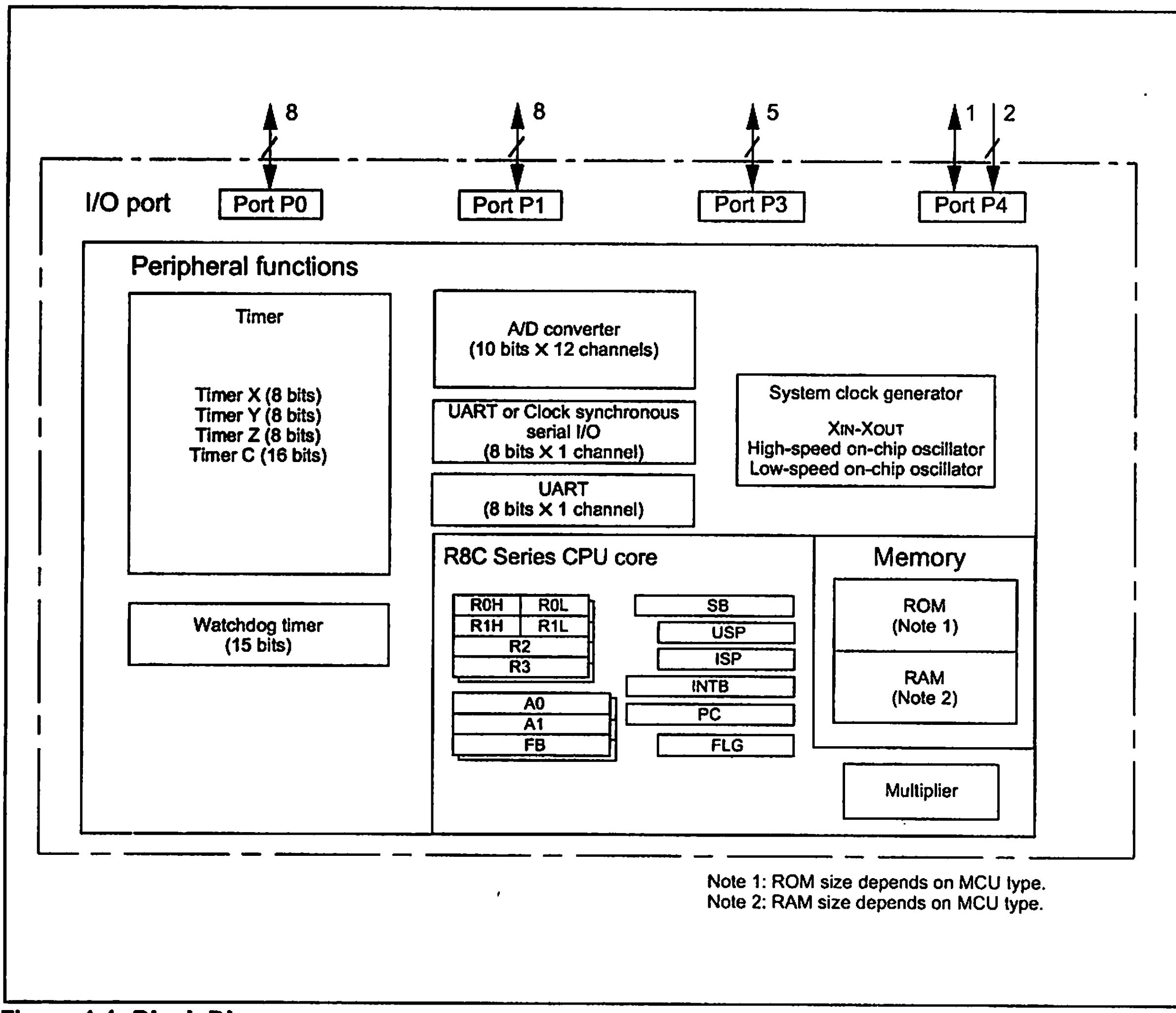


Figure 1.1 Block Diagram

1.4 Product Information

Table 1.2 lists the products.

Table 1.2 Product List

As of April 2005

Type No.	ROM capacity		RAM capacity	Package type	Remarks
	Program area	Data area			
R5F21132FP	8K bytes	2K bytes x 2	512 bytes	PLQP0032GB-A	Flash memory version
R5F21133FP	12K bytes	2K bytes x 2	768 bytes	PLQP0032GB-A	
R5F21134FP	16K bytes	2K bytes x 2	1K bytes	PLQP0032GB-A	
R5F21132DFP	8K bytes	2K bytes x 2	512 bytes	PLQP0032GB-A	D version
R5F21133DFP	12K bytes	2K bytes x 2	768 bytes	PLQP0032GB-A	
R5F21134DFP	16K bytes	2K bytes x 2	1K bytes	PLQP0032GB-A	

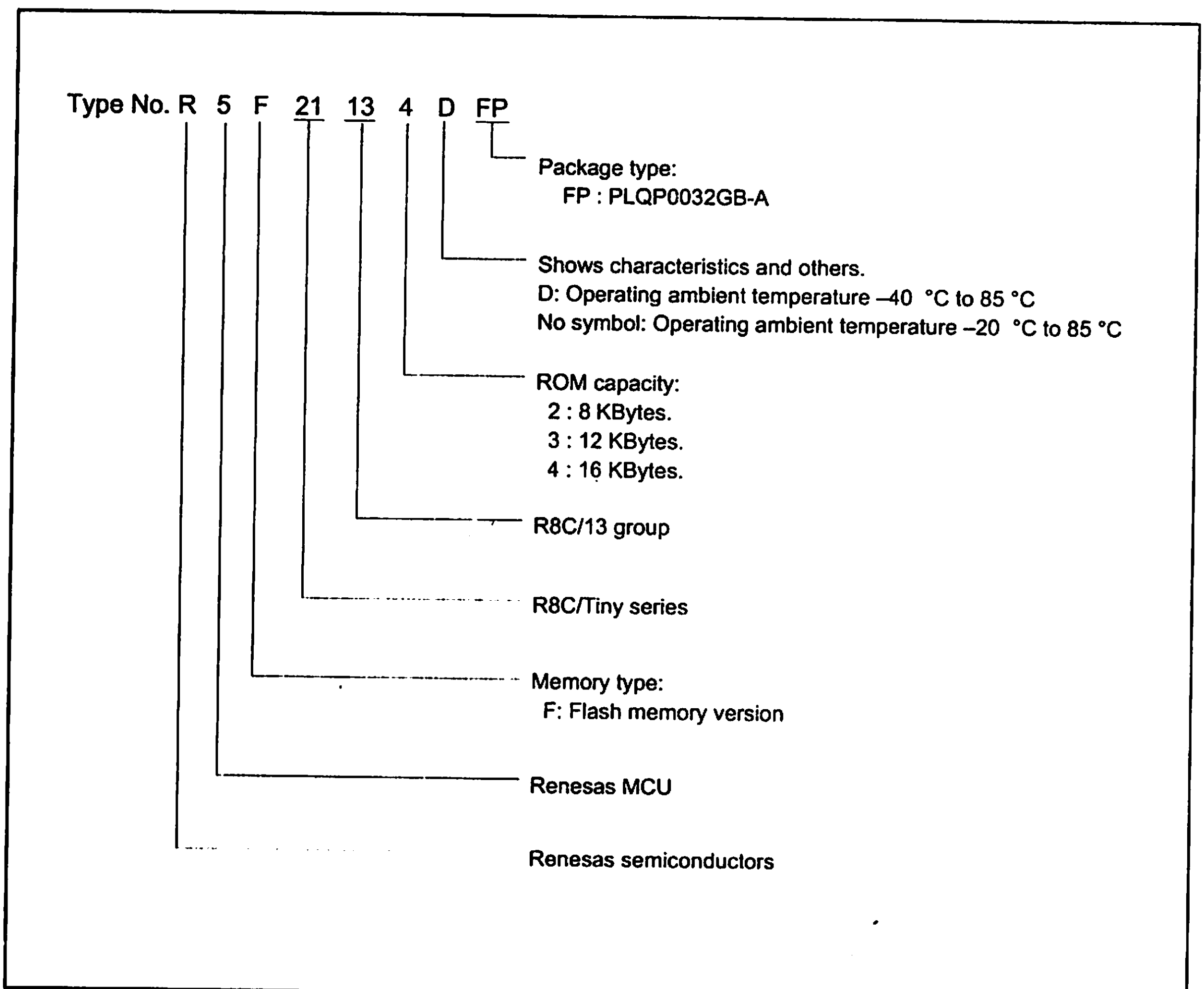
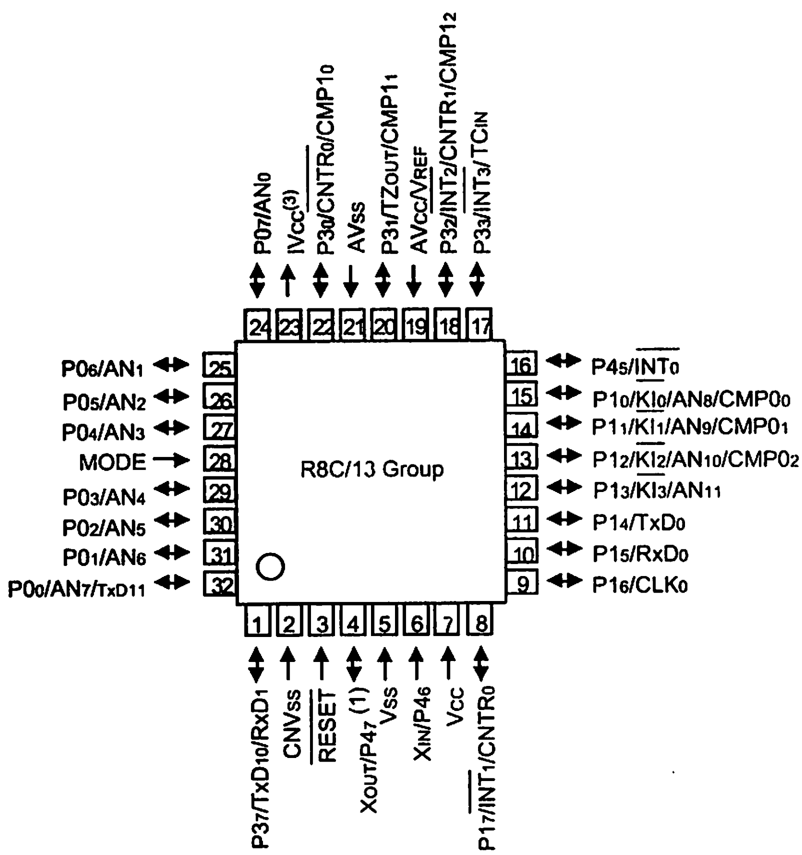


Figure 1.2 Type No., Memory Size, and Package

1.5 Pin Assignments

Figure 1.3 shows the pin configuration (top view).

PIN Assignments (top view)



NOTES:

1. P47 functions only as an input port.
2. When using On-chip debugger, do not use P00/AN7/TxD11 and P37/TxD10/RxD1 pins.
3. Do not connect IVcc to Vcc.

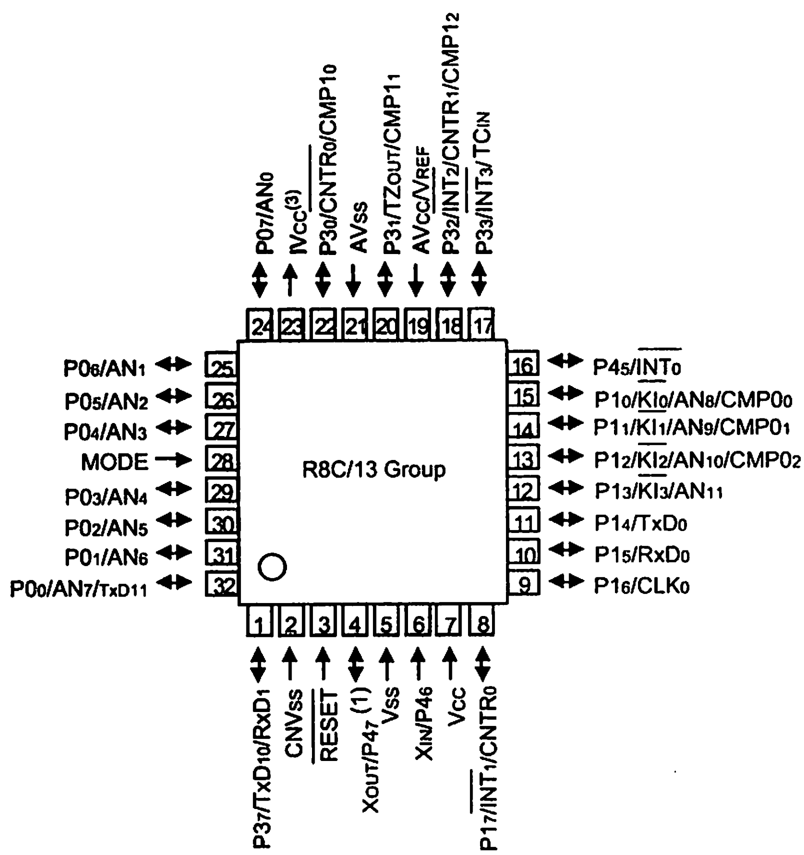
Package: PLQP0032GB-A (32P6U-A)

Figure 1.3 Pin Assignments (Top View)

1.5 Pin Assignments

Figure 1.3 shows the pin configuration (top view).

PIN Assignments (top view)



NOTES:

1. P47 functions only as an input port.
2. When using On-chip debugger, do not use P00/AN7/TxD11 and P37/TxD10/RxD1 pins.
3. Do not connect IVcc to Vcc.

Package: PLQP0032GB-A (32P6U-A)

Figure 1.3 Pin Assignments (Top View)

1.6 Pin Description

Table 1.3 shows the pin description

Table 1.3 Pin description

Signal name	Pin name	I/O type	Function
Power supply input	Vcc, Vss	I	Apply 2.7 V to 5.5 V to the Vcc pin. Apply 0 V to the Vss pin.
IVcc	IVcc	O	This pin is to stabilize internal power supply Connect this pin to Vss via a capacitor (0.1 μF) Do not connect to Vcc
Analog power supply input	AVcc, AVss	I	These are power supply input pins for A/D converter. Connect the AVcc pin to Vcc. Connect the AVss pin to Vss. Connect a capacitor between pins AVcc and AVss.
Reset input	$\overline{\text{RESET}}$	I	"L" on this input resets the MCU.
CNVss	CNVss	I	Connect this pin to Vss via a resistor[1]
MODE	MODE	I	Connect this pin to Vcc via a resistor
Main clock input	X_{IN}	I	These pins are provided for the main clock generating circuit I/O. Connect a ceramic resonator or a crystal oscillator between the X_{IN} and X_{OUT} pins. To use an externally derived clock, input it to the X_{IN} pin and leave the X_{OUT} pin open.
Main clock output	X_{OUT}	O	
$\overline{\text{INT}}$ interrupt input	$\overline{\text{INT}_0}$ to $\overline{\text{INT}_3}$	I	These are $\overline{\text{INT}}$ interrupt input pins.
Key input interrupt input	$\overline{\text{KI}_0}$ to $\overline{\text{KI}_3}$	I	These are key input interrupt pins.
Timer X	$CNTR_0$	I/O	This is the timer X I/O pin.
	$\overline{\text{CNTR}_0}$	O	This is the timer X output pin.
Timer Y	$CNTR_1$	I/O	This is the timer Y I/O pin.
Timer Z	TZ_{OUT}	O	This is the timer Z output pin.
Timer C	TC_{IN}	I	This is the timer C input pin.
	$CMP0_0$ to $CMP0_3$, $CMP1_0$ to $CMP1_3$	O	These are the timer C output pins.
Serial interface	CLK_0	I/O	This is a transfer clock I/O pin.
	RxD_0, RxD_1	I	These are serial data input pins.
	TxD_0, TxD_{10}, TxD_{11}	O	These are serial data output pins.
Reference voltage input	V_{REF}	I	This is a reference voltage input pin for A/D converter. Connect the V_{REF} pin to Vcc.
A/D converter	AN_0 to AN_{11}	I	These are analog input pins for A/D converter.
I/O port	$P0_0$ to $P0_7$, $P1_0$ to $P1_7$, $P3_0$ to $P3_3$, $P3_7$, $P4_5$	I/O	These are 8-bit CMOS I/O ports. Each port has an I/O select direction register, allowing each pin in that port to be directed for input or output individually. Any port set to input can select whether to use a pull-up resistor or not by program. $P1_0$ to $P1_7$ also function as LED drive ports.
Input port	$P4_6$, $P4_7$	I	These are input only pins.

2. Central Processing Unit (CPU)

Figure 2.1 shows the CPU registers. The CPU has 13 registers. Of these, R0, R1, R2, R3, A0, A1 and FB comprise a register bank. There are two register banks.

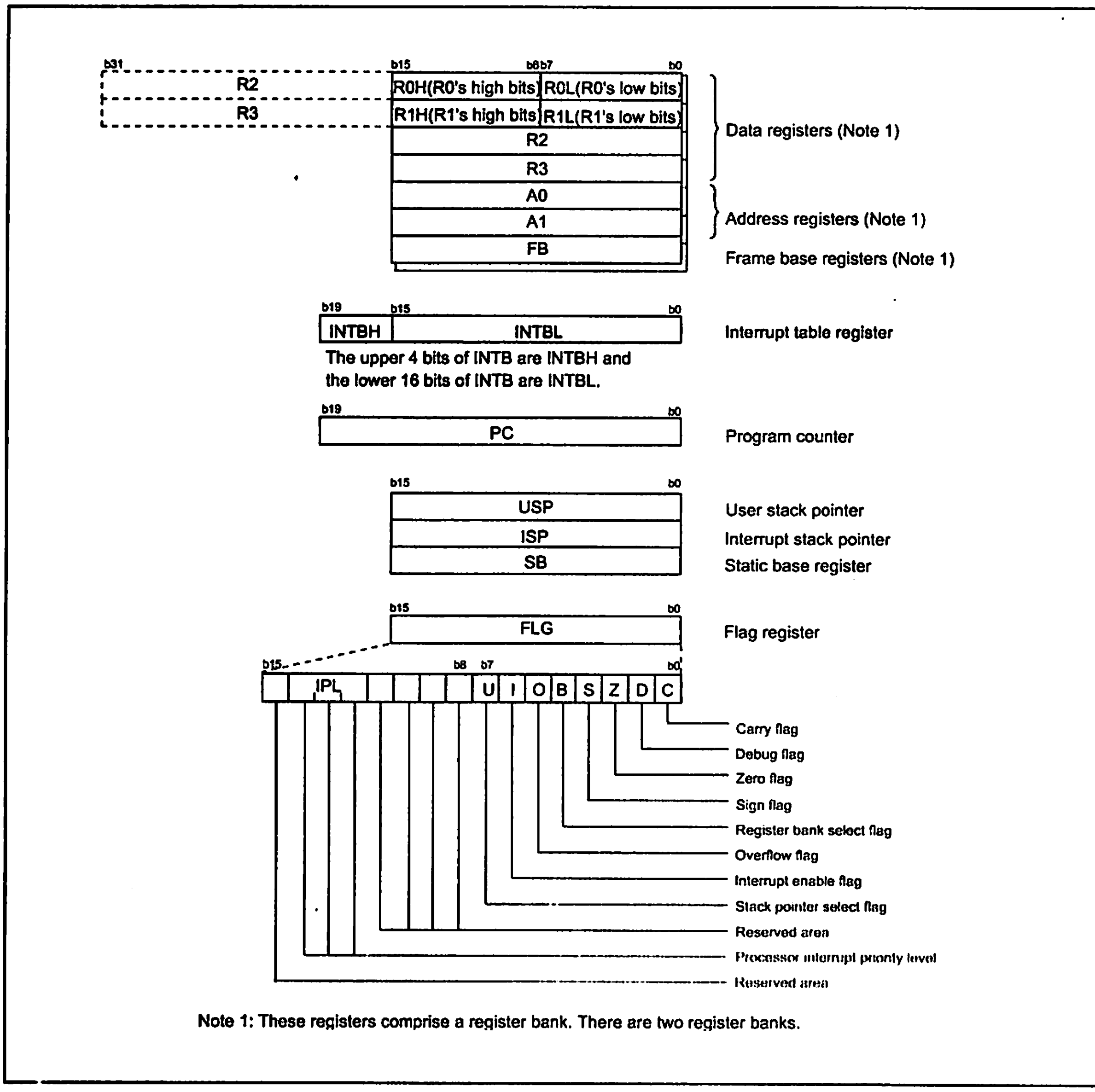


Figure 2.1 Central Processing Unit Register

2.1 Data Registers (R0, R1, R2 and R3)

The R0 register consists of 16 bits, and is used mainly for transfers and arithmetic/logic operations. R1 to R3 are the same as R0.

The R0 register can be separated between high (R0H) and low (R0L) for use as two 8-bit data registers. R1H and R1L are the same as R0H and R0L. Conversely, R2 and R0 can be combined for use as a 32-bit data register (R2R0). R3R1 is the same as R2R0.

2.2 Address Registers (A0 and A1)

The register A0 consists of 16 bits, and is used for address register indirect addressing and address register relative addressing. They also are used for transfers and logic/logic operations. A1 is the same as A0.
In some instructions, registers A1 and A0 can be combined for use as a 32-bit address register (A1A0).

2.3 Frame Base Register (FB)

FB is configured with 16 bits, and is used for FB relative addressing.

2.4 Interrupt Table Register (INTB)

INTB is configured with 20 bits, indicating the start address of an interrupt vector table.

2.5 Program Counter (PC)

PC is configured with 20 bits, indicating the address of an instruction to be executed.

2.6 User Stack Pointer (USP) and Interrupt Stack Pointer (ISP)

Stack pointer (SP) comes in two types: USP and ISP, each configured with 16 bits.
Your desired type of stack pointer (USP or ISP) can be selected by the U flag of FLG.

2.7 Static Base Register (SB)

SB is configured with 16 bits, and is used for SB relative addressing.

2.8 Flag Register (FLG)

FLG consists of 11 bits, indicating the CPU status.

2.8.1 Carry Flag (C Flag)

This flag retains a carry, borrow, or shift-out bit that has occurred in the arithmetic/logic unit.

2.8.2 Debug Flag (D Flag)

The D flag is used exclusively for debugging purpose. During normal use, it must be set to "0".

2.8.3 Zero Flag (Z Flag)

This flag is set to "1" when an arithmetic operation resulted in 0; otherwise, it is "0".

2.8.4 Sign Flag (S Flag)

This flag is set to "1" when an arithmetic operation resulted in a negative value; otherwise, it is "0".

2.8.5 Register Bank Select Flag (B Flag)

Register bank 0 is selected when this flag is "0" ; register bank 1 is selected when this flag is "1".

2.8.6 Overflow Flag (O Flag)

This flag is set to "1" when the operation resulted in an overflow; otherwise, it is "0".

2.8.7 Interrupt Enable Flag (I Flag)

This flag enables a maskable interrupt.
Maskable interrupts are disabled when the I flag is "0", and are enabled when the I flag is "1". The I flag is cleared to "0" when the interrupt request is accepted.

2.8.8 Stack Pointer Select Flag (U Flag)

ISP is selected when the U flag is "0"; USP is selected when the U flag is "1".
The U flag is cleared to "0" when a hardware interrupt request is accepted or an INT instruction for software interrupt Nos. 0 to 31 is executed.

2.8.9 Processor Interrupt Priority Level (IPL)

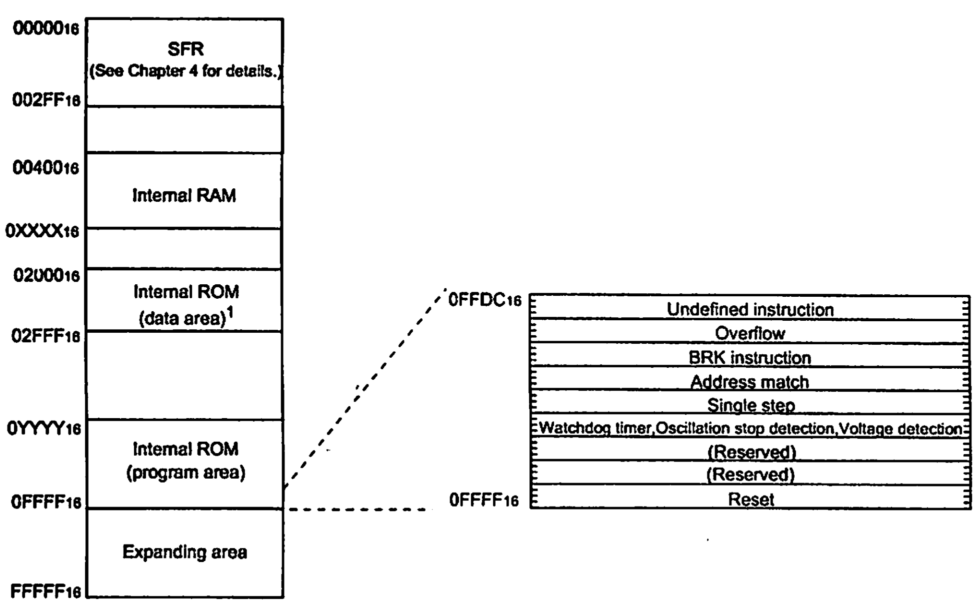
IPL is configured with three bits, for specification of up to eight processor interrupt priority levels from level 0 to level 7.
If a requested interrupt has priority greater than IPL, the interrupt is enabled.

2.8.10 Reserved Area

When write to this bit, write "0". When read, its content is indeterminate.

3. Memory

Figure 3.1 is a memory map of this MCU. The address space extends the 1M bytes from address 00000_{16} to $FFFFF_{16}$.
The internal ROM (program area) is allocated in a lower address direction beginning with address $0FFFF_{16}$. For example, a 16-Kbyte internal ROM is allocated to the addresses from $0C000_{16}$ to $0FFFF_{16}$.
The fixed interrupt vector table is allocated to the addresses from $0FFDC_{16}$ to $0FFFF_{16}$. Therefore, store the start address of each interrupt routine here.
The internal ROM (data area) is allocated to the addresses from 02000_{16} to $02FFF_{16}$.
The internal RAM is allocated in an upper address direction beginning with address 00400_{16}. For example, a 1-Kbyte internal RAM is allocated to the addresses from 00400_{16} to $007FF_{16}$. In addition to storing data, the internal RAM also stores the stack used when calling subroutines and when interrupts are generated.
Special function registers (SFR) are allocated to the addresses from 00000_{16} to $002FF_{16}$. Peripheral function control registers are located here. Of the SFR, any space which has no functions allocated is reserved for future use and cannot be used by users.



NOTES:
1. The data flash ROM block A (2K bytes) and block B (2K bytes) are shown.
2. Blank spaces are reserved. No access is allowed.

Type name	Internal ROM		Internal RAM	
	Size	Address $0YYYY_{16}$	Size	Address $0XXXX_{16}$
R5F21134FP, R5F21134DFP	16K bytes	$0C000_{16}$	1K bytes	$007FF_{16}$
R5F21133FP, R5F21133DFP	12K bytes	$0D000_{16}$	768 bytes	$006FF_{16}$
R5F21132FP, R5F21132DFP	8K bytes	$0E000_{16}$	512 bytes	$005FF_{16}$

Figure 3.1 Memory Map

4. Special Function Register (SFR)

SFR(Special Function Register) is the control register of peripheral functions. Tables 4.1 to 4.4 list the SFR information

Table 4.1 SFR Information(1)[1]

Address	Register	Symbol	After reset
0000$_{16}$			
0001$_{16}$			
0002$_{16}$			
0003$_{16}$			
0004$_{16}$	Processor mode register 0 [1]	PM0	00$_{16}$
0005$_{16}$	Processor mode register 1	PM1	00$_{16}$
0006$_{16}$	System clock control register 0	CM0	01101000$_{2}$
0007$_{16}$	System clock control register 1	CM1	00100000$_{2}$
0008$_{16}$	High-speed on-chip oscillator control register 0	HR0	00$_{16}$
0009$_{16}$	Address match interrupt enable register	AIER	XXXXXX00$_{2}$
000A$_{16}$	Protect register	PRCR	00XXX000$_{2}$
000B$_{16}$	High-speed on-chip oscillator control register 1	HR1	40$_{16}$
000C$_{16}$	Oscillation stop detection register	OCD	00000100$_{2}$
000D$_{16}$	Watchdog timer reset register	WDTR	XX$_{16}$
000E$_{16}$	Watchdog timer start register	WDTS	XX$_{16}$
000F$_{16}$	Watchdog timer control register	WDC	00011111$_{2}$
0010$_{16}$	Address match interrupt register 0	RMAD0	00$_{16}$
0011$_{16}$			00$_{16}$
0012$_{16}$			X0$_{16}$
0013$_{16}$			
0014$_{16}$	Address match interrupt register 1	RMAD1	00$_{16}$
0015$_{16}$			00$_{16}$
0016$_{16}$			X0$_{16}$
0017$_{16}$			
0018$_{16}$			
0019$_{16}$	Voltage detection register 1 [2]	VCR1	00001000$_{2}$
001A$_{16}$	Voltage detection register 2 [2]	VCR2	00$_{16}$ [3] 10000000$_{2}$ [4]
001B$_{16}$			
001C$_{16}$			
001D$_{16}$			
001E$_{16}$	$\overline{INT0}$ input filter select register	INT0F	XXXXX000$_{2}$
001F$_{16}$	Voltage detection interrupt register [2]	D4INT	00$_{16}$ [3] 01000001$_{2}$ [4]
0020$_{16}$			
0021$_{16}$			
0022$_{16}$			
0023$_{16}$			
0024$_{16}$			
0025$_{16}$			
0026$_{16}$			
0027$_{16}$			
0028$_{16}$			
0029$_{16}$			
002A$_{16}$			
002B$_{16}$			
002C$_{16}$			
002D$_{16}$			
002E$_{16}$			
002F$_{16}$			
0030$_{16}$			
0031$_{16}$			
0032$_{16}$			
0033$_{16}$			
0034$_{16}$			
0035$_{16}$			
0036$_{16}$			
0037$_{16}$			
0038$_{16}$			
0039$_{16}$			
003A$_{16}$			
003B$_{16}$			
003C$_{16}$			
003D$_{16}$			
003E$_{16}$			
003F$_{16}$			

X : Undefined

NOTES:

1. Blank columns are all reserved space. No access is allowed.
2. Software reset or the watchdog timer reset does not affect this register.
3. Owing to Reset input.
4. In the case of $\overline{RESET}$ pin = H retaining.

Table 4.2 SFR Information(2)[1]

Address	Register	Symbol	After reset
0040_{16}			
0041_{16}			
0042_{16}			
0043_{16}			
0044_{16}			
0045_{16}			
0046_{16}			
0047_{16}			
0048_{16}			
0049_{16}			
$004A_{16}$			
$004B_{16}$			
$004C_{16}$			
$004D_{16}$	Key input interrupt control register	KUPIC	$XXXXX000_2$
$004E_{16}$	AD conversion interrupt control register	ADIC	$XXXXX000_2$
$004F_{16}$			
0050_{16}	Compare 1 interrupt control register	CMP1IC	$XXXXX000_2$
0051_{16}	UART0 transmit interrupt control register	S0TIC	$XXXXX000_2$
0052_{16}	UART0 receive interrupt control register	S0RIC	$XXXXX000_2$
0053_{16}	UART1 transmit interrupt control register	S1TIC	$XXXXX000_2$
0054_{16}	UART1 receive interrupt control register	S1RIC	$XXXXX000_2$
0055_{16}	INT2 interrupt control register	INT2IC	$XXXXX000_2$
0056_{16}	Timer X interrupt control register	TXIC	$XXXXX000_2$
0057_{16}	Timer Y interrupt control register	TYIC	$XXXXX000_2$
0058_{16}	Timer Z interrupt control register	TZIC	$XXXXX000_2$
0059_{16}	INT1 interrupt control register	INT1IC	$XXXXX000_2$
$005A_{16}$	INT3 interrupt control register	INT3IC	$XXXXX000_2$
$005B_{16}$	Timer C interrupt control register	TCIC	$XXXXX000_2$
$005C_{16}$	Compare 0 interrupt control register	CMP0IC	$XXXXX000_2$
$005D_{16}$	INT0 interrupt control register	INT0IC	$XX00X000_2$
$005E_{16}$			
$005F_{16}$			
0060_{16}			
0061_{16}			
0062_{16}			
0063_{16}			
0064_{16}			
0065_{16}			
0066_{16}			
0067_{16}			
0068_{16}			
0069_{16}			
$006A_{16}$			
$006B_{16}$			
$006C_{16}$			
$006D_{16}$			
$006E_{16}$			
$006F_{16}$			
0070_{16}			
0071_{16}			
0072_{16}			
0073_{16}			
0074_{16}			
0075_{16}			
0076_{16}			
0077_{16}			
0078_{16}			
0079_{16}			
$007A_{16}$			
$007B_{16}$			
$007C_{16}$			
$007D_{16}$			
$007E_{16}$			
$007F_{16}$			

X : Undefined

NOTES.

1. Blank columns are all reserved space. No access is allowed.

Table 4.3 SFR Information(3)[1]

Address	Register	Symbol	After reset
0080_{16}	Timer Y, Z mode register	TYZMR	00_{16}
0081_{16}	Prescaler Y	PREY	FF_{16}
0082_{16}	Timer Y secondary	TYSC	FF_{16}
0083_{16}	Timer Y primary	TYPR	FF_{16}
0084_{16}	Timer Y, Z waveform output control register	PUM	00_{16}
0085_{16}	Prescaler Z	PREZ	FF_{16}
0086_{16}	Timer Z secondary	TZSC	FF_{16}
0087_{16}	Timer Z primary	TZPR	FF_{16}
0088_{16}			
0089_{16}			
$008A_{16}$	Timer Y, Z output control register	TYZOC	00_{16}
$008B_{16}$	Timer X mode register	TXMR	00_{16}
$008C_{16}$	Prescaler X	PREX	FF_{16}
$008D_{16}$	Timer X register	TX	FF_{16}
$008E_{16}$	Count source set register	TCSS	00_{16}
$008F_{16}$			
0090_{16}	Timer C register	TC	00_{16}
0091_{16}			00_{16}
0092_{16}			
0093_{16}			
0094_{16}			
0095_{16}			
0096_{16}	External input enable register	INTEN	00_{16}
0097_{16}			
0098_{16}	Key input enable register	KIEN	00_{16}
0099_{16}			
$009A_{16}$	Timer C control register 0	TCC0	00_{16}
$009B_{16}$	Timer C control register 1	TCC1	00_{16}
$009C_{16}$	Capture, compare 0 register	TM0	00_{16}
$009D_{16}$			00_{16}[2]
$009E_{16}$	Compare 1 register	TM1	FF_{16}
$009F_{16}$			FF_{16}
$00A0_{16}$	UART0 transmit/receive mode register	U0MR	00_{16}
$00A1_{16}$	UART0 bit rate register	U0BRG	XX_{16}
$00A2_{16}$	UART0 transmit buffer register	U0TB	XX_{16}
$00A3_{16}$			XX_{16}
$00A4_{16}$	UART0 transmit/receive control register 0	U0C0	00001000_2
$00A5_{16}$	UART0 transmit/receive control register 1	U0C1	00000010_2
$00A6_{16}$	UART0 receive buffer register	U0RB	XX_{16}
$00A7_{16}$			XX_{16}
$00A8_{16}$	UART1 transmit/receive mode register	U1MR	00_{16}
$00A9_{16}$	UART1 bit rate register	U1BRG	XX_{16}
$00AA_{16}$	UART1 transmit buffer register	U1TB	XX_{16}
$00AB_{16}$			XX_{16}
$00AC_{16}$	UART1 transmit/receive control register 0	U1C0	00001000_2
$00AD_{16}$	UART1 transmit/receive control register 1	U1C1	00000010_2
$00AE_{16}$	UART1 receive buffer register	U1RB	XX_{16}
$00AF_{16}$			XX_{16}
$00B0_{16}$	UART transmit/receive control register 2	UCON	00_{16}
$00B1_{16}$			
$00B2_{16}$			
$00B3_{16}$			
$00B4_{16}$			
$00B5_{16}$			
$00B6_{16}$			
$00B7_{16}$			
$00B8_{16}$			
$00B9_{16}$			
$00BA_{16}$			
$00BB_{16}$			
$00BC_{16}$			
$00BD_{16}$			
$00BE_{16}$			
$00BF_{16}$			

X : Undefined

NOTES:

1. Blank columns are all reserved space. No access is allowed.
2. When the output compare mode is selected (the TCC13 bit in the TCC1 register = 1), the value is set to $FFFF_{16}$.

Table 4.4 SFR Information(4)(1)

Address	Register	Symbol	After reset
00C0₁₆	AD register	AD	XX16
00C1₁₆			XX16
00C2₁₆			
00C3₁₆			
00C4₁₆			
00C5₁₆			
00C6₁₆			
00C7₁₆			
00C8₁₆			
00C9₁₆			
00CA₁₆			
00CB₁₆			
00CC₁₆			
00CD₁₆			
00CE₁₆			
00CF₁₆			
00D0₁₆			
00D1₁₆			
00D2₁₆			
00D3₁₆			
00D4₁₆	AD control register 2	ADCON2	0016
00D5₁₆			
00D6₁₆	AD control register 0	ADCON0	00000XXX2
00D7₁₆	AD control register 1	ADCON1	0016
00D8₁₆			
00D9₁₆			
00DA₁₆			
00DB₁₆			
00DC₁₆			
00DD₁₆			
00DE₁₆			
00DF₁₆			
00E0₁₆	Port P0 register	P0	XX16
00E1₁₆	Port P1 register	P1	XX16
00E2₁₆	Port P0 direction register	PD0	0016
00E3₁₆	Port P1 direction register	PD1	0016
00E4₁₆			
00E5₁₆	Port P3 register	P3	XX16
00E6₁₆			
00E7₁₆	Port P3 direction register	PD3	0016
00E8₁₆	Port P4 register	P4	XX16
00E9₁₆			
00EA₁₆	Port P4 direction register	PD4	0016
00EB₁₆			
00EC₁₆			
00ED₁₆			
00EE₁₆			
00EF₁₆			
00F0₁₆			
00F1₁₆			
00F2₁₆			
00F3₁₆			
00F4₁₆			
00F5₁₆			
00F6₁₆			
00F7₁₆			
00F8₁₆			
00F9₁₆			
00FA₁₆			
00FB₁₆			
00FC₁₆	Pull-up control register 0	PUR0	00XX00002
00FD₁₆	Pull-up control register 1	PUR1	XXXXXX0X2
00FE₁₆	Port P1 drive capacity control register	DRR	0016
00FF₁₆	Timer C output control register	TCOUT	0016
≈			
01B3₁₆	Flash memory control register 4	FMR4	010000002
01B4₁₆			
01B5₁₆	Flash memory control register 1	FMR1	1000000X2
01B6₁₆			
01B7₁₆	Flash memory control register 0	FMR0	000000012
0FFFF₁₆	Option function select register (2)	OFS	Note 2

X : Undefined

NOTES:

1. The blank areas, 0100₁₆ to 01B2₁₆ and 01B8₁₆ to 02FF₁₆ are reserved and cannot be used by users.
2. The watchdog timer control bit is assigned. Refer to "Figure11.2 OFS, WDC, WDTR and WDTS registers" of Hardware Manual for details

5. Electrical Characteristics

Table 5.1 Absolute Maximum Ratings

Symbol	Parameter	Condition	Rated value	Unit
V_{CC}	Supply voltage	Vcc=AVcc	-0.3 to 6.5	V
AV_{CC}	Analog supply voltage	Vcc=AVcc	-0.3 to 6.5	V
V_I	Input voltage		-0.3 to Vcc+0.3	V
V_O	Output voltage		-0.3 to Vcc+0.3	V
P_d	Power dissipation	Topr=25°C	300	mW
T_{opr}	Operating ambient temperature		-20 to 85 / -40 to 85 (D version)	°C
T_{stg}	Storage temperature		-65 to 150	°C

Table 5.2 Recommended Operating Conditions

Symbol	Parameter		Conditions	Standard Min.	Standard Typ.	Standard Max.	Unit
V_{CC}	Supply voltage			2.7		5.5	V
AV_{CC}	Analog supply voltage				Vcc[3]	—	V
V_{SS}	Supply voltage				0		V
AV_{SS}	Analog supply voltage				0		V
V_{IH}	"H" input voltage			0.8Vcc		Vcc	V
V_{IL}	"L" input voltage			0		0.2Vcc	V
$I_{OH(sum)}$	"H" peak all output currents	Sum of all pins' IOH (peak)				-60.0	mA
$I_{OH(peak)}$	"H" peak output current					-10.0	mA
$I_{OH(avg)}$	"H" average output current					-5.0	mA
$I_{OL(sum)}$	"L" peak all output currents	Sum of all pins' IOL (peak)				60	mA
$I_{OL(peak)}$	"L" peak output current	Except $P1_0$ to $P1_7$				10	mA
		$P1_0$ to $P1_7$	Drive ability HIGH			30	mA
			Drive ability LOW			10	mA
$I_{OL(avg)}$	"L" average output current	Except $P1_0$ to $P1_7$				5	mA
		$P1_0$ to $P1_7$	Drive ability HIGH			15	mA
			Drive ability LOW			5	mA
$f(X_{IN})$	Main clock input oscillation frequency		3.0V ≤ Vcc ≤ 5.5V	0		20	MHz
			2.7V ≤ Vcc < 3.0V	0		10	MHz

Note

1: Referenced to Vcc = AVcc = 2.7 to 5.5V at Topr = -20 to 85 °C / -40 to 85 °C unless otherwise specified.

2: The mean output current is the mean value within 100ms.

3: Set Vcc=AVcc

Table 5.3 A/D Conversion Characteristics

Symbol	Parameter		Measuring condition	Standard Min.	Standard Typ.	Standard Max.	Unit
–	Resolution		V_{ref} =VCC			10	Bit
–	Absolute accuracy	10 bit mode	øAD=10 MHz, Vref=Vcc=5.0V			±3	LSB
		8 bit mode	øAD=10 MHz, Vref=Vcc=5.0V			±2	LSB
		10 bit mode	øAD=10 MHz, Vref=Vcc=3.3V[3]			±5	LSB
		8 bit mode	øAD=10 MHz, Vref=Vcc=3.3V[3]			±2	LSB
R_{LADDER}	Ladder resistance		VREF=VCC	10		40	kΩ
t_{CONV}	Conversion time	10 bit mode	øAD=10 MHz, Vref=Vcc=5.0V	3.3			μs
		8 bit mode	øAD=10 MHz, Vref=Vcc=5.0V	2.8			μs
V_{REF}	Reference voltage				Vcc[4]		V
V_{IA}	Analog input voltage			0		V_{ref}	V
–	A/D operation clock frequency[2]	Without sample & hold		0.25		10	MHz
		With sample & hold		1.0		10	MHz

Note

1: Referenced to Vcc=AVcc=2.7 to 5.5V at Topr = -20 to 85 °C / -40 to 85 °C unless otherwise specified.

2: When f_{AD} is 10 MHz more, divide the f_{AD} and make A/D operation clock frequency ($Ø_{AD}$) lower than 10 MHz.

3: When the AVcc is less than 4.2V, divide the f_{AD} and make A/D operation clock frequency ($Ø_{AD}$) lower than $f_{AD}/2$.

4: Set Vcc=Vref

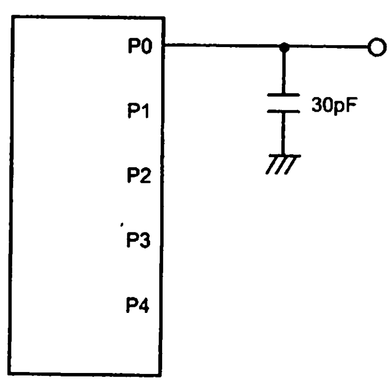


Figure 5.1 Port P0 to P4 measurement circuit

Table 5.4 Flash Memory (Program area) Electrical Characteristics

Symbol	Parameter	Measuring condition	Standard			Unit
			Min.	Typ.	Max	
–	Program/Erase cycle [2]		1000[3]	—	—	cycle
–	Byte program time	Vcc = 5.0 V at Topr = 25 °C	—	50	—	µs
–	Block erase time	Vcc = 5.0 V at Topr = 25 °C	—	0.4	—	s
$t_{d(SR-ES)}$	Time delay from Suspend Request until Erase Suspend		—	—	8	ms
–	Erase Suspend Request Interval		10	—	—	ms
–	Program, Erase Voltage		2.7	—	5.5	V
–	Read Voltage		2.7	—	5.5	V
–	Program, Erase Temperature		0	—	60	°C
–	Data-retention duration	Topr = 55 °C	20	—	—	year

Table 5.5 Flash Memory (Data area Block A, Block B) Electrical Characteristics [4]

Symbol	Parameter	Measuring condition	Standard			Unit
			Min.	Typ.	Max	
–	Program/Erase endurance[2]		10000 [3]	—	—	times
–	Byte program time(program/erase endurance ≤1000 times)	Vcc = 5.0 V at Topr = 25 °C	—	50	400	µs
–	Byte program time(program/erase endurance >1000 times)	Vcc = 5.0 V at Topr = 25 °C	—	65	—	µs
–	Block erase time(program/erase endurance ≤1000 times)	Vcc = 5.0 V at Topr = 25 °C	—	0.2	9	s
–	Block erase time(program/erase endurance >1000 times)	Vcc = 5.0 V at Topr = 25 °C	—	0.3	—	s
$t_{d(SR-ES)}$	Time delay from Suspend Request until Erase Suspend		—	—	8	ms
–	Erase Suspend Request Interval		10	—	—	ms
–	Program, Erase Voltage		2.7	—	5.5	V
–	Read Voltage		2.7	—	5.5	V
–	Program/Erase Temperature		-20(-40)[8]	—	85	°C
–	Data-retention duration	Topr = 55 °C	20	—	—	year

Note

1: Referenced to Vcc=AVcc=2.7 to 5.5V at Topr = 0°C to 60°C unless otherwise specified.

2: Definition of Program/Erase
The cycle of Program/Erase shows a cycle for each block.
If the program/erase number is "n" (n = 1000, 10000), "n" times erase can be performed for each block.
For example, if performing one-byte write to the distinct addresses on Block A of 2K-byte block 2048 times and then erasing that block, the number of Program/Erase cycles is one time.
However, performing multiple writes to the same address before an erase operation is prohibited (overwriting prohibited).

3: Maximum numbers of Program/Erase cycles for which all electrical characteristics is guaranteed.

4: Table 16.5 applies for Block A or B when the Program/Erase cycles are more than 1000. The byte program time up to 1000 cycles are the same as that of the program area (see Table 5.4).

5: To reduce the number of Program/Erase cycles, a block erase should ideally be performed after writing in series as many distinct addresses (only one time each) as possible. If programming a set of 16 bytes, write up to 128 sets and then erase them one time. This will result in ideally reducing the number of Program/Erase cycles. Additionally, averaging the number of Program/Erase cycles for Block A and B will be more effective. It is important to track the total number of block erases and restrict the number.

6: If error occurs during block erase, attempt to execute the clear status register command, then the block erase command at least three times until the erase error disappears.

7: Customers desiring Program/Erase failure rate information should contact their Renesas technical support representative.

8: -40 °C for D version.

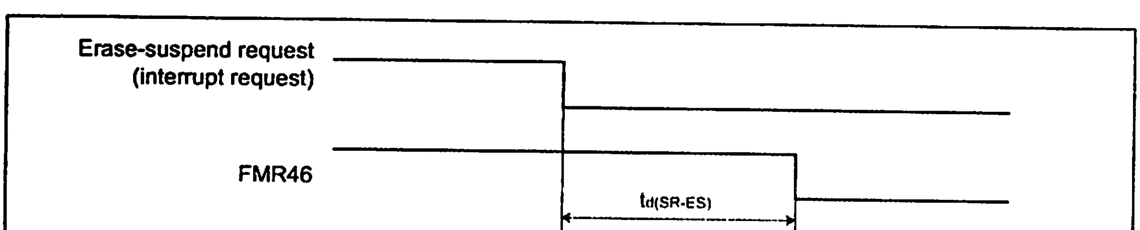


Figure 5.2 Time delay from Suspend Request until Erase Suspend

Table 5.6 Voltage Detection Circuit Electrical Characteristics

Symbol	Parameter	Measuring condition	Standard Min.	Standard Typ.	Standard Max.	Unit
Vdet	Voltage detection level		3.3	3.8	4.3	V
	Voltage detection interrupt request generating time[2]			40		µs
—	Voltage detection circuit self consumption current	VC27=1, VCC=5.0V		600		nA
td(E-A)	Waiting time until voltage detection circuit operation starts[3]				20	µs
Vccmin	Microcomputer operation voltage minimum value		2.7			V

NOTES:
1. The measuring condition is Vcc=AVcc=2.7V to 5.5V and Topr=-40°C to 85°C.
2. This shows the time until the voltage detection interrupt request is generated since the voltage passes Vdet.
3. This shows the required time until the voltage detection circuit operates when setting to "1" again after setting the VC27 bit in the VCR2 register to "0".

Table 5.7 Reset Circuit Electrical Characteristics (When Using Hardware Reset 2[1, 3])

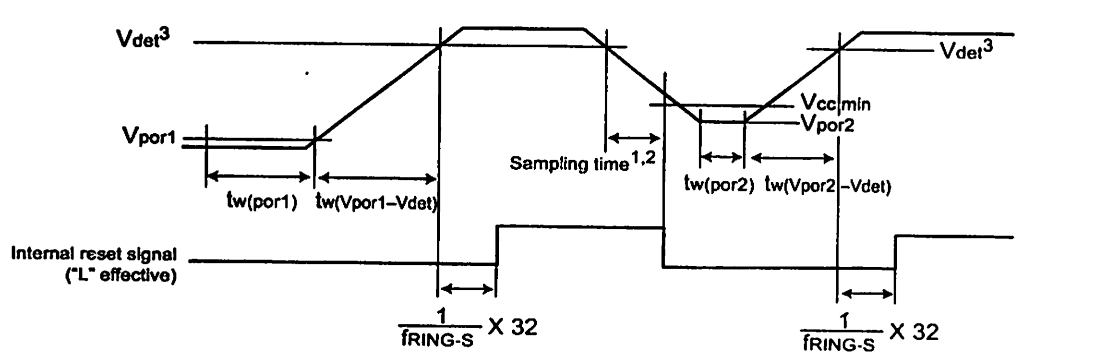
Symbol	Parameter	Measuring condition	Standard Min.	Standard Typ.	Standard Max.	Unit
Vpor2	Power-on reset valid voltage	$-20°C \le Topr < 85°C$	—	—	Vdet	V
tw(Vpor2-Vdet)	Supply voltage rising time when power-on reset is canceled[2]	$-20°C \le Topr < 85°C$, $tw(por2) \ge 0s$[4]			100	ms

NOTES:
1. The voltage detection circuit which is embedded in a microcomputer is a factor to generate the hardware reset 2. Refer to 5.1.2 Hardware Reset 2.
2. This condition is not applicable when using $Vcc \ge 1.0V$.
3. When turning power on after the external power has been held below the valid voltage for greater than 10 seconds, refer to Table 16.8 Reset Circuit Electrical Characteristics (When Not Using Hardware Reset 2).
4. tw(por2) is time to hold the external power below effective voltage (Vpor2).

Table 5.8 Reset Circuit Electrical Characteristics (When Not Using Hardware Reset 2)

Symbol	Parameter	Measuring condition	Standard Min.	Standard Typ.	Standard Max.	Unit
Vpor1	Power-on reset valid voltage	$-20°C \le Topr < 85°C$			0.1	V
tW(Vpor1-Vdet)	Supply voltage rising time when power-on reset is canceled	$0°C \le Topr \le 85°C$, $tw(por1) \ge 10s$[2]			100	ms
tW(Vpor1-Vdet)	Supply voltage rising time when power-on reset is canceled	$-20°C \le Topr < 0°C$, $tw(por1) \ge 30s$[2]			100	ms
tW(Vpor1-Vdet)	Supply voltage rising time when power-on reset is canceled	$-20°C \le Topr < 0°C$, $tw(por1) \ge 10s$[2]			1	ms
tW(Vpor1-Vdet)	Supply voltage rising time when power-on reset is canceled	$0°C \le Topr \le 85°C$, $tw(por1) \ge 1s$[2]			0.5	ms

NOTES:
1. When not using hardware reset 2, use with $Vcc \ge 2.7V$.
2. tw(por1) is time to hold the external power below effective voltage (Vpor1).



NOTES:
1. Hold the voltage of the microcomputer operation voltage range (Vccmin or above) within sampling time.
2. A sampling clock is selectable. Refer to "5.4 Voltage Detection Circuit" for details.
3. Vdet shows the voltage detection level of the voltage detection circuit. Refer to "5.4 Voltage Detection Circuit" for details.

Figure 5.3 Reset Circuit Electrical Characteristics

Table 5.9 High-speed On-Chip Oscillator Circuit Electrical Characteristics

Symbol	Parameter	Measuring condition	Standard Min.	Standard Typ.	Standard Max.	Unit
---	High-speed on-chip oscillator frequency 1 / (td(HRoffset)+td(HR)) when the reset is released	VCC=5.0V, Topr=25 °C Set "40_{16}" in the HR1 register		8		MHz
td(HRoffset)	Settable high-speed on-chip oscillator minimum period	VCC=5.0V, Topr=25 °C Set "00_{16}" in the HR1 register		61		ns
td(HR)	High-speed on-chip oscillator period adjusted unit	Differences when setting "01_{16}" and "00_{16}" in the HR register		1		ns
---	High-speed on-chip oscillator temperature dependence(1)	Frequency fluctuation in temperature range of -10 °C to 50 °C		±5		%
---	High-speed on-chip oscillator temperature dependence(2)	Frequency fluctuation in temperature range of -40 °C to 85 °C		±10		%

NOTES:
1. The measuring condition is Vcc=AVcc=5.0 V and Topr=25 °C.

Table 5.10 Power Circuit Timing Characteristics

Symbol	Parameter	Measuring condition	Standard Min.	Standard Typ.	Standard Max.	Unit
td(P-R)	Time for internal power supply stabilization during powering-on[2]		1		2000	µs
td(R-S)	STOP release time[3]				150	µs

Note
1: The measuring condition is Vcc=AVcc=2.7 to 5.5 V and Topr=25 °C.
2: This shows the wait time until the internal power supply generating circuit is stabilized during power-on.
3: This shows the time until BCLK starts from the interrupt acknowledgement to cancel stop mode.

Table 5.11 Electrical Characteristics (1) [Vcc=5V]

Symbol	Parameter		Measuring condition		Standard Min.	Standard Typ.	Standard Max.	Unit
V_{OH}	"H" output voltage	Except X_{OUT}	I_{OH}=-5mA		Vcc-2.0		Vcc	V
			I_{OH}=-200µA		Vcc-0.3		Vcc	V
		X_{OUT}	Drive capacity HIGH	I_{OH}=-1 mA	Vcc-2.0		Vcc	V
			Drive capacity LOW	I_{OH}=-500µA	Vcc-2.0		Vcc	V
V_{OL}	"L" output voltage	P10 to P17 Except X_{OUT}	I_{OL}= 5 mA				2.0	V
			I_{OL}= 200 µA				0.45	V
		P10 to P17	Drive capacity HIGH	I_{OL}= 15 mA			2.0	V
			Drive capacity LOW	I_{OL}= 5 mA			2.0	V
			Drive capacity LOW	I_{OL}= 200 µA			0.45	V
		X_{OUT}	Drive capacity HIGH	I_{OL}= 1 mA			2.0	V
			Drive capacity LOW	I_{OL}=500 µA			2.0	V
V_{T+}-V_{T-}	Hysteresis	$\overline{INT_0}$, $\overline{INT_1}$, $\overline{INT_2}$, $\overline{INT_3}$, $\overline{KI_0}$, $\overline{KI_1}$, $\overline{KI_2}$, $\overline{KI_3}$, $CNTR_0$, $CNTR_1$, TC_{IN}, RxD_0, RxD_1, P45			0.2		1.0	V
		$\overline{RESET}$			0.2		2.2	V
I_{IH}	"H" input current		V_I=5V				5.0	µA
I_{IL}	"L" input current		V_I=0V				-5.0	µA
R_{PULLUP}	Pull-up resistance		V_I=0V		30	50	167	kΩ
R_{fXIN}	Feedback resistance	X_{IN}				1.0		MΩ
f_{RING-S}	Low-speed on-chip oscillator frequency				40	125	250	kHz
V_{RAM}	RAM retention voltage		At stop mode		2.0			V

Note
1 : Referenced to Vcc=AVcc=4.2 to 5.5V at Topr = -20 to 85 °C / -40 to 85 °C, f(X_{IN})=20MHz unless otherwise specified.

Table 5.12 Electrical Characteristics (2) [Vcc=5V]

Symbol	Parameter	Measuring condition		Standard Min.	Standard Typ.	Standard Max.	Unit
Icc	Power supply current (Vcc=3.3 to 5.5V) In single-chip mode, the output pins are open and other pins are Vss	High-speed mode	X_{IN}=20 MHz (square wave) High-speed on-chip oscillator off Low-speed on-chip oscillator on=125 kHz No division		9	15	mA
			X_{IN}=16 MHz (square wave) High-speed on-chip oscillator off Low-speed on-chip oscillator on=125 kHz No division		8	14	mA
			X_{IN}=10 MHz (square wave) High-speed on-chip oscillator off Low-speed on-chip oscillator on=125 kHz No division		5		mA
		Medium-speed mode	X_{IN}=20 MHz (square wave) High-speed on-chip oscillator off Low-speed on-chip oscillator on=125 kHz Division by 8		4		mA
			X_{IN}=16 MHz (square wave) High-speed on-chip oscillator off Low-speed on-chip oscillator on=125 kHz Division by 8		3		mA
			X_{IN}=10 MHz (square wave) High-speed on-chip oscillator off Low-speed on-chip oscillator on=125 kHz Division by 8		2		mA
		High-speed on-chip oscillator mode	Main clock off High-speed on-chip oscillator on=8 MHz Low-speed on-chip oscillator on=125 kHz No division		4	8	mA
			Main clock off High-speed on-chip oscillator on=8 MHz Low-speed on-chip oscillator on=125 kHz Division by 8		1.5		mA
		Low-speed on-chip oscillator mode	Main clock off High-speed on-chip oscillator off Low-speed on-chip oscillator on=125 kHz Division by 8		470	900	µA
		Wait mode	Main clock off High-speed on-chip oscillator off Low-speed on-chip oscillator on=125 kHz When a WAIT instruction is executed[2] Peripheral clock operation VC27="0"		40	80	µA
		Wait mode	Main clock off High-speed on-chip oscillator off Low-speed on-chip oscillator on=125 kHz When a WAIT instruction is executed[2] Peripheral clock off VC27="0"		38	76	µA
		Stop mode	Main clock off High-speed on-chip oscillator off Low-speed on-chip oscillator off CM10="1" Peripheral clock off VC27="0"		0.8	3.0	µA

NOTES
1: The power supply current measuring is executed using the measuring program on flash memory.
2: Timer Y is operated with timer mode.

Timing requirements (Unless otherwise noted: Vcc = 5V, Vss = 0V at Ta = 25 °C) [Vcc=5V]

Table 5.13 XIN input

Symbol	Parameter	Standard		Unit
		Min.	Max.	
tc(XIN)	XIN input cycle time	50		ns
twH(XIN)	XIN input HIGH pulse width	25		ns
twL(XIN)	XIN input LOW pulse width	25		ns

Table 5.14 CNTR0 input, CNTR1 input, $\overline{INT2}$ input

Symbol	Parameter	Standard		Unit
		Min.	Max.	
tc(CNTR0)	CNTR0 input cycle time	100		ns
twH(CNTR0)	CNTR0 input HIGH pulse width	40		ns
twL(CNTR0)	CNTR0 input LOW pulse width	40		ns

Table 5.15 TCIN input, $\overline{INT3}$ input

Symbol	Parameter	Standard		Unit
		Min.	Max.	
tc(TCIN)	TCIN input cycle time	400 [1]		ns
twH(TCIN)	TCIN input HIGH pulse width	200 [2]		ns
twL(TCIN)	TCIN input LOW pulse width	200 [2]		ns

NOTES

1 :When using the Timer C input capture mode, adjust the cycle time above (1/ Timer C count source frequency x 3).

2 : When using the Timer C input capture mode, adjust the pulse width above (1/ Timer C count source frequency x 1.5).

Table 5.16 Serial Interface

Symbol	Parameter	Standard		Unit
		Min.	Max.	
tc(CK)	CLKi input cycle time	200		ns
tw(CKH)	CLKi input HIGH pulse width	100		ns
tw(CKL)	CLKi input LOW pulse width	100		ns
td(C-Q)	TxDi output delay time		80	ns
th(C-Q)	TxDi hold time	0		ns
tsu(D-C)	RxDi input setup time	35		ns
th(C-D)	RxDi input hold time	90		ns

Table 5.17 External interrupt $\overline{INT0}$ input

Symbol	Parameter	Standard		Unit
		Min.	Max.	
tw(INH)	$\overline{INT0}$ input HIGH pulse width	250 [1]		ns
tw(INL)	$\overline{INT0}$ input LOW pulse width	250 [2]		ns

NOTES

1 : When selecting the digital filter by the $\overline{INT0}$ input filter select bit, use the $\overline{INT0}$ input HIGH pulse width to the greater value,either (1/ digital filter clock frequency x 3) or the minimum value of standard.

2 : When selecting the digital filter by the $\overline{INT0}$ input filter select bit, use the $\overline{INT0}$ input LOW pusle width to the greater value,either (1/ digital filter clock frequency x 3) or the minimum value of standard.

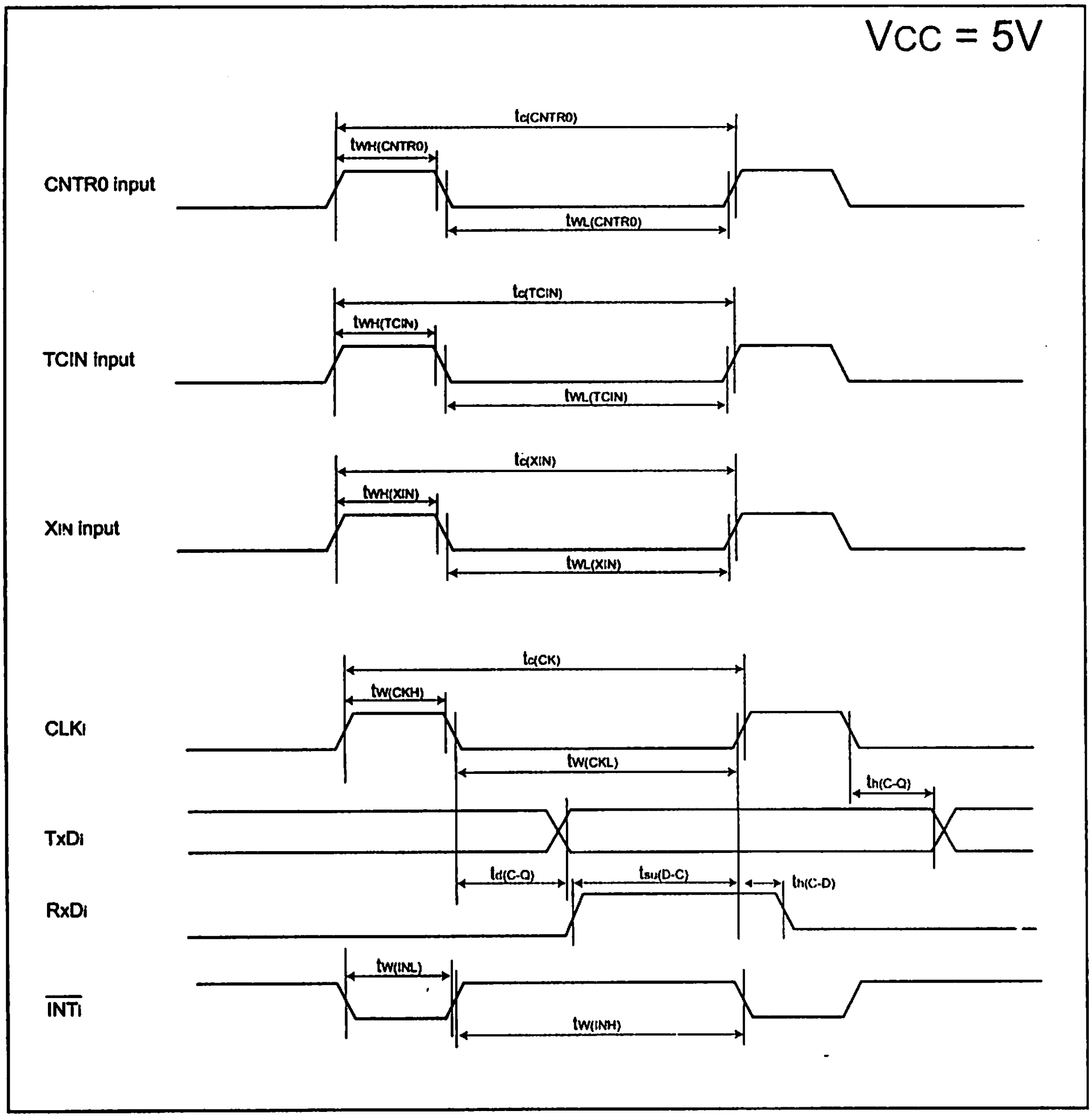


Figure 5.4 Vcc=5V timing diagram

Table 5.18 Electrical Characteristics (3) [Vcc=3V]

Symbol	Parameter		Measuring condition		Standard Min.	Standard Typ.	Standard Max.	Unit
V_{OH}	"H" output voltage	Except X_{OUT}	I_{OH}=-1mA		Vcc-0.5		Vcc	V
		X_{OUT}	Drive capacity HIGH	I_{OH}=-0.1 mA	Vcc-0.5		Vcc	V
			Drive capacity LOW	I_{OH}=-50 μA	Vcc-0.5		Vcc	V
V_{OL}	"L" output voltage	P10 to P17 Except X_{OUT}	I_{OL}= 1 mA			—	0.5	V
		P10 to P17	Drive capacity HIGH	I_{OL}= 2 mA			0.5	V
			Drive capacity LOW	I_{OL}= 1 mA			0.5	V
		X_{OUT}	Drive capacity HIGH	I_{OL}= 0.1 mA	—		0.5	V
			Drive capacity LOW	I_{OL}=50 μA	—		0.5	V
V_{T+}-V_{T-}	Hysteresis	$\overline{INT0}$, $\overline{INT1}$, $\overline{INT2}$, $\overline{INT3}$, $\overline{KI0}$, $\overline{KI1}$, $\overline{KI2}$, $\overline{KI3}$, CNTR0, CNTR1, TCIN, RxD0, RxD1, P45			0.2		0.8	V
		$\overline{RESET}$			0.2		1.8	V
I_{IH}	"H" input current		V_I=3V		—		4.0	μA
I_{IL}	"L" input current		V_I=0V			—	-4.0	μA
R_{PULLUP}	Pull-up resistance		V_I=0V		66	160	500	kΩ
R_{fXIN}	Feedback resistance	X_{IN}				3.0		MΩ
f_{RING-S}	Low-speed on-chip oscillator frequency				40	125	250	kHz
V_{RAM}	RAM retention voltage		At stop mode		2.0			V

Note
1 : Referenced to Vcc=AVcc=2.7 to 3.3V at Topr = -20 to 85 °C / -40 to 85 °C, f(XIN)=10MHz unless otherwise specified.

Table 5.19 Electrical Characteristics (4) [Vcc=3V]

Symbol	Parameter	Measuring condition		Min.	Standard Typ.	Max.	Unit
Icc	Power supply current (Vcc=2.7 to 3.3V) In single-chip mode, the output pins are open and other pins are Vss	High-speed mode	X_{IN}=20 MHz (square wave) High-speed on-chip oscillator off Low-speed on-chip oscillator on=125 kHz No division		8	13	mA
			X_{IN}=16 MHz (square wave) High-speed on-chip oscillator off Low-speed on-chip oscillator on=125 kHz No division		7	12	mA
			X_{IN}=10 MHz (square wave) High-speed on-chip oscillator off Low-speed on-chip oscillator on=125 kHz No division		5		mA
		Medium-speed mode	X_{IN}=20 MHz (square wave) High-speed on-chip oscillator off Low-speed on-chip oscillator on=125 kHz Division by 8		3		mA
			X_{IN}=16 MHz (square wave) High-speed on-chip oscillator off Low-speed on-chip oscillator on=125 kHz Division by 8		2.5		mA
			X_{IN}=10 MHz (square wave) High-speed on-chip oscillator off Low-speed on-chip oscillator on=125 kHz Division by 8		1.6		mA
		High-speed on-chip oscillator mode	Main clock off High-speed on-chip oscillator on=8 MHz Low-speed on-chip oscillator on=125 kHz No division		3.5	7.5	mA
			Main clock off High-speed on-chip oscillator on=8 MHz Low-speed on-chip oscillator on=125 kHz Division by 8		1.5		mA
		Low-speed on-chip oscillator mode	Main clock off High-speed on-chip oscillator off Low-speed on-chip oscillator on=125 kHz Division by 8		420	800	μA
		Wait mode	Main clock off High-speed on-chip oscillator off Low-speed on-chip oscillator on=125 kHz When a WAIT instruction is executed[2] Peripheral clock operation VC27="0"		37	74	μA
		Wait mode	Main clock off High-speed on-chip oscillator off Low-speed on-chip oscillator on=125 kHz When a WAIT instruction is executed[2] Peripheral clock off VC27="0"		35	70	μA
		Stop mode	Main clock off High-speed on-chip oscillator off Low-speed on-chip oscillator off CM10="1" Peripheral clock off VC27="0"		0.7	3.0	μA

NOTES

1: The power supply current measuring is executed using the measuring program on frash memory.

2: Timer Y is operated with timer mode.

Timing requirements (Unless otherwise noted: Vcc = 3V, Vss = 0V at Ta = 25 °C) [Vcc=3V]

Table 5.20 XIN input

Symbol	Parameter	Standard		Unit
		Min.	Max.	
tc(XIN)	XIN input cycle time	100		ns
tWH(XIN)	XIN input HIGH pulse width	40		ns
tWL(XIN)	XIN input LOW pulse width	40		ns

Table 5.21 CNTR0 input, CNTR1 input, $\overline{INT2}$ input

Symbol	Parameter	Standard		Unit
		Min.	Max.	
tc(CNTR0)	CNTR0 input cycle time	300		ns
tWH(CNTR0)	CNTR0 input HIGH pulse width	120		ns
tWL(CNTR0)	CNTR0 input LOW pulse width	120		ns

Table 5.22 TCIN input, $\overline{INT3}$ input

Symbol	Parameter	Standard		Unit
		Min.	Max.	
tc(TCIN)	TCIN input cycle time	1200 [1]		ns
tWH(TCIN)	TCIN input HIGH pulse width	600 [2]		ns
tWL(TCIN)	TCIN input LOW pulse width	600 [2]		ns

NOTES

1 :When using the Timer C input capture mode, adjust the cycle time above (1/ Timer C count source frequency x 3).

2 : When using the Timer C input capture mode, adjust the pulse width above (1/ Timer C count source frequency x 1.5).

Table 5.23 Serial Interface

Symbol	Parameter	Standard		Unit
		Min.	Max.	
tc(CK)	CLKi input cycle time	300		ns
tw(CKH)	CLKi input HIGH pulse width	150		ns
tw(CKL)	CLKi input LOW pulse width	150		ns
td(C-Q)	TxDi output delay time		160	ns
th(C-Q)	TxDi hold time	0		ns
tsu(D-C)	RxDi input setup time	55		ns
th(C-D)	RxDi input hold time	90		ns

Table 5.24 External interrupt $\overline{INT0}$ input

Symbol	Parameter	Standard		Unit
		Min.	Max.	
tw(INH)	$\overline{INT0}$ input HIGH pulse width	380 [1]		ns
tw(INL)	$\overline{INT0}$ input LOW pulse width	380 [2]		ns

NOTES

1 : When selecting the digital filter by the $\overline{INT0}$ input filter select bit, use the $\overline{INT0}$ input HIGH pulse width to the greater value,either (1/ digital filter clock frequency x 3) or the minimum value of standard.

2 : When selecting the digital filter by the $\overline{INT0}$ input filter select bit, use the $\overline{INT0}$ input LOW pusle width to the greater value,either (1/ digital filter clock frequency x 3) or the minimum value of standard.

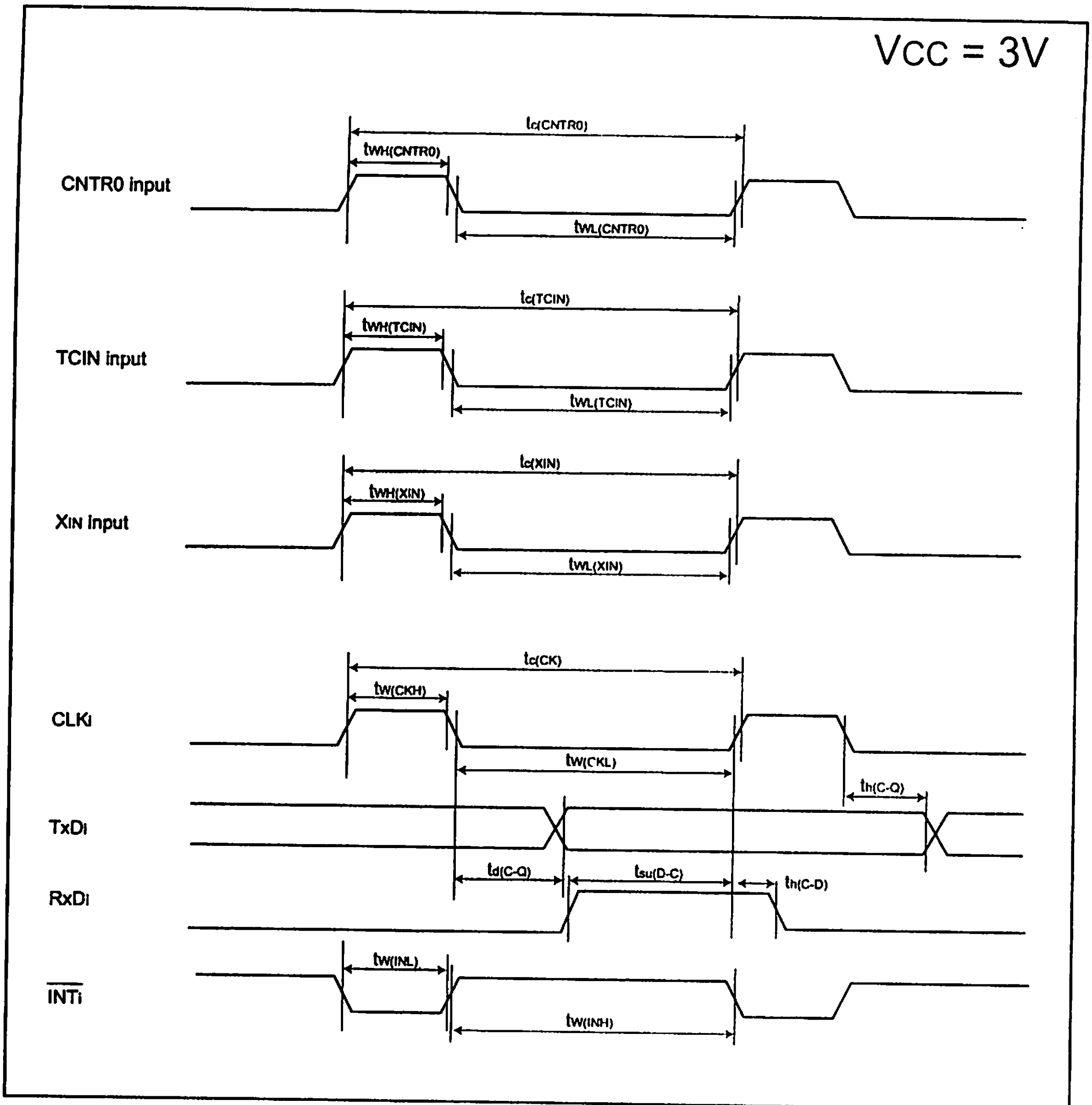
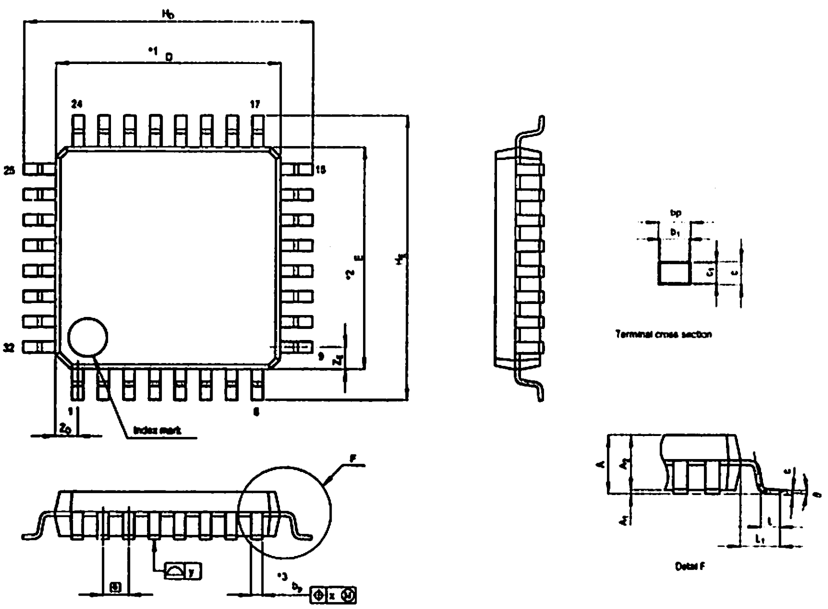


Figure 5.5 Vcc=3V timing diagram

Package Dimensions

JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
P-LQFP32-7x7-0.80	PLQP0032GB-A	32P6U-A	0.2g



NOTE)
1. DIMENSIONS "*1" AND "*2" DO NOT INCLUDE MOLD FLASH
2. DIMENSION "*3" DOES NOT INCLUDE TRIM OFFSET

Reference Symbol	Dimension in Millimeters		
	Min	Nom	Max
D	6.9	7.0	7.1
E	6.9	7.0	7.1
A_2	—	1.4	—
H_D	8.8	9.0	9.2
H_E	8.8	9.0	9.2
A	—	—	1.7
A_1	0	0.1	0.2
b_p	0.32	0.37	0.42
b_1	—	0.35	—
c	0.09	0.145	0.20
c_1	—	0.125	—
θ	0°	—	8°
e	—	0.8	—
x	—	—	0.20
y	—	—	0.10
Z_D	—	0.7	—
Z_E	—	0.7	—
L	0.3	0.5	0.7
L_1	—	1.0	—

REVISION HISTORY	R8C/13 Group Datasheet

Rev.	Date	Description	
		Page	Summary
0.10	Oct 28, 2003		First edition issued
0.20	Dec05, 2003	5	Figure 1.3 revised
		10	Chapter 4, NOTES revised
		16	Table 5.4 revised Table 5.5 revised
		17	Table 5.6 revised Figure 5.3 added
		18	Table 5.8 revised Table 5.10 revised
		21	Figure 5.3 revised to Figure 5.4
		22	Table 5.17 revised
		25	Figure 5.4 revised to Figure 5.5
1.00	Sep 30, 2004	All pages	Words standardized (on-chip oscillator, serial interface, A/D)
		2	Table 1.1 revised
		5	Figure 1.3, NOTES 3 added
		6	Table 1.3 revised
		9	Figure 3.1, NOTES added
		10-13	One body sentence in chapter 4 added ; Titles of Table 4.1 to 4.4 added
		12	Table 4.3 revised ; Table 4.4 revised
		14	Table 5.2 revised
		15	Table 5.3 revised
		16	Table 5.4 and Table 5.5 revised
		17	Table 5.6, 5.7 and 5.8 revised ; Figure 5.3 revised
		18	Table 5.9 and 5.11 revised
		19	Table 5.12 revised
		20	Table 5.13 revised
		22	Table 5.18 revised
		23	Table 5.19 revised
		24	Table 5.20 and Table 5.24 revised
1.10	Apr.27.2005	4	Table 1.2, Figure 1.2 package name revised
		5	Figure 1.3 package name revised
		10	Table 4.1 revised
		12	Table 4.3 revised
		15	Table 5.3 partly revised
		16	Table 5.4, Table 5.5 partly added

REVISION HISTORY	R8C/13 Group Datasheet

Rev.	Date	Description	
		Page	Summary
1.10	Apr.27.2005	17	Table 5.7, 5.8 revised
		18	Table 5.10, Table 5.11 partly revised
		22	Table 5.18 partly revised
		26	Package Dimensions revised

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