SKRIPSI

PERENCANAAN DAN PEMBUATAN *TOUCH* SCREEN

Disusun Oleh:
APRIYANTO ARIBOWO
00.17.160

JURUSAN TEKNIK ELEKTRO S-1
KONSENTRASI TEKNIK ELEKTRONIKA
FAKULTAS TEKNOLOGI INDUSTRI
INSTITUT TEKNOLOGI NASIONAL MALANG
2009

LEMBAR PERSETUJUAN

SKRIPSI
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TOUCH SCREEN

Disusun dan Diajukan untuk Melengkapi dan Memenuhi Syarat
Guna Mencapai Gelar Sarjana Teknik Elektro S-1

disusun oleh :
Nama : Apriyanto Aribowo
NIM : 00.17.160

Diperiksa dan Disetujui :

Dosen Pembimbing I,

Ir. F. Yudi Limpraptono, MT
NIP Y. 1039500274

Dosen Pembimbing II,

23/7 '09

Sotyohadi, ST
NIP Y. 1039700309

Menyetujui :
Ketua Jurusan T.Elektro S1,

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

Ir. F. Yudi Limpraptono, MT
NIP Y. 1039500274

JURUSAN TEKNIK ELEKTRO-S1
KONSENTRASI ELEKTRONIKA
FAKULTAS TEKNOLOGI INDUSTRI
INSTITUT TEKNOLOGI NASIONAL MALANG
MALANG
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ABSTRAKSI

Mode yang kini dimanfaatkan orang-orang kota adalah minimalis dan praktis, yang memanfaatkan fasilitas teknologi canggih. Penemuan atau inovasi dari tiap orang dapat sangat bermanfaat dan meluas disertai daya jual tinggi walaupun pada awalnya sebuah inovasi itu susah untuk diimplementasikan.

Bagaimana merencanakan dan membuat *interface* sederhana yang membantu orang tanpa adanya saklar, tombol atau *keypad.* Inilah fungsi *Touch Screen* yaitu mempermudah pengoperasian suatu alat dengan sentuhan langsung pada tampilan *LCD.*

Sangat mungkin sekali bagi akademika untuk merencanakan dan membuat sistem *Touch Screen* ini tanpa diperlukan biaya yang tinggi, hanya diperlukan sedikit kecerdasan untuk merencanakan menu yang interaktif dan fleksibel.

Kata-kata Kunci : *Touch Screen, Infra Red, LCD, AT89S51.*

Apriyanto. 2009. **Perencanaan dan Pembuatan *Touch Screen*.** Skripsi. Konsentrasi Elektronika Teknik Elektro ITN Malang. Pembimbing: Ir. Felix Yudi Limpraptono, MT, Sotyohadi, ST.

KATA PENGANTAR

Alhamdulillah atas terselesaikannya skripsi ini serta salam dan sholawat kepada Nabi Muhammad.

Skripsi ini merupakan syarat bagi akademika untuk mendapatkan gelar kesarjanaan. Dengan judul yang berhasil dipertahankan pada seminar judul yaitu "**Perencanaan dan Pembuatan *Touch Screen***", namun dengan adanya revisi pada seminar hasil dan ujian skripsi pada setiap pembahasannya. Dan inilah akhirnya sebagaimana yang terlihat.

Skripsi ini tidak lepas dari campur tangan banyak orang yang melalui kesempatan ini penyusun haturkan terima kasih yaitu kepada:

1. Bapak Ir. Felix Yudi Limpraptono, MT yang merupakan Dosen Pembimbing sekaligus Ketua Jurusan Elektro S1.
2. Bapak Sotyohadi, ST selaku Dosen Pembimbing.
3. Keluarga tercinta: Ayahanda, Ibunda, Adinda serta istri.
4. Alan Rozy, Dwi Bagus, Imam, Achmad Fadlil serta seluruh teman-teman aktivis dari berbagai UKM,
5. Semua pihak yang tidak mungkin penyusun sebut satu-persatu disini.

Penyusun sadari skripsi ini masih ada kekurangan, saran dan kritik akan penyusun terima. Dan kepada pembaca, penyusun ucapkan terima kasih atas waktu dan kesempatannya yang telah diluangkan.

Malang, 1 April 2009

Penyusun,

DAFTAR ISI

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BAB I

PENDAHULUAN

1.1. Latar Belakang

Mahasiswa kini dituntut mampu bersaing dalam dunia kerja untuk menghindari predikat menganggur karena tidak adanya kelebihan yang dimiliki. Suatu pembuatan *interface* yang sudah dipelajari pada bangku kuliah sangat dapat dimanfaatkan karena memang kuliah untuk mendapatkan pekerjaan profesional, jika hanya sekedar pekerjaan biasa maka perlu dipertanyakan alasan menempuh pendidikan Teknik khususnya Elektronika.

Keahlian dalam bidang *mikrokontroller* baik komponen dan *assembler* sudah diberikan pada bangku kuliah dapat hilang jika tidak dilatih dan dikembangkan lagi. Dan diperlukan kreativitas untuk menunjukkan *kompetensi* kita dibanding orang lain.

Mode yang kini dimanfaatkan orang-orang kota adalah minimalis dan praktis, yang memanfaatkan fasilitas teknologi canggih. Penemuan atau *inovasi* dari tiap orang dapat sangat bermanfaat dan meluas disertai daya jual tinggi walaupun pada awalnya sebuah *inovasi* itu susah untuk diimplementasikan.

Penggunaan *touch screen* sendiri muncul untuk memenuhi kepuasan masyarakat dalam menggunakan peralatan agar lebih efisien dan praktis. Langsung menyentuh tulisan tanpa adanya saklar, tombol ataupun keypad. Sistem ini menggunakan koordinat yang mengenali baik x dan y. Umumnya panelnya menggunakan mode *resistif* atau *kapasitif*. Namun kini penyusun mencoba dengan *infra red* karena harganya murah.

Penyusun hanya berharap sistem *interface* ini dapat kita kuasai agar lulusan ITN menguasai *interface touch screen*.

1.2. Tujuan

Tujuan yang ingin dicapai dalam skripsi ini adalah merencanakan dan membuat *Touch Screen* sebagai sistem *interface* dengan mikrokontroler AT89S51 dan *infra red*.

1.3. Rumusan Masalah

Dalam penyusunan skripsi ini akan muncul permasalahan yaitu:

- Bagaimana merencanakan suatu menu tampilan yang interaktif pada *LCD* dengan pilihan.
- Bagaimana mendapatkan suatu koordinat sentuhan yang terdapat pada tampilan pilihan *LCD*.
- Bagaimana merencanakan mikrokontroller agar dapat menghubungkan (*interface*) antara koordinat sentuhan dan pilihan.
- Bagaimana penyusunan alat agar seminim mungkin.

1.4. Batasan Masalah

Agar permasalahan tidak terlalu meluas, maka penulis perlu membatasi permasalahan hanya pada hal-hal berikut ini:

- Sistem *mikrokontroller* yang digunakan adalah *MCS51* dengan sebuah IC AT89S51.
- Tampilan *LCD* menggunakan *LCD* modul karakter 16 x 2
- Modul koordinat dirancang menggunakan infra red 8 x 2
- Bahasa yang digunakan adalah *macro assembler*
- Tidak membahas pilihan tampilan *LCD* apakah akan digunakan untuk pengontrol alat lain, namun hanya mengontrol *LED* sebagai contoh saja.
- Tidak membahas penentuan koordinat untuk jenis *touch screen* lain.

1.5. Metodologi Penulisan

Metodologi penulisan yang akan digunakan dalam penulisan skripsi ini adalah sebagai berikut :

1. Pada bab 1 dijelaskan latar belakang judul, masalah, batasan masalah, tujuan dan metodologi penulisan.
2. Pada bab 2 dibahas teori-teori yang mendukung dalam perencanaan dan pembuatan *Touch Screen.*
3. Pada bab 3 dibahas tentang proses perencanaan dan pembuatan alat yang meliputi perangkat keras dan perangkat lunaknya.
4. Pada bab 4 dijelaskan hasil pengujian dan analisis alat yang sudah direalisasikan.
5. Pada bab 5 dijelaskan kesimpulan dan saran.

BAB II

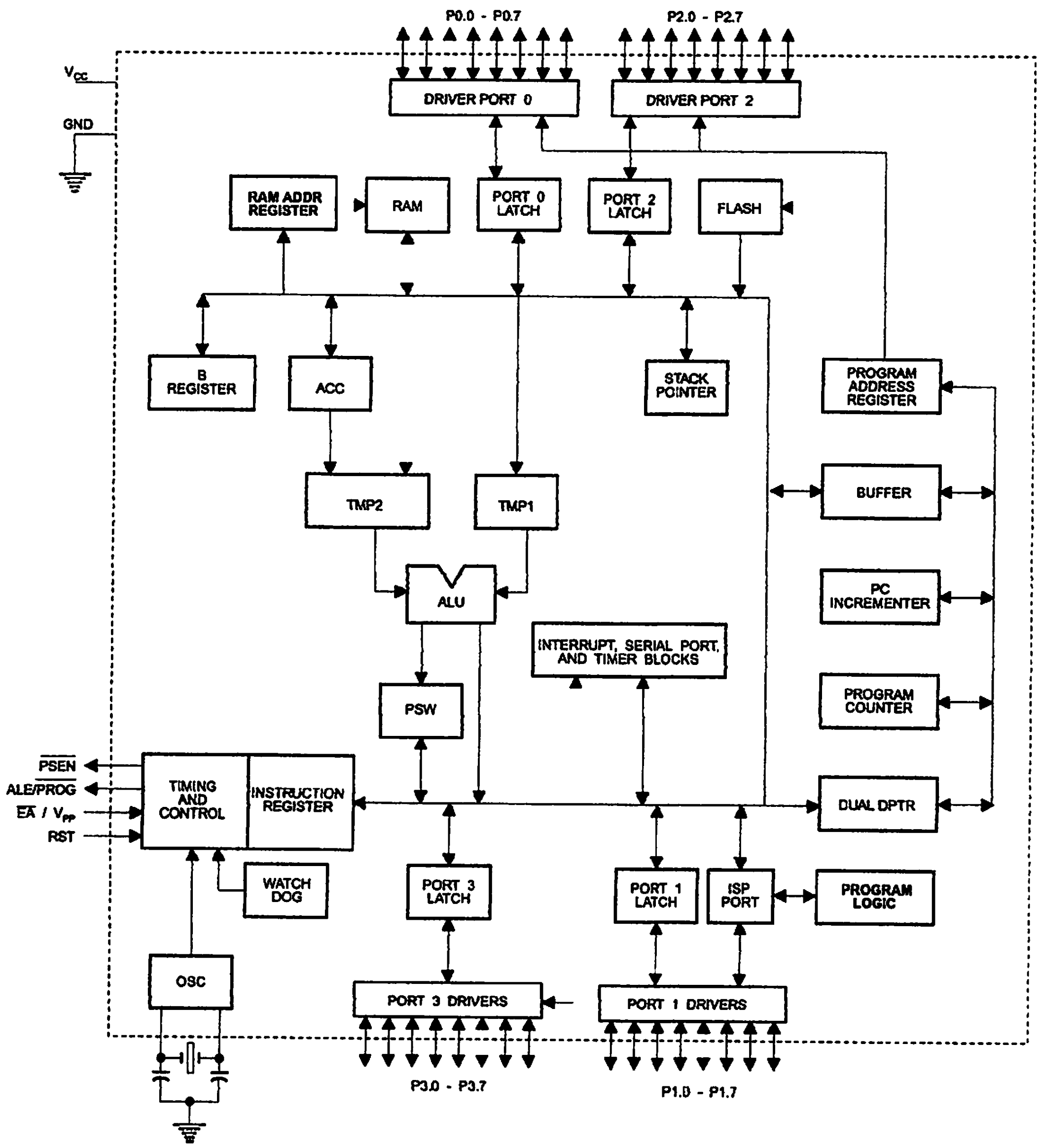
LANDASAN TEORI

Dalam merencanakan dan merealisasikan Perencanaan dan Pembuatan alat *Touch Screen* ini dibutuhkan pemahaman tentang berbagai hal yang mendukung, antara lain :

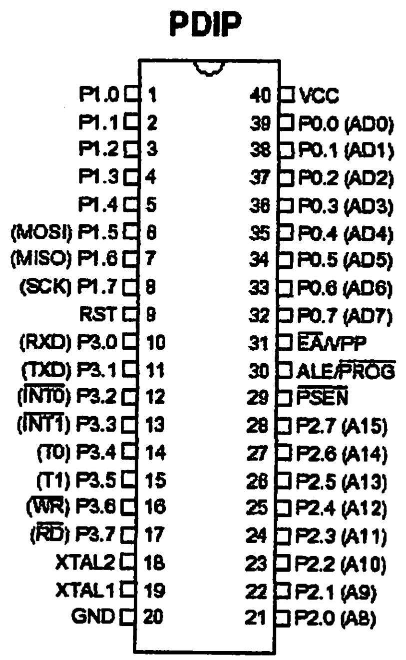
1. Mikrokontroler AT89C51.
2. *LCD* YJ1602A.
3. *Infra Red.*
4. *Photodioda.*

2.1. IC AT89S51

89S51 merupakan varian dari MCS-51. jenis ini sudah memiliki 4 Kbyte PEROM (*Programmable and Eraseable Read Only Memory)*, AT89S51 memiliki memori dengan teknologi *nonvolatile memory,* isi memory tersebut dapat diisi ulang ataupun dihapus berkali-kali. Memori ini bisa digunakan untuk menyimpan instruksi (perintah) berstandart kode MCS-51 sehingga memungkinkan mikrokontroler ini untuk bekerja dalam mode *single chip operation* (mode operasi tunggal) yang tidak memerlukan *external memory* (memory luar). Pada jenis ini PEROM sudah dapat diisi dengan sistem pemrograman serial ISP (*In-System Programmable*).



Gambar 2-1. Arsitektur AT89S51
Sumber: Datasheet AT89S51 Rev.2487A-10/01



Gambar 2-2. Susunan Pin AT89S51
Sumber: Datasheet AT89S51 Rev.2487A-10/01

2.1.1. Susunan Pin AT89S51

VCC Tegangan 5 V

GND *Ground*

Port 0 Merupakan Port I/O dua arah 8 *bit*. Sebagai port output, tiap pin mampu menerima delapan input TTL. Saat 1 ditulis ke pin port 0, pin-pinnya dapat digunakan sebagai input impedansi tinggi. Port 0 juga dapat digunakan menjadi bus data/address *low-order multiplex* selama mengakses memory *external*. Mode ini, P0 memiliki Pull-up internal. Port 0 juga menerima *byte-byte* kode selama pemrograman Flash dan mengirim *byte-byte* kode selama verifikasi program. Pull-up *external* dibutuhkan selama verifikasi program.

Port 1 Merupakan Port I/O dua arah 8 bit dengan pull-up *internal.* Port 1 dapat dipakai sebagai empat *buffer* TTL. Saat high ditulis ke pin port 1, maka oleh pull-up internal akan dinaikkan dan dapat digunakan sebagai input. Sebagai input, pin-pin port 1 yang dari luar diturunkan kini akan menjadi sumber arus (I_{IL}) karena pull-up *internal.* Port 1 juga bertugas menerima *byte-byte* adress *low-order* selama pemrograman dan verifikasi *Flash.* Dengan fungsi berikut:

Tabel 2-1. Fungsi Alternatif Port 1

PIN PORT	FUNGSI PEMROGRAMAN ISP
P1.5	MOSI (data Serial Input)
P1.6	MISO (data Serial Output)
P1.7	SCK (sinyal *clock*)

Sumber: Datasheet AT89S51 Rev.2487A-10/01

Port 2 Merupakan Port I/O dua arah 8 bit dengan pull-up *internal.* Port 2 dapat dipakai sebagai empat *buffer* TTL. Saat high ditulis ke pin port 2, maka oleh pull-up *internal* akan dinaikkan dan dapat digunakan sebagai input. Sebagai input, pin-pin port 2 yang dari luar diturunkan kini akan menjadi sumber arus (I_{IL}) karena pull-up *internal.* Dalam rangkaian Port 2 mengatasi *byte* adress *high-order* dari memory program *external* dan selama mengakses memory data *external* dengan menggunakan address 16-*bit* (**MOVX @ DPTR**). Pada rangkaian ini, Port 2 memakai pull-up *internal* yang kuat saat mengirim *high.* Selama mengakses memory data *external* yang menggunakan address 8-*bit* (**MOVX @ RI**), Port 2 menuliskan isi dari Special Function Register P2. Port 2 juga menerima *bit-bit* address *high-order* dan beberapa sinyal kontrol selama pemrogramam dan verifikasi *Flash*

Port 3 Merupakan Port I/O dua arah 8 bit dengan pull-up *internal.* Port 3 dapat dipakai sebagai empat *buffer TTL.* Saat *high* ditulis ke pin port 3, maka oleh pull-up *internal* akan dinaikkan dan dapat digunakan sebagai input. Sebagai input, pin-pin port 3 yang dari luar diturunkan kini akan menjadi sumber arus (I_{IL}) karena pull-up *internal.* Port 3 menerima *bit-bit* address *high-order* dan beberapa sinyal kontrol selama pemrogramam dan verifikasi *Flash.* Port 3 juga melayani fungsi dari berbagai fitur special dari AT89S51, seperti yang ditunjukkan pada tabel berikut:

Tabel 2-2. Fungsi Alternatif Port 3

PIN PORT	FUNGSI ALTERNATIF
P3.0	RXD (port input serial)
P3.1	TXD (port output serial)
P3.2	INT0 (interrupt 0 external)
P3.3	INT1 (interrupt 1 external)
P3.4	T0 (input external timer 0)
P3.5	T1 (input external timer 1)
P3.6	WR (strobe write untuk memory data external)
P3.7	RD (strobe read untuk memory data external)

Sumber: Datasheet AT89S51 Rev.2487A-10/01

RST Input Reset. Saat osilator berjalan jika selama dua *cycle* pin ini diberi *high* maka akan mereset alat.

ALE/PROG Address Latch Enable (ALE) adalah sinyal output untuk memisahkan *byte low* dari address selama akses ke memory *external*. Pin ini juga input sinyal program (PROG) selama pemrograman *Flash*. Pada operasi biasa, ALE teremisi pada nilai konstan 1/6 frekuensi oscillator dan dapat digunakan untuk *timing external* atau *clock*.

PSEN *Program Store Enable* (PSEN) *strobe* pembaca ke memory program *external*. Saat AT89S51 menjalankan kode dari memory program *external*, PSEN diaktifkan dua kali tiap *machine cycle*, kecuali dua aktifasi PSEN terlewati selama tiap akses ke memory data *external*.

EA/VPP *External Access Enable*. EA harus dihubungkan ke GND jika alat ingin menggunakan lokasi memory program *external*, mulai 0000H hingga FFFFH. Dan EA harus dihubungkan ke VCC untuk menjalankan program *internal*. Pin ini juga menerima Volt Program (VPP) 12 Volt selama pemrograman *Flash*.

XTAL1 Input ke *amplifier osilator inverting* dan input ke rangkaian dengan operasi *clock internal*.

XTAL2 Output dari *amplifier osilator inverting*.

2.1.2. Organisasi Memori

AT89S51 mempunyai struktur memori yang terdiri atas :

1. RAM *Internal*, memori sebesar 128 *byte* yang biasanya digunakan untuk menyimpan *variabel* atau data yang bersifat sementara.
2. Special Function Register (Register fungsi khusus), memori yang berisi *register-register* yang mempunyai fungsi-fungsi khusus yang disediakan oleh mikrokontroler tersebut, seperti *timer, serial* dan lain-lain.
3. *Flash* PEROM, memori yang digunakan untuk menyimpan instruksi-instruksi MCS51. disini sebesar 4 Kbyte

AT89S51 mempunyai struktur memori yang terpisah antara RAM *Internal* dan *Flash* PEROM-nya. RAM *Internal* dialamati oleh RAM Address Register (Register Alamat RAM) sedangkan *Flash* PEROM yang menyimpan perintah-perintah MCS-51 dialamati oleh Program Address Register (Register Alamat Program). Dengan adanya struktur memori yang terpisah tersebut, walaupun RAM *Internal* dan *Flash* PEROM, mempunyai alamat awal yang sama, yaitu alamat 00, namun secara fisiknya kedua memori tersebut tidak saling berhubungan.

2.1.2.1 RAM *Internal*

A. *Register* Bank-Bank

AT89S51 mempunyai 8 buah *register* yang terdiri atas R0 hingga R7. kedelapan buah *register* ini selalu terletak alamat 00H hingga 07H pada setiap kali sistem kali direset. Namun posisi R0 hingga R7 dapat dipindah ke bank 1 (08 hingga 0FH), bank 2 (10H hingga 17H) atau Bank 3 (18H hingga 1 FH) dengan mengatur *bit* RS0 dan RS1.

Byte Adress	*Bit adress*							
7F – 30	*General Purpose RAM* (GPR)							
2F	7F	7E	7D	7C	7B	7A	79	78
2E	77	76	75	74	73	72	71	70
2D	6F	6E	6D	6C	6B	6A	69	68
2C	67	66	65	64	63	62	61	60
2B	5F	5E	5D	5C	5B	5A	59	58
2A	57	56	55	54	53	52	51	50
29	4F	4E	4D	4C	4B	4A	49	48
28	47	46	45	44	43	42	41	40
27	3F	3E	3D	3C	3B	3A	39	38
26	37	36	35	34	33	32	31	30
25	2F	2E	2D	2C	2B	2A	29	28
24	27	26	25	24	23	22	21	20
23	1F	1E	1D	1C	1B	1A	19	18
22	17	16	15	14	13	12	11	10
21	0F	0E	0D	0C	0B	0A	09	08
20	07	06	05	04	03	02	01	00
1F – 18	BANK 3							
17 – 10	BANK 2							
0F – 08	BANK 1							
07 – 00	BANK 0 *Default register* R0 – R7							

Gambar 2-3. Arsitektur Memori AT89S51
Sumber: Paulus Andi Nalwan, 2003 : 9

B. *Bit Addressable* RAM

RAM pada alamat 20H hingga 2FH dapat diakses secara pengalamatan bit (***bit addressable***) sehingga hanya dengan sebuah instruksi saja setiap *bit* dalam area ini dapat di-SET, CLEAR, AND dan OR. Sebagai contoh, pada saat terjadi instruksi **SETB 67H**, hal ini sama dengan menset *bit* MSB dari alamat 2C, yaitu :

MOV A,2CH ; Pindahkan data dari alamat 2CH ke Acc A

ORL A,#10000000 ; Set MSB Akumulator A

MOV 2CH, A ; Pindahkan data dari Acc A ke alamat 2CH

Dengan adanya sistem *bit addressable* RAM, proses yang seharusnya dijalankan dengan 3 *cycle* seperti listing di atas dapat digantikan dengan sebuah instruksi yang hanya membutuhkan satu *cycle* saja.

Dalam aplikasinya, lokasi yang dapat diakses dengan pengalamatan *bit* ini dapat juga digunakan untuk menandai suatu lokasi *bit* tertentu baik berupa *Register* Fungsi Khusus yang dapat dialamati secara *bit* (termasuk Register I/O) ataupun lokasi-lokasi tertentu yang dapat dialamati secara *bit.*

2.1.2.2 RAM Biasa

RAM biasa dimulai dari alamat 30H sampai 7FH dan dapat diakses dengan pengalamatan langsung maupun tak langsung. Pengalamatan langsung dilakukan ketika salah satu *operand* merupakan bilangan yang menunjukkan lokasi yang dialamati.

Sedangkan pengalamatan secara tak langsung pada lokasi dari RAM *internal* ini adalah akses data dari memori ketika alamat tersebut tersimpan dalam suatu *Register* R0 atau R1. R0 dan R1 adalah dua buah *register* pada mikrokontroler berarsitektur MCS51 yang dapat digunakan sebagai *pointer* (pemandu) dari sebuah lokasi memori pada RAM *internal.* Pengalamatan secara tak langsung biasa digunakan untuk mengakses beberapa lokasi memori dengan letak yang beraturan.

2.1.2.3 *Register* Fungsi Khusus

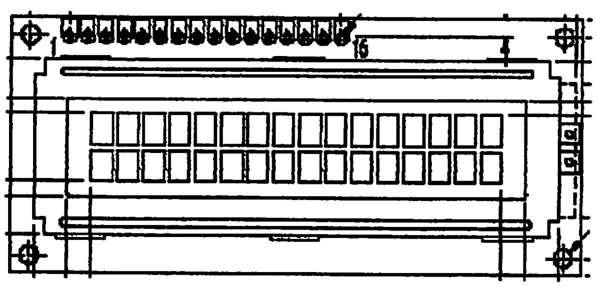
AT89S51 mempunyai 21 ***Special Function Register*** (*Register* Fungsi Khusus) yang terletak pada antara alamat 80H hingga FFH seperti gambar 4 dibawah ini. Beberapa dari *register-register* ini juga mampu dialamati dengan pengalamatan *bit* sehingga dapat dioperasikan seperti yang ada pada RAM yang lokasinya dapat dialamati dengan pengalamatan *bit.*

0F8H									0FFH
0F0H	B 00000000								0F7H
0E8H									0EFH
0E0H	ACC 00000000								0E7H
0D8H									0DFH
0D0H	PSW 00000000								0D7H
0C8H									0CFH
0C0H									0C7H
0B8H	IP XX000000								0BFH
0B0H	P3 11111111								0B7H
0A8H	IE 0X000000								0AFH
0A0H	P2 11111111		AUXR1 XXXXXXX0				WDTRST XXXXXXXX		0A7H
98H	SCON 00000000	SBUF XXXXXXXX							9FH
90H	P1 11111111								97H
88H	TCON 00000000	TMOD 00000000	TL0 00000000	TL1 00000000	TH0 00000000	TH1 00000000	AUXR XXX00XX0		8FH
80H	P0 11111111	SP 00000111	DP0L 00000000	DP0H 00000000	DP1L 00000000	DP1H 00000000		PCON 0XXX0000	87H

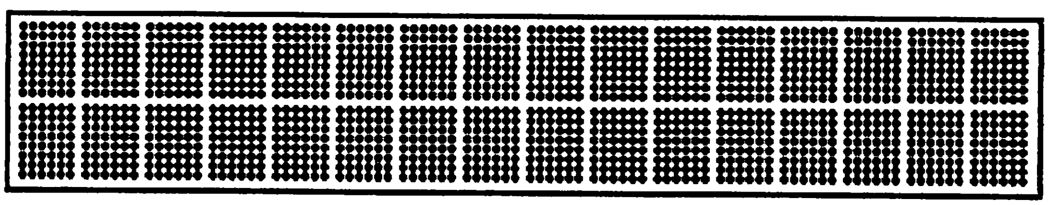
Gambar 2-4. Susunan SFR (Special Function Register)
Sumber: Datasheet AT89S51 Rev.2487A-10/01

2.2. *Liquid Crystal Display* (LCD)

LCD merupakan suatu bentuk revolusi teknologi dalam pembuatan tampilan (*display*) yang dimodifikasi dari *matriks* LED. LCD terdiri dari tumpukan tipis antar sel dari dua lembar kaca yang pinggirannya tertutup rapat. Diantara kedua lapisan tersebut diberi kristal cair yang tembus cahaya. Permukaan luar masing-masing negatif kaca memiliki lapisan penghantar tembus cahaya. Sel memiliki ketebalan kira-kira 1 x 100000 nm yang diisi dengan kristal cair. LCD yang digunakan penyusun memiliki 2 baris tampilan dengan 16 karakter setiap barisnya.



Gambar 2.5. Modul LCD YJ1602A
Sumber: Datasheet Displaytech Ltd 162A series ver 1.1

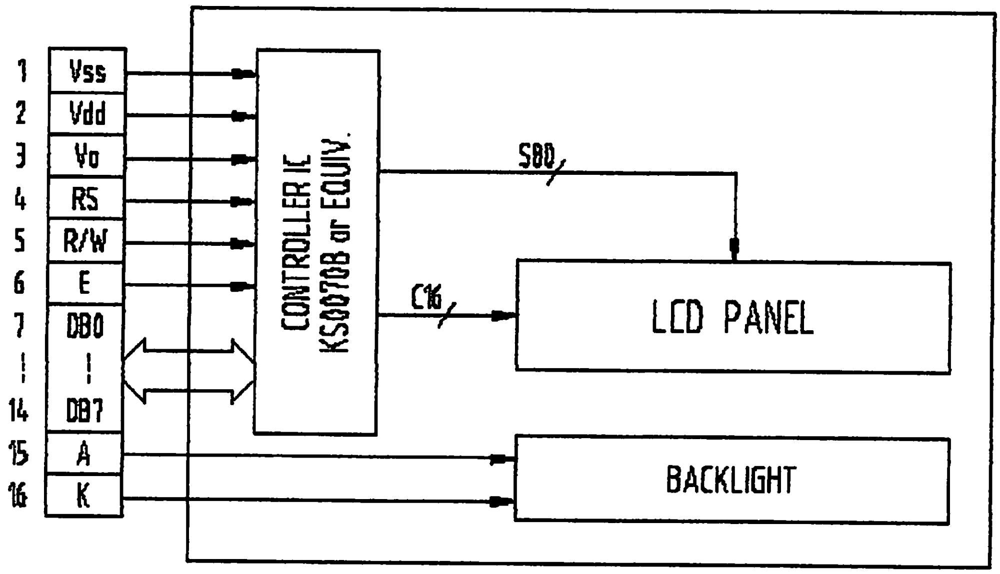


Gambar 2-6. Bentuk Dot Matriks LCD

Tampilan ini terbentuk dari *dot matriks*. Adapun karakteristiknya adalah sebagai berikut :

- 16 x 2 karakter dengan 5 x 7 *dot matriks* ditambah kursor pada bagian bawah
- ROM *generator* karakter dengan 192 tipe karakter

- RAM *generator* karakter dengan 8 tipe karakter (Untuk program write)
- 80 x 8 Bit RAM *data display* dengan 80 karakter maksimal
- RAM data RAM *generator* karakter dapat dibaca dari MCU
- Rangkaian osilator *internal*
- Power Supply hanya +5 Volt
- Reset otomatis *internal*
- Temperatur kerja antara 0° C sampai 50°



Gambar 2-7. Blok Diagram dalam LCD
Sumber: Datasheet Displaytech Ltd 162A series ver 1.1

Dari blok diagram terlihat kita tidak perlu menghidupkan *dot matriks* satu-persatu karena sudah ada KS0070B sebagai *driver*nya, jadi kita hanya tinggal berkomunikasi dengan *driver* ini saja.

Adapun untuk menampilkan karakter yang ada, dilakukan dengan cara memberikan kode karakter untuk tiap-tiap karakter yang diinginkan pada bus data dan dengan menggunakan sinyal kontrol E, RS, R/W.

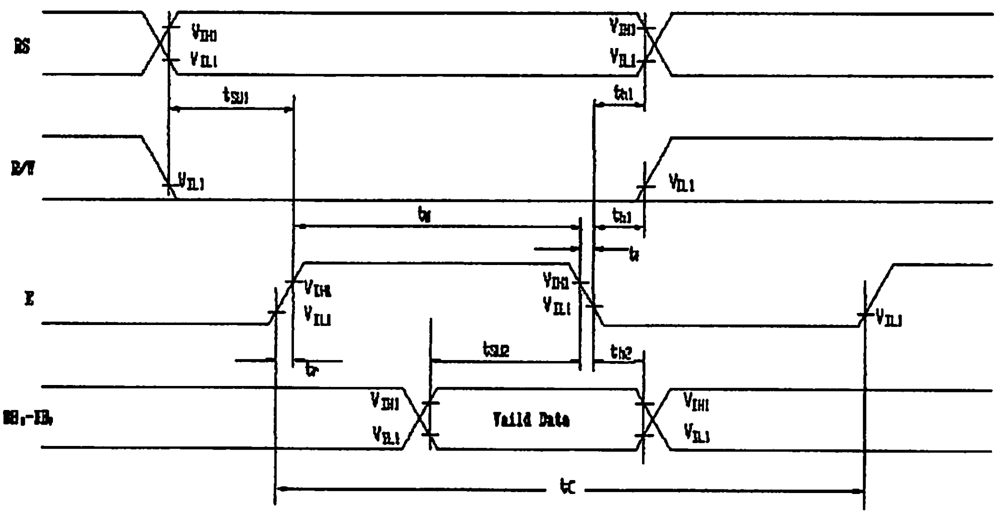
Tabel 2-3. Konfigurasi Pin LCD 1602A

Pin NO.	Symbol	Level	Description
1	VSS	0V	Ground
2	VDD	5.0V	Supply voltage for logic
3	VO	---	Input voltage for LCD
4	RS	H/L	H : Data, L : Instruction code
5	R/W	H/L	H : Read mode, L : Write mode
6	E	H, H → L	Chip enable signal
7	DB0	H/L	Data bit 0
8	DB1	H/L	Data bit 1
9	DB2	H/L	Data bit 2
10	DB3	H/L	Data bit 3
11	DB4	H/L	Data bit 4
12	DB5	H/L	Data bit 5
13	DB6	H/L	Data bit 6
14	DB7	H/L	Data bit 7
15	A	---	Backlight anode
16	K	---	Backlight cathode

Sumber: Datasheet Displaytech Ltd 162A series ver 1.1

Untuk berhubungan dengan mikrokontroler pemakai, *1602A* dilengkapi dengan 8 jalur data (DB0...DB7) yang dipakai untuk menyalurkan kode *ASCII* maupun perintah pengatur kerja *1602A.* Selain dilengkapi dengan E, R/W dan RS. Kombinasi lain antara E dan R/W merupakan sinyal standart. Sebaliknya sinyal-sinyal dari MCS51 merupakan sinyal khas Intel dengan kombinasi sinyal WR dan RD.

RS *(Register* Select*)* dipakai untuk membedakan jenis data yang dikirim ke *1602A,* jika RS=0 maka *bit* data yang dikirim adalah instruksi untuk mengatur *1602A,* jika RS=1 maka *bit* data yang dikirim adalah data untuk diolah.



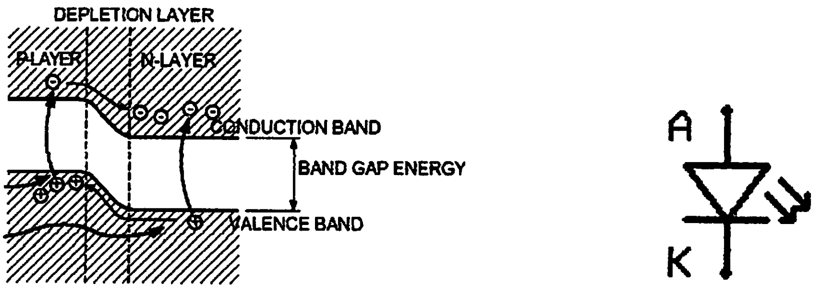
Gambar 2-8. *Timing Diagram* Mengirim Data ke *LCD*
Sumber: Datasheet Displaytech Ltd 162A series ver 1.1

Untuk mengambil data dari *1602A* sinyal R/W di-*high*-kan, menyusul sinyal E di-*high*-kan pula. Pada saat E menjadi 1, *1602A* akan meletakkan datanya di DB0...Db7, dan data ini harus diambil sebelum sinyal E di-nol-kan kembali.

1602A mempunyai seperangkat perintah untuk mengatur tata kerjanya, dimana perangkat perintah tersebut meliputi : perintah untuk menghapus tampilan, meletakkan kembali *kursor* pada baris huruf pertama baris pertama, menghidupkan atau mematikan tampilan, dan lain sebagainya.

2.3. *Light Emitting Diode* (LED) *Infra Red*

LED *infra red* digunakan untuk menghasilkan sinar *infra red* yang tidak tampak. Pada saat LED *infra red* dibias *forward* yaitu *anoda* diberi tegangan dan *katoda* ke *ground*, maka LED menjadi **On** dan arus akan mengalir dari *anoda* ke *katoda* dimana *elektron pita konduksi* melewati *junction* dari tipe P ke tipe N dan jatuh ke *hole pita valensi* (disini hole/arus mengalir dari tipe N ke tipe P).



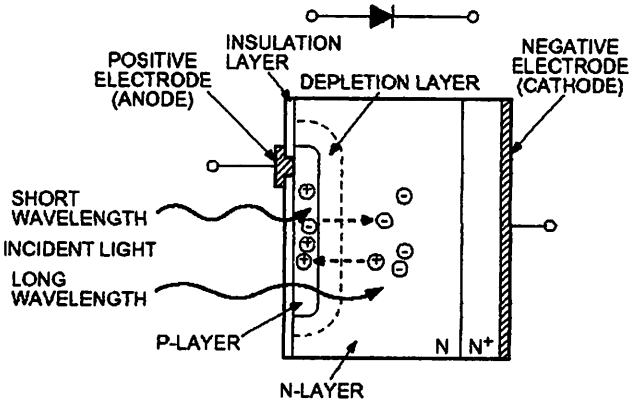
Gambar 2-9. Perubahan Energi dan Simbol LED
Sumber: Everlight Electronics Co., Ltd

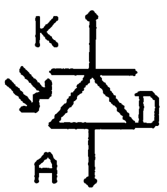
Pada saat elekron-elektron jatuh pada *pita konduksi* ke *pita valensi,* mereka memancarkan energi. Pada dioda penyearah, energi ini keluar sebagai panas. Akan tetapi pada LED, energi dipancarkan sebagai cahaya.

Dengan menggunakan unsur-unsur seperti *gallium, arsen* dan *phosphor* dapat dibuat LED yang memancarkan sinar warna merah, kuning, serta *infra red* (warna yang tak terlihat oleh mata). LED yang menghasilkan pancaran yang kelihatan warnanya dapat digunakan pada display peralatan. Sedangkan LED *infra red* digunakan dalam sistem keamanan yang tidak tampak sinarnya oleh pencuri. Penggunaan LED yang perlu diperhatikan adalah arus yang melewatinya. Secara umum arus maksimal yang mampu dilewati oleh LED sebesar 35 mA, sehingga tegangan yang dipakai dapat bervariasi. Simbol LED ditunjukkan pada gambar 2-9

2.4. *Photo Dioda*

Photodioda adalah salah satu jenis *semikonduktor* yang peka terhadap cahaya. Suatu sumber cahaya menghasilkan energi panas begitu pula dengan spektrum *infra red.* Spektrum *infra red* mempunyai energi panas yang lebih besar dari cahaya tampak. Sehingga *photodioda* lebih peka menangkap *radiasi* dari *infra red.* Saat *photodioda* mendapatkan cahaya pada permukaan tertentu membuat *junction* bekerja mengalirkan arus dari *anoda* ke *katoda.*





Gambar 2-10. Perubahan Energi dan Simbol Photodioda
Sumber: Hamamatsu Photodiode Technical Information

Semakin besar intensitas cahaya yang diterima maka sinyal arus listrik yang dihasilkan akan baik. Tetapi jika intensitas cahaya yang diterima lemah atau kecil maka penerima harus mempunyai pengumpul cahaya *(light collector)* yang cukup baik dan sinyal arus yang dihasilkan oleh sensor cahaya ini harus dikuatkan. Simbol dari *photodioda* ditunjukkan oleh gambar 2-10.

BAB III

PERENCANAAN DAN PEMBUATAN ALAT

Pada bab ini dibahas mengenai desain dan perencanaan pembuatan alat. Tahap-tahap perencanaan meliputi spesifikasi alat, perencanaan blok rangkaian, perencanaan sistem, dan pembuatan *flowchart* program untuk kinerja sistem.

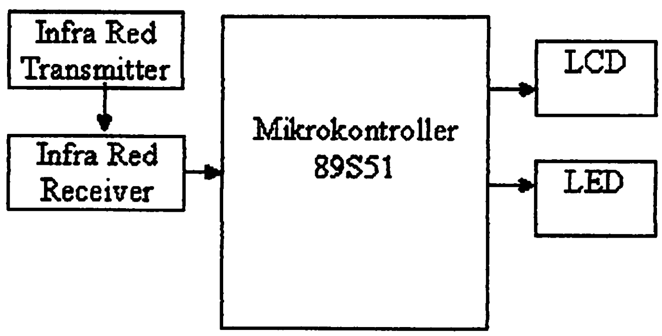
3.1 Spesifikasi Alat

Dalam perencanaan ini spesifikasi alat yang akan direalisasikan adalah:

- Sistem mikrokontroler AT89S51 sebagai sistem pengendali.
- Menggunakan *LCD* modul 16 x 2 karakter merk *YJ1602A*
- Koordinat *Infra Red* menggunakan pasangan *LED infra red* dan *photodioda.*
- Menu tampilan harus mampu mengendalikan nyala *LED.*

3.2. Perencanaan Blok Diagram

Agar perencanaan dan pembuatan alat dapat dilakukan dengan sistematis dan terstruktur maka perlu dibuat blok diagram yang menjelaskan sistem yang direncanakan. Blok diagram sistem ditunjukkan dalam gambar.



Gambar 3-1. Perencanaan Blok Diagram

- Modul *LCD.* Menggunakan Modul *LCD* karakter 16x2
- Modul *Infra Red* direncanakan membentuk sistem koordinat 8 x 2 yang berfungsi menangkap sentuhan jari.
- MCS51. berupa sebuah IC AT89S51 yang memiliki kapasitas *PEROM* 4 kByte. Berfungsi sebagai pengendali utama.
- *LED* sebagai simulasi pengontrolan. Pada skripsi ini hanya dicontohkan mengendalikan *LED.*

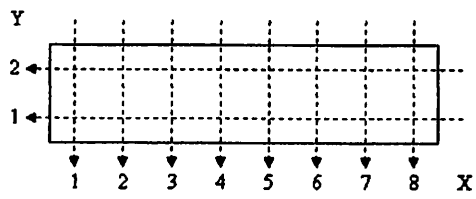
3.3. Prinsip Kerja Alat

Alat menampilkan menu pilihan untuk *LED,* dengan empat kemungkinan input yaitu "←", "→", "ON" atau "OFF", jika tidak ada sentuhan maka alat akan tetap menunggu. Jika ada sentuhan maka alat akan menyesuaikan antara koordinat sentuhan dengan pilihan menu.

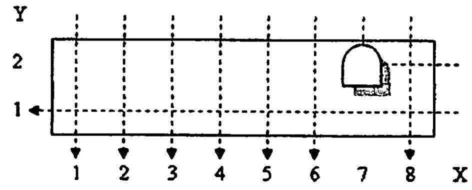
3.4. Perencanaan dan Pembuatan Alat

3.4.1. Sistem Koordinat

Agar posisi sentuhan diketahui maka digunakan sistem koordinat. Variabel yang digunakan adalah axis (x) untuk mendatar dan ordinat (y) untuk menurun. *Infra Red* diposisikan berjajar seperti gambar 3-2, terlihat bahwa koordinat akan didapat dengan diketahui X dan Y jika terjadi sentuhan seperti gambar 3-3.



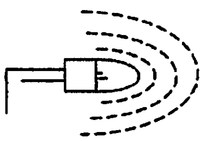
Gambar 3-2. Koordinat Infra Red



Gambar 3-3. Sentuhan pada Koordinat

Dari gambar diatas ditunjukkan bahwa sentuhan akan menghalangi sinar pada sumbu X=7 dan Y=2 dan *photodioda* X7 dan Y2 tidak akan mendapat sinar (sinyal). Maka pada MCU akan mengetahui bahwa koordinat sentuhan adalah (7,2). Untuk kemudian akan dibandingkan apakah pada koordinat tersebut akan mengaktifkan pilihan pada menu. Dengan dibentuk sistem koordinat akan mudah untuk mencocokkan antara menu dengan posisi sentuhan.

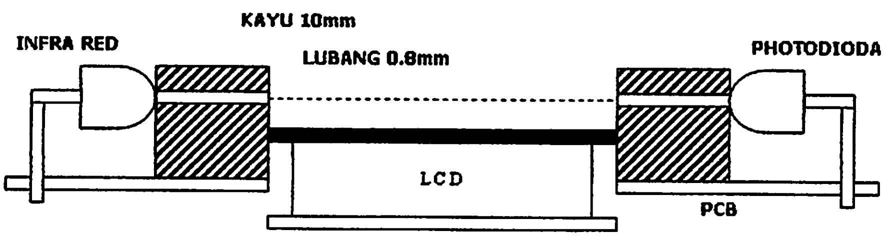
Sinar *Infra Red* lebih kuat daripada sinar tampak dan sama-sama menyebar. Laser lebih kuat lagi dan lebih terfokus tidak menyebar, namun harganya mahal.



Gambar 3-4. Sifat Sinar *Infra Red.*

Dengan sinar yang kuat dan tidak tampak mata, *Infra Red* dipilih penyusun karena lebih murah daripada Laser.

Agar memiliki arah yang tegak lurus dan tidak menyebar ke segala arah, maka sinar *infra red* harus diluruskan. Bentuk perencanaan seperti dibawah ini karena dibutuhkan agar didapatkan koordinat yang tidak miring dan tidak *interferensi* antar sesama *Infra Red* yang berdekatan.



Gambar 3-5. Posisi *Infra Red* dan *Photodioda*

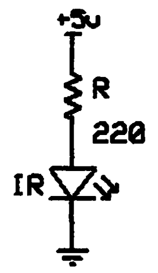
3.4.2. LED *Infra Red*

Dari karakteristik *datasheet* didapat besaran arus referensi pada infrared (I.inf) hingga 20 mA, dan tegangan referensinya (V_{inf}) adalah 1,45-1,65 V. Maka untuk menentukan nilai-nilai resistansi (R_{inf}) yang digunakan adalah :

$$R_{inf} = \frac{V_{CC} - V_{inf}}{I_{inf}} \text{......... (diambil } V_{forward} = 1{,}6\text{ V dan } I_{forward} = 15\text{mA)}$$

$$= \frac{5V - 1{,}6V}{15mA}$$

$$= 226\ \Omega \text{................ (diambil } R_{inf} = 220\Omega\text{)}$$



Gambar 3-6. Perencanaan LED *Infra Red*

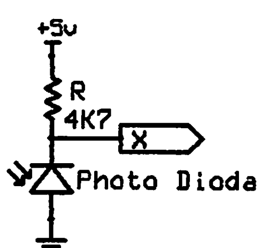
Sebagai transmitter harus dipastikan bahwa LED *Infra Red* benar-benar mengirimkan sinyal untuk diterima *photodioda.*

3.4.3. *Photodioda*

Photodioda pada rangkaian berfungsi menerima sinar *infra red* yang dipancarkan oleh LED *infra red.* Fungsi *photodioda* selanjutnya membias *dioda* yang difungsikan sebagai saklar (switching). Dari datasheet tegangan bias inversenya (V_{bi}) adalah 0,2–0,3 V. Agar output berlogika '1' maka I_{IL} yang direncanakan sebesar 1 mA, sehingga didapatkan nilai resistansi R sebesar :

$$R_{pd} = \frac{V_{CC} - V_{Bi}}{I_{IL}} \quad \text{........................(diambil } V_{Bi} = 0{,}2 \text{ V)}$$

$$R_{pd} = \frac{5V - 0{,}2V}{1mA} = 4{,}8 \text{ k}\Omega \text{..........(diambil } R_{inf} = 4k7\Omega\text{)}$$



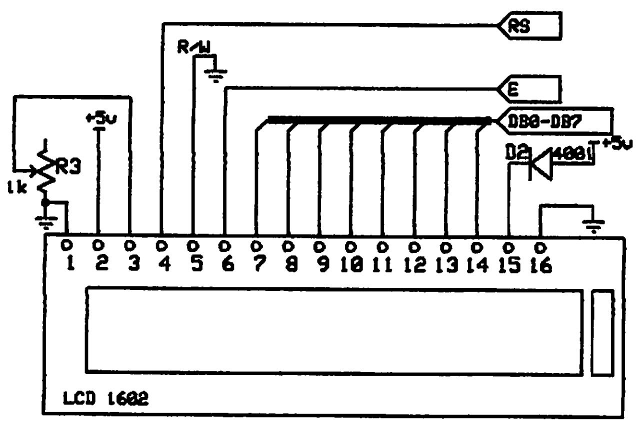
Gambar 3-7. Perencanaan Photodioda

3.4.4. LCD YJ1602A

Sesuai Datasheet pada modul *LCD* YJ1602A *pin-pin* nya dihubungkan seperti tertulis pada Bab 2 yaitu sebagai berikut:

- *Pin* 1 dihubungkan ke Ground
- *Pin* 2 dihubungkan ke VCC 5V
- *Pin* 3 dihubungkan ke Ground melalui trimpot 10kOhm.
- *Pin* 4 dihubungkan ke MCU
- *Pin* 5 dihubungkan ke Ground
- *Pin* 6 dihubungkan ke MCU
- *Pin* 7-14 dihubungkan ke MCU Port 0
- *Pin* 15 diberi VCC melalui dioda 4001
- *Pin* 16 dihubungkan ke Ground

Sehingga bentuk perencanaan LCD adalah seperti berikut:

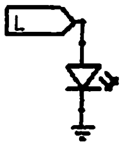


Gambar 3-8. Perencanaan Rangkaian LCD YJ1602A

3.4.5. LED Kontrol Monitor

Karena skripsi yang penyusun pilih adalah interface maka untuk pengendaliannya hanya diambil contoh untuk mengendalikan LED saja. Adapun untuk pengembangannya dapat digantikan dengan Relay Kontrol untuk berbagai peralatan ataupun mesin. Disini rangkaian LED-nya sederhana sekali.

LED membutuhkan 35mA untuk beroperasi.. Dan disini diberi 8 buah LED untuk dikontrol.



Gambar 3-9. Perencanaan Rangkaian Monitor

3.4.6. 89S51

MCU yang dipilih adalah *MCS51* dengan IC AT89S51 karena diperkirakan sudah cukup mampu menangani sistem *Touch Screen* yang sederhana ini sebagai *CPU*.

Komponen utama yang diperlukan adalah IC AT89S51. untuk membuat AT89S51 aktif komponen berikutnya adalah:

- **Power**

Karena sifatnya yang *low-power* (berdaya rendah) AT89S51 cukup di beri tegangan 5V Vcc dengan 25mA Icc (125mWatt) yang dihubungkan pada *pin* 40 dan Ground dihubungkan pada *pin* 20[1].

[1] Datasheet AT89S51 Rev.2487A-10/01

- **Osilator**

Agar osilator pada 89S51 aktif maka perlu diberi kristal dan dua buah capasitor keramik. Nilai kristal dipilih 12MHz agar cepat dan C dipilih 33pF[2].

- **EA/VPP**

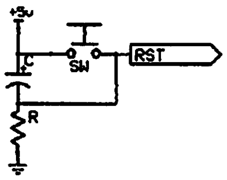
Karena memory program external tidak digunakan maka EA/VPP dihubungkan ke VCC 5V[3].

- **RST**

Untuk me-reset 89S51 maka diperlukan sinyal high pada *pin* RST waktu yang dibutuhkan untuk mereset adalah dua kali *duty cycle machine*:

$$t=2\cdot\left(\frac{12}{F.Osc}\right)=2\cdot\left(\frac{12}{12MHz}\right)=2\ \mu\text{detik}$$

Rangkaian yang mampu mensuplai tegangan dalam tempo tertentu adalah rangkaian seperti berikut:



Gambar 3-10. Rangkaian Reset AT89S51

Saat saklar ditekan maka Kapasitor yang telah terisi akan terhabiskan isinya dan kemudian dalam kondisi mengisi kembali.

$$Vrst=\frac{R}{R+\frac{1}{sC}}\cdot Vcc=\frac{sCR}{sCR+1}\cdot Vcc$$

dan Vcc diketahui 5V, dalam Laplace adalah 5/s

[2] Datasheet AT89S51 Rev.2487A-10/01

[3] Datasheet AT89S51 Rev.2487A-10/01

$$Vrst = \frac{sCR}{sCR+1} \cdot \frac{5}{s} = \frac{CR}{sCR+1} \cdot 5 = 5 \cdot \left[\frac{1}{s + \frac{1}{RC}} \right]$$

$$Vrst = 5 \cdot e^{\frac{-t}{RC}}$$

$$\frac{5}{Vrst} = e^{\frac{t}{RC}}$$

$$\ln \frac{5}{Vrst} = \frac{t}{RC}$$

Dengan menggunakan tegangan logika high minimal yang dijinkan pin RST, maka Vrst = 3,5 V sehingga

$$t = RC \left[\ln \frac{5}{3,5} \right]$$

Dari rangkaian tadi maka persamaannya adalah :

t=0,357·R·C

sedangkan <u>t minimal</u> adalah 2μdetik, maka

$$2 \cdot 10^{-6} = 0,357 \cdot R \cdot C$$

Jika diambil resistor 10kΩ, maka nilai <u>C minimal</u> adalah:

$$C = \left(\frac{2\mu}{0,357 \cdot 10k} \right) = 0,56nF = 560pF$$

- **Pull-Up**

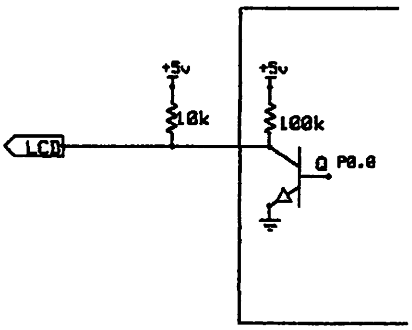
Untuk menaikkan arus yang keluar dari port 0 maka diberi Pull-Up.

$$I_{DD} = \frac{V_{MC}}{R_{MC}} + \frac{V_{CC}}{R_{PULL}}$$ (diperlukan I_{DD}=0.45mA)

$$0.45mA = \frac{5}{100k} + \frac{5}{R_{PULL}}$$

$$0.45mA = 0.05mA + \frac{5}{R_{PULL}}$$

$$R_{PULL} = \frac{5}{0.45mA - 0.05mA} = 12{,}5\ K\Omega \text{ .... (diambil R=10k}\Omega)$$



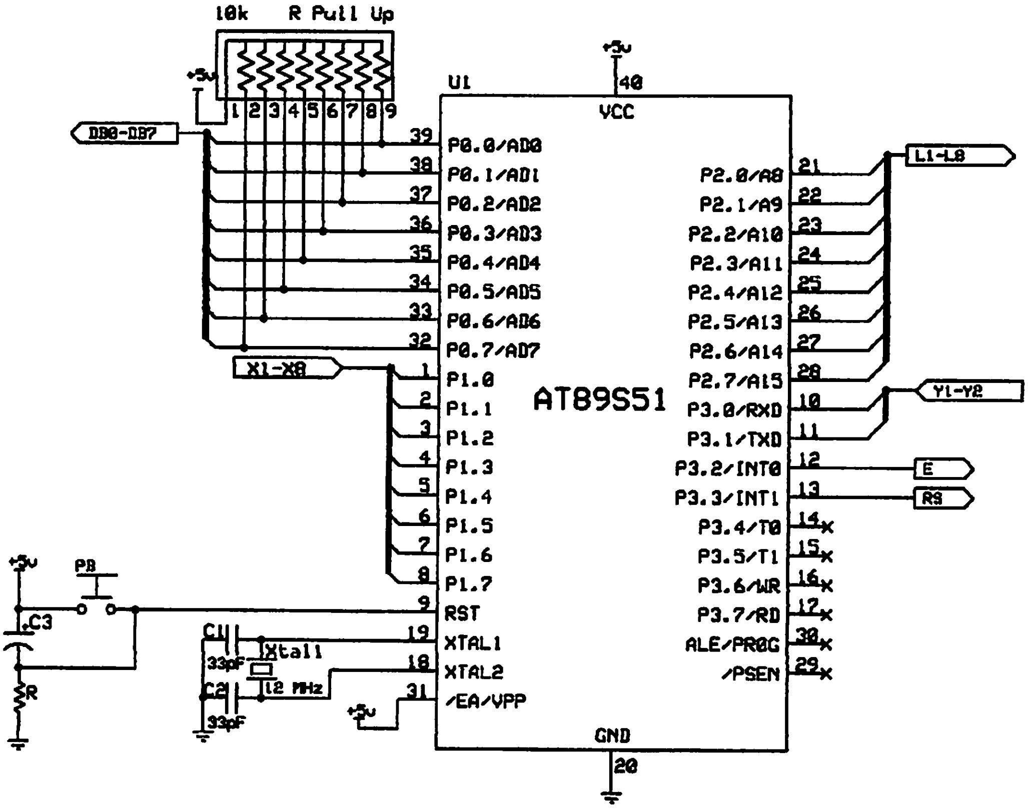
Gambar 3-11 Impedansi Internal Mikrokontroller

Pada port 0 arus yang keluar sangat kecil dan diperlukan resistor Pull-Up agar nilai arus dapat lebih besar. Pada delapan buah pin dapat diberi sebuah resistor pack 10kOhm yang berisi delapan resistor dengan commonnya dihubungkan ke VCC 5V.

Kemudian sebagai pengendali utama maka hubungan Port 89S51 adalah:

- Port 0 sebagai data-bus LCD
- Port 1 sebagai pembaca *Infra Red* X1-X8
- Port 2 sebagai monitor LED
- Port 3.0-3.1 sebagai pembaca *Infra Red* Y1-Y2
- Port 3.2-3.3 sebagai LCD Control (EN dan RS)
- Port 3.4-3.7 tidak dihubungkan

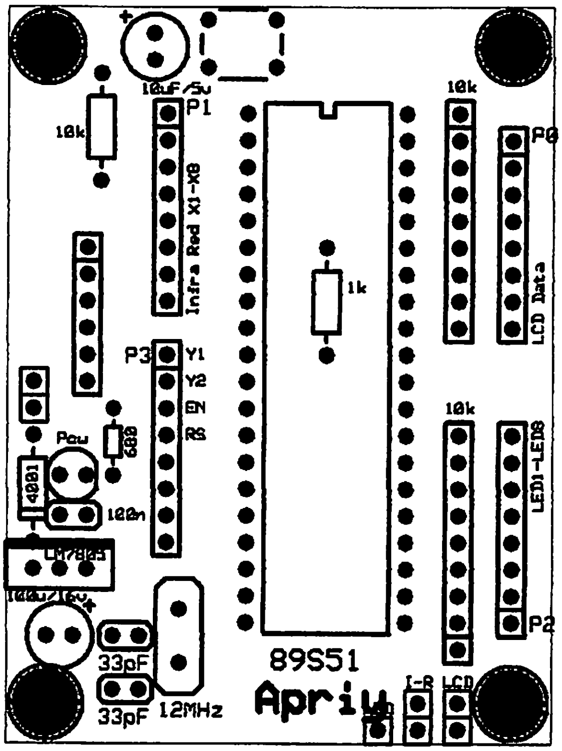
Maka rangkaian AT89S51 menjadi:



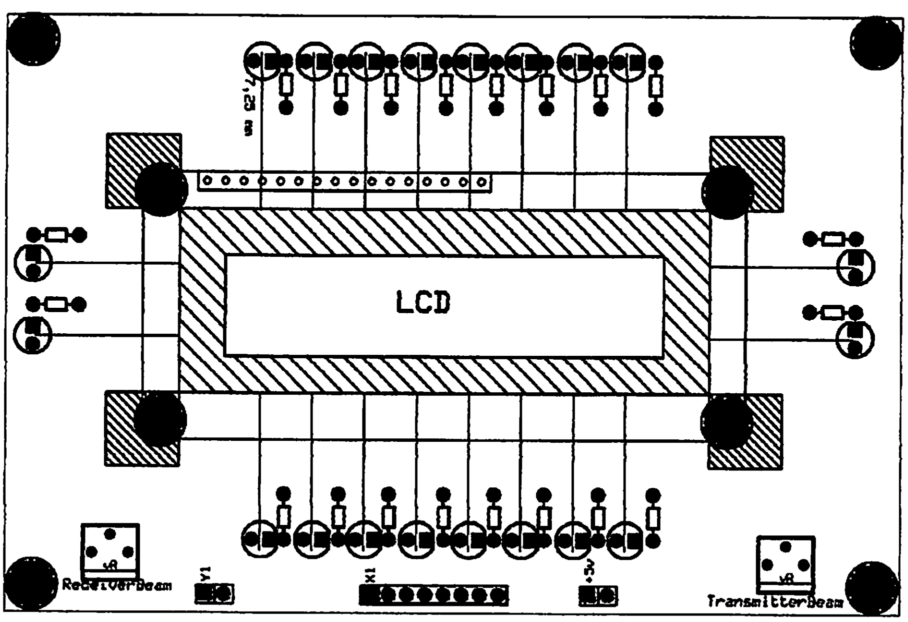
Gambar 3-12. Rangkaian AT89S51

3.5. Perencanaan Pembuatan PCB

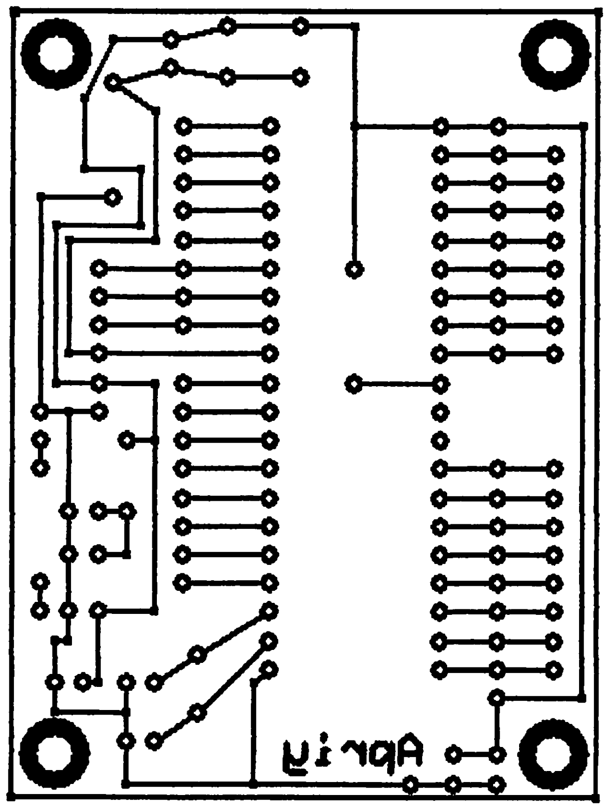
Perencanaan pembuatan PCB meliputi perencanaan pembuatan tata letak komponen dan pembuatan jalur pengawatan. Perencanaan pembuatan PCB dilakukan dengan bantuan program ExpressPCB Versi 6.1.4 tahun 2008 yang didapat gratis dari *www.expresspcb.com.*



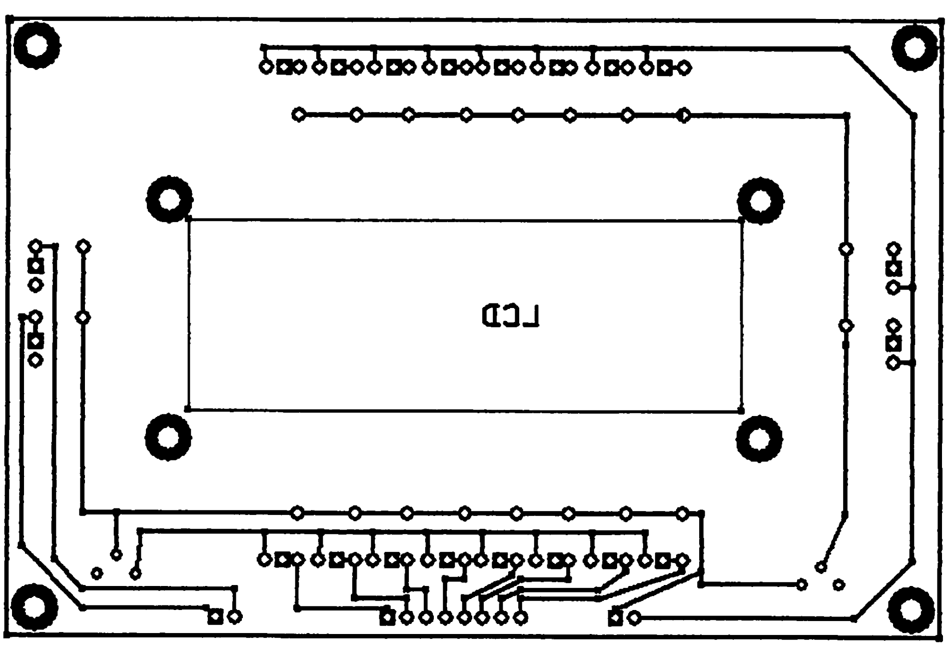
Gambar 3-13. Tata Letak Sistem AT89S51



Gambar 3-14. Tata Letak LCD dan Infra Red



Gambar 3-15. Pengawatan AT89S51



Gambar 3-16. Pengawatan LCD dan Panel Infra Red

3.6. Perencanaan Program 89S51

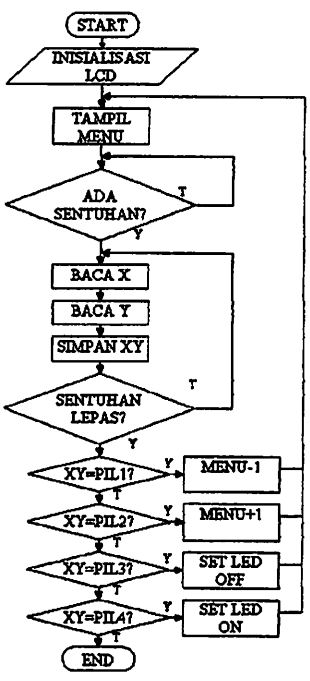
3.6.1. Algoritma Program

Program utama yang menjadi pengendali jalannya rangkaian ini mempunyai beberapa tugas sebagai berikut :

- Menampilkan
- Menangkap
- Menerjemahkan koordinat dengan
- Mengaktifkan atau mematikan keluaran kontrol

3.6.2. Diagram Alir (*Flowchart*)

Diagram alir (*Flowchart*) program haruslah tepat tanpa ada kemungkinan suatu kondisi yang terlewati. Adapun perencanaan flowchart yang dihasilkan penyusun adalah sebagai berikut:



Gambar 3-17. Flowchart Touch Screen

3.6.3. Bahasa Assembler

Dari Flowchart yang disusun perencanaan Assemblernya yaitu:

```
        org     0h
        jmp     mulai
;=====================;
;  Program Utama      ;
;=====================;
mulai:
        acall   LCD_init
menu_depan:
        mov     DPTR,#mhsw
        acall   tulis
        mov     DPTR,#judul
        acall   tulis
        mov     DPTR,#dosen
        acall   tulis
menu_0: mov     DPTR,#menu0
        acall   tulis
        ;==============;
        ;  menu led 1  ;
        ;==============;
menu_1: mov     DPTR,#menu1
        acall   tulis_atas
        mov     DPTR,#menubawah
        acall   tulis_bawah
        acall   scankor
        acall   pilih
        mov     a,pil
off1:   cjne    a,#1h,on1
        acall   L1off
        jmp     menu_1
on1:    cjne    a,#2h,back1
        acall   L1on
        jmp     menu_1
back1:  cjne    a,#3h,next1
        jmp     menu_0
next1:  cjne    a,#4h,menu_1
        jmp     menu_2
        ;==============;
        ;  menu led 2  ;
        ;==============;
menu_2: mov     DPTR,#menu2
        acall   tulis_atas
        acall   scankor
        acall   pilih
        mov     a,pil
off2:   cjne    a,#1h,on2
        acall   L2off
        jmp     menu_2
on2:    cjne    a,#2h,back2
        acall   L2on
        jmp     menu_2
back2:  cjne    a,#3h,next2
        jmp     menu_1
next2:  cjne    a,#4h,menu_2
        jmp     menu_3
        ;==============;
        ;  menu led 3  ;
        ;==============;
menu_3: mov     DPTR,#menu3
        acall   tulis_atas
        acall   scankor
        acall   pilih
        mov     a,pil
off3:   cjne    a,#1h,on3
        acall   L3off
        jmp     menu_3
on3:    cjne    a,#2h,back3
        acall   L3on
        jmp     menu_3
back3:  cjne    a,#3h,next3
        jmp     menu_2
next3:  cjne    a,#4h,menu_3
        jmp     menu_4
        ;==============;
        ;  menu led 4  ;
        ;==============;
menu_4: mov     DPTR,#menu4
        acall   tulis_atas
        acall   scankor
        acall   pilih
        mov     a,pil
off4:   cjne    a,#1h,on4
        acall   L4off
        jmp     menu_4
on4:    cjne    a,#2h,back4
        acall   L4on
        jmp     menu_4
back4:  cjne    a,#3h,next4
        jmp     menu_3
next4:  cjne    a,#4h,menu_4
        jmp     menu_5
        ;==============;
        ;  menu led 5  ;
        ;==============;
menu_5: mov     DPTR,#menu5
        acall   tulis_atas
        acall   scankor
        acall   pilih
        mov     a,pil
off5:   cjne    a,#1h,on5
        acall   L5off
        jmp     menu_5
on5:    cjne    a,#2h,back5
        acall   L5on
        jmp     menu_5
back5:  cjne    a,#3h,next5
        jmp     menu_4
next5:  cjne    a,#4h,menu_5
        jmp     menu_6
        ;==============;
        ;  menu led 6  ;
        ;==============;
menu_6: mov     DPTR,#menu6
        acall   tulis_atas
        acall   scankor
        acall   pilih
        mov     a,pil
off6:   cjne    a,#1h,on6
        acall   L6off
        jmp     menu_6
on6:    cjne    a,#2h,back6
        acall   L6on
        jmp     menu_6
back6:  cjne    a,#3h,next6
        jmp     menu_5
next6:  cjne    a,#4h,menu_6
        jmp     menu_7
        ;==============;
        ;  menu led 7  ;
```

```
        ;===============;
menu_7: mov     DPTR,#menu7
        acall   tulis_atas
        acall   scankor
        acall   pilih
        mov     a,pil
off7:   cjne    a,#1h,on7
        acall   L7off
        jmp     menu_7
on7:    cjne    a,#2h,back7
        acall   L7on
        jmp     menu_7
back7:  cjne    a,#3h,next7
        jmp     menu_6
next7:  cjne    a,#4h,menu_7
        jmp     menu_8
        ;===============;
        ;  menu led 8   ;
        ;===============;
menu_8: mov     DPTR,#menu8
        acall   tulis_atas
        acall   scankor
        acall   pilih
        mov     a,pil
off8:   cjne    a,#1h,on8
        acall   L8off
        jmp     menu_8
on8:    cjne    a,#2h,back8
        acall   L8on
        jmp     menu_8
back8:  cjne    a,#3h,next8
        jmp     menu_7
next8:  cjne    a,#4h,menu_8
        jmp     menu_0
;=============================;
;  Untuk baca Infra Red       ;
;=============================;
        x       data    11h
        y       data    12h
        xy      data    13h
scankor:
        acall   urutx
        acall   uruty
        mov     a,x
        orl     a,y
        mov     xy,a
        acall   nokor
        ret
urutx:  jnb     p1.0,x1
        jnb     p1.1,x2
        jnb     p1.2,x3
        jnb     p1.3,x4
        jnb     p1.4,x5
        jnb     p1.5,x6
        jnb     p1.6,x7
        jnb     p1.7,x8
        sjmp    urutx
x1:     mov     x,#10h
        ret
x2:     mov     x,#20h
        ret
x3:     mov     x,#30h
        ret
x4:     mov     x,#40h
        ret
x5:     mov     x,#50h
        ret
x6:     mov     x,#60h
        ret
x7:     mov     x,#70h
        ret
x8:     mov     x,#80h
        ret
uruty:  jnb     p3.0,y1
        jnb     p3.1,y2
        sjmp    uruty
y1:     mov     y,#01h
        ret
y2:     mov     y,#02h
        ret
nokor:  jnb     p3.0,nokor
        jnb     p3.1,nokor
        ret
;===============;
;  Untuk LCD    ;
;===============;
        LCD_DAT data    P0
        LCD_en  bit     P3.3
        LCD_rs  bit     P3.2
tulis:  acall   tulis_atas
        acall   tulis_bawah
        acall   Ldelay
        ret
tulis_atas:
        mov     R1,#80h
        acall   kirim_inst
        acall   cetak_baris
        ret
tulis_bawah:
        mov     R1,#0C0h
        acall   kirim_inst
        acall   cetak_baris
        ret
cetak_baris:
        mov     R3,#16
cetak:  clr     A
        movc    A,@A+DPTR
        mov     R1,A
        acall   kirim_data
        Inc     DPTR
        djnz    R3,cetak
        ret
mhsw:   DB      '**  APRIYANTO **'
        DB      '**  00.17.160 **'
judul:  DB      '*    T O U C H *'
        DB      '*   S C R E E N *'
dosen:  DB      'Ir. F.Yudi L. MT'
        DB      '  Sotyohadi,ST  '
menu0:  DB      ' contoh kontrol '
        DB      '   8 led kecil  '
menubawah: DB 7fh,'  OFF   ON    ',7eh
menu1:  DB 7fh,'  L E D   1   ',7eh
menu2:  DB 7fh,'  L E D   2   ',7eh
menu3:  DB 7fh,'  L E D   3   ',7eh
menu4:  DB 7fh,'  L E D   4   ',7eh
menu5:  DB 7fh,'  L E D   5   ',7eh
menu6:  DB 7fh,'  L E D   6   ',7eh
menu7:  DB 7fh,'  L E D   7   ',7eh
menu8:  DB 7fh,'  L E D   8   ',7eh
kirim_inst:
        mov     LCD_DAT,R1
        clr     LCD_rs
        setb    LCD_en
        clr     LCD_en
        acall   delay
        ret
kirim_data:
        mov     LCD_DAT,R1
        setb    LCD_rs
        setb    LCD_en
```

```
        clr     LCD_en
        acall   delay
        ret
LCD_init:
        mov     R1,#03Fh
        acall   kirim_inst
        acall   kirim_inst
        mov     R1,#0Dh
        acall   kirim_inst
        mov     R1,#06h
        acall   kirim_inst
        mov     R1,#01h
        acall   kirim_inst
        mov     R1,#0Ch
        acall   kirim_inst
        ret
;==============================;
;  Untuk Penentu Pilihan        ;
;==============================;
;pil=1  offled                  ;
;pil=2  onled                   ;
;pil=3  back menu               ;
;pil=4  next menu               ;
;------------------------------;
        pil     data    14h
pilih:  mov     a,xy
kor11:  cjne    a,#11h,kor12
        mov     pil,#3h
        ret
kor12:  cjne    a,#11h,kor13
        mov     pil,#3h
        ret
kor13:  cjne    a,#11h,kor14
        mov     pil,#1h
        ret
kor14:  cjne    a,#11h,kor15
        mov     pil,#1h
        ret
kor15:  cjne    a,#11h,kor16
        mov     pil,#2h
        ret
kor16:  cjne    a,#11h,kor17
        mov     pil,#2h
        ret
kor17:  cjne    a,#11h,kor18
        mov     pil,#4h
        ret
kor18:  cjne    a,#11h,kor21
        mov     pil,#4h
        ret
kor21:  cjne    a,#11h,kor22
        mov     pil,#3h
        ret
kor22:  cjne    a,#11h,kor23
        mov     pil,#3h
        ret
kor23:  cjne    a,#11h,kor24
        mov     pil,#1h
        ret
kor24:  cjne    a,#11h,kor25
        mov     pil,#1h
        ret
kor25:  cjne    a,#11h,kor26
        mov     pil,#2h
        ret
kor26:  cjne    a,#11h,kor27
        mov     pil,#2h
        ret
kor27:  cjne    a,#11h,kor28
        mov     pil,#4h
        ret
kor28:  cjne    a,#11h,kor11
        mov     pil,#4h
        ret
;==============================;
;  Untuk        L  E  D         ;
;==============================;
L1off:  clr     p2.0
        ret
L1on:   setb    p2.0
        ret
L2off:  clr     p2.1
        ret
L2on:   setb    p2.1
        ret
L3off:  clr     p2.2
        ret
L3on:   setb    p2.2
        ret
L4off:  clr     p2.3
        ret
L4on:   setb    p2.3
        ret
L5off:  clr     p2.4
        ret
L5on:   setb    p2.4
        ret
L6off:  clr     p2.5
        ret
L6on:   setb    p2.5
        ret
L7off:  clr     p2.6
        ret
L7on:   setb    p2.6
        ret
L8off:  clr     p2.7
        ret
L8on:   setb    p2.7
        ret
;==============;
;  delay       ;
;==============;
delay:  mov     R0,#150
delay1: mov     R5,#50h
        djnz    R5,$
        djnz    R0,delay1
        ret
Ldelay: mov     R2,#040h
Ld1:    acall   delay
        djnz    R2,Ld1
        ret
end
```

BAB IV

PENGUJIAN ALAT

Setelah dirancang keseluruhan sub sistem, selanjutnya dilakukan pengujian agar diketahui unjuk kerja masing-masing sub sistem, apakah sudah sesuai dengan yang direncanakan. Setelah dilakukan pengujian terhadap masing-masing sub sistem. Selanjutnya seluruh sub-sistem tersebut digabungkan membentuk suatu sistem *Touch Screen* dan sistem diuji secara keseluruhan. Bagian-bagian yang diuji adalah :

1. Sistem Mikrokontroller 89S51
2. Sistem Modul LCD dengan 89S51
3. Sistem Infra Red Transmitter dan Receiver

Setelah semua bagian di atas diuji, langkah berikutnya adalah pengujian sistem secara keseluruhan. Dalam setiap pengujian dijelaskan tujuan pengujian dan analisa pengujian.

4.1. Pengujian Sistem Mikrokontroller 89S51

4.1.1. Tujuan

Untuk memastikan mikrokontroller dalam kondisi yang baik, dengan bahasa Assembler.

4.1.2. Peralatan yang Digunakan

1. Minimum Sistem Mikrokontroller AT89S51
2. Komputer

3. SPI-Flash Programmer Version 3.7
4. ISP Kabel dari LPT
5. ASEM-51 Macro Assembler Version 1.3
6. LED

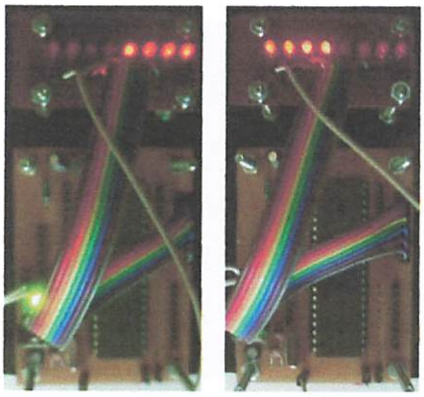
4.1.3. Prosedur Pengujian

1. Dibuat program dengan bahasa assembler untuk mengaktifkan seluruh port dan mematikan secara simultan dengan delay.
2. Dirangkaikan minimum sistem mikrokontroller, kabel isp, komputer dan power supply.
3. Program dicompile dengan ASEM-51, kemudian diisikan ke 89S51 dengan SPI-Flash Programmer.
4. Dilihat nyala LED untuk tiap port.

Adapun listing programnya adalah sebagai berikut:

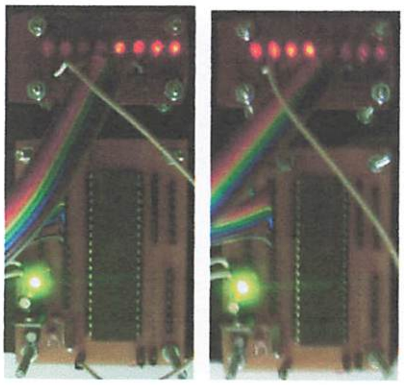
```
            ORG     00H
MULAI:MOV               P0,#00001111B
            MOV         P1,#00001111B
            MOV         P2,#00001111B
            MOV         P3,#00001111B
            ACALL DELAY
            MOV         P0,#11110000B
            MOV         P1,#11110000B
            MOV         P2,#11110000B
            MOV         P3,#11110000B
            ACALL DELAY
            JMP         MULAI
DELAY:MOV         R0,#200
DELAY1:     MOV         R1,#100
DELAY2:     MOV         R2,#28
            DJNZ        R2,$
            DJNZ        R1,DELAY2
            DJNZ        R0,DELAY1
            RET
END
```

4.1.4. Hasil Pengujian



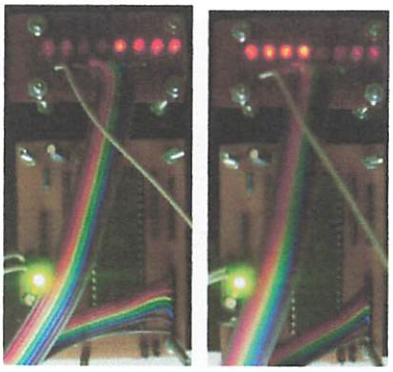
Gambar 4-1. Hasil Pengujian 89S51 Port 0

Dari gambar diatas terlihat bahwa port 0 dalam kondisi baik, dapat mengeluarkan data sesuai yang diinginkan.



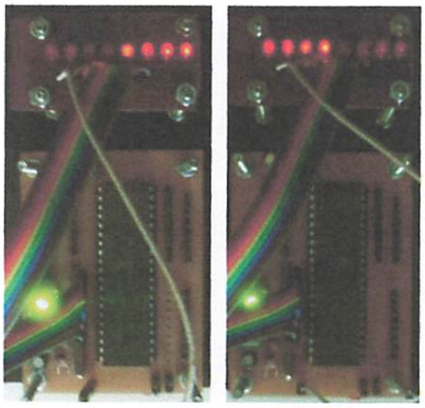
Gambar 4-2. Hasil Pengujian 89S51 Port 1

Dari gambar diatas terlihat bahwa port 1 dalam kondisi baik, dapat mengeluarkan data sesuai yang diinginkan.



Gambar 4-3. Hasil Pengujian 89S51 Port 2

Dari gambar diatas terlihat bahwa port 2 dalam kondisi baik, dapat mengeluarkan data sesuai yang diinginkan.



Gambar 4-4. Hasil Pengujian 89S51 Port 3

Dari gambar diatas terlihat bahwa port 3 dalam kondisi baik, dapat mengeluarkan data sesuai yang diinginkan.

Ternyata semua port dalam kondisi baik. Hal ini berarti 89S51 dalam kondisi baik.

4.2.Pengujian Sistem Modul LCD dengan 89S51

4.2.1. Tujuan

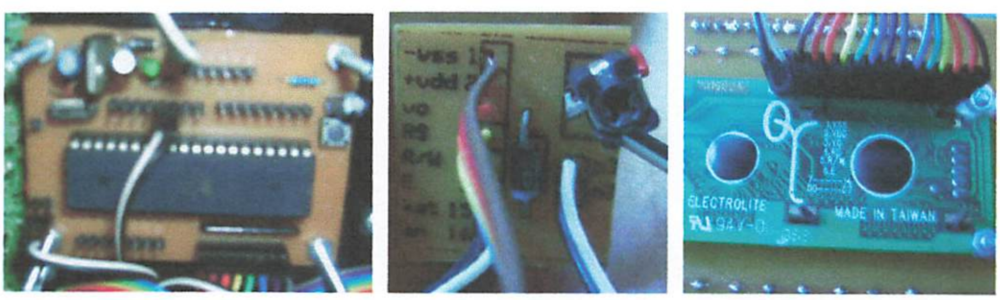
Untuk memastikan bahwa modul LCD dalam kondisi baik, dengan diaktifkan melalui 89S51 sebagai *mpu.*

4.2.2. Peralatan yang Digunakan

1. Minimum Sistem Mikrokontroller AT89S51
2. Modul LCD 2x16 karakter
2. Komputer
3. SPI-Flash Programmer Version 3.7
4. ISP Kabel dari LPT
5. ASEM-51 Macro Assembler Version 1.3

4.2.3. Prosedur Pengujian

1. Dibuat program dengan bahasa assembler untuk menulis ke LCD 2 baris 16 karakter..
2. Dirangkaikan modul LCD, minimum sistem mikrokontroller, kabel isp, komputer dan power supply.



Gambar 4-5. Pemasangan Rangkaian Pengujian *LCD*

3. Program dicompile dengan ASEM-51, kemudian diisikan ke 89S51 dengan SPI-Flash Programmer.
4. Dilihat tulisan LCD yang muncul.

Adapun listing programnya adalah sebagai berikut:

```
        org    00h
        lcd_data     equ    p0
        lcd_rs       bit    p3.3
        lcd_en       bit    p3.2
lcd:    acall lcd_init
        mov   dptr,#satu
        acall lcd_cur1
        acall lcd_brs
        mov   dptr,#dua
        acall lcd_cur2
        acall lcd_brs
        acall delay_1
        ajmp  lcd
satu:db 7fh,' touch screen',7eh
dua: db 7fh,'  apriyanto  ',7eh
lcd_init: mov r1,#038h
        acall tul_inst
        acall tul_inst
        acall tul_inst
        mov   r1,#0fh
        acall tul_inst
        mov   r1,#06h
        acall tul_inst
        mov   r1,#01h
        acall tul_inst
        mov   r1,#0fh
        acall tul_inst
        mov   r1,#02h
        acall tul_inst
        ret
lcd_cur1: mov r1,#10000000b
        acall tul_inst
        ret
lcd_cur2: mov r1,#11000000b
        acall tul_inst
        ret
lcd_brs: mov r0,#16
ketik: clr  a
        movc  a,@a+dptr
        mov   r1,a
        inc   dptr
        acall tul_data
        djnz  r0,ketik
        ret
tul_inst: mov lcd_data,r1
        clr   lcd_rs
        setb  lcd_en
        clr   lcd_en
        acall delay
        ret
tul_data: mov lcd_data,r1
        setb  lcd_rs
        setb  lcd_en
        clr   lcd_en
        acall delay
        ret
delay: mov  r2,#200
delay1: mov r3,#50
        djnz  r3,$
        djnz  r2,delay1
        ret
delay_1: mov      r4,#10h
delay_11: acall   delay
        djnz  r4,delay_11
        ret
end
```

4.2.4. Hasil Pengujian

Gambar 4-6. Hasil Pengujian Modul *LCD*

Dengan dilihat tampilan LCD ternyata dapat menampilkan tulisan. Hal ini berarti modul LCD dalam kondisi baik.

4.3.Pengujian Sistem *Infra Red* dan *Photodioda*

4.3.1. Tujuan

Untuk memastikan bahwa modul semua pasangan *Infra Red* dan *Photodioda* dalam kondisi baik, dengan dimasukkan melalui port 1 89S51 dan hasilnya keluar pada port 2 yang diberi LED.

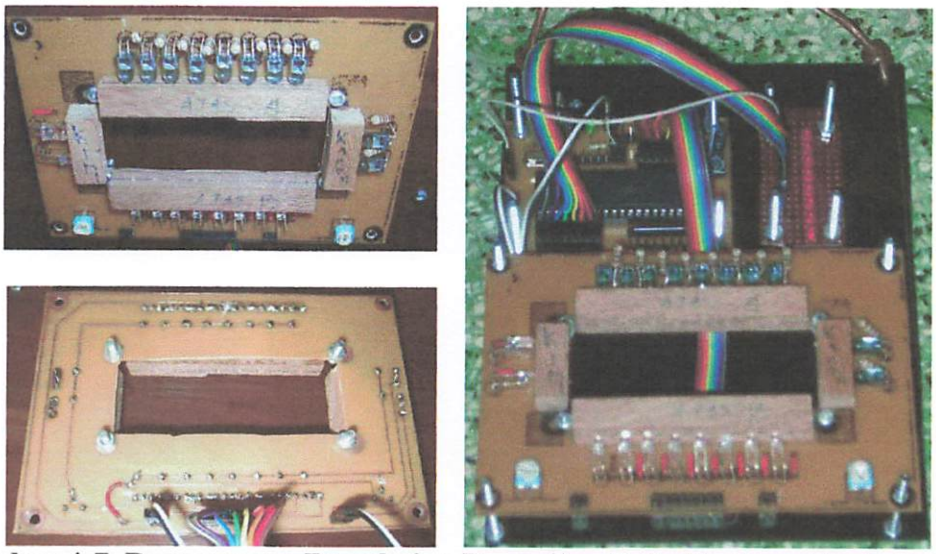
4.3.2. Peralatan yang Digunakan

1. Minimum Sistem Mikrokontroller AT89S51
2. Modul Infra Red
2. Komputer
3. SPI-Flash Programmer Version 3.7
4. ISP Kabel dari LPT
5. ASEM-51 Macro Assembler Version 1.3
6. LED

4.3.3. Prosedur Pengujian

1. Dibuat program dengan bahasa assembler untuk mengambil port 1 dan ditampilkan ke port 2.
2. Dirangkaikan modul Infra Red, minimum sistem mikrokontroller, kabel isp, komputer dan power supply.

3. Program dicompile dengan ASEM-51, kemudian diisikan ke 89S51 dengan SPI-Flash Programmer.



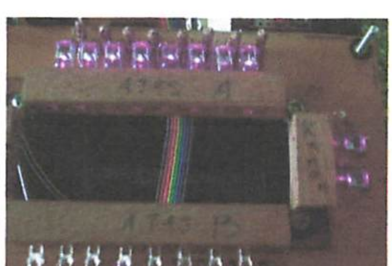
Gambar 4-7. Pemasangan Rangkaian Pengujian *Infra Red* dan *Photodioda*

4. Setiap pasangan *Infra Red* dan *Photodioda* dites satu-persatu dengan dihalangi jari.
5. Dilihat nyala *LED* apakah sesuai dengan penghalangan jari.

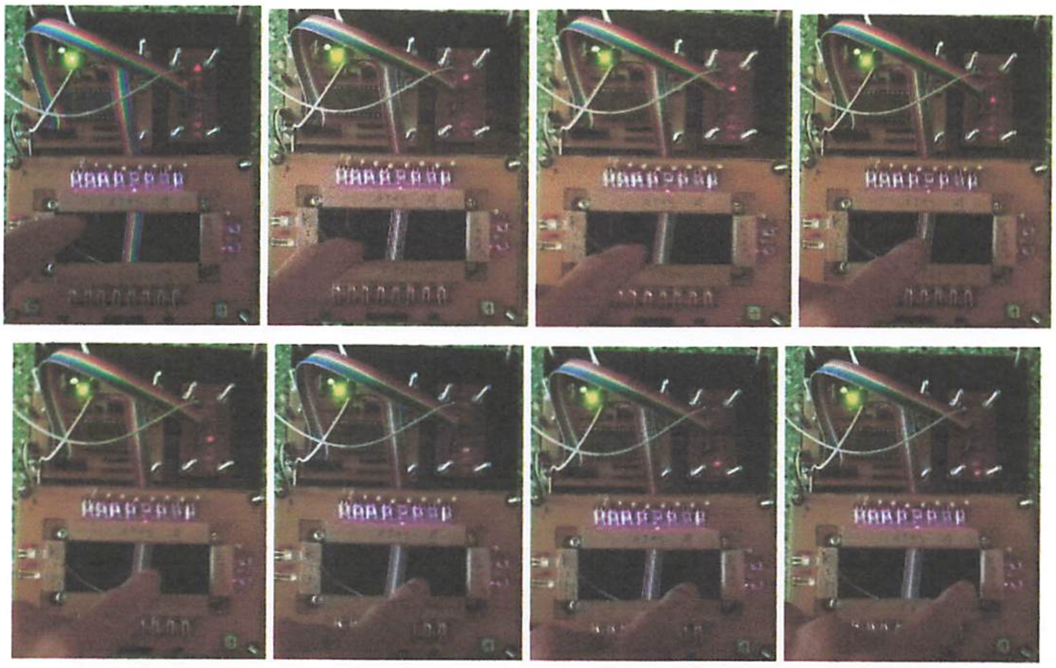
Adapun listing programnya adalah sebagai berikut:

```
        org     00h
        ir      equ     p1
        led     equ     p2
mulai:  mov     a,ir
        cpl     a
        mov     led,a
        jmp     mulai
end
```

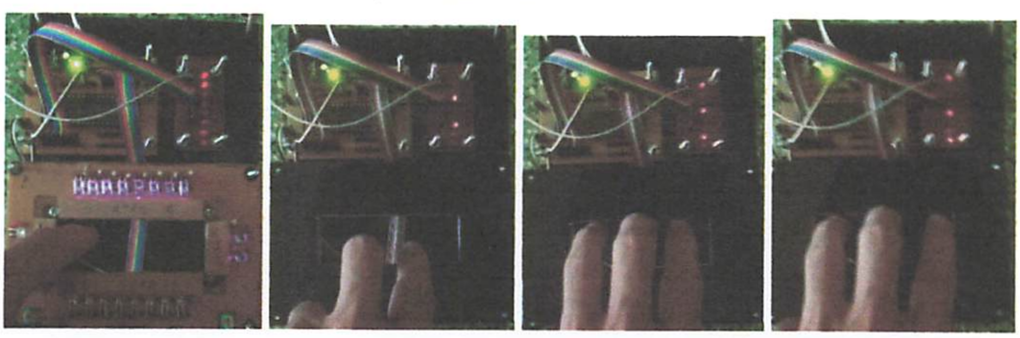
4.3.4. Hasil Pengujian



Gambar 4-8. Sinar Infra Red yang Dapat Ditangkap Kamera



Gambar 4-9. Hasil Pengujian Infra Red dan Photodioda untuk X1 - X8



Gambar 4-10.Hasil Pengujian Infra Red dan Photodioda Jari Banyak

Dengan dilihat nyala *LED* dapat diketahui hasil pengujian. Dari program diatas ternyata nyala *LED* sesuai dengan penghalangan *Infra Red.* Hal ini berarti semua sensor *Infra Red* dalam kondisi baik.

4.4.Pengujian Alat Keseluruhan

4.4.1. Tujuan

Pengujian agar diketahui apakah sistem *interface* ini sudah cukup baik, dengan memasang semua alat sesuai perencanaan dan melihat hasilnya.

4.4.2. Peralatan yang Digunakan

1. Minimum Sistem Mikrokontroller AT89S51
2. Modul LCD 2x16 karakter
3. Modul Infra Red
4. Modul LED sebagai tes keluaran
5. Komputer
6. SPI-Flash Programmer Version 3.7
7. ISP Kabel dari LPT
8. ASEM-51 Macro Assembler Version 1.3

4.4.3. Prosedur Pengujian

1. Diketik program sesuai perencanaan pada **Bab 3**.
2. Dirangkaikan modul LCD, modul Infra Red, modul LED, minimum sistem mikrokontroller, kabel isp, komputer dan power supply.
3. Program dicompile dengan ASEM-51, kemudian diisikan ke 89S51 dengan SPI-Flash Programmer.

4. Alat Dihidupkan apakah LCD menampilkan Nama dan NIM

Gambar 4-11. Tampilan Nama dan NIM saat Alat Dihidupkan

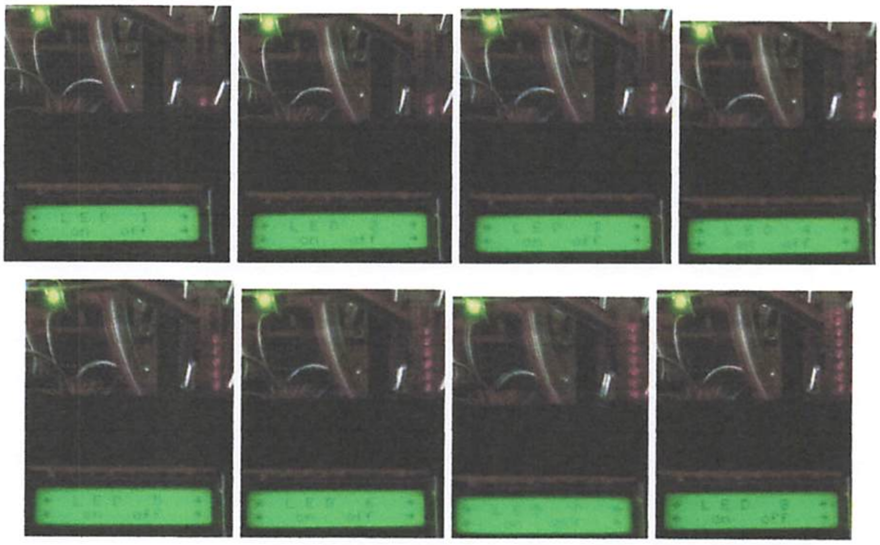
5. Layar disentuh, apakah LCD menampilkan judul skripsi

Gambar 4-12. Tampilan Judul saat Diberi Sentuhan

6. Layar disentuh, apakah LCD menampilkan dosen pembimbing

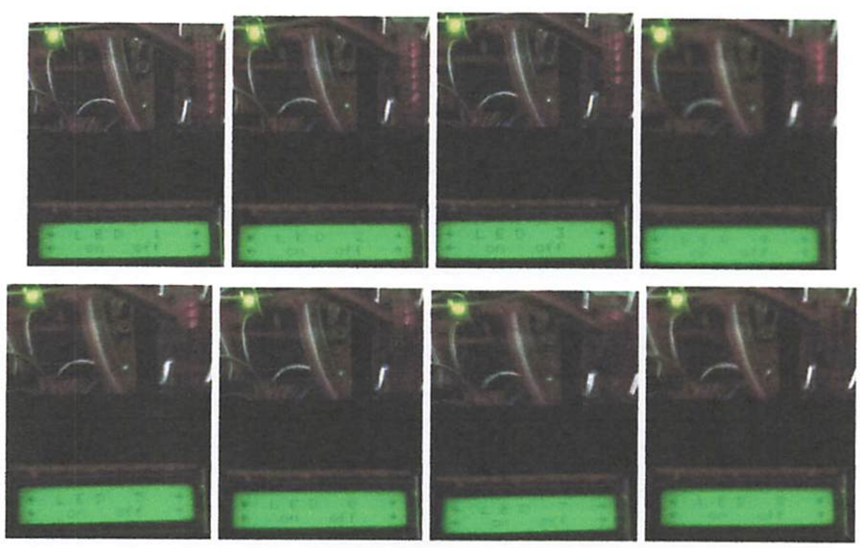
Gambar 4-13. Tampilan Dosen Pembimbing saat Diberi Sentuhan

7. Melalui menu dihidupkan semua LED satu-persatu, apakah hidup semua.



Gambar 4-14. Pengujian LED 1 - LED 8 Dihidupkan Satu-Persatu

8. Melalui menu dimatikan semua LED satu-persatu, apakah mati semua.



Gambar 4-15. Pengujian LED 1 - LED 8 Dimatikan Satu-Persatu

4.4.4. Hasil Pengujian

Dari hasil pengujian menu dapat diganti mulai menu LED 1 hingga menu LED 8, dan keseluruhan LED dapat dikontrol (hidup/mati). Keseluruhan prosedur dapat dilalui dengan baik.

Saat pengujian dilakukan ternyata alat ini dapat terganggu oleh terangnya lampu TL pada ruangan, dan alat dapat berjalan jika *photodioda* dilindungi dari cahaya terang.

BAB V

PENUTUP

5.1. Kesimpulan

Dari tujuan, proses perencanaan dan hasil pengujian sistem Touch Screen dapat disimpulkan bahwa:

- Ternyata *Photodioda* dapat terinterferensi oleh lampu TL.
- Sistem *interface* mampu menggantikan fungsi dari saklar, tombol dan keypad sebagai pengendali LED.
- Tampilan menu atau fungsi lainnya dapat diganti sesuai keperluan dengan kekreatifan sesuai keinginan pemakai.

5.2. Saran-saran

Saran penyusun agar sistem Touch Screen lebih baik yaitu:

- *Photodioda* diberi pelindung plastik atau kertas agar cahaya terang dari luar baik sinar matahari atau lampu TL.
- Sebaiknya menu dirancang sesuai keperluan dan disusun sesuai kriteria fungsi yang sama atau disusun sesuai tata letak.

DAFTAR PUSTAKA

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SEIKO, "*Liquid Crystal Module M1632 User Manual*", 1987

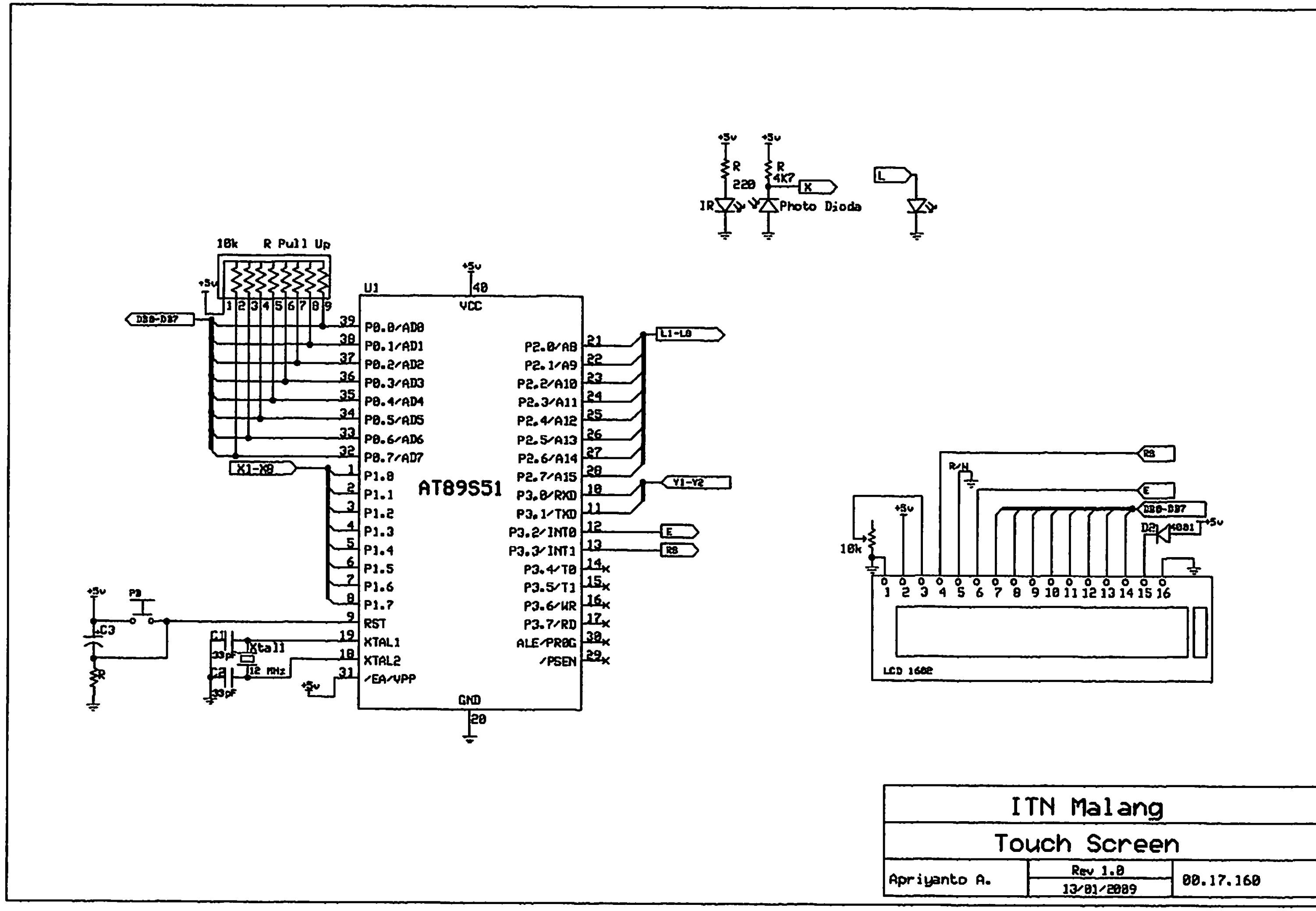
DISPLAY TECH, "*162 Series Product Specifications*", 1994

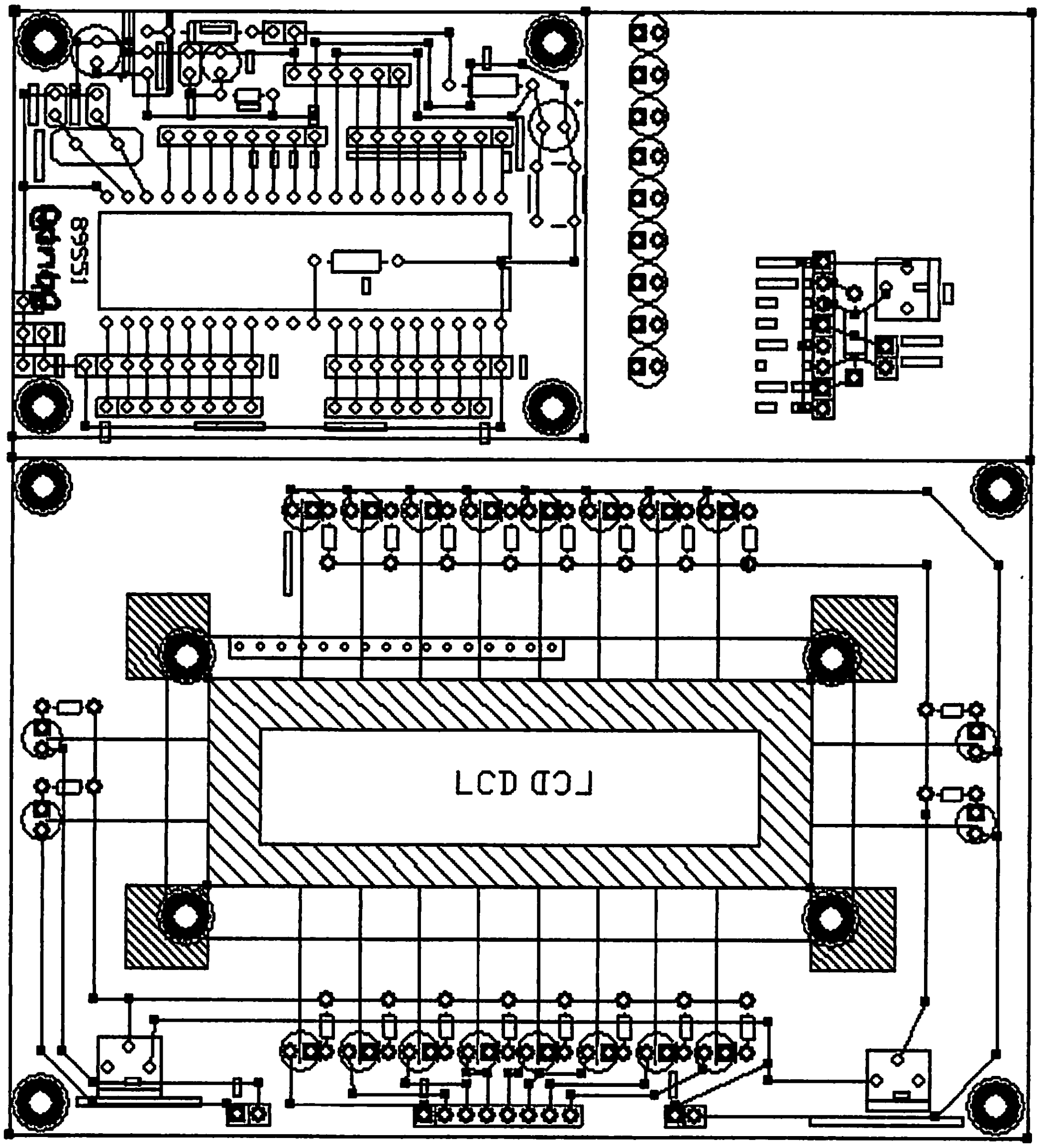
HAMAMATSU, "*Photodiode Technical Information*' 2001

Andreas Holzinger: *Finger Instead of Mouse: Touch Screens as a means of enhancing Universal Access*, In: Carbonell, N.; Stephanidis C. (Eds): Universal Access, Theoretical Perspectives, Practice, and Experience. Lecture Notes in Computer Science. Vol. 2615. Berlin, Heidelberg, New York: Springer, 2003, ISBN 3-540-00855-1, 387–397

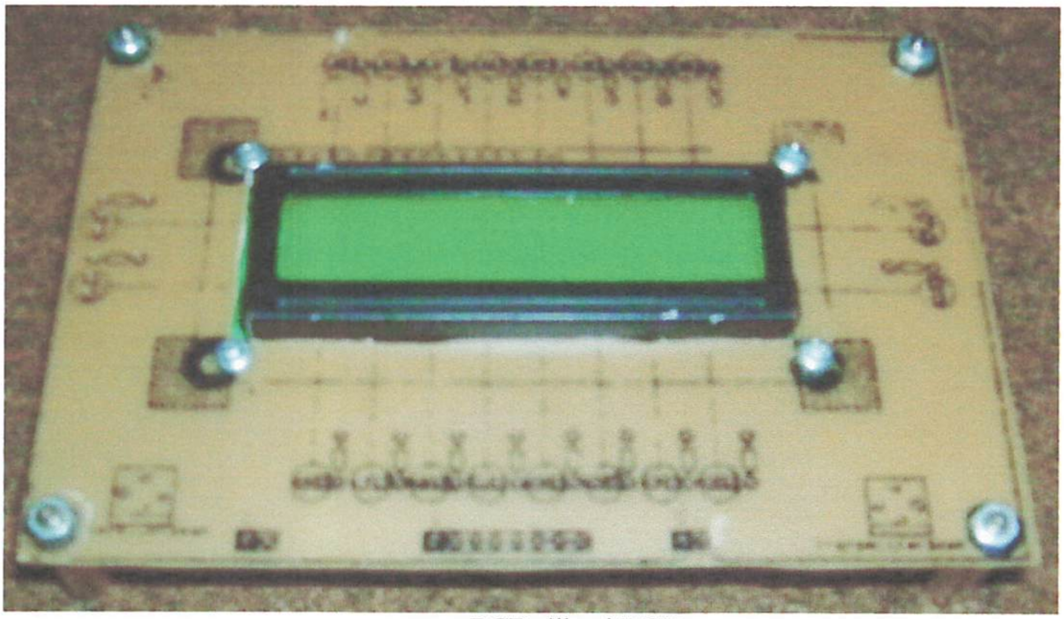
Lampiran

Skema Rangkaian Keseluruhan

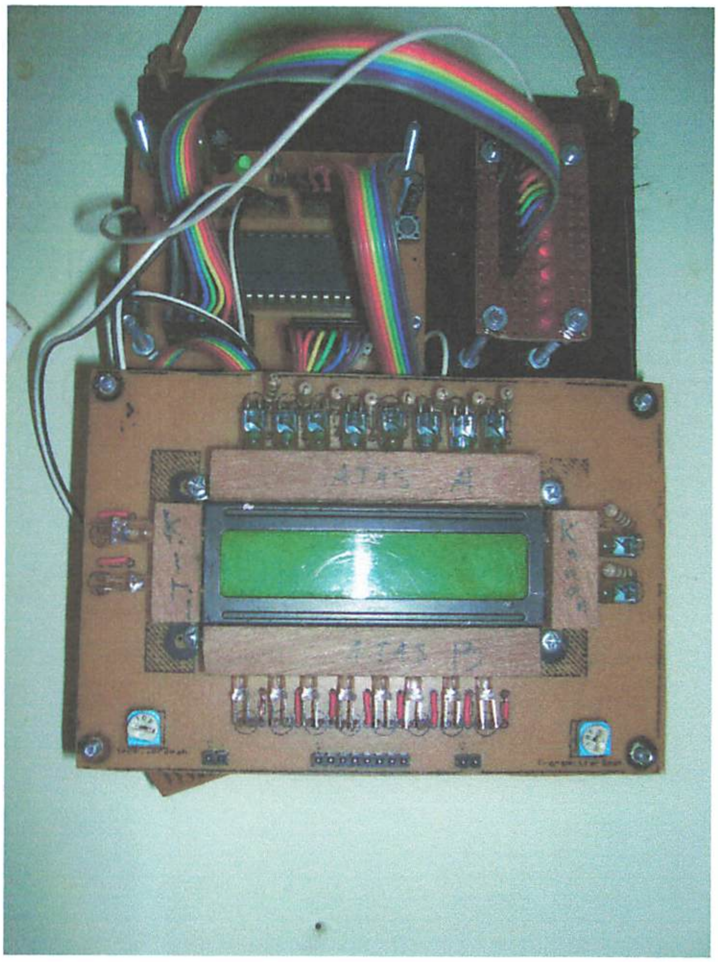




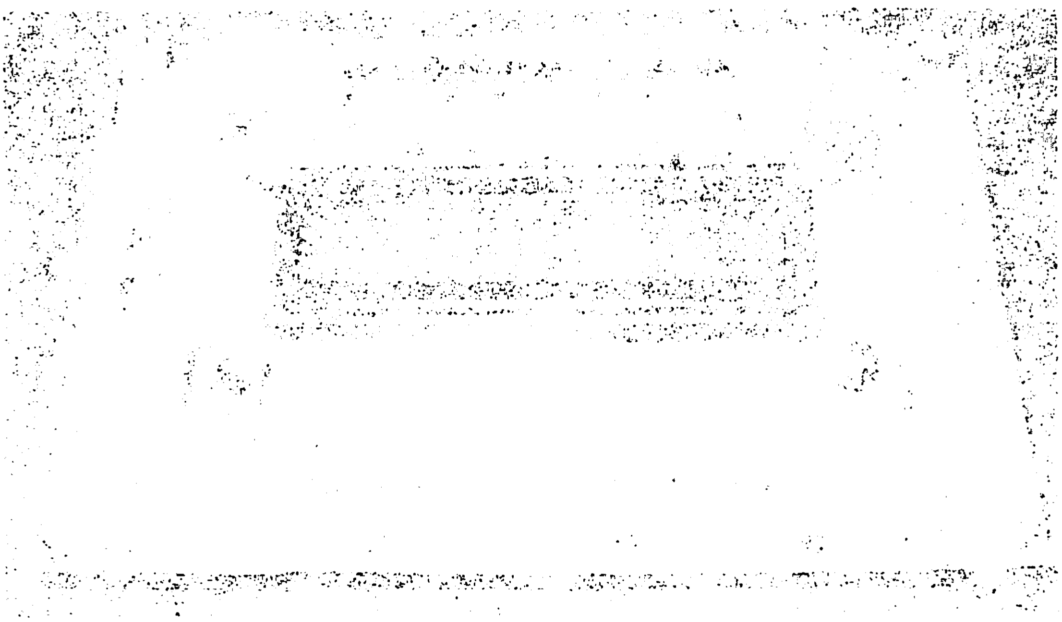
PCB Rangkaian Keseluruhan

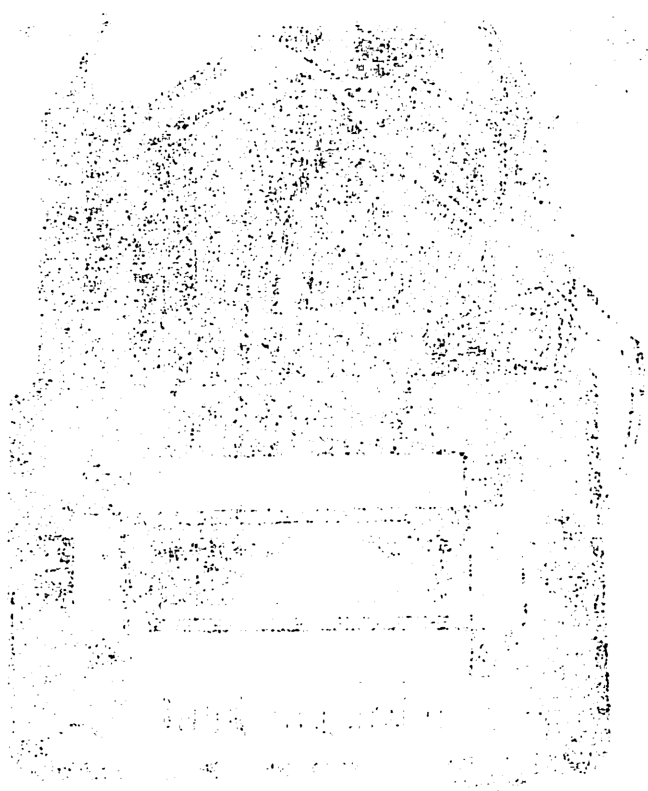


PCB diberi LCD



PCB diberi *Infra Red* dan *Photodioda*





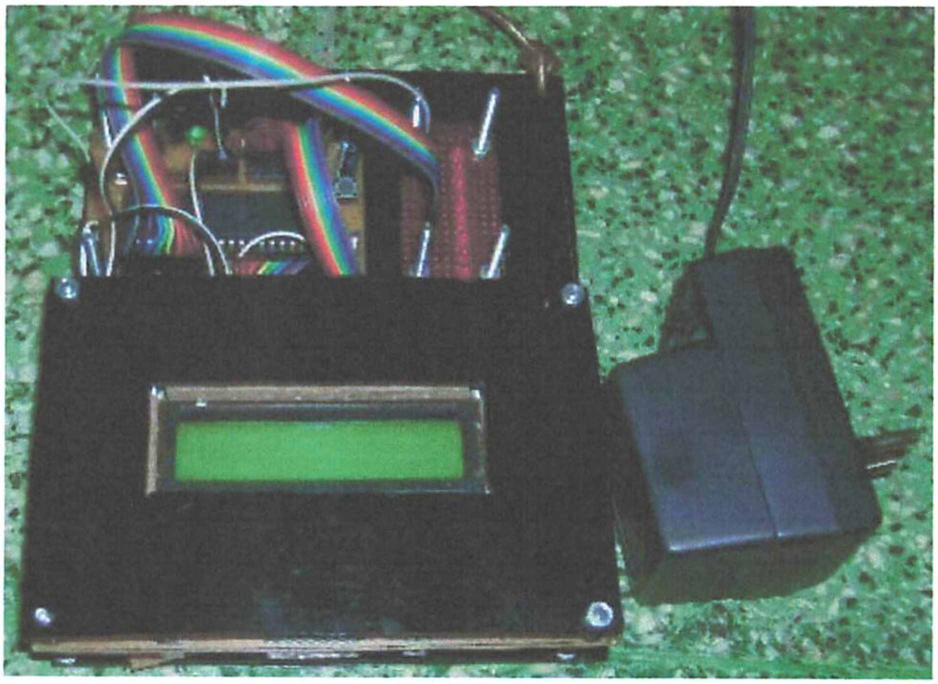


Foto Keseluruhan Alat

Features

- Compatible with MCS-51® Products
- 4K Bytes of In-System Programmable (ISP) Flash Memory
  - Endurance: 1000 Write/Erase Cycles
- 4.0V to 5.5V Operating Range
- Fully Static Operation: 0 Hz to 33 MHz
- Three-level Program Memory Lock
- 128 x 8-bit Internal RAM
- 32 Programmable I/O Lines
- Two 16-bit Timer/Counters
- Six Interrupt Sources
- Full Duplex UART Serial Channel
- Low-power Idle and Power-down Modes
- Interrupt Recovery from Power-down Mode
- Watchdog Timer
- Dual Data Pointer
- Power-off Flag
- Fast Programming Time
- Flexible ISP Programming (Byte and Page Mode)

8-bit Microcontroller with 4K Bytes In-System Programmable Flash

AT89S51

Description

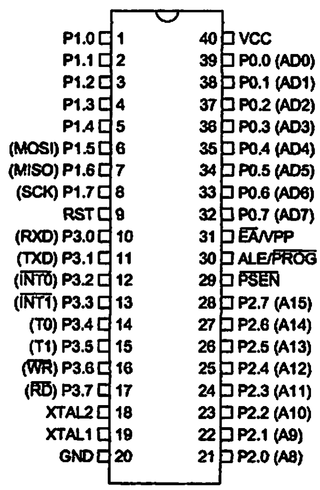
The AT89S51 is a low-power, high-performance CMOS 8-bit microcontroller with 4K bytes of in-system programmable Flash memory. The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry-standard 80C51 instruction set and pinout. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. By combining a versatile 8-bit CPU with in-system programmable Flash on a monolithic chip, the Atmel AT89S51 is a powerful microcontroller which provides a highly-flexible and cost-effective solution to many embedded control applications.

The AT89S51 provides the following standard features: 4K bytes of Flash, 128 bytes of RAM, 32 I/O lines, Watchdog timer, two data pointers, two 16-bit timer/counters, a five-vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator, and clock circuitry. In addition, the AT89S51 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port, and interrupt system to continue functioning. The Power-down mode saves the RAM contents but freezes the oscillator, disabling all other chip functions until the next external interrupt or hardware reset.

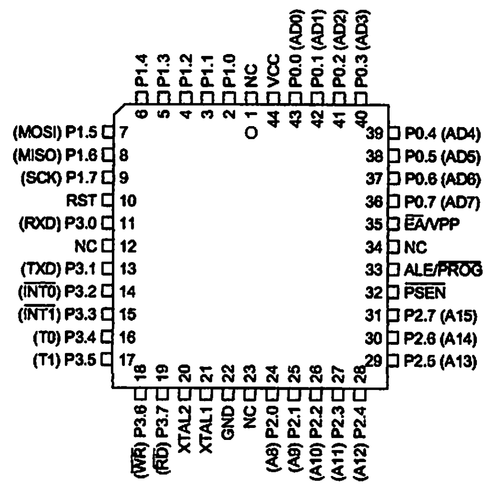
Rev. 2487A–10/01

Pin Configurations

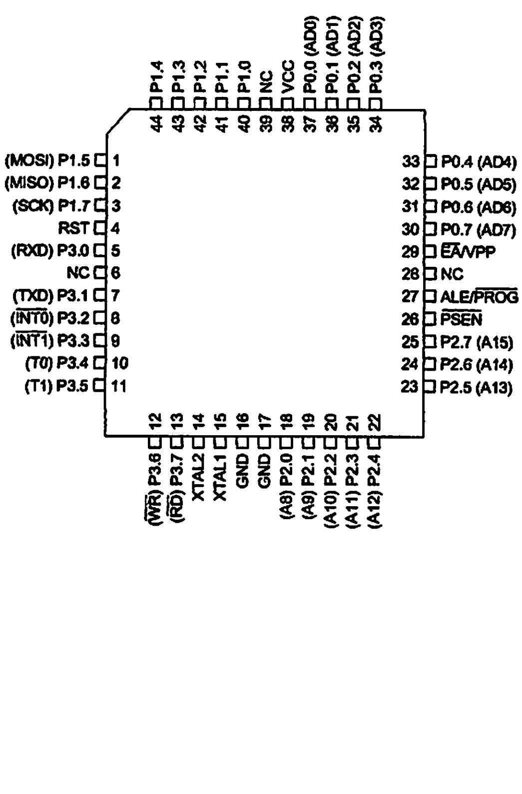
PDIP



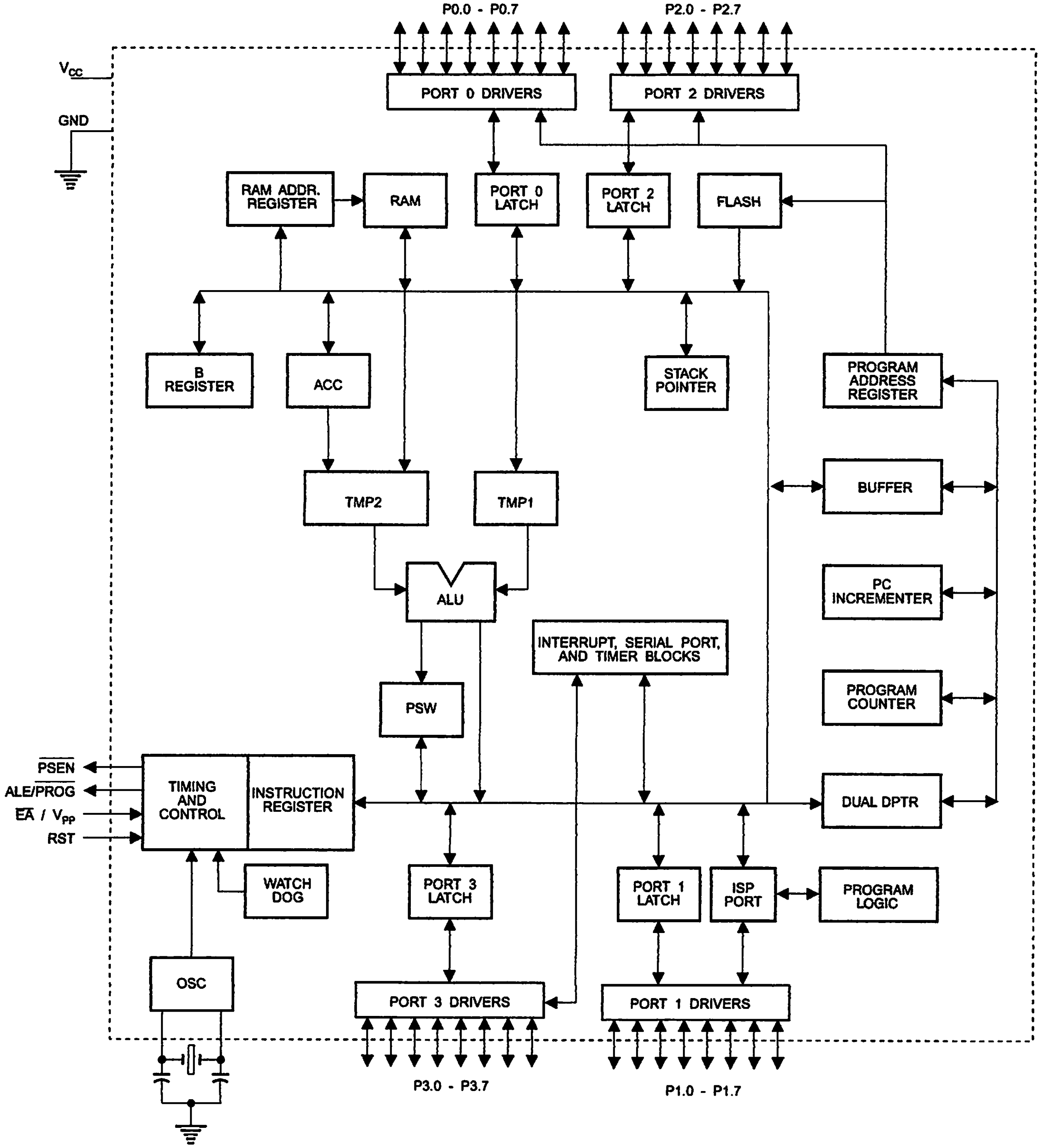
PLCC



TQFP



Block Diagram



Pin Description

VCC Supply voltage.

GND Ground.

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

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

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

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

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

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

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

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

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

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

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

Port 3 also serves the functions of various special features of the AT89S51, as shown in the following table.

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

RST

Reset input. A high on this pin for two machine cycles while the oscillator is running resets the device. This pin drives High for 98 oscillator periods after the Watchdog times out. The DISRTO bit in SFR AUXR (address 8EH) can be used to disable this feature. In the default state of bit DISRTO, the RESET HIGH out feature is enabled.

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

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

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

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

$\overline{\text{PSEN}}$

Program Store Enable ($\overline{\text{PSEN}}$) is the read strobe to external program memory.

When the AT89S51 is executing code from external program memory, $\overline{\text{PSEN}}$ is activated twice each machine cycle, except that two $\overline{\text{PSEN}}$ activations are skipped during each access to external data memory.

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

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

$\overline{\text{EA}}$ should be strapped to V_{CC} for internal program executions.

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

XTAL1

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

XTAL2

Output from the inverting oscillator amplifier

Special Function Registers

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

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

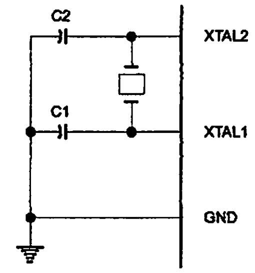
Table 1. AT89S51 SFR Map and Reset Values

0F8H									0FFH
0F0H	B 00000000								0F7H
0E8H									0EFH
0E0H	ACC 00000000								0E7H
0D8H									0DFH
0D0H	PSW 00000000								0D7H
0C8H									0CFH
0C0H									0C7H
0B8H	IP XX000000								0BFH
0B0H	P3 11111111								0B7H
0A8H	IE 0X000000								0AFH
0A0H	P2 11111111		AUXR1 XXXXXXX0				WDTRST XXXXXXXX		0A7H
98H	SCON 00000000	SBUF XXXXXXXX							9FH
90H	P1 11111111								97H
88H	TCON 00000000	TMOD 00000000	TL0 00000000	TL1 00000000	TH0 00000000	TH1 00000000	AUXR XXX00XX0		8FH
80H	P0 11111111	SP 00000111	DP0L 00000000	DP0H 00000000	DP1L 00000000	DP1H 00000000		PCON 0XXX0000	87H

Oscillator Characteristics

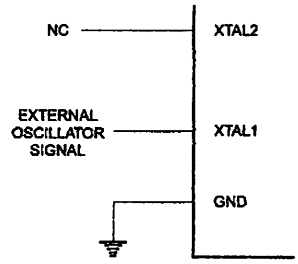
XTAL1 and XTAL2 are the input and output, respectively, of an inverting amplifier that can be configured for use as an on-chip oscillator, as shown in Figure 2. Either a quartz crystal or ceramic resonator may be used. To drive the device from an external clock source, XTAL2 should be left unconnected while XTAL1 is driven, as shown in Figure 3. There are no requirements on the duty cycle of the external clock signal, since the input to the internal clocking circuitry is through a divide-by-two flip-flop, but minimum and maximum voltage high and low time specifications must be observed.

Figure 2. Oscillator Connections



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

Figure 3. External Clock Drive Configuration



Idle Mode

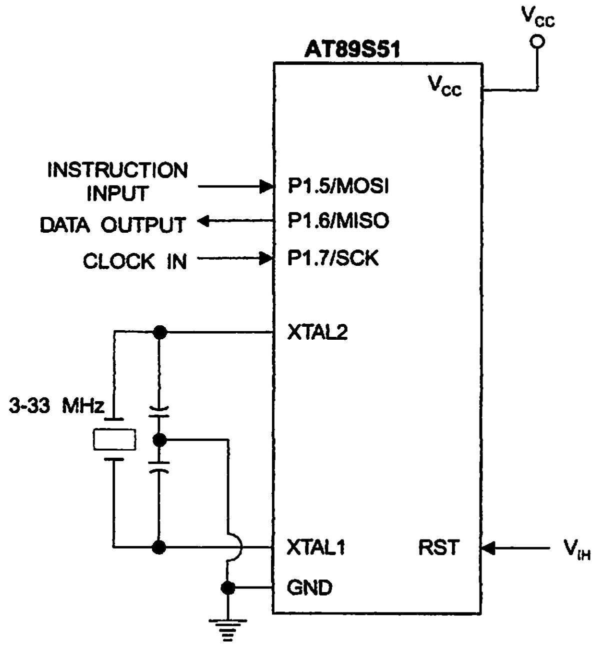
In idle mode, the CPU puts itself to sleep while all the on-chip peripherals remain active. The mode is invoked by software. The content of the on-chip RAM and all the special function registers remain unchanged during this mode. The idle mode can be terminated by any enabled interrupt or by a hardware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

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

Power-down Mode

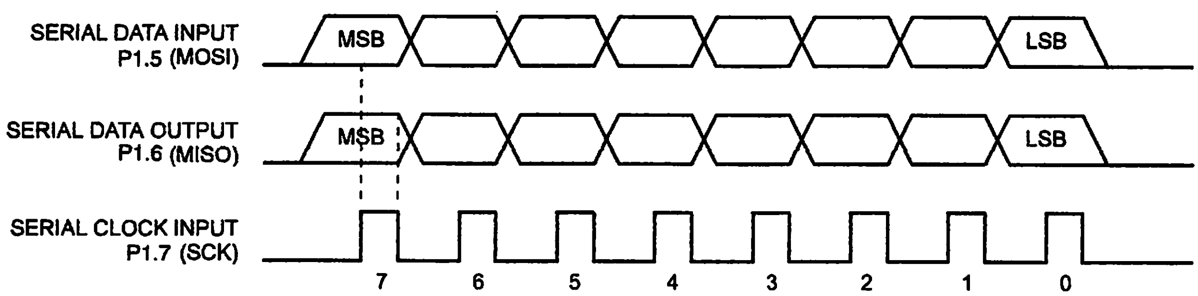
In the Power-down mode, the oscillator is stopped, and the instruction that invokes Power-down is the last instruction executed. The on-chip RAM and Special Function Registers retain their values until the Power-down mode is terminated. Exit from Power-down mode can be initiated either by a hardware reset or by activation of an enabled external interrupt into $\overline{INT0}$ or $\overline{INT1}$. Reset redefines the SFRs but does not change the on-chip RAM. The reset should not be activated before V_{CC} is restored to its normal operating level and must be held active long enough to allow the oscillator to restart and stabilize.

Figure 7. Flash Memory Serial Downloading



Flash Programming and Verification Waveforms – Serial Mode

Figure 8. Serial Programming Waveforms



Serial Programming Characteristics

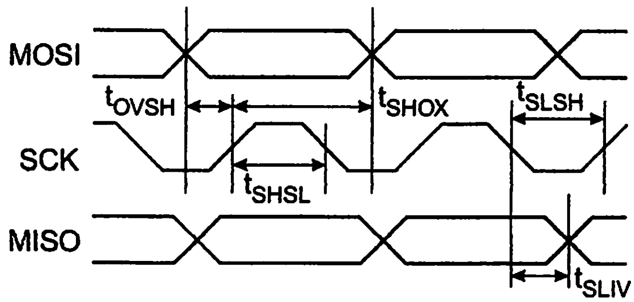


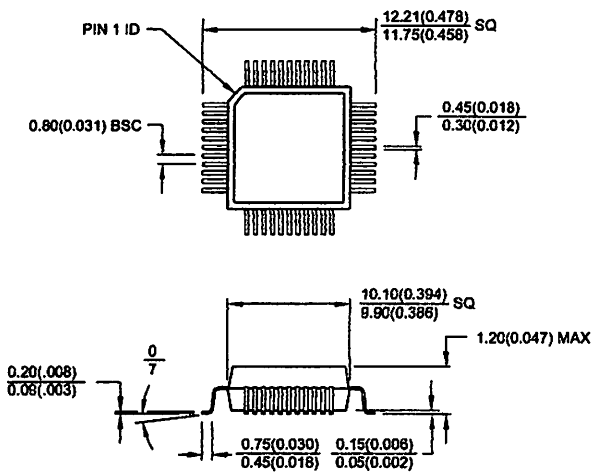
Figure 9. Serial Programming Timing

Table 9. Serial Programming Characteristics, T_A = -40°C to 85°C, V_{CC} = 4.0 - 5.5V (Unless Otherwise Noted)

Symbol	Parameter	Min	Typ	Max	Units
$1/t_{CLCL}$	Oscillator Frequency	0		33	MHz
t_{CLCL}	Oscillator Period	30			ns
t_{SHSL}	SCK Pulse Width High	8 t_{CLCL}			ns
t_{SLSH}	SCK Pulse Width Low	8 t_{CLCL}			ns
t_{OVSH}	MOSI Setup to SCK High	t_{CLCL}			ns
t_{SHOX}	MOSI Hold after SCK High	2 t_{CLCL}			ns
t_{SLIV}	SCK Low to MISO Valid	10	16	32	ns
t_{ERASE}	Chip Erase Instruction Cycle Time			500	ms
t_{SWC}	Serial Byte Write Cycle Time			64 t_{CLCL} + 400	µs

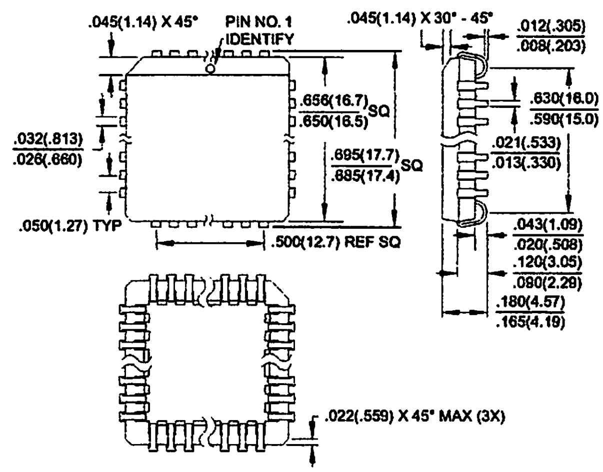
Packaging Information

44A, 44-lead, Thin (1.0 mm) Plastic Gull Wing Quad Flat Package (TQFP)
Dimensions in Millimeters and (Inches)*

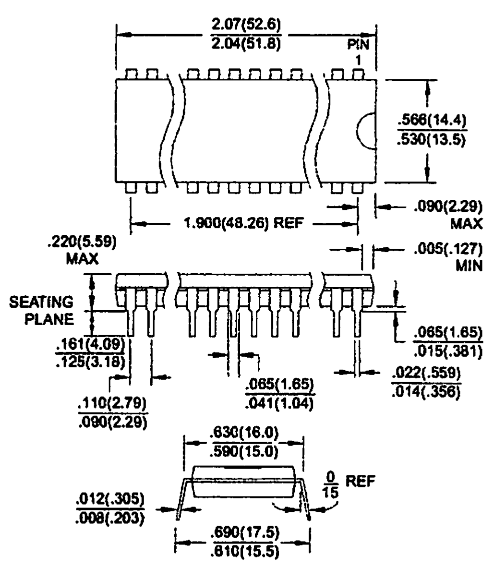


*Controlling dimension: millimeters

44J, 44-lead, Plastic J-leaded Chip Carrier (PLCC)
Dimensions in Inches and (Millimeters)



40P6, 40-pin, 0.600" Wide, Plastic Dual Inline Package (PDIP)
Dimensions in Inches and (Millimeters)
JEDEC STANDARD MS-011 AC



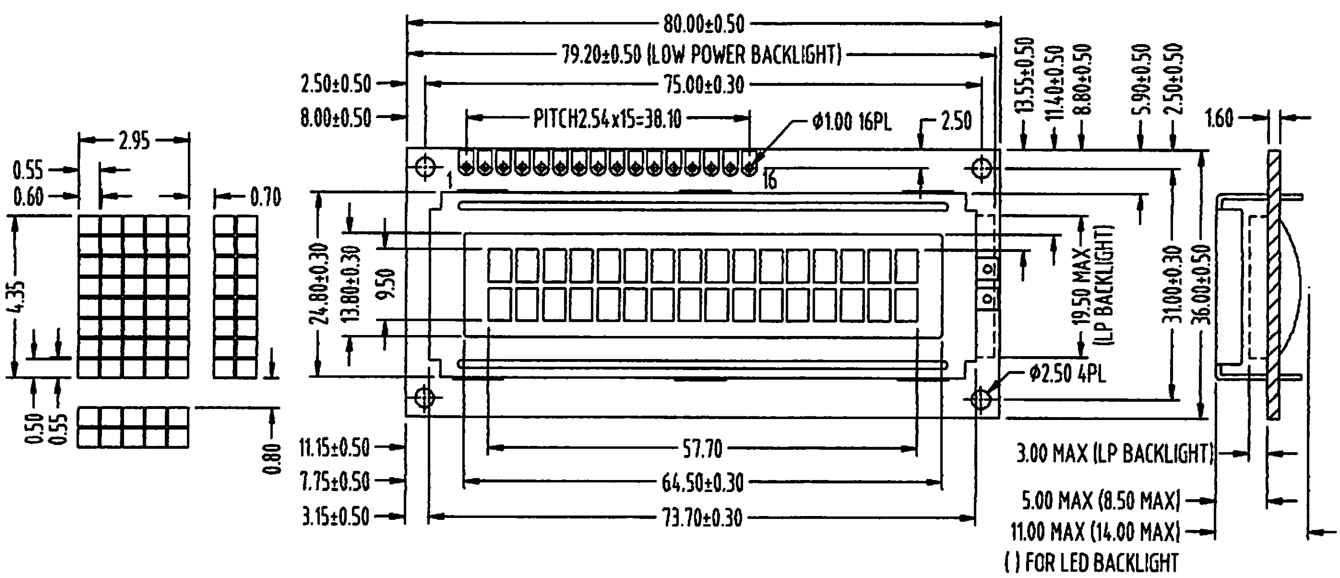
PRODUCT SPECIFICATIONS

- PHYSICAL DATA
- EXTERNAL DIMENSIONS
- BLOCK DIAGRAM
- ABSOLUTE MAXIMUM RATINGS
- ELECTRICAL CHARACTERISTICS
- OPERATING PRINCIPLES & METHODS
- DISPLAY DATA RAM ADDRESS MAP
- ELECTRO-OPTICAL CHARACTERISTICS
- INTERFACE PIN CONNECTIONS
- CIRCUIT DIAGRAM
- RELIABILITY
- QUALITY GUARANTEE
- INSPECTION CRITERIA
- PRECAUTIONS FOR USING LCD MODULES
- USING LCD MODULES

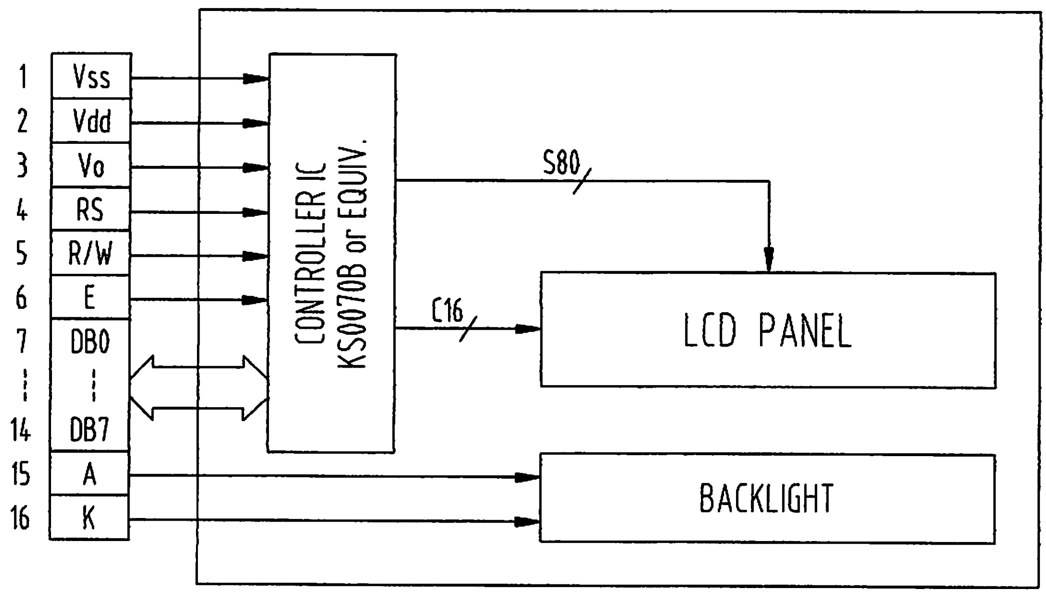
■ PHYSICAL DATA

Item	Contents	Unit
LCD type	TN / STN / FSTN	---
LCD duty	1/16	---
LCD bias	1/5	---
Viewing direction	6 / 12	o'clock
Module size (W×H×T)	80.0 × 36.0 × 11.0 MAX (14.0 MAX W/LED BACKLIGHT)	mm
Viewing area (W×H)	64.5 × 13.8	mm
Number of characters (characters×lines)	16 × 2	---
Character matrix (W×H)	5 × 8	dots
Character size (W×H)	2.95 × 4.35	mm
Dot size (W×H)	0.55 × 0.50	mm
Dot pitch (W×H)	0.60 × 0.55	mm

■ EXTERNAL DIMENSIONS



■ BLOCK DIAGRAM



■ ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Parameter	Symbol	Min	Max	Unit
Supply voltage for logic	VDD	-0.3	7.0	V
Supply voltage for LCD	VDD - VO	-0.3	VDD+0.3	V
Input voltage	VI	-0.3	VDD+0.3	V
Normal operating temperature	TOP	0	50	°C
Normal storage temperature	TST	-10	60	°C
Wide operating / storage temperature (except FSTN)	TOP / TST	-30	80	°C
Wide operating / storage temperature (FSTN)	TOP / TST	-30	70	°C

■ ELECTRICAL CHARACTERISTICS (VDD = +5V±10% , VSS = 0V, Ta = 25°C)

◆ DC Characteristics

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Supply voltage for logic	VDD	---	4.5	5.0	5.5	V
Supply current for logic	IDD	---	---	1.38	3	mA
Operating voltage for LCD	VDD - VO	25°C	4.5	4.8	5.1	V
Input voltage ' H ' level	VIH	---	2.2	---	VDD	V
Input voltage ' L ' level	VIL	---	-0.3	---	0.6	V

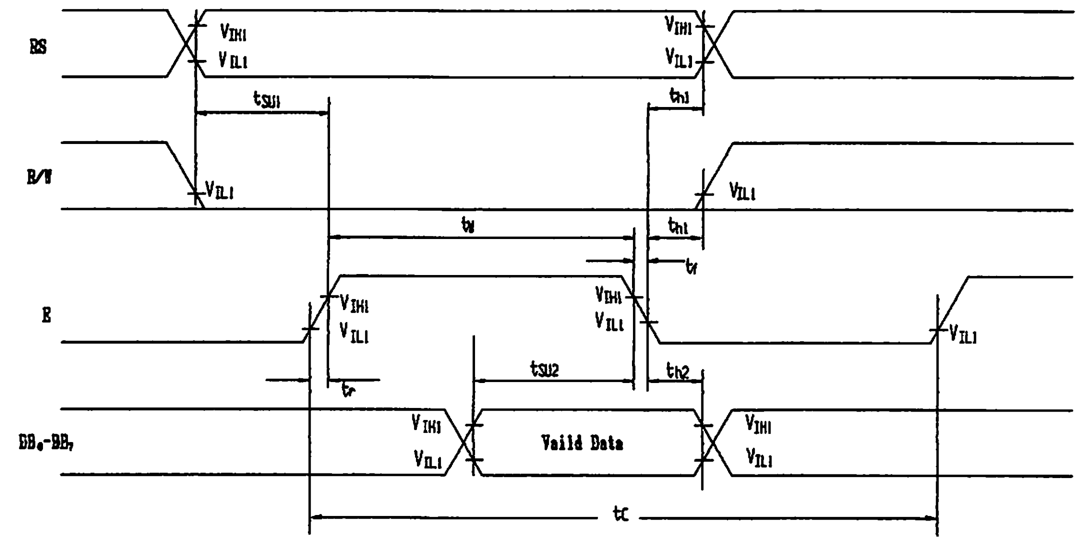
● Backlight operating information (Ta = 25°C)

	Supply voltage VF (V)			Supply current IF (mA)		
LED Backlight	Min	Typ	Max	Min	Typ	Max
Light box Y/G (-2)	---	4.2	4.6	---	80	120
White (-3LP)	---	3.4	3.5	---	20	25
Blue (-4LP)	---	3.4	3.5	---	20	25
Green (-5LP)	---	3.4	3.5	---	20	25
Amber (-6LP)	---	1.8	1.9	---	20	25
	EL Enable voltage EON (VAC)			EL frequency LF (Hz)		
EL Backlight	Min	Typ	Max	Min	Typ	Max
EL (B)	---	100	150	---	400	1000

◆ AC Characteristics

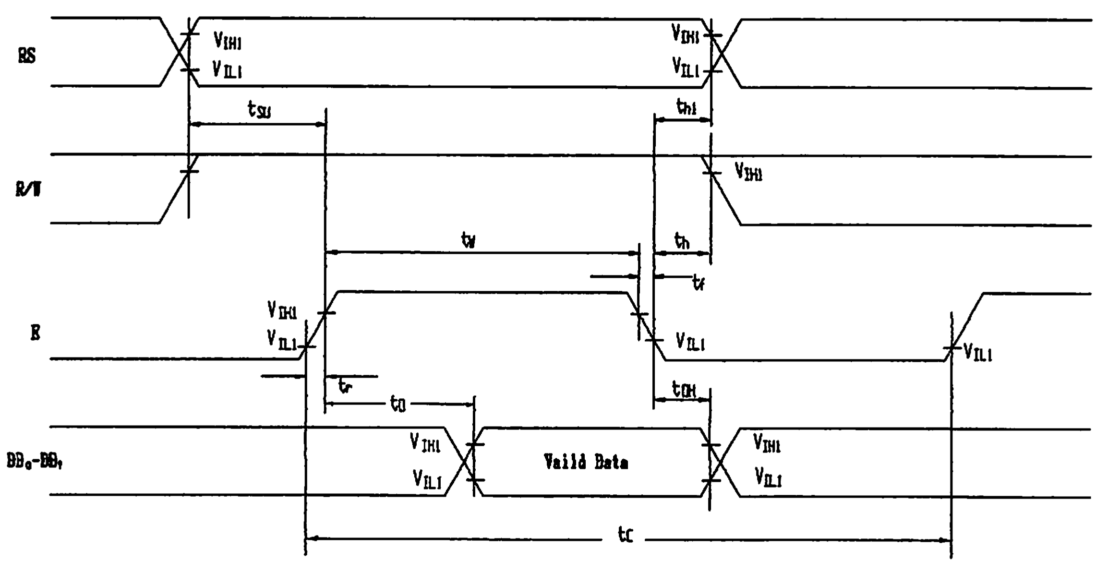
● Write mode

Characteristic	Symbol	Min.	Typ.	Max.	Unit	Test pin
E cycle time	t_C	500	---	---	ns	E
E rise time	t_r	---	---	25	ns	E
E fall time	t_f	---	---	25	ns	E
E pulse width (High, Low)	t_W	220	---	---	ns	E
R/W and RS set-up time	t_{SU1}	40	---	---	ns	R/W, RS
R/W and RS hold time	t_{h1}	10	---	---	ns	R/W, RS
Data set-up time	t_{SU2}	60	---	---	ns	$DB_0 \sim DB_7$
Data hold time	t_{h2}	10	---	---	ns	$DB_0 \sim DB_7$



● Read mode

Characteristic	Symbol	Min.	Typ.	Max.	Unit	Test pin
E cycle time	t_C	500	---	---	ns	E
E rise time	t_r	---	---	25	ns	E
E fall time	t_f	---	---	25	ns	E
E pulse width	t_W	220	---	---	ns	E
R/W and RS set-up time	t_{SU}	40	---	---	ns	R/W, RS
R/W and RS hold time	t_h	10	---	---	ns	R/W, RS
Data output delay time	t_D	---	---	120	ns	$DB_0 \sim DB_7$
Data hold time	t_{DH}	20	---	---	ns	$DB_0 \sim DB_7$



■ OPERATING PRINCIPLES & METHODS

◆ Control and Display Command

Command	RS	R/W	DB_7	DB_6	DB_5	DB_4	DB_3	DB_2	DB_1	DB_0	Execution Time (f_{osc} = 250kHz)	Remark
DISPLAY CLEAR	L	L	L	L	L	L	L	L	L	H	1.64ms	
RETURN HOME	L	L	L	L	L	L	L	L	H	X	1.64ms	Cursor move to first digit
ENTRY MODE SET	L	L	L	L	L	L	L	H	I/D	SH	42μs	• I/D : Set cursor move direction I/D: H Increase; L Decrease • SH : Specifies shift of display SH: H Display is shifted; L Display is not shifted
DISPLAY ON/OFF	L	L	L	L	L	L	H	D	C	B	42μs	• Display D: H Display on; L Display off • Cursor C: H Cursor on; L Cursor off • Blinking B: H Blinking on; L Blinking off
SHIFT	L	L	L	L	L	H	S/C	R/L	X	X	42μs	S/C: H Display shift; L Cursor move R/L: H Right shift; L Left shift
SET FUNCTION	L	L	L	L	H	DL	N	F	X	X	42μs	DL: H 8 bits interface; L 4 bits interface N: H 2 line display; L 1 line display F: H 5 X 10 dots; L 5 X 7 dots
SET CG RAM ADDRESS	L	L	L	H	CG RAM address (corresponds to cursor address)						42μs	CG RAM Data is sent and received after this setting
SET DD RAM ADDRESS	L	L	H	DD RAM address							42μs	DD RAM Data is sent and received after this setting
READ BUSY FLAG & ADDRESS	L	H	BF	Address Counter used for both DD & CG RAM address							0μs	BF: H Busy; L Ready – Reads BF indication internal operating is being performed – Reads address counter contents
WRITE DATA	H	L	Write Data								46μs	Write data into DD or CG RAM
READ DATA	H	H	Read Data								46μs	Read data from DD or CG RAM

X : Don't care

◆ Initializing by Internal Reset Circuit

The KS0070B automatically initializes (resets) when the power is on using the internal reset circuit. The following instruction are executed in initialization. The busy flag is kept in busy state (BF=1) until initialization ends. The busy state is 10ms after VDD rises to 4.5V.

(1) Display Clear
(2) Function Set
   DL = 1 : 8-bit interface data
   N = 0 : 1-line display
   F = 0 : 5x7-dot character font
(3) Display On/Off Control
   D = 0 : Display Off
   C = 0 : Cursor Off
   B = 0 : Blink Off
(4) Entry Mode Set
   I/D = 1 : +1 (Increment)
   S = 0 : No Shift

◆ Initializing by Instruction

Power On

↓

Wait for more than 15ms after VDD rises to 4.5V

↓

RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	0	0	0	1	1	*	*	*	*

BF cannot be checked before this instruction.
Function Set

↓

Wait for more than 4.1ms

↓

RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	0	0	0	1	1	*	*	*	*

BF cannot be checked before this instruction.
Function Set

↓

Wait for more than 100μs

↓

RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	0	0	0	1	1	*	*	*	*

BF cannot be checked before this instruction.
Function Set

↓

BF can be checked after following instruction.
When BF is not checked, the waiting time between instructions is longer than execution instruction time.

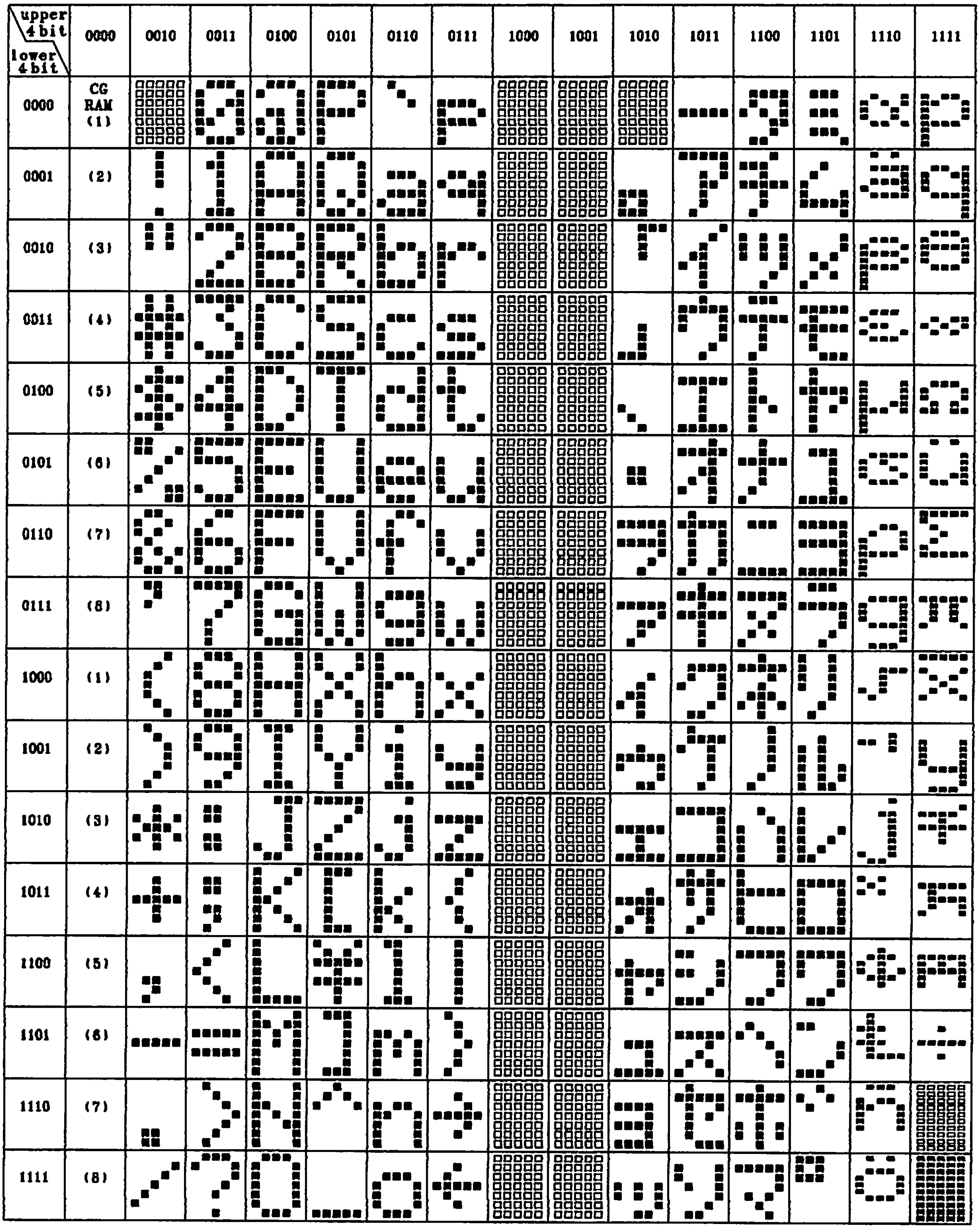
↓

RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0	
0	0	0	0	1	1	N	F	*	*	Function Set (Specify the number of display lines and character font.) The number of display lines and character font cannot be changed afterwards.
0	0	0	0	0	0	1	0	0	0	Display Off
0	0	0	0	0	0	0	0	0	1	Display Clear
0	0	0	0	0	0	0	1	I/D	S	Entry Mode Set

↓

Initialization ends

◆ **Standard Character Pattern**



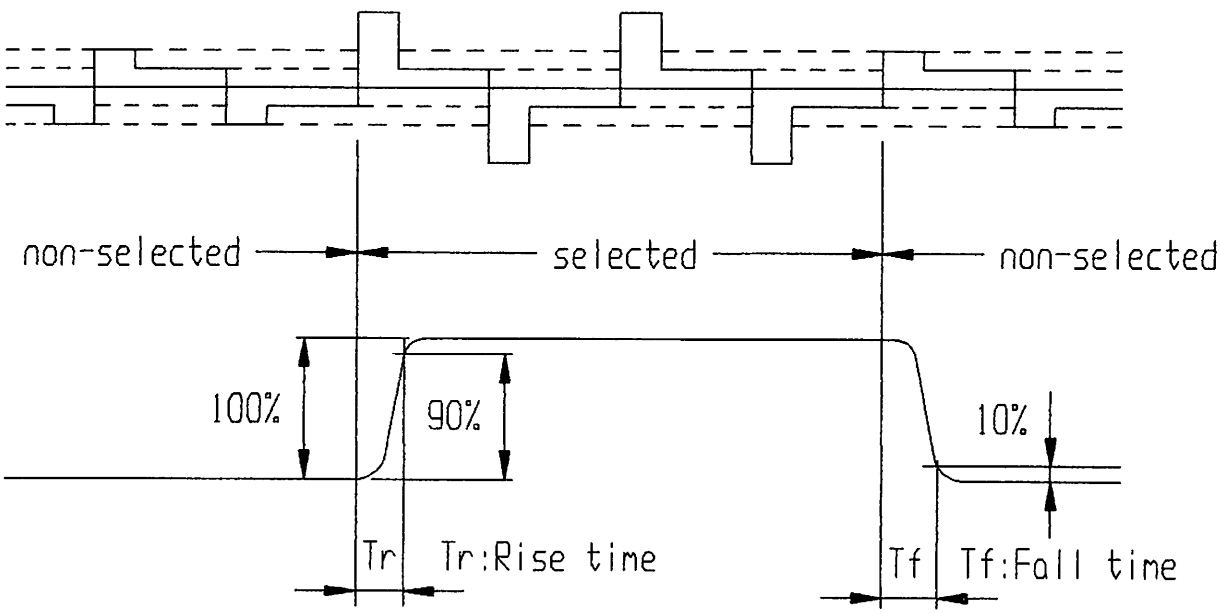
■ DISPLAY DATA RAM ADDRESS MAP

Characters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
First line	00H	01H	02H	03H	04H	05H	06H	07H	08H	09H	0AH	0BH	0CH	0DH	0EH	0FH
Second line	40H	41H	42H	43H	44H	45H	46H	47H	48H	49H	4AH	4BH	4CH	4DH	4EH	4FH

■ ELECTRO-OPTICAL CHARACTERISTICS (V_{OP} = 5.0V, Ta = 25°C, Transflective version)

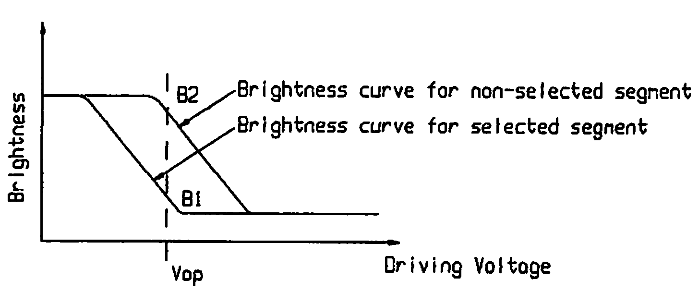
LCD mode	Typ response time Tr (ms)		Typ response time Tf (ms)		Typ contrast ratio Cr	Typ viewing angle θ (deg)			
	Normal temp	Wide temp	Normal temp	Wide temp		Ø = 0°	Ø = 90°	Ø = 180°	Ø = 270°
TN (A)	275	147	61	57	28	20	40	5	40
STN Y/G (B)					30	60	48	57	47
STN Blue (C)					6	52	25	33	33
STN Grey (D)					12	60	37	55	38
FSTN (F)					38	65	49	58	48
FSTN Negative (G)					18	53	25	34	33

Note1: Definition of response time.

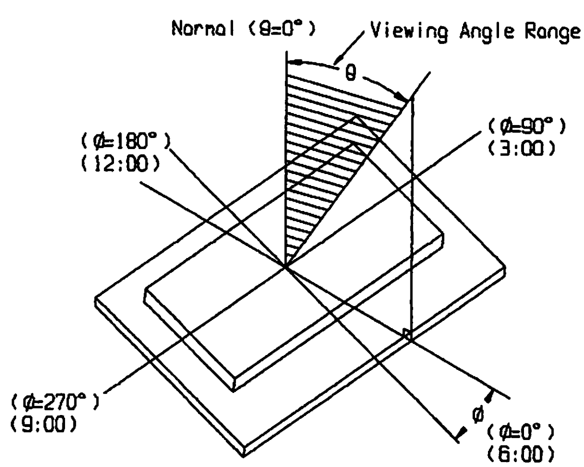


Note2: Definition of contrast ratio 'Cr' .

$$Cr = \frac{\text{Brightness of non-selected segment(B2)}}{\text{Brightness of selected segment(B1)}}$$



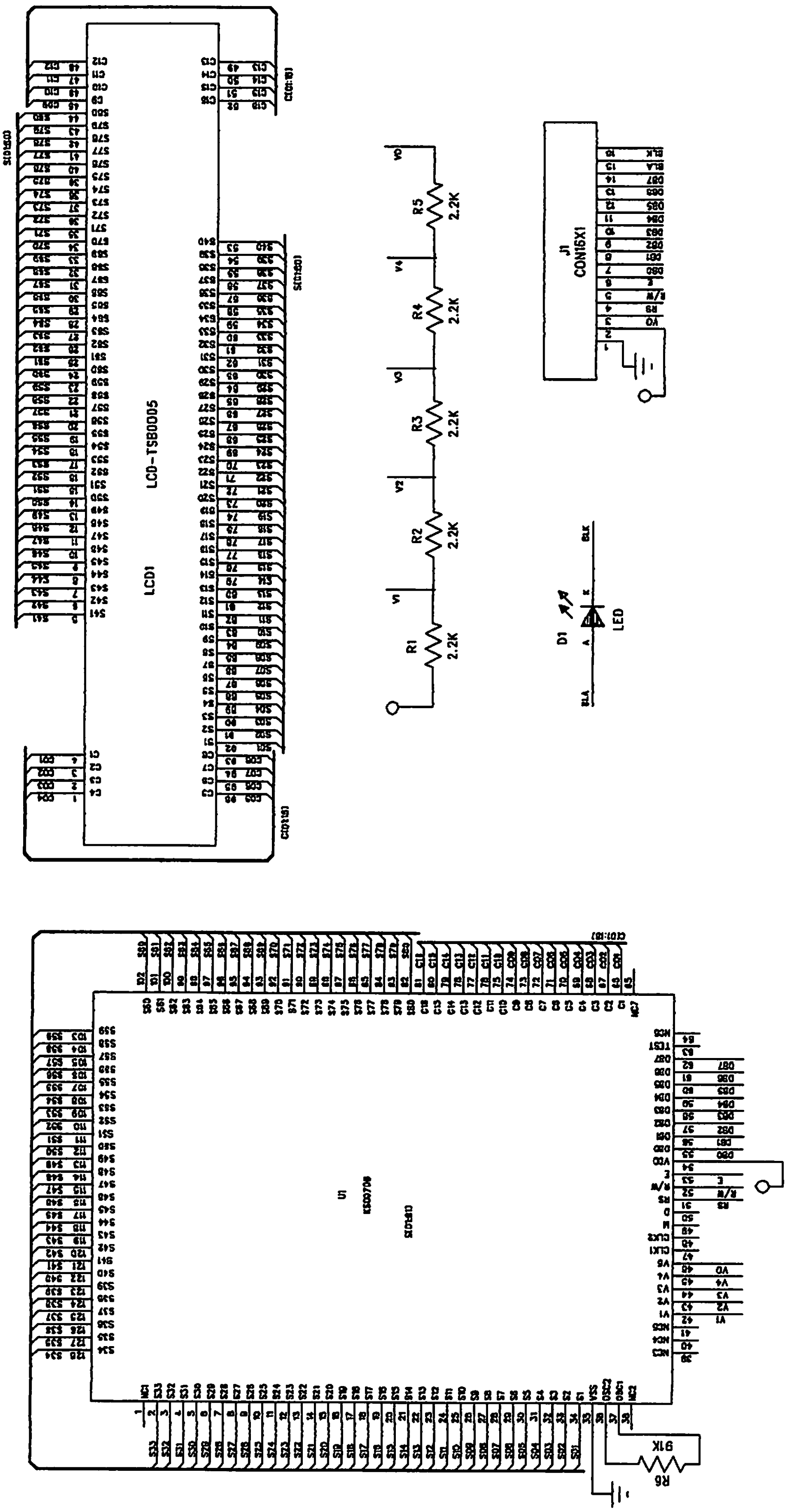
Note3: Definition of viewing angle range 'θ'.



■ INTERFACE PIN CONNECTIONS

Pin NO.	Symbol	Level	Description
1	VSS	0V	Ground
2	VDD	5.0V	Supply voltage for logic
3	VO	---	Input voltage for LCD
4	RS	H/L	H : Data, L : Instruction code
5	R/W	H/L	H : Read mode, L : Write mode
6	E	H, H → L	Chip enable signal
7	DB0	H/L	Data bit 0
8	DB1	H/L	Data bit 1
9	DB2	H/L	Data bit 2
10	DB3	H/L	Data bit 3
11	DB4	H/L	Data bit 4
12	DB5	H/L	Data bit 5
13	DB6	H/L	Data bit 6
14	DB7	H/L	Data bit 7
15	A	---	Backlight anode
16	K	---	Backlight cathode

■ CIRCUIT DIAGRAM



■ RELIABILITY

◆ Content of Reliability Test

No.	Test Item	Content of Test	Test Condition	Applicable Standard
Environmental Test				
1	High temperature storage	Endurance test applying the high storage temperature for a long time.	60 °C 200 hrs	------
2	Low temperature storage	Endurance test applying the low storage temperature for a long time.	-10 °C 200 hrs	------
3	High temperature operation	Endurance test applying the electric stress (Voltage & Current) and the thermal stress to the element for a long time.	50 °C 200 hrs	------
4	Low temperature operation	Endurance test applying the electric stress under low temperature for a long time.	0 °C 200 hrs	------
5	High temperature / Humidity storage	Endurance test applying the high temperature and high humidity storage for a long time.	60 °C , 90 %RH 96 hrs	MIL-202E-103B JIS-C5023
6	High temperature / Humidity operation	Endurance test applying the electric stress (Voltage & Current) and temperature / humidity stress to the element for a long time.	40 °C , 90 %RH 96 hrs	MIL-202E-103B JIS-C5023
7	Temperature cycle	Endurance test applying the low and high temperature cycle. -10°C 30min ⇄ 25°C 5min. ⇄ 60°C 30min ←— 1 cycle —→	-10°C / 60°C 10 cycles	------
Mechanical Test				
8	Vibration test	Endurance test applying the vibration during transportation and using.	10~22Hz → 1.5mmp-p 22~500Hz → 1.5G Total 0.5hrs	MIL-202E-201A JIS-C5025 JIS-C7022-A-10
9	Shock test	Constructional and mechanical endurance test applying the shock during transportation.	50G half sign wave 11 msedc 3 times of each direction	MIL-202E-213B
10	Atmospheric pressure test	Endurance test applying the atmospheric pressure during transportation by air.	115 mbar 40 hrs	MIL-202E-105C
Others				
11	Static electricity test	Endurance test applying the electric stress to the terminal.	VS=800V , RS=1.5 kΩ CS=100 pF 1 time	MIL-883B-3015.1

*** Supply voltage for logic system = 5V. Supply voltage for LCD system = Operating voltage at 25°C.

◆ Failure Judgement Criterion

Criterion Item	Test Item No.											Failure Judgment Criterion
	1	2	3	4	5	6	7	8	9	10	11	
Basic specification												Out of the Basic Specification
Electrical characteristic												Out of the DC and AC Characterstic
Mechanical characterstic												Out of the Mechanical Specification Color change : Out of Limit Apperance Specification
Optical characterstic												Out of the Apperance Standard

■ QUALITY GUARANTEE

◆ Acceptable Quality Level

Each lot should satisfy the quality level defined as follows.

- Inspection method : MIL-STD-105E LEVEL II Normal one time sampling
- AQL

Partition	AQL	Definition
A: Major	0.4%	Functional defective as product
B: Minor	1.5%	Satisfy all functions as product but not satisfy cosmetic standard

◆ Definition of 'LOT'

One lot means the delivery quantity to customer at one time.

◆ Conditions of Cosmetic Inspection

● Environmental condition

The inspection should be performed at the 1m of height from the LCD module under 2 pieces of 40W white fluorescent lamps (Normal temperature 20~25°C and normal humidity 60±15%RH).

● Inspection method

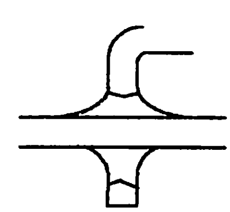
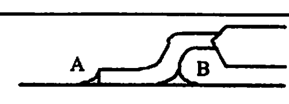
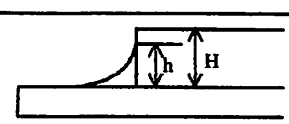
The visual check should be performed vertically at more than 30cm distance from the LCD panel.

● Driving voltage

The Vo value which the most optimal contrast can be obtained near the specified Vo in the specification. (Within ±0.5V of the typical value at 25°C.).

■ INSPECTION CRITERIA

◆ Module Cosmetic Criteria

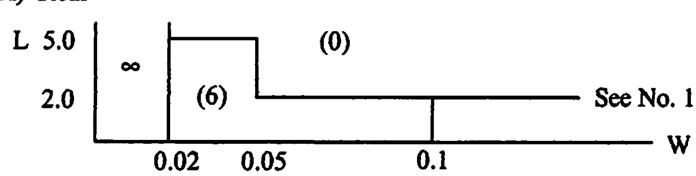
No.	Item	Judgement Criterion	Partition
1	Difference in Spec.	None allowed	Major
2	Pattern peeling	No substrate pattern peeling and floating	Major
3	Soldering defects	No soldering missing No soldering bridge No cold soldering	Major Major Minor
4	Resist flaw on substrate	Invisible copper foil (Ø0.5mm or more) on substrate pattern	Minor
5	Accretion of metallic Foreign matter	No soldering dust No accretion of metallic foreign matters (Not exceed Ø0.2mm)	Minor Minor
6	Stain	No stain to spoil cosmetic badly	Minor
7	Plate discoloring	No plate fading, rusting and discoloring	Minor
8	Solder amount 1. Lead parts	a. Soldering side of PCB Solder to form a 'Filet' all around the lead. Solder should not hide the lead form perfectly. (too much) b. Components side (In case of 'Through Hole PCB')  Solder to reach the Components side of PCB.	Minor
	2. Flat packages	Either 'toe' (A) or 'heal' (B) of the lead to be covered by 'Filet'. Lead form to be assume over solder. 	Minor
	3. Chips	(3/2) H ≥ h ≥ (1/2) H 	Minor

◆ Screen Cosmetic Criteria (Non-Operating)

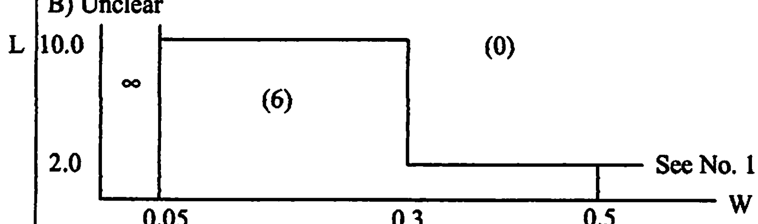
<table>
<tr><th>No.</th><th>Defect</th><th>Judgement Criterion</th><th>Partition</th></tr>
<tr><td>1</td><td>Spots</td><td>In accordance with Screen Cosmetic Criteria (Operating) No.1.</td><td>Minor</td></tr>
<tr><td>2</td><td>Lines</td><td>In accordance with Screen Cosmetic Criteria (Operating) No.2.</td><td>Minor</td></tr>
<tr><td>3</td><td>Bubbles in polarizer</td><td><table>
<tr><th>Size : d mm</th><th>Acceptable Qty in active area</th></tr>
<tr><td>d ≤ 0.3</td><td>Disregard</td></tr>
<tr><td>0.3 < d ≤ 1.0</td><td>3</td></tr>
<tr><td>1.0 < d ≤ 1.5</td><td>1</td></tr>
<tr><td>1.5 < d</td><td>0</td></tr>
</table></td><td>Minor</td></tr>
<tr><td>4</td><td>Scratch</td><td>In accordance with spots and lines operating cosmetic criteria. When the light reflects on the panel surface, the scratches are not to be remarkable.</td><td>Minor</td></tr>
<tr><td>5</td><td>Allowable density</td><td>Above defects should be separated more than 30mm each other.</td><td>Minor</td></tr>
<tr><td>6</td><td>Coloration</td><td>Not to be noticeable coloration in the viewing area of the LCD panels.
Back-lit type should be judged with back-lit on state only.</td><td>Minor</td></tr>
<tr><td>7</td><td>Contamination</td><td>Not to be noticeable.</td><td>Minor</td></tr>
</table>

◆ Screen Cosmetic Criteria (Operating)

<table>
<tr><th>No.</th><th>Defect</th><th>Judgement Criterion</th><th>Partition</th></tr>
<tr><td>1</td><td>Spots</td><td>A) Clear
<table>
<tr><th>Size : d mm</th><th>Acceptable Qty in active area</th></tr>
<tr><td>d ≤ 0.1</td><td>Disregard</td></tr>
<tr><td>0.1 < d ≤ 0.2</td><td>6</td></tr>
<tr><td>0.2 < d ≤ 0.3</td><td>2</td></tr>
<tr><td>0.3 < d</td><td>0</td></tr>
</table>
Note : Including pin holes and defective dots which must be within one pixel size.
B) Unclear
<table>
<tr><th>Size : d mm</th><th>Acceptable Qty in active area</th></tr>
<tr><td>d ≤ 0.2</td><td>Disregard</td></tr>
<tr><td>0.2 < d ≤ 0.5</td><td>6</td></tr>
<tr><td>0.5 < d ≤ 0.7</td><td>2</td></tr>
<tr><td>0.7 < d</td><td>0</td></tr>
</table></td><td>Minor</td></tr>
<tr><td>2</td><td>Lines</td><td>A) Clear

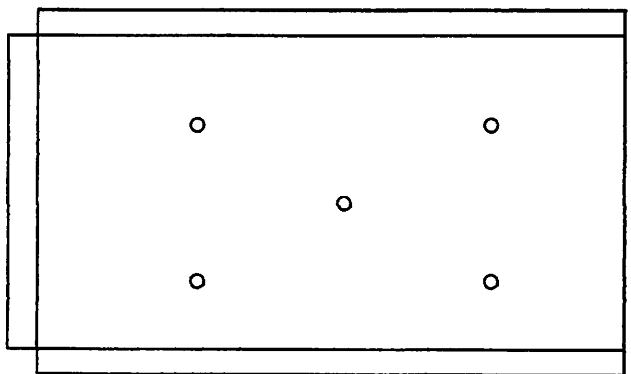


Note : ( ) - Acceptable Qty in active area
L - Length (mm)
W - Width (mm)
∞ - Disregard
B) Unclear


</td><td>Minor</td></tr>
</table>

'Clear' = The shade and size are not changed by Vo.
'Unclear' = The shade and size are changed by Vo.

◆ Screen Cosmetic Criteria (Operating) (Continued)

No.	Defect	Judgement Criterion	Partition
3	Rubbing line	Not to be noticeable.	
4	Allowable density	Above defects should be separated more than 10mm each other.	Minor
5	Rainbow	Not to be noticeable.	Minor
6	Dot size	To be 95% ~ 105% of the dot size (Typ.) in drawing. Partial defects of each dot (ex. pin-hole) should be treated as 'spot'. (see *Screen Cosmetic Criteria (Operating) No.1*)	Minor
7	Uneven brightness (only back-lit type module)	Uneven brightness must be BMAX / BMIN ≤ 2 - BMAX : Max. value by measure in 5 points - BMIN : Min. value by measure in 5 points Divide active area into 4 vertically and horizontally. Measure 5 points shown in the following figure.  O : Measuring points	Minor

Note :

(1) Size : d = (long length + short length) / 2

(2) The limit samples for each item have priority.

(3) Complexed defects are defined item by item, but if the number of defects are defined in above table, the total number should not exceed 10.

(4) In case of 'concentration', even the spots or the lines of 'disregarded' size should not allowed. Following three situations should be treated as 'concentration'.

- 7 or over defects in circle of Ø5mm.
- 10 or over defects in circle of Ø10mm.
- 20 or over defects in circle of Ø20mm.

■ PRECAUTIONS FOR USING LCD MODULES

◆ Handing Precautions

(1) The display panel is made of glass. Do not subject it to a mechanical shock by dropping it or impact.

(2) If the display panel is damaged and the liquid crystal substance leaks out, be sure not to get any in your mouth. If the substance contacts your skin or clothes, wash it off using soap and water.

(3) Do not apply excessive force to the display surface or the adjoining areas since this may cause the color tone to vary.

(4) The polarizer covering the display surface of the LCD module is soft and easily scratched. Handle this polarizer carefully.

(5) If the display surface becomes contaminated, breathe on the surface and gently wipe it with a soft dry cloth. If it is heavily contaminated, moisten cloth with one of the following solvents :

- Isopropyl alcohol
- Ethyl alcohol

(6) Solvents other than those above-mentioned may damage the polarizer. Especially, do not use the following.

- Water
- Ketone
- Aromatic solvents

(7) Exercise care to minimize corrosion of the electrode. Corrosion of the electrodes is accelerated by water droplets, moisture condensation or a current flow in a high-humidity environment.

(8) Install the LCD Module by using the mounting holes. When mounting the LCD module make sure it is free of twisting, warping and distortion. In particular, do not forcibly pull or bend the I/O cable or the backlight cable.

(9) Do not attempt to disassemble or process the LCD module.

(10) NC terminal should be open. Do not connect anything.

(11) If the logic circuit power is off, do not apply the input signals.

(12) To prevent destruction of the elements by static electricity, be careful to maintain an optimum work environment.

- Be sure to ground the body when handling the LCD modules.
- Tools required for assembling, such as soldering irons, must be properly grounded.
- To reduce the amount of static electricity generated, do not conduct assembling and other work under dry conditions.
- The LCD module is coated with a film to protect the display surface. Exercise care when peeling off this protective film since static electricity may be generated.

◆ Storage Precautions

When storing the LCD modules, avoid exposure to direct sunlight or to the light of fluorescent lamps. Keep the modules in bags (avoid high temperature / high humidity and low temperatures below 0°C). Whenever possible, the LCD modules should be stored in the same conditions in which they were shipped from our company.

◆ Others

Liquid crystals solidify under low temperature (below the storage temperature range) leading to defective orientation or the generation of air bubbles (black or white). Air bubbles may also be generated if the module is subject to a low temperature.

If the LCD modules have been operating for a long time showing the same display patterns, the display patterns may remain on the screen as ghost images and a slight contrast irregularity may also appear. A normal operating status can be regained by suspending use for some time. It should be noted that this phenomenon does not adversely affect performance reliability.

To minimize the performance degradation of the LCD modules resulting from destruction caused by static electricity etc., exercise care to avoid holding the following sections when handling the modules.

- Exposed area of the printed circuit board.
- Terminal electrode sections.

■ USING LCD MODULES

◆ Liquid Crystal Display Modules

LCD is composed of glass and polarizer. Pay attention to the following items when handling.

(1) Please keep the temperature within specified range for use and storage. Polarization degradation, bubble generation or polarizer peel-off may occur with high temperature and high humidity.

(2) Do not touch, push or rub the exposed polarizers with anything harder than an HB pencil lead (glass, tweezers, etc.).

(3) N-hexane is recommended for cleaning the adhesives used to attach front/rear polarizers and reflectors made of organic substances which will be damaged by chemicals such as acetone, toluene, ethanol and isopropylalcohol.

(4) When the display surface becomes dusty, wipe gently with absorbent cotton or other soft material like chamois soaked in petroleum benzin. Do not scrub hard to avoid damaging the display surface.

(5) Wipe off saliva or water drops immediately, contact with water over a long period of time may cause deformation or color fading.

(6) Avoid contacting oil and fats.

(7) Condensation on the surface and contact with terminals due to cold will damage, stain or dirty the polarizers. After products are tested at low temperature they must be warmed up in a container before coming is contacting with room temperature air.

(8) Do not put or attach anything on the display area to avoid leaving marks on.

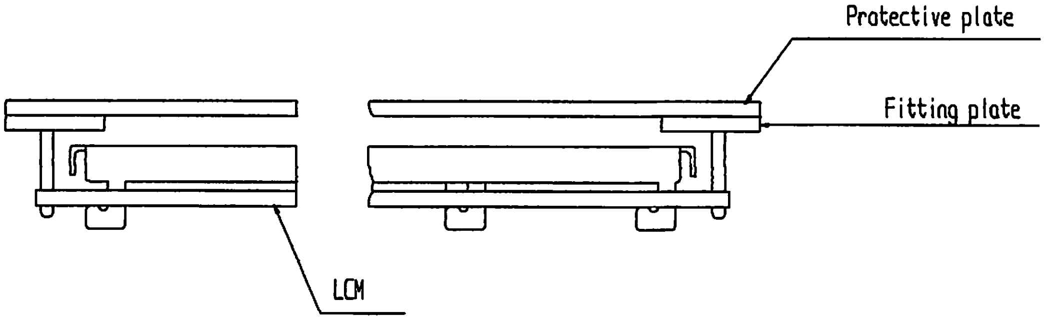
(9) Do not touch the display with bare hands. This will stain the display area and degradate insulation between terminals (some cosmetics are determinated to the polarizers).

(10) As glass is fragile. It tends to become or chipped during handling especially on the edges. Please avoid dropping or jarring.

◆ Installing LCD Modules

The hole in the printed circuit board is used to fix LCM as shown in the picture below. Attend to the following items when installing the LCM.

(1) Cover the surface with a transparent protective plate to protect the polarizer and LC cell.



(2) When assembling the LCM into other equipment, the spacer to the bit between the LCM and the fitting plate should have enough height to avoid causing stress to the module surface, refer to the individual specifications for measurements. The measurement tolerance should be ±0.1mm.

◆ Precaution for Handing LCD Modules

Since LCM has been assembled and adjusted with a high degree of precision, avoid applying excessive shocks to the module or making any alterations or modifications to it.

(1) Do not alter, modify or change the the shape of the tab on the metal frame.

(2) Do not make extra holes on the printed circuit board, modify its shape or change the positions of components to be attached.

(3) Do not damage or modify the pattern writing on the printed circuit board.

(4) Absolutely do not modify the zebra rubber strip (conductive rubber) or heat seal connector.

(5) Except for soldering the interface, do not make any alterations or modifications with a soldering iron.

(6) Do not drop, bend or twist LCM.

◆ Electro-Static Discharge Control

Since this module uses a CMOS LSI, the same careful attention should be paid to electrostatic discharge as for an ordinary CMOS IC.

(1) Make certain that you are grounded when handing LCM.

(2) Before remove LCM from its packing case or incorporating it into a set, be sure the module and your body have the same electric potential.

(3) When soldering the terminal of LCM, make certain the AC power source for the soldering iron does not leak.

(4) When using an electric screwdriver to attach LCM, the screwdriver should be of ground potentiality to minimize as much as possible any transmission of electromagnetic waves produced sparks coming from the commutator of the motor.

(5) As far as possible make the electric potential of your work clothes and that of the work bench the ground potential.

(6) To reduce the generation of static electricity be careful that the air in the work is not too dried. A relative humidity of 50%-60% is recommended.

◆ Precaution for soldering to the LCM

(1) Observe the following when soldering lead wire, connector cable and etc. to the LCM.

- Soldering iron temperature : 280°C ± 10°C.
- Soldering time : 3-4 sec.
- Solder : eutectic solder.

If soldering flux is used, be sure to remove any remaining flux after finishing to soldering operation. (This does not apply in the case of a non-halogen type of flux.) It is recommended that you protect the LCD surface with a cover during soldering to prevent any damage dur to flux spatters.

(2) When soldering the electroluminescent panel and PC board, the panel and board should not be detached more than three times. This maximum number is determined by the temperature and time conditions mentioned above, though there may be some variance depending on the temperature of the soldering iron.

(3) When remove the electoluminescent panel from the PC board, be sure the solder has completely melted, the soldered pad on the PC board could be damaged.

◆ Precautions for Operation

(1) Viewing angle varies with the change of liquid crystal driving voltage (Vo). Adjust Vo to show the best contrast.

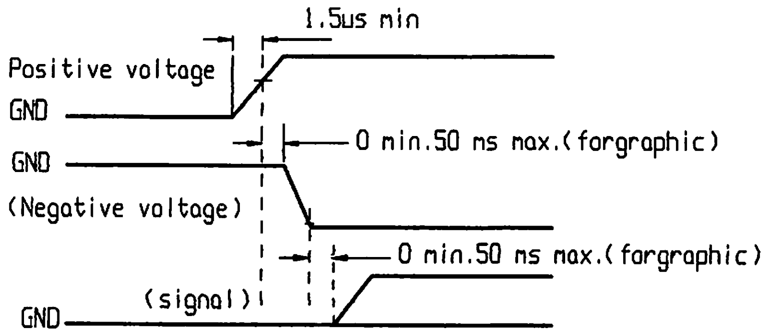
(2) Driving the LCD in the voltage above the limit shortens its life.

(3) Response time is greatly delayed at temperature below the operating temperature range. However, this does not mean the LCD will be out of the order. It will recover when it returns to the specified temperature range.

(4) If the display area is pushed hard during operation, the display will become abnormal. However, it will return to normal if it is turned off and then back on.

(5) Condensation on terminals can cause an electrochemical reaction disrupting the terminal circuit. Therefore, it must be used under the relative condition of 40°C , 50% RH.

(6) When turning the power on, input each signal after the positive/negative voltage becomes stable.



◆ Storage

When storing LCDs as spares for some years, the following precaution are necessary.

(1) Store them in a sealed polyethylene bag. If properly sealed, there is no need for dessicant.

(2) Store them in a dark place. Do not expose to sunlight or fluorescent light, keep the temperature between 0°C and 35°C.

(3) The polarizer surface should not come in contact with any other objects. (We advise you to store them in the container in which they were shipped.)

(4) Environmental conditions :

- Do not leave them for more than 168hrs. at 60°C.
- Should not be left for more than 48hrs. at -20°C.

◆ Safety

(1) It is recommended to crush damaged or unnecessary LCDs into pieces and wash them off with solvents such as acetone and ethanol, which should later be burned.

(2) If any liquid leakes out of a damaged glass cell and comes in contact with the hands, wash off thoroughly with soap and water.

◆ Limited Warranty

Unless agreed between DISPLAYTECH and customer, DISPLAYTECH will replace or repair any of its LCD modules which are found to be functionally defective when inspected in accordance with DISPLAYTECH LCD acceptance standards (copies available upon request) for a period of one year from date of shipments. Cosmetic/visual defects must be returned to DISPLAYTECH within 90 days of shipment. Confirmation of such date shall be based on freight documents. The warranty liability of DISPLAYTECH limited to repair and/or replacement on the terms set forth above. DISPLAYTECH will not be responsible for any subsequent or consequential events.

◆ Return LCM under warranty

No warranty can be granted if the precautions stated above have been disregarded. The typical examples of violations are :

- Broken LCD glass.
- PCB eyelet's damaged or modified.
- PCB conductors damaged.
- Circuit modified in any way, including addition of components.
- PCB tampered with by grinding, engraving or painting varnish.
- soldering to or modifying the bezel in any manner.

Module repairs will be invoiced to the customer upon mutual agreement. Modules must be returned with sufficient description of the failures or defects. Any connectors or cable installed by the customer must be removed completely without damaging the PCB eyelet's, conductors and terminals.

5mm Infrared LED

MODEL NO : HIR4254C

Features :

- High radiant intensity
- Peak wavelength λp=850nm
- View angle 60°
- High reliability

Description :

- EVERLIGHT's Infrared Emitting Diode (HIR4254C) is a high intensity diode, molded in a water clear plastic package.

  The device is spectrally matched with phototransistor, photodiode and infrared receiver module.

Applications :

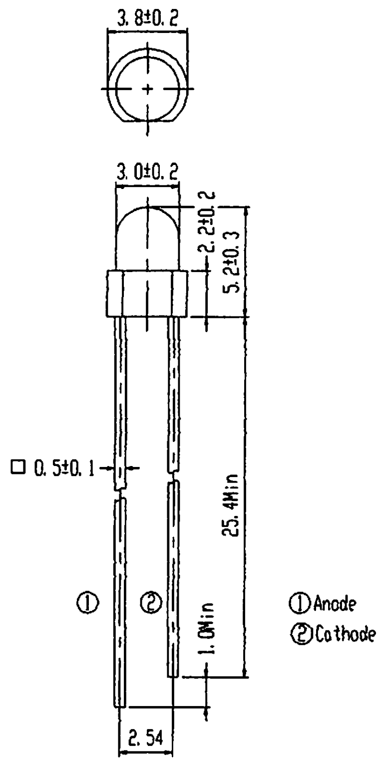
- Free air transmission system
- Optoelectronic switch
- Infrared remote control units with high power requirement
- Floppy disk drive

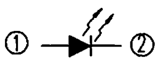
PART NO.	CHIP MATERIAL	LENS COLOR
HIR	GaAlAs	Water clear

5mm Infrared LED

MODEL NO : HIR4254C

Package Dimensions :





Notes :

1.All dimensions are in millimeter.
2.Protruded resin under flange 1.5 mm Max.
3.Lead spacing is measured where the lead emerge from the package.
4.Lens color：Water clear.
5.Above specification may be changed without notice. EVERLIGHT will reserve authority on material change for above specification.
6.These specification sheets include materials protected under copyright of EVERLIGHT corporation . Please don't reproduce or cause anyone to reproduce them without EVERLIGHT's consent.
7.When using this product , please observe the absolute maximum ratings and the instructions for use outlined in these specification sheets. EVERIGHT assumes no responsibility for any damage resulting from use of the product which does not comply with the absolute maximum ratings and the instructions included in these specification sheets.

5mm Infrared LED

MODEL NO : HIR4254C

■ Absolute Maximum Ratings at T_A = 25℃

Parameter	Symbol	Rating	Unit	Notice
Continuous Forward Current	I_F	50	mA	
Peak Forward Current Pulse width=100μs,Duty cycle=1%	I_{FP}	1.0	A	
Reverse Voltage	V_R	5	V	
Operating Temperature	Topr	-40 ~ +85	℃	
Storage Temperature	Tstg	-40 ~ +85	℃	
Soldering Temperature	Tsol	260	℃	4mm from mold body less than 5 seconds
Power Dissipation at(or below) 25℃ Free Air Temperature	Pd	100	mW	

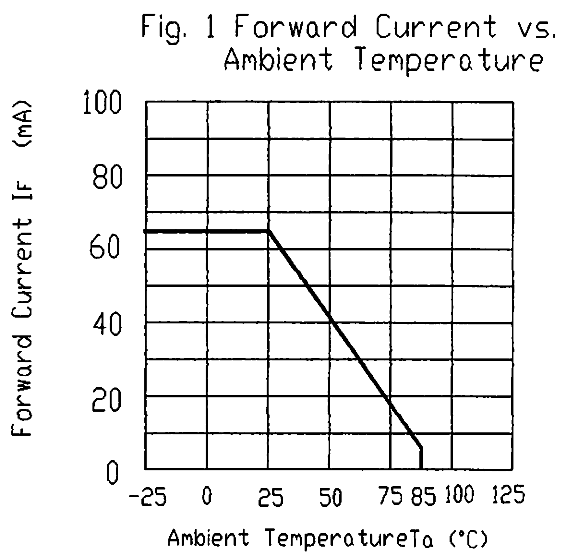
■ Electronic Optical Characteristics :

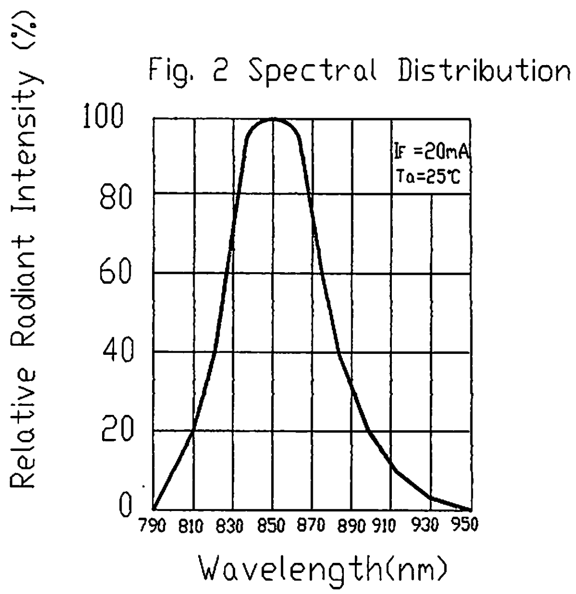
Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Radiant Intensity	Ee	2.8	4.5	----	mW/sr	I_F=20mA
		----	20	----		I_F=100mA,tp=100μs, t_p/T=0.01
		----	250	----		I_F=1A,tp=100μs, t_p/T=0.01
Peak Wavelength	λ_P	----	850	----	nm	I_F=20mA
Spectral Bandwidth	$\Delta\lambda$	---	45	---	nm	I_F=20mA
Forward Voltage	V_F	---	1.45	1.65	V	I_F=20mA
		---	1.80	2.40		I_F=100mA,tp=100μs, t_p/T=0.01
		---	4.10	5.25		I_F=1A,tp=100μs, t_p/T=0.01
Reverse Current	I_R	---	---	10	μA	V_R=5V
View Angle	2Θ1/2	----	60	----	deg	I_F=20mA

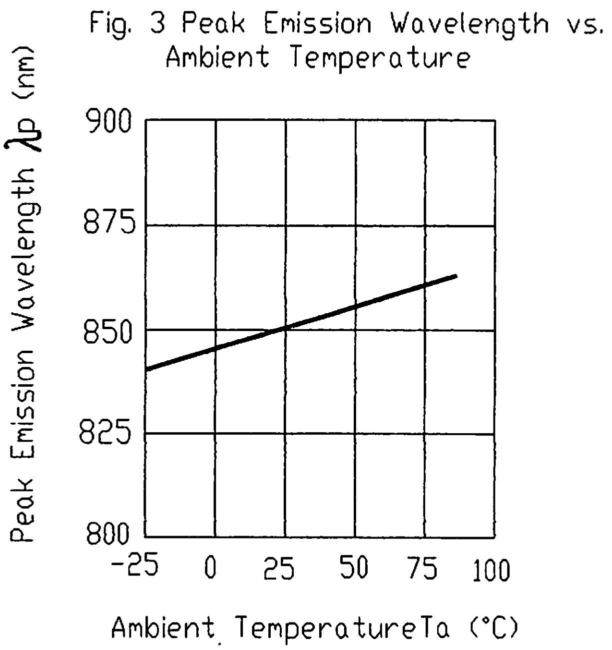
5mm Infrared LED

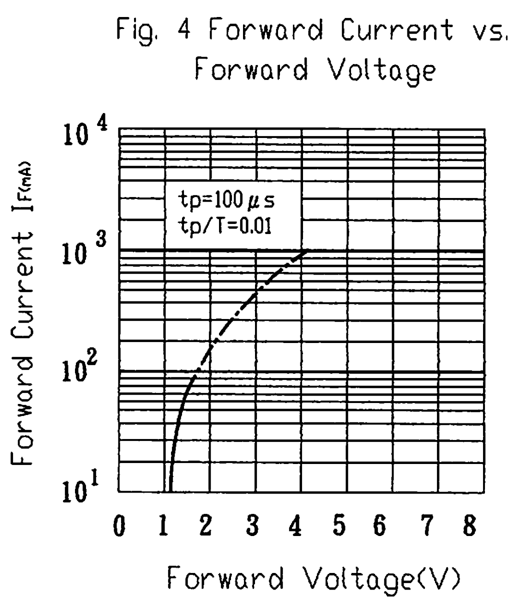
MODEL NO : HIR4254C

Typical Electrical/Optical/Characteristics Curves









5mm Infrared LED

MODEL NO : HIR4254C

Typical Electrical/Optical/Characteristics Curves

Fig. 5 Relative Intensity vs. Forward Current

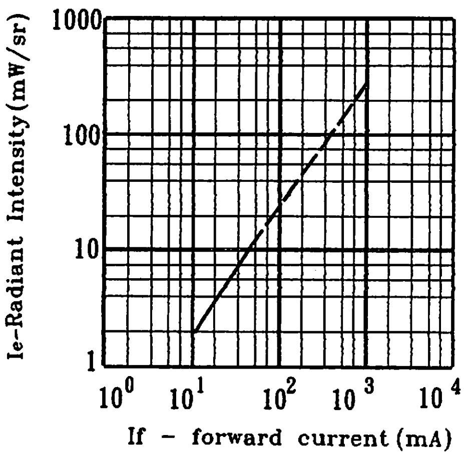


Fig. 6 Relative Radiant Intensity vs. Angular Displacement

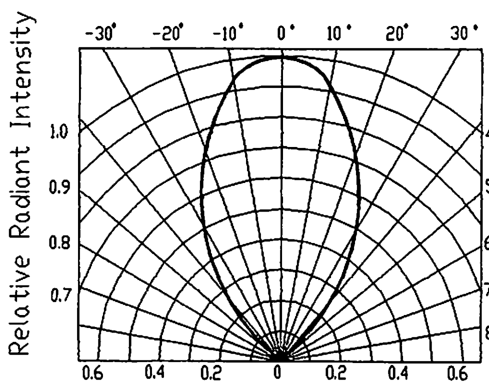


Fig. 7 Relative Intensity vs. Ambient Temperature(℃)

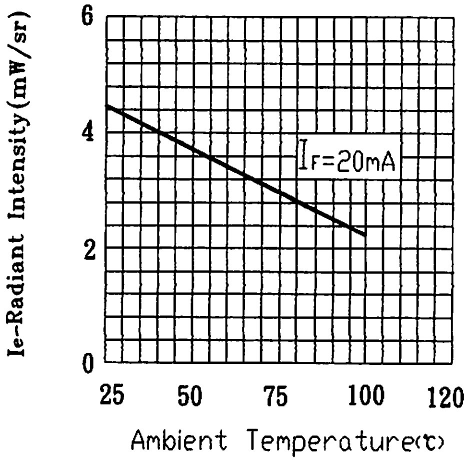
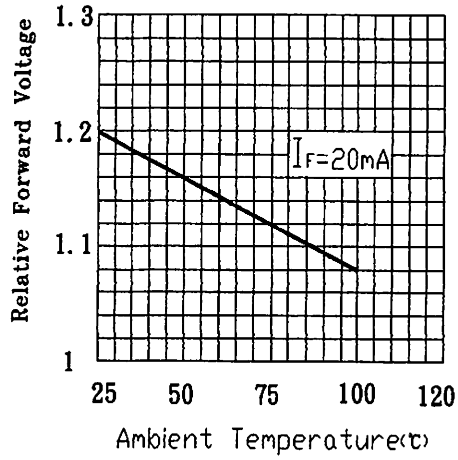


Fig. 8 Forward Current vs. Ambient Temperature(℃)



5mm Infrared LED

MODEL NO : HIR4254C

■ Reliability Test Item And Condition

The reliability of products shall be satisfied with items listed below.
Confidence level:90%
LTPD:10%

NO.	Item	Test Conditions	Test Hours/ Cycle	Sample Size	Failure Judgement Criteria	Ac/Re
1	Solder Heat	TEMP : 260℃ ±5 ℃	5 sec	22 PCs		0/1
2	Temperature Cycle	H : +85℃ 30 min ↕ 5 min L : -55℃ 30 min	50 cycle	22 PCs	$I_R \geq U \times 2$ $E_e \leq L \times 0.8$ $V_F \geq U \times 1.2$	0/1
3	Thermal Shock	H : +100℃ 5 min ↕ 10 sec L : -10℃ 30 min	50 cycle	22 PCs	U :Upper specification limit L :Lower specification limit	0/1
4	High Temperature Storage	TEMP. : +100℃	1000 hrs	22 PCs		0/1
5	Low Temperature Storage	TEMP. : -55℃	1000 hrs	22 PCs		0/1
6	DC Operating Life	I_F=20mA	1000 hrs	22 PCs		0/1
7	High Temperature / High Humidity	85℃ / 85% R.H.	1000 hrs	22 PCs		0/1

5mm Infrared LED

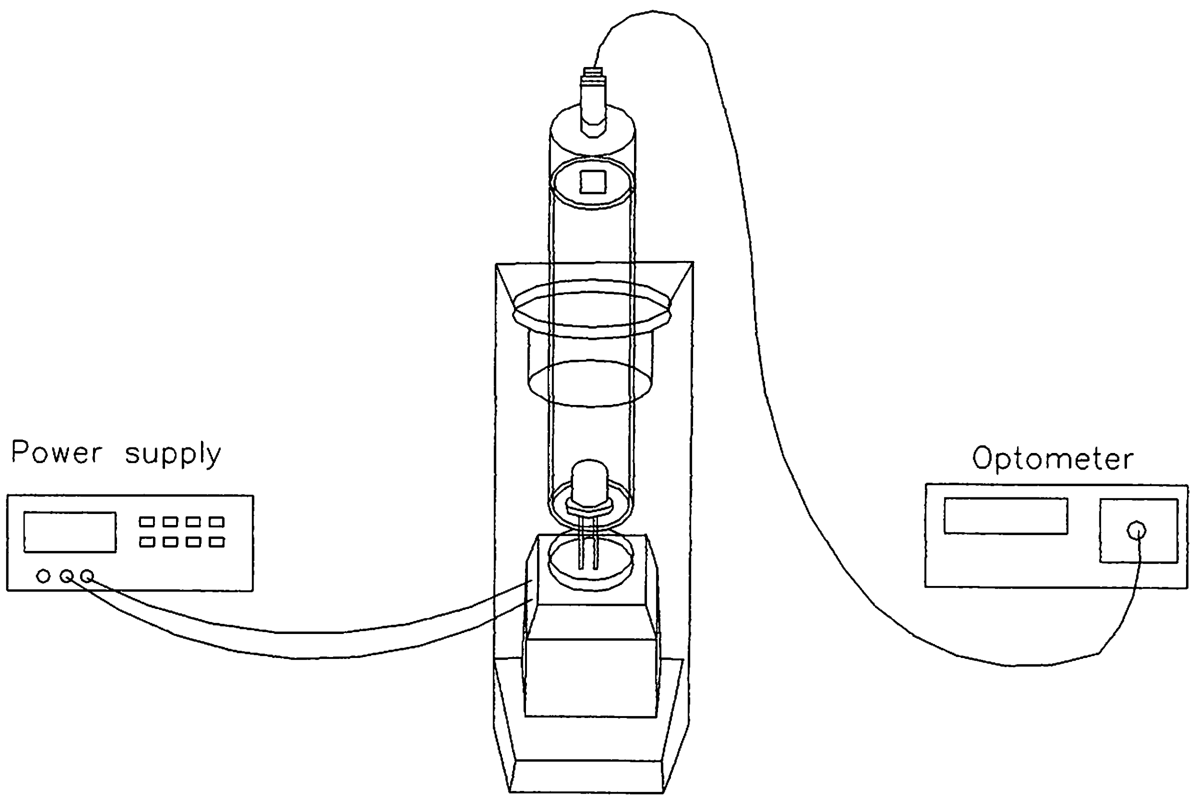
MODEL NO : HIR4254C

Test Method For Power :

Condition : I_F=20 mA

Test Item : Radiant Intensity

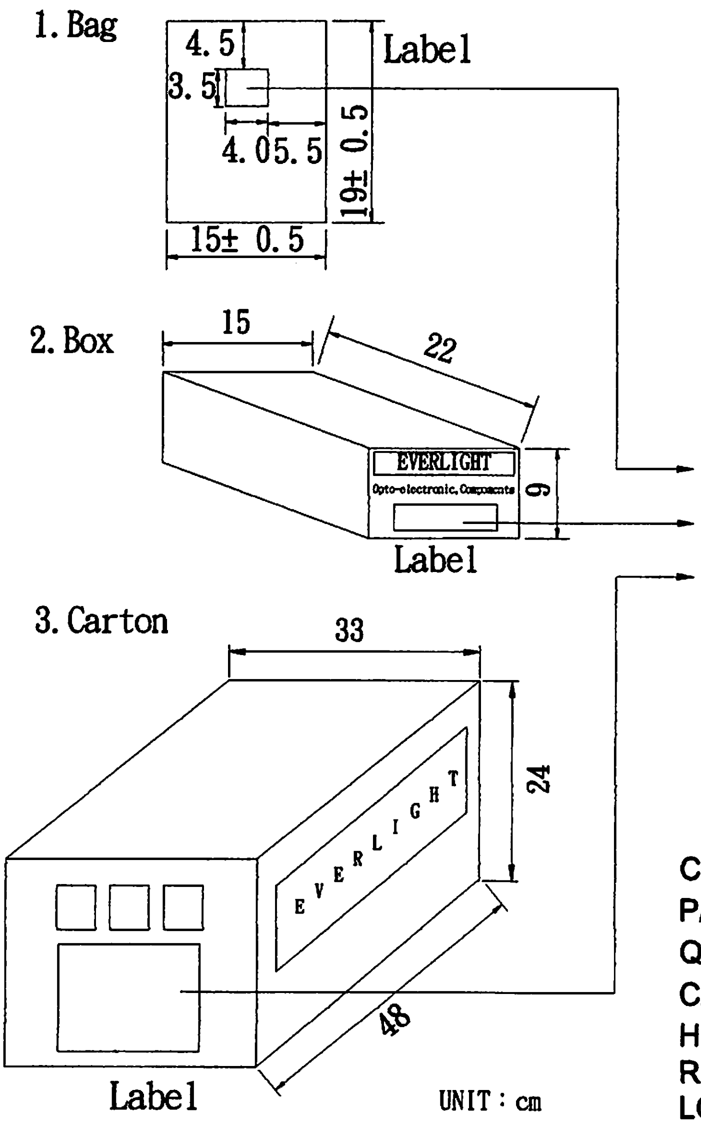
Unit : mW/sr



5mm Infrared LED

MODEL NO : HIR4254C

Packing Specifications

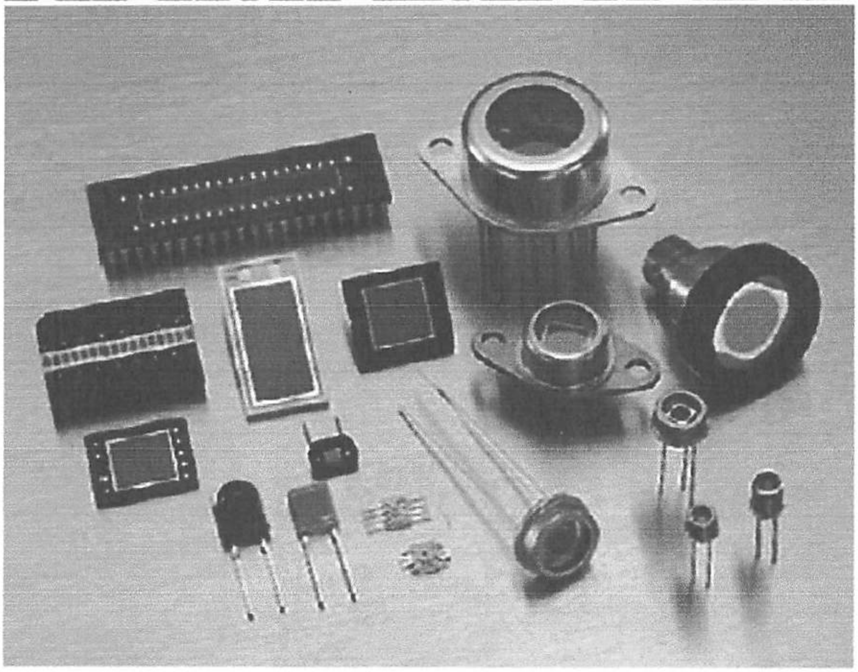


CPN : Customer's Production Number
P/N : Production Number
QTY : Packing Quantity
CAT : Ranks
HUE : Peak Wavelength
REF : Reference
LOT NO : Lot Number
MADE IN TAIWAN : Production place

Packing Quantity Specification

1. 500Pcs/1Bag，6 Bags/1Box
2. 10 Boxes/1Carton

HAMAMATSU



Photodiode Technical Information

Table of Contents

Description of terms

1. Spectral response
The photocurrent produced by a given level of incident light varies with the wavelength. This relation between the photoelectric sensitivity and wavelength is referred to as the spectral response characteristic and is expressed in terms of photo sensitivity, quantum efficiency, etc.

2. Photo sensitivity: S
This measure of sensitivity is the ratio of radiant energy expressed in watts (W) incident on the device, to the resulting photocurrent expressed in amperes (A). It may be represented as either an absolute sensitivity (A/W) or as a relative sensitivity normalized for the sensitivity at the peak wavelength, usually expressed in percent (%) with respect to the peak value. For the purpose of this catalog, the photo sensitivity is represented as the absolute sensitivity, and the spectral response range is defined as the region in which the relative sensitivity is higher than 5 % of the peak value.

3. Quantum efficiency: QE
The quantum efficiency is the number of electrons or holes that can be detected as a photocurrent divided by the number of the incident photons. This is commonly expressed in percent (%). The quantum efficiency and photo sensitivity S have the following relationship at a given wavelength (nm):

$$QE = \frac{S \times 1240}{\lambda} \times 100\ [\%] \quad \text{............ (1)}$$

where S is the photo sensitivity in A/W at a given wavelength and λ is the wavelength in nm (nanometers).

4. Short circuit current: Isc, open circuit voltage: Voc
The short circuit current is the output current which flows when the load resistance is 0 and is nearly proportional to the device active area. This is often called "white light sensitivity" with regards to the spectral response. This value is measured with light from a tungsten lamp of 2856 K distribution temperature (color temperature), providing 100 time illuminance. The open circuit voltage is a photovoltaic voltage developed when the load resistance is infinite and exhibits a constant value independent of the device active area.

5. Infrared sensitivity ratio
This is the ratio of the output current I_R measured with a light flux (2856 K, 100 time) passing through an R-70 (t=2.5 mm) infrared filter to the short circuit current Isc measured without the filter. It is commonly expressed in percent, as follows:

$$\text{Infrared sensitivity ratio} = \frac{I_R}{Isc} \times 100\ [\%] \quad \text{............ (2)}$$

6. Dark current: I_D, shunt resistance: Rsh
The dark current is a small current which flows when a reverse voltage is applied to a photodiode even in dark state. This is a major source of noise for applications in which a reverse voltage is applied to photodiodes (PIN photodiode, etc.). In contrast, for applications where no reverse voltage is applied, noise resulting from the shunt resistance becomes predominant. This shunt resistance is the voltage-to-current ratio in the vicinity of 0 V and defined as follows:

$$Rsh = \frac{10\ [mV]}{I_D}\ [\Omega] \quad \text{............ (3)}$$

where I_D is the dark current at V_R=10 mV.

7. Terminal capacitance: Ct
An effective capacitor is formed at the PN junction of a photodiode. Its capacitance is termed the junction capacitance and is the major factor in determining the response speed of the photodiode. And it probably causes a phenomenon of gain peaking in I-V conversion circuit using operational amplifier. In Hamamatsu, the terminal capacitance including this junction capacitance plus package stray capacitance is listed.

8. Rise time: tr
This is the measure of the time response of a photodiode to a stepped light input, and is defined as the time required for the output to change from 10 % to 90 % of the steady output level. The rise time depends on the incident light wavelength and load resistance. For the purpose of data sheets, it is measured with a light source of GaAsP LED (655 nm) or GaP LED (560 nm) and load resistance of 1 kΩ.

9. Cut-off frequency: fc
This is the measure used to evaluate the time response of high-speed APD (avalanche photodiodes) and PIN photodiodes to a sinewave-modulated light input. It is defined as the frequency at which the photodiode output decreases by 3 dB from the output at 100 kHz. The light source used is a laser diode (830 nm) and the load resistance is 50 Ω. The rise time tr has a relation with the cut-off frequency fc as follows:

$$tr = \frac{0.35}{fc} \quad \text{............ (4)}$$

10. NEP (Noise Equivalent Power)
The NEP is the amount of light equivalent to the noise level of a device. Stated differently, it is the light level required to obtain a signal-to-noise ratio of unity. In data sheets lists the NEP values at the peak wavelength λp. Since the noise level is proportional to the square root of the frequency bandwidth, the NEP is measured at a bandwidth of 1 Hz.

$$NEP\ [W/Hz^{1/2}] = \frac{\text{Noise current } [A/Hz^{1/2}]}{\text{Photo sensitivity at } \lambda p\ [A/W]} \quad \text{............ (5)}$$

11. Maximum reverse voltage: V_R Max.
Applying a reverse voltage to a photodiode triggers a breakdown at a certain voltage and causes severe deterioration of the device performance. Therefore the absolute maximum rating is specified for reverse voltage at the voltage somewhat lower than this breakdown voltage. The reverse voltage shall not exceed the maximum rating, even instantaneously.

Reference

● Physical constant

Constant	Symbol	Value	Unit
Electron charge	e or q	1.602×10^{-19}	c
Speed of light in vacuum	c	2.998×10^{8}	m/s
Planck's constant	h	6.626×10^{-34}	Js
Boltzmann's constant	k	1.381×10^{-23}	J/K
Room temperature thermal energy	KT (T=300 K)	0.0259	eV
1 eV energy	eV	1.602×10^{-19}	J
Wavelength in vacuum corresponding to 1 eV	-	1240	nm
Dielectric constant of vacuum	ε o	8.854×10^{-12}	F/m
Dielectric constant of silicon	ε si	Approx. 12	-
Dielectric constant of silicon oxide	ε ox	Approx. 4	-
Energy gap of silicon	Eg	Approx. 1.12 (T=25 °C)	eV

12. D* (Detectivity: detection capacity)

D, which is the reciprocal of NEP, is the value used to indicate detectivity, or detection capacity. However, because the noise level is normally proportional to the square root of the sensitive area, NEP and D characteristics have improved, enabling detection of even small photo-sensitive elements. This makes it possible to observe the characteristics of materials by multiplying the square root of the sensitive area and D, with the result being used as D*. The peak wavelength is recorded in units expresseed as cm $Hz^{1/2}$ /W, as it is for the NEP.

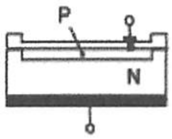
$$D^* = \frac{[\text{Effective Sensitive Area } (cm^2)]^{1/2}}{NEP}$$

Construction

Hamamatsu photodiodes can be classified by manufacturing method and construction into five types of silicon photodiodes and two types each of GaAsP and GaP photodiodes.

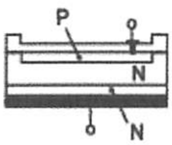
Planar Diffusion Type

An SiO2 coating is applied to the P-N junction surface, yielding a photodiode with a low level dark current.



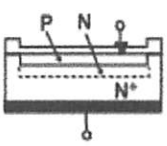
Low-Capacitance Planar Diffusion Type

A high-speed version of the planar diffusion type photodiode. This type makes use of a highly pure, high-resistance N-type material to enlarge the depletion layer and thereby decrease the junction capacitance, thus lowering the response time to 1/10 the normal value. The P layer is made extra thin for high ultraviolet response.



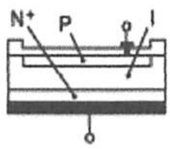
PNN+ Type

A low-resistance N+ material layer is made thick to bring the NN+ boundary close to the depletion layer. This somewhat lowers the sensitivity to infrared radiation, making this type of device useful for measurements of short wavelengths.



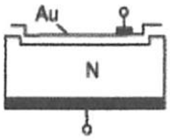
PIN Type

An improved version of the low-capacitance planar diffusion device, this type makes use of an extra high-resistance I layer between the P- and N-layers to improve response time. This type of device exhibits even further improved response time when used with reversed bias and so is designed with high resistance to breakdown and low leakage for such applications.



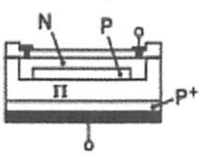
Schottky Type

A thin gold coating is sputtered onto the N material layer to form a Schottky Effect P-N junction. Since the distance from the outer surface to the junction is small, ultraviolet sensitivity is high.



Avalanche Type

If a reverse bias is applied to a P-N junction and a high-field formed within the depletion layer, photon carriers will be accelerated by this field. They will collide with atoms in the field and secondary carriers are produced, this process occurring repeatedly. This is known as the avalanche effect and, since it results in the signal being amplified, this type of device is ideal for detecting extremely low level light



Characteristic and use

Introduction

Photodiodes are semiconductor light sensors that generate a current or voltage when the P-N junction in the semiconductor is illuminated by light. The term photodiode can be broadly defined to include even solar batteries, but it usually refers to sensors used to detect the intensity of light. Photodiodes can be classified by function and construction as follows:

Photodiode type

1) PN photodiode
2) PIN photodiode
3) Schottky type photodiode
4) APD (Avalanche photodiode)

All of these types provide the following features and are widely used for the detection of the intensity, position, color and presence of light.

Features of photodiode

1) Excellent linearity with respect to incident light
2) Low noise
3) Wide spectral response
4) Mechanically rugged
5) Compact and lightweight
6) Long life

1. Principle of operation

Figure 1-1 shows a cross section of a photodiode. The P-layer material at the active surface and the N material at the substrate form a PN junction which operates as a photoelectric converter. The usual P-layer for a Si photodiode is formed by selective diffusion of boron, to a thickness of approximately 1 μm or less and the neutral region at the junction between the P- and N-layers is known as the depletion layer. By controlling the thickness of the outer P-layer, substrate N-layer and bottom N^+-layer as well as the doping concentration, the spectral response and frequency response can be controlled. When light strikes a photodiode, the electron within the crystal structure becomes stimulated. If the light energy is greater than the band gap energy Eg, the electrons are pulled up into the conduction band, leaving holes in their place in the valence band. (See Figure 1-2) These electron-hole pairs occur throughout the P-layer, depletion layer and N-layer materials. In the depletion layer the electric field accelerates these electrons toward the N-layer and the holes toward the P-layer. Of the electron-hole pairs generated in the N-layer, the electrons, along with electrons that have arrived from the P-layer, are left in the N-layer conduction band. The holes at this time are being diffused through the N-layer up to the depletion layer while being accelerated, and collected in the P-layer valence band. In this manner, electron-hole pairs which are generated in proportion to the amount of incident light are collected in the N- and P-layers. This results in a positive charge in the P-layer and a negative charge in the N-layer. If an external circuit is connected between the P- and N-layers, electrons will flow away from the N-layer, and holes will flow away from the P-layer toward the opposite respective electrodes. These electrons and holes generating a current flow in a semiconductor are called the carriers.

Figure 1-1 Photodiode cross section

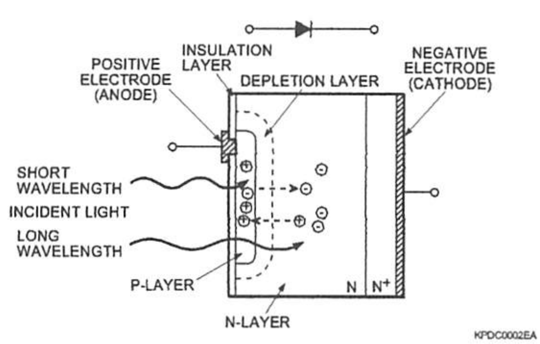
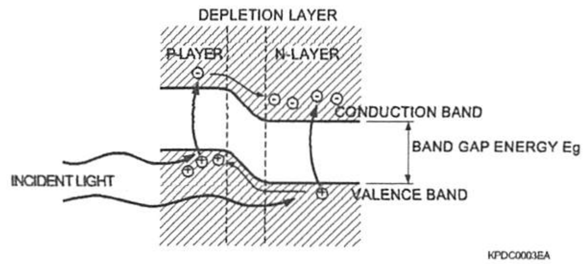


Figure 1-2 Photodiode P-N junction state

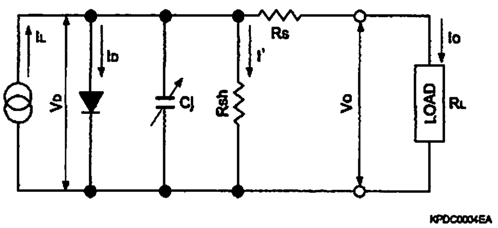


2. Si photodiode

2-1. Equivalent circuit

An equivalent circuit of a photodiode is shown in Figure 2-1.

Figure 2-1 Photodiode equivalent circuit



IL : Current generated by the incident light (proportional to the amount of light)
ID : Diode current
Cj : Junction capacitance
Rsh : Shunt resistance
Rs : Series resistance
I' : Shunt resistance current
VD : Voltage across the diode
Io : Output current
Vo : Output voltage

Using the above equivalent circuit, the output current Io is given as follows:

$$Io = IL - ID - I' = IL - Is\,(exp\,\frac{eVD}{kT} - 1) - I' \;\text{............}\; (2\text{-}1)$$

Is: Photodiode reverse saturation current
e : Electron charge
k : Boltzmann's constant
T : Absolute temperature of the photodiode

The open circuit voltage Voc is the output voltage when Io equals 0. Thus Voc becomes

$$Voc = \frac{kT}{e}\; ln\left(\frac{IL - I'}{Is} + 1\right) \;\text{............}\; (2\text{-}2)$$

If I' is negligible, since Is increases exponentially with respect to ambient temperature, Voc is inversely proportional to the ambient temperature and proportional to the log of IL. However, this relationship does not hold for very low light levels.
The short circuit current Isc is the output current when the load resistance RL equals 0 and Vo equals 0, yielding:

$$Isc = IL - Is\left(exp\,\frac{e \cdot (Isc \cdot Rs)}{kT} - 1\right) - \frac{Isc \cdot Rs}{Rsh} \;\text{......}\; (2\text{-}3)$$

In the above relationship, the 2nd and 3rd terms limit the linearity of Isc. However, since Rs is several ohms and Rsh is 10^7 to 10^{11} ohms, these terms become negligible over quite a wide range.

2-2. Current vs. voltage characteristic

When a voltage is applied to a photodiode in the dark state, the current vs. voltage characteristic observed is similar to the curve of a conventional rectifier diode as shown in Figure 2-2 ①. However, when light strikes the photodiode, the curve at ① shifts to ② and, increasing the amount of incident light shifts this characteristic curve still further to position ③ in parallel, according to the incident light intensity. As for the characteristics of ② and ③, if the photodiode terminals are shorted, a photocurrent Isc or Isc proportional to the light intensity will flow in the direction from the anode to the cathode. If the circuit is open, an open circuit voltage Voc or Voc' will be generated with the positive polarity at the anode.
The short circuit current Isc is extremely linear with respect to the incident light level. When the incident light is within a range of 10^{-12} to 10^{-2} W, the achievable range of linearity is higher than 9 orders of magnitude, depending on the type of photodiode and its operating circuit. The lower limit of this linearity is determined by the NEP, while the upper limit depends on the load resistance and reverse bias voltage, and is given by the following equation:

$$Psat = \frac{VBi + VR}{(Rs + RL) \cdot S\lambda} \;\text{............}\; (2\text{-}4)$$

Psat : Input energy (W) at upper limit of linearity $Psat \leq 10$ mW
VBi : Contact voltage (V) <0.2 to 0.3 V>
VR : Reverse voltage (V)
RL : Load resistance (Ω)
Sλ : Photo sensitivity at wavelength λ (A/W)
Rs : Photodiode series resistance (several Ω)

When laser light is condensed on a small spot, however, the actual series resistance element increases, and linearity deteriorates.
Voc varies logarithmically with respect to a change of the light level and is greatly affected by variations in temperature, making it unsuitable for light intensity measurements. Figure 2-3 shows the result of plotting Isc and Voc as a function of incident light illuminance.

Figure 2-2 Current vs. voltage characteristic

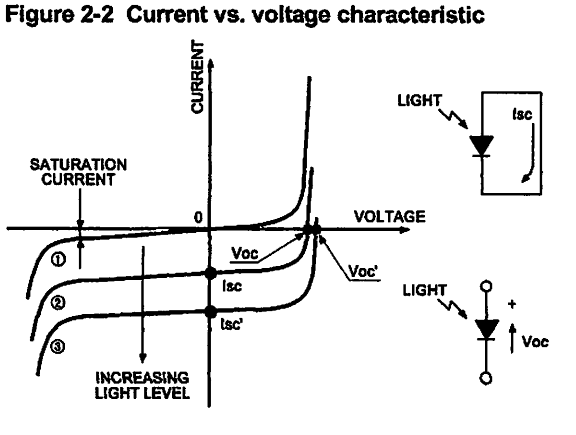
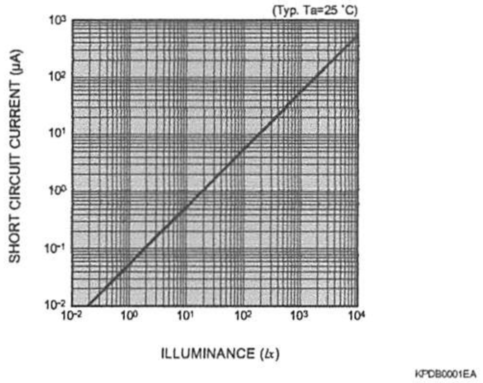


Figure 2-3 Output signal vs. incident light level (S2386-5K)

(a) Short circuit current



(b) Open circuit voltage

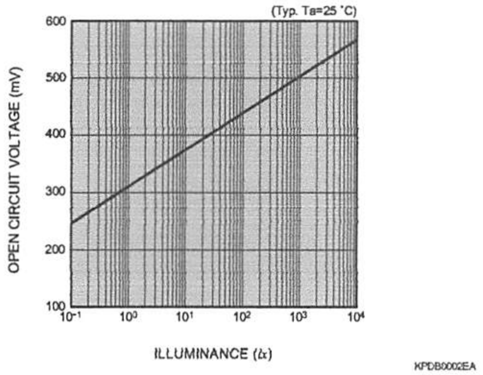
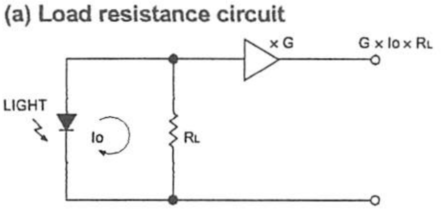


Figure 2-4 (a) and (b) show methods of measuring light by measuring the photocurrent I_L or Isc. In the circuit shown at (a), the voltage ($I_O \times R_L$) is amplified by an amplifier with gain G, although the circuit does have limitations on its linearity according to equation (2-4). This condition is shown in Figure 2-5. Figure 2-4 (b) is a circuit using an operational amplifier. If we set the open loop gain of the operational amplifier as A, the characteristics of the feedback circuit allows the equivalent input resistance (equivalent to load resistance R_L) to be $\frac{Rf}{A}$ which is several orders of magnitude smaller than Rf. Thus this circuit enables ideal Isc measurement over a wide range. For measuring a wide range, R_L and Rf must be adjusted as needed.

Figure 2-4 Photodiode operational circuits

(a) Load resistance circuit



(b) Op-amp circuit

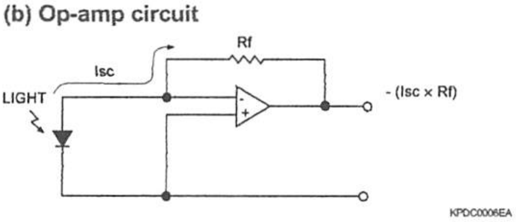
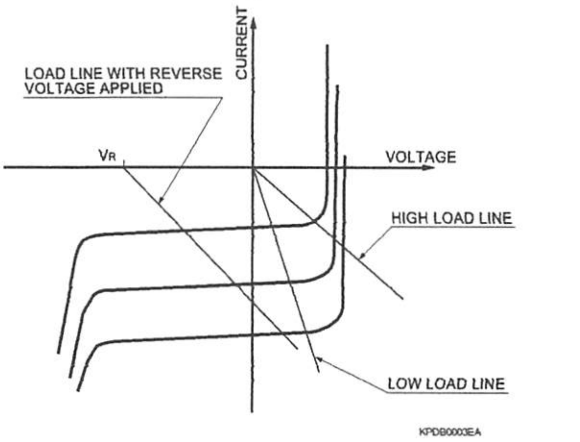
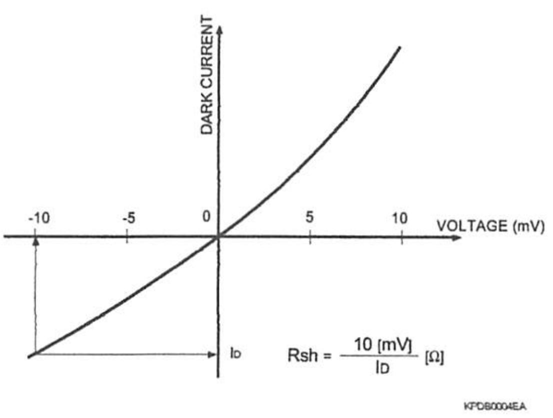


Figure 2-5 Current vs. voltage characteristic and load line



If the zero region of Figure 2-2 ① is magnified, we see, as shown in Figure 2-6, that the dark current I_D is approximately linear in a voltage range of about ±10 mV. The slope in this region indicates the shunt resistance Rsh and this resistance is the cause of the thermal noise current described later. In data sheets, values of Rsh are given using a dark current I_D measured with -10 mV applied.

Figure 2-6 Dark current vs. voltage (Enlarged zero region)



2-3. Spectral response

As explained in the section on principle of operation, when the energy of absorbed photons is lower than the band gap energy Eg, the photovoltaic effect does not occur. The limiting wavelength λh can be expressed in terms of Eg as follows:

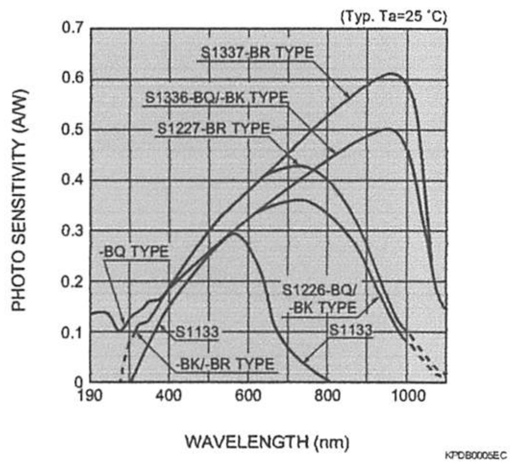
$$\lambda h = \frac{1240}{Eg} \text{ [nm] .... (2-5)}$$

At room temperatures, Eg is 1.12 eV for Si and 1.8 eV for GaAsP, so that the limiting wavelength will be 1100 nm and 700 nm, respectively. For short wavelengths, however, the degree of light absorption within the surface diffusion layer becomes very large. Therefore, the thinner the diffusion layer is and the closer the P-N junction is to the surface, the higher the sensitivity will be. (See Figure 1-1.) For normal photodiodes the cut-off wavelength is 320 nm, whereas for UV-enhanced photodiodes (e.g. S1226/S1336 series) it is 190 nm.

The cut-off wavelength is determined by the intrinsic material properties of the photodiode, but it is also affected by the spectral transmittance of the window material. For borosilicate glass and plastic resin coating, wavelengths below approximately 300 nm are absorbed. If these materials are used as the window, the short wavelength sensitivity will be lost. For wavelengths below 300 nm, photodiodes with quartz windows are used. For measurements limited to the visible light region, a visual-compensation filter is used as the light-receiving window.

Figure 2-7 shows the spectral response characteristics for various photodiode types. The BQ type shown uses a quartz window, the BK type a borosilicate glass window and the BR type a resin-coated window. S1133 is a visible photodiode with a visual-compensated filter.

Figure 2-7 Spectral response example



2-4. Noise characteristic

Like other types of light sensors, the lower limits of light detection for photodiodes are determined by the noise characteristics of the device. The photodiode noise in is the sum of the thermal noise (or Johnson noise) *ij* of a resistor which approximates the shunt resistance and the shot noise *isD* and *isL* resulting from the dark current and the photocurrent.

$$in = \sqrt{ij^2 + isD^2 + isL^2} \ [A] \ \text{............} \ (2\text{-}6)$$

ij is viewed as the thermal noise of Rsh and is given as follows:

$$ij = \sqrt{\frac{4\,kTB}{Rsh}} \ [A] \ \text{............} \ (2\text{-}7)$$

k: Boltzmann's constant
T: Absolute temperature of the element
B: Noise bandwidth

When a bias voltage is applied as in Figure 3-1, there is always a dark current. The shot noise *isD* originating from the dark current is given by

$$isD = \sqrt{2qI_DB} \ [A] \ \text{............} \ (2\text{-}8)$$

q : Electron charge
ID: Dark current
B : Noise bandwidth

With the application of incident light, a photocurrent IL exists so *isL* is given by

$$isL = \sqrt{2qI_LB} \ [A] \ \text{............} \ (2\text{-}9)$$

If IL >> 0.026/Rsh or IL >> ID, the shot noise current of equation (2-9) becomes predominant instead of the noise factor of eqaution (2-7) or (2-8).

The amplitudes of these noise sources are each proportional to the square root of the measured bandwidth B so that they are expressed in units of $A/Hz^{1/2}$.

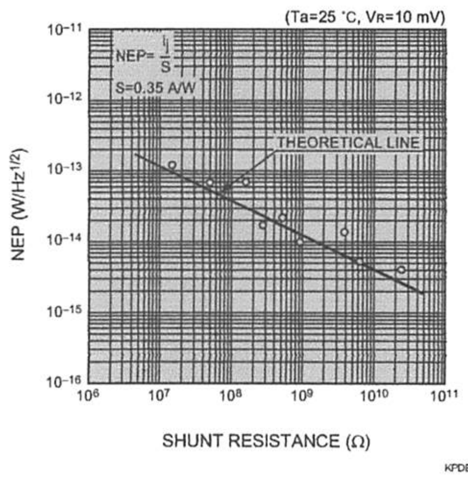
The lower limit of light detection for a photodiode is usually expressed as the intensity of incident light required to generate a current equal to the noise current as expressed in equation (2-7) or (2-8). Essentially this is the noise equivalent power (NEP).

$$NEP = \frac{in}{S} \ [W/Hz^{1/2}] \ \text{............} \ (2\text{-}10)$$

in: Noise current ($A/Hz^{1/2}$)
S : Photo sensitivity (A/W)

Figure 2-8 shows the relationship between NEP and shunt resistance, from which a photodiode is agreement with the theoretical relationship.

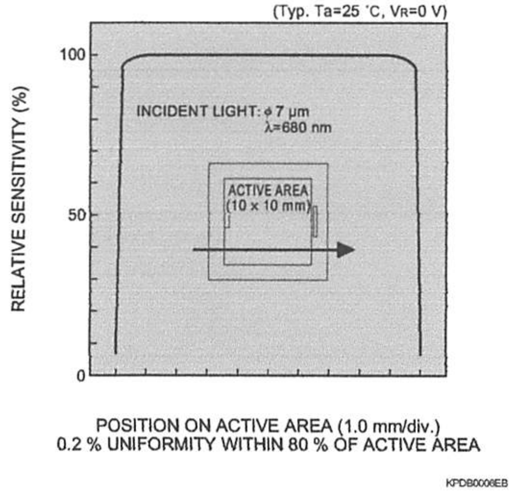
Figure 2-8 NEP vs. shunt resistance (S1226-5BK)



2-5. Spatial response uniformity

This is the measure of the variation in sensitivity with the position of the active area. Photodiodes offer excellent uniformity, usually less than 1 %. This uniformity is measured with light from a laser diode (680 nm) condensed to a small spot from several microns to several dozen microns in diameter.

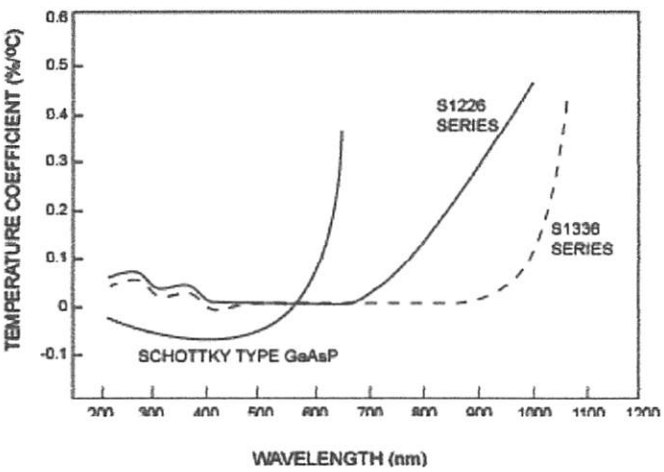
Figure 2-9 Spatial response uniformity (S1227-1010BQ)



2-6 Temperature Characteristics

Ambient temperature variations greatly affect photodiode sensitivity and dark current. The cause of this is variation in the light absorption coefficient which is temperature related. For long wavelengths, sensitivity increases with increasing temperature and this increase become prominent at wavelengths longer than the peak wavelength. For short wavelengths, it decreases. Since ultraviolet enhanced photodiodes are designed to have low absorption in the short wavelength region, the temperature coefficient is extremely small at wavelengths shorter than the peak wavelength. Figure 2-10 shows examples of temperature coefficients of photodiodes sensitivity for a variety of photodiodes types.

Figure 2-10 Temperature Coefficient vs. Wavelength



The variation in dark current with respect to temperature occurs as a result of increasing temperatures causing electrons in the valence band to become excited, pulling them into the conduction band. A constant increase in dark current is shown with increasing temperature. Figure 2-11 indicates a twofold increase in dark current for a temperature rise from 5°C to 10°C. This is equivalent to a reduction of the shunt resistance Rsh and a subsequent increase in thermal and shot noise. Figure 2-12 shows an example of the temperature characteristics of open-circuit voltage Vop, indicating linearity with respect to temperature change.

Figure 2-11: Dark Current Temperature Dependence (S2387)

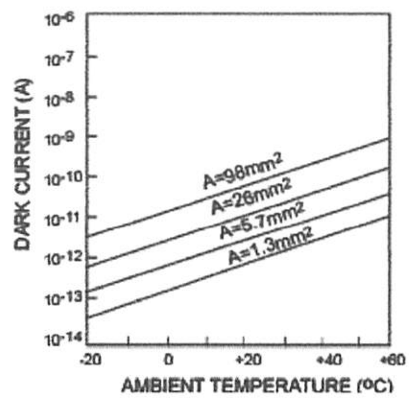
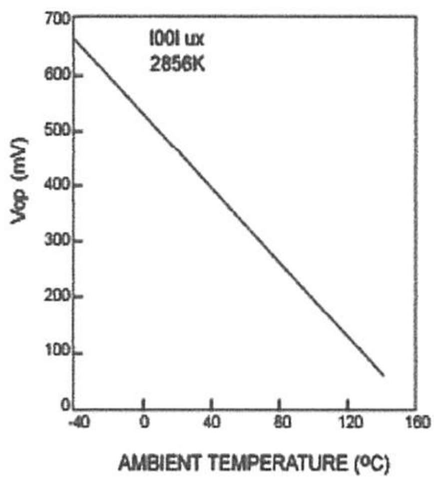


Figure 2-12 : Vop Temperature Dependence (S2387)

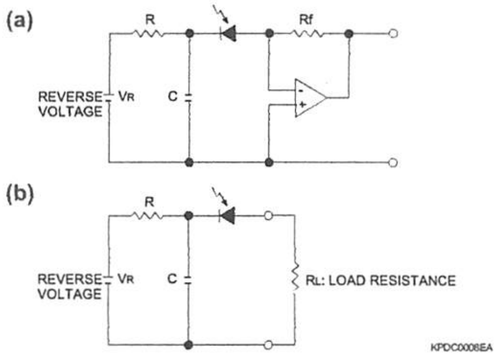


3. Si PIN photodiode

3-1. Reverse voltage

Because photodiodes generate a power due to the photovoltaic effect, they can operate without the need for an external power source. However, frequency response and linearity can be improved by using an external reverse voltage VR. It should be borne in mind that the signal current flowing in a photodiode circuit is determined by the number of photovoltaically generated electron-hole pairs and that the application of a reverse voltage does not affect the signal current nor impair the photoelectric conversion linearity. Figure 3-1 shows examples of reverse voltage connection. Figures 3-2 and 3-3 show the effect of reverse voltage on cut-off frequency and linearity limits, respectively. While application of a reverse voltage to a photodiode is very useful in improving frequency response and linearity, it has the accompanying disadvantage of increasing dark current and noise levels along with the danger of damaging the device by excessive applied reverse voltage. Thus, care is required to maintain the reverse voltage within the maximum ratings and to ensure that the cathode is maintained at a positive potential with respect to the anode.

Figure 3-1 Reverse voltage connection



For use in applications such as optical communications and remote control which require high response speed, the PIN photodiode provides not only good response speed but excellent dark current and voltage resistance characteristics with reverse voltage applied. Note that the reverse voltages listed in data sheets are recommended values and each PIN photodiode is designed to provide optimum performance at the recommended reverse voltage.

Figure 3-2 Cut-off frequency vs. reverse voltage (S5973 series, S7911, S7912)

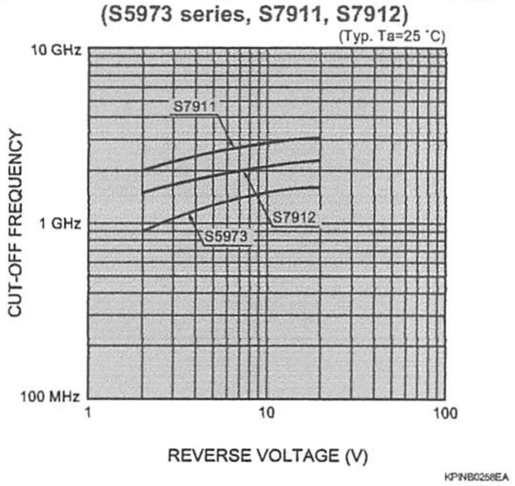


Figure 3-3 Output current vs. illuminance (S1223)

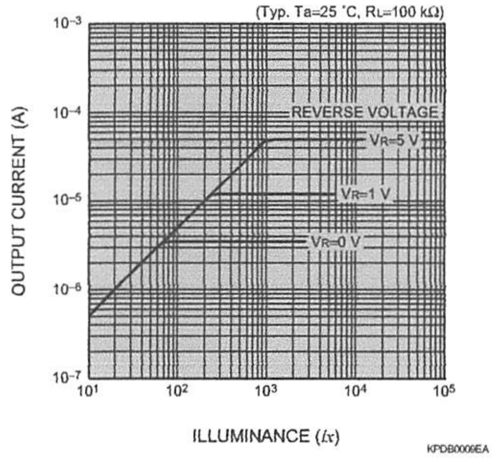
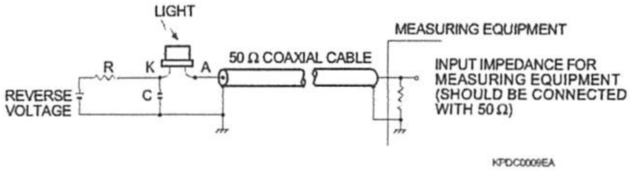


Figure 3-4 shows an example of the actual connection shown in Figure 3-1 (b) with a load resistance 50 Ω. The ceramic capacitor C is used to enable a reduction of the bias supply impedance, while resistor R is used to protect the photodiode. The resistor value is selected such that the voltage drop caused by the maximum photocurrent is sufficiently smaller than the reverse voltage. The photodiode and capacitor leads, coaxial cable and other wire carrying high-speed pulses should be kept as short as possible.

Figure 3-4 Connection to coaxial cable



3-2. Response speed and frequency response

The response speed of a photodiode is a measure of the time required for the accumulated charge to become an external current and is generally expressed as the rise time or cut-off frequency. The rise time is the time required for the output signal to change from 10 % to 90 % of the peak output value and is determined by the following factors:

1) Terminal capacitance Ct and time constant t1 of load resistance RL

Time constant t_1 determined by the terminal capacitance Ct of the photodiode and the load resistance R_L.

Ct is the sum of the package capacitance and the photodiode junction capacitance. t_1 is given by

$$t_1 = 2.2 \times Ct \times R_L \quad \text{.......... (3-1)}$$

To shorten t_1, the design must be such that either Ct or R_L is made smaller. Cj is nearly proportional to the active area A and inversely proportional to the second to third root of the depletion layer width d. Since the depletion layer width is proportional to the product of the resistivity ρ of the substrate material and reverse voltage V_R, the following equation is established as:

$$Cj \propto A\,\{(V_R + 0.5) \times \rho\}^{-1/2 \text{ to } -1/3} \quad \text{........... (3-2)}$$

Accordingly, to shorten t_1, a photodiode with a small A and large ρ should be used with a reverse voltage applied. However, reverse voltage also increases dark current so caution is necessary for use in low-light-level detection.

2) Diffusion time t_2 of carriers generated outside the depletion layer

Carriers may generate outside the depletion layer when incident light misses the P-N junction and is absorbed by the surrounding area of the photodiode chip and the substrate section which is below the depletion area. The time t_2 required for these carriers to diffuse may sometimes be greater than several microseconds.

3) Carrier transit time t_3 in the depletion layer

The transit speed vd at which the carriers travel in the depletion layer is expressed using the traveling rate μ and the electric field E developed in the depletion layer, as in vd = μE. If we let the depletion layer width be d and the applied voltage be V_R, the average electric field $E=V_R/d$, and thus t_3 can be approximated as follows:

$$t_3 = d / vd = d^2 / (\mu V_R) \quad \text{............ (3-3)}$$

To achieve a fast response time for t_3, the moving distance of carriers should be short and the reverse voltage larger.

The above three factors determine the rise time tr of a photodiode and rise time tr is approximated by the following equation:

$$tr = \sqrt{t_1^2 + t_2^2 + t_3^2} \quad \text{............ (3-4)}$$

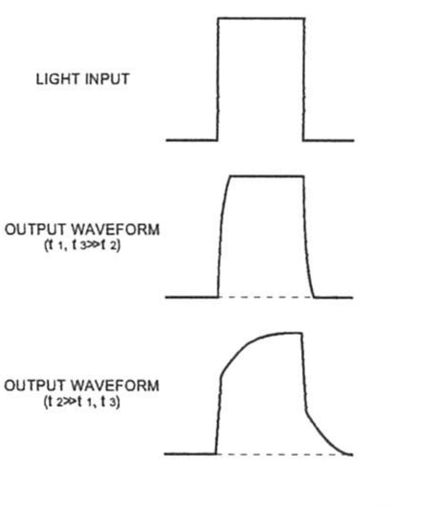
PIN photodiodes and avalanche photodiodes are designed such that less carriers are generated outside the depletion layer, Ct is small and the carrier transit time in the depletion layer is short. Therefore, these types are ideally suited for high-speed light detection.

The cut-off frequency fc is the frequency at which the photodiode output decreases by 3 dB from the output at 100 kHz when the photodiode receives sinewave-modulated light from a laser diode. The rise time tr roughly approximates this fc in the formula:

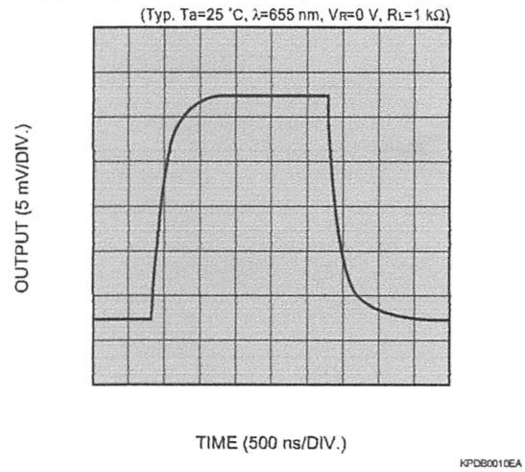
$$tr = \frac{0.35}{fc} \quad \text{............ (3-5)}$$

Figures 3-5 (a), (b) and (c) show examples of the response waveform and frequency response characteristics for typical photodiodes.

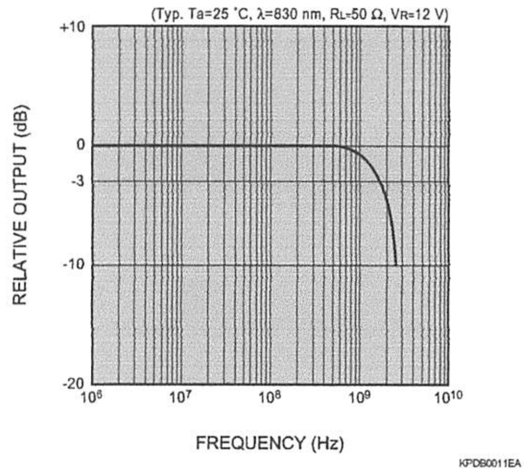
Figure 3-5 (a) Photodiode response waveform example



(b) Response waveform (S2386-18K)



(c) Frequency response (S5973)

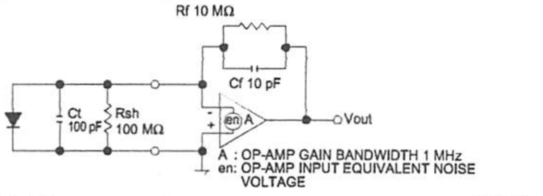


4. Si photodiode with preamp

4-1. Feedback circuit

Figure 4-1 shows a basic circuit connection of an operational amplifier and photodiode. The output voltage Vout from DC through the low-frequency region is 180 degrees out of phase with the input current Isc. The feedback resistance Rf is determined by Isc and the required output voltage Vout. If, however, Rf is made greater than the photodiode internal resistance Rsh, the operational amplifier's input noise voltage en and offset voltage will be multiplied by $\left(1+\frac{Rf}{Rsh}\right)$. This is superimposed on the output voltage Vout, and the operational amplifier's bias current error (described later) will also increase. It is therefore not practical to use an infinitely large Rf. If there is an input capacitance Ct, the feedback capacitance Ct prevents high-frequency oscillations and also forms a lowpass filter with a time constant Cf × Rf value. The value of Cf should be chosen according to the application. If the input light is similar to a discharge spark, and it is desired to integrate the amount of light, Rf can be removed so that the operational amplifier and Cf act as an integrating circuit. However, a switch is required to discharge Cf before the next integration.

Figure 4-1 Basic photodiode connection



4-2. Bias current

Since the actual input impedance of an operational amplifier is not infinite, some bias current that will flows into or out of the input terminals. This may result in error, depending upon the magnitude of the detected current. The bias current which flows in an FET input operational amplifier is sometimes lower than 0.1 pA. Bipolar operational amplifiers, however, have bias currents ranging from several hundred pA to several hundred nA. However, the bias current of an FET operational amplifier increases two-fold for every increase of 5 to 10 °C in temperature, whereas that of bipolar amplifiers decreases with increasing temperature. The use of bipolar amplifiers should be considered when designing circuits for high temperature operation.

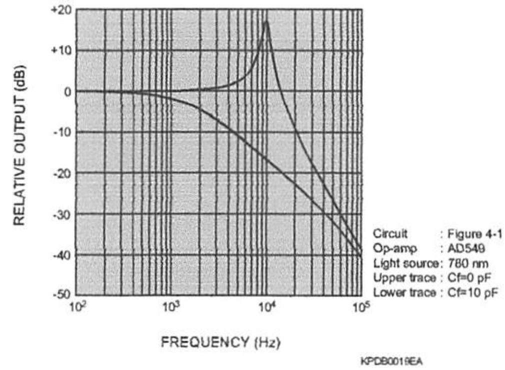
As is the case with offset voltage, the error voltage attributable to the bias current can be adjusted by means of a potentiometer connected to the offset adjustment terminals. Furthermore, leakage currents on the PC board used to house the circuit may be greater than the operational amplifier's bias current. Consideration must be given to the circuit pattern design and parts layout, as well as the use of Teflon terminals and guard rings.

4-3. Gain peaking

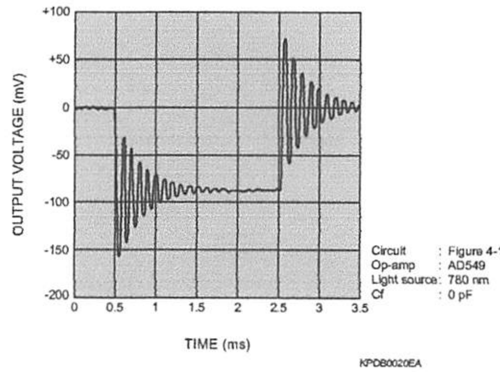
The frequency response of a photodiode and operational amplifier circuit is determined by the time constant Rf × Cf. However, for large values of terminal capacitance (i.e. input capacitance) a phenomenon known as gain peaking will occur. Figure 4-2 shows an example of such a frequency response. It can be seen from the figure that the output voltage increases sharply in the high frequency region, causing significant ringing [See the upper trace in (a).] in the output voltage waveform in response to the pulsed light input. This gain operates in the same manner with respect to operational amplifier input noise and may result in abnormally high noise levels. [See the upper trace in (c).] This occurs at the high frequency region when the reactance of the input capacitance and the feedback capacitance of the operational amplifier circuit jointly form an unstable amplifier with respect to input amplifier noise. In such a case, loss of measurement accuracy may result.

Figure 4-2 Gain peaking

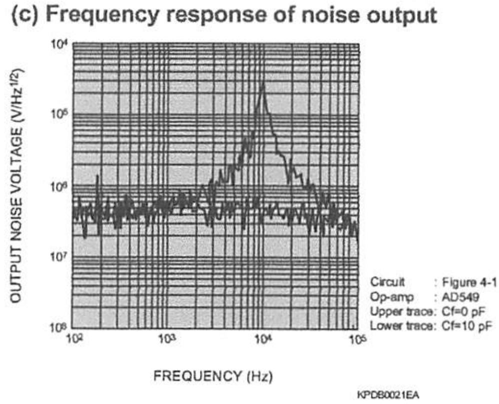
(a) Frequency response



(b) Light pulse response



(c) Frequency response of noise output

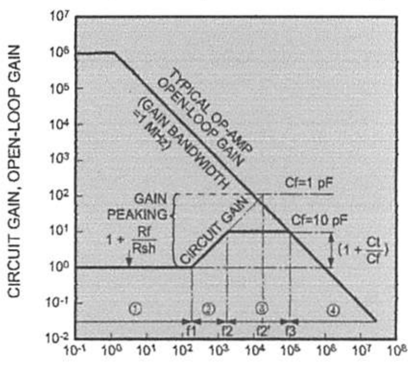


4-4. Gain peaking elimination

To achieve a wide frequency characteristic without gain peaking and ringing phenomena, it is necessary to select the optimum relationship between the photodiode, operational amplifier and feedback element. It will prove effective in the case of photodiodes to reduce the terminal capacitance Ct, as was previously explained in the section on Response speed and frequency response. In the operational amplifier, the higher the speed and the wider the bandwidth, the less the gain peaking that occurs. However, if adequate internal phase compensation is not provided, oscillation may be generated as a result. A feedback element, not only the resistance but also the feedback capacitance should be connected in parallel, as explained previously, in order to avoid gain peaking. The gain peaking phenomena can be explained as follows, using the circuit shown in Figure 4-1. As shown in Figure 4-3, the circuit gain of the operational amplifier is determined for the low-frequency region ① simply by the resistance ratio of Rsh to Rf. From the frequency $f1 = \frac{Rsh + Rf}{2\pi RshRf(Cf + Ct)}$ gain begins to increase with frequency as shown in region ②.

Next, at the frequency $f2 = \frac{1}{2\pi CfRf}$ and above, the circuit gain of the operational amplifier enters a flat region (region ③) which is determined by the ratio of Ct and Cf. At the point where frequency f3 intersects the open-loop gain frequency response at rolloff (6 dB/octave) of the operational amplifier, region ④ is entered. In this example, f1 and f2 correspond to 160 Hz and 1.6 kHz respectively under the conditions of Figure 4-1. If Cf is made 1 pF, f2 shifts to f2' and circuit gain increases further. What should be noted here is that, since the setting of increasing circuit gain in region ③ exceeds the open-loop gain curve, region ③ actually does not exist. As a result, ringing occurs in the pulsed light response of the operational amplifier circuit, and the gain peaking occurs in the frequency, then instability results. (See Figure 4-2.)

Figure 4-3 Graphical representation of gain peaking



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To summarize the above points:

a) When designing Rf and Cf, f2 should be set to a value such that region ③ in Figure 4-3 exists.

b) When f2 is positioned to the right of the open-loop gain line of the operational amplifier, use the operational amplifier which has a high frequency at which the gain becomes 1 (unity gain bandwidth), and set region ③.

The above measures should reduce or prevent ringing. However, in the high-frequency region ③, circuit gain is present, and the input noise of the operational amplifier and feedback resistance noise are not reduced, but rather, depending on the circumstances, may even be amplified and appear in the output. The following method can be used to prevent this situation.

c) Replace a photodiode with a low Ct value. In the example shown in the figure, $\left(1 + \frac{Ct}{Cf}\right)$ should be close to 1.

Using the above procedures, the S/N deterioration caused by ringing and gain peaking can usually be solved. However, regardless of the above measures, if load capacitance from several hundred pF to several nF or more, for example, a coaxial cable of several meters or more and a capacitor is connected to the operational amplifier output, oscillation may occur in some types of operational amplifiers. Thus the capacitance load must be set as small as possible.

5. Si APD

5-1. Advantage of APD

When using a opto-semiconductor for low-light-level measurement, it is necessary to take overall performance into account, including not only the opto-semiconductor characteristics but also the readout circuit (operational amplifier, etc.) noise.

When a Si photodiode is used as a photodetector, the lowest detection limit is usually determined by the readout circuit noise because photodiode noise level is very low. This tendency becomes more obvious when the higher frequency of signal to be detected.

This is because the high-speed readout circuit usually exhibits larger noise, resulting in a predominant source of noise in the entire circuit system.

In such cases, if the detector itself has an internal gain mechanism and if the output signal from the detector is thus adequately amplified, the readout circuit can be operated so that its noise contribution is minimized to levels equal to one divided by gain (1/10 th to 1/100 th).

In this way, when the lowest detection limit is determined by the readout circuit, use of an APD offers the advantage that the lowest detection limit can be improved by the APD gain factor to a level 1/10 th to 1/100 th of the lowest detection limit obtained with normal photodiodes.

5-2. Noise characteristic of APD

When the signal is amplified, the inherent excess noise resulting from statistical current fluctuation current fluctuation in the avalanche multiplication process is also generated. This noise current can be expressed by the following equation:

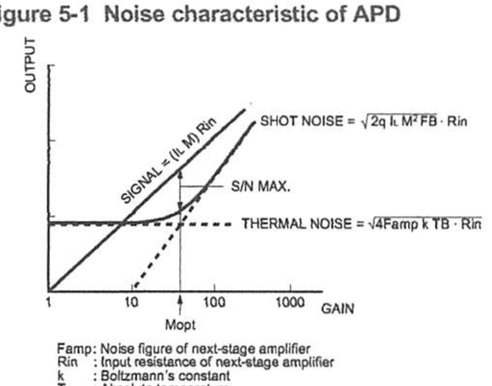
$$in = \sqrt{2\, qI_L M^2 FB} \quad \text{............ (5-1)}$$

In the range of M=10 to 100, F is approximated M^x.

$\left(\begin{array}{l}\text{F: Excess noise factor, M: Gain, } I_L\text{: Photocurrent at M=1,}\\ \text{q: Electron charge, B: Bandwidth, x: Excess noise index}\end{array}\right)$

In PIN photodiodes, using a large load resistance is not practical since it limits the response speed, so the circuit noise is usually dominated by the thermal noise of the photodiode. In contrast, the gain of an APD, which is internally amplified, can be increased until the shot noise reaches the same level as the thermal noise. The APD can therefore offer an improved S/N without impairing the response speed.

Figure 5-1 Noise characteristic of APD



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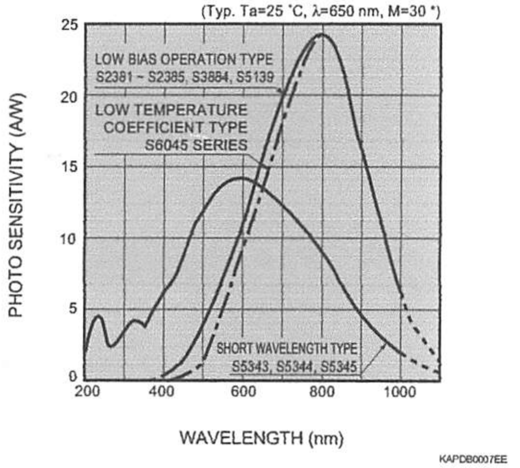
5-3. Spectral response of APD

The spectral response characteristics of the APD are almost the same as those of normal photodiodes if a bias voltage is not applied. When a bias voltage is applied, the spectral response curve will change. This means that the gain changes depending on the incident light wavelength. This is because the penetration depth of light into the silicon substrate depends on the wavelength so that the wavelength absorption efficiency in the light absorption region differs depending on the APD structure. It is therefore important to select a suitable APD.
To allow selection of spectral response characteristics, Hamamatsu provides two types of Si APDs: S2381 series and S6045 series for near infrared detection and S5343 series for light detection at shorter wavelengths.
Figure 5-2 shows typical spectral response characteristics measured with a gain of 30 at 650 nm wavelength.

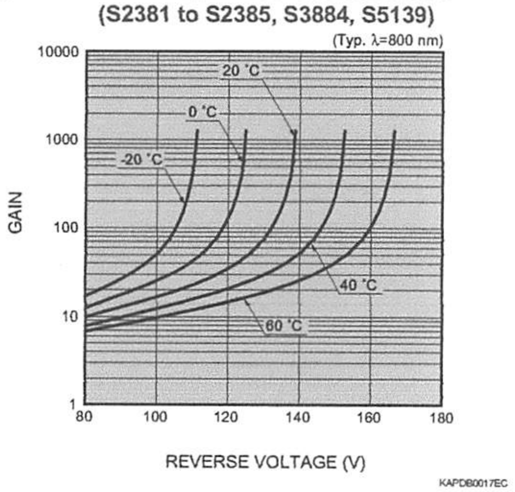
Figure 5-2 Spectral response



5-4. Temperature characteristic of gain

APD gain varies with temperature. For example, when an APD is operated at a constant bias voltage, the gain decreases with increasing temperature. Therefore, in order to obtain a constant output, it is necessary to vary the bias voltage according to the APD temperature or to keep the APD at a constant temperature. In S2381 series, the temperature coefficient of the bias voltage is nearly equal to that of the breakdown voltage which is 0.65 V/°C Typ. at a gain of 100.
Hamamatsu also provides S6045 series APDs which are designed to have an improved temperature coefficient (0.4 V/°C Typ.).

Figure 5-3 Gain temperature characteristics (S2381 to S2385, S3884, S5139)

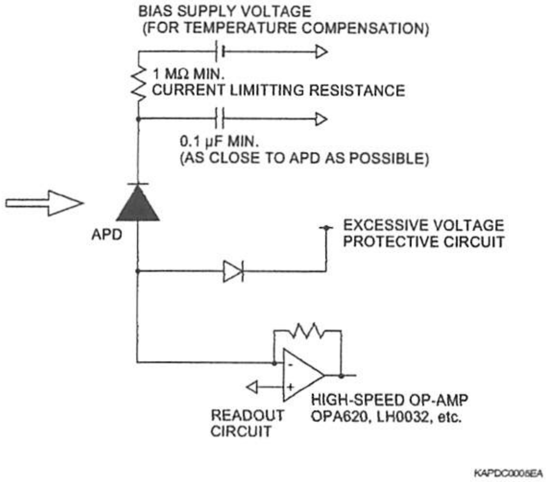


5-5. Connection to peripheral circuits

APDs can be handled in the same manner as normal photodiodes except that a high bias voltage is required. However the following precautions should be taken because APDs have an internal gain mechanism and are operated at a high voltage.

1) APDs consume a considerably large amount of power during operation, which is given by the product of the signal power × sensitivity (e.g. 0.5 A/W at 800 nm) × gain × bias voltage. To deal with this, a protective resistor should be added to the bias circuit or a current limiting circuit should be used.
2) A low-noise readout circuit usually has a high impedance, so if an excessive voltage higher than the supply voltage for the readout circuit flows into the readout circuit, the first stage tends to be damaged. To prevent this, a protective circuit (diode) should be connected so that excessive voltage is diverted to the power supply voltage line.
3) As stated above, APD gain depends on temperature. The S2381 series has a typical temperature coefficient of 0.65 V/°C, but there is no problem with using the APD at a gain of around M=30 and 25 °C±3 °C. However, when used at a higher gain or wider temperature range, it is necessary to use some kind of temperature offset (to control the bias voltage according to temperature) or temperature control (to maintain the APD at a constant temperature).
4) When detecting low-level light signals, the detection limit can be determined by the shot noise of background light. If background light enters the APD, then the S/N may deteriorate due to the shot noise. As a countermeasure for minimizing background light, use of an optical filter, improving laser modulation or restricting the field of view is necessary.

Figure 5-4 Peripheral circuit example of APD



Reliability

If used within the specified operating ratings, chips of photodiodes will exhibit virtually no deterioration of characteristics. Deterioration can often be attributed to package, lead or filter failure. Package leakage at high temperatures and humidity, in particular, often causes the dark current to increase. Therefore, plastic and ceramic package photodiodes have a somewhat limited temperature and humidity range. In contrast, metal package types feature excellent resistance to ambient humidity. Photodiodes with filters are greatly affected by endurance of the filter to environmental conditions. These factors must be taken into consideration when using and storing photodiodes.

Hamamatsu photodiodes are subjected to reliable test based on JEITA (Japan Electronic Information and Technology Association). Reliable tests are also performed in compliance with MIL (US Military) standards and IEC (International Electrotechnical Commission) standards acording to the product applications. The major reliability test standards used by Hamamatsu are summarized below in major reliability test standards.

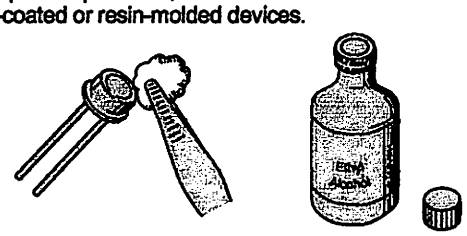
Major reliability test standards

Test item	Condition	ED-4701	Criteria
Terminal strength	Pulling 10 seconds, bending 90˚ two times	A-111	Damage to terminal, etc.
Vibration	100 to 2000 Hz, 200 m/s² XYZ directions, 4 minutes, 4 times each (total 48 minutes)	A-121	Appearance and electrical characteristics
Shock	1000 m/s², 6 ms XYZ directions, 3 times each	A-122	
Solderability	235 ± 5 ˚C, 5 or 2 seconds, 1 to 1.5 mm	A-131	Solderability
Resistance to soldering heat (except surface mount type)	260 ± 5 ˚C, 10 seconds, 1 to 1.5 mm	A-132	Appearance and electrical characteristics
Resistance to soldering heat (surface mount type)	Reflow 235 ˚C, 10 seconds	A-133	
High temperature storage	Tstg (Max.) : 1000 hours	B-111	
Low temperature storage	Tstg (Min.) : 1000 hours	B-112	
High temperature, high humidity storage	60 ˚C, 90 %: 1000 hours	B-121	
Temperature cycle	Tstg Min. to Tstg Max., in air, 30 minutes each, 10 cycles	B-131	
Electrostatic discharge	R=1.5 kΩ, C=100 pF, E=±1000 V, 3 times	C-111	
Resistance to solvent	Isopropyl alchohol, 23 ± 5 ˚C, 5 minutes	C-121	Marking legibility, paint peeling
High temperature reverse bias	Topr Max., V_R Max.: 1000 hours	D-212	Appearance and electrical characteristics

Note 1) Reference standards
Test method: JEITA-ED-4701 "Environmental and endurance test methods for semiconductor devices"
Note 2) Breakdown criteria standards
Test conditions and breakdown criteria standards table for collecting reliability test data
(National Institute of Advanced Industrial Science and Technology)

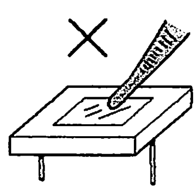
● Window

Care should be taken not to touch the window with bare hands, especially in the case of ultraviolet detection since foreign materials on the window can seriously affect transmittance in the ultraviolet range. (There have been occasions where contamination of the window by oil from hands reduced sensitivity at 250 nm by as much as 30 %.)
If the window needs to be cleaned, use ethyl alcohol and wipe off the window gently. Avoid using any other organic solvents than ethyl alcohol as they may cause deterioration of the device's resin coating or filter.
When using tweezers or other hard tools, be careful not to allow the tip or any sharp objects to touch the window surface. If the window is scratched or damaged, accurate measurement cannot be expected when detecting a small light spot. In particular, use sufficient care when handling resin-coated or resin-molded devices.



Lightly wipe dirt of the window using ethyl alcohol.

KRDC0027EA



Avoid scratching the light input window with pointed objects (tweezers tip, etc.) or rubbing it with a hard flat surface.

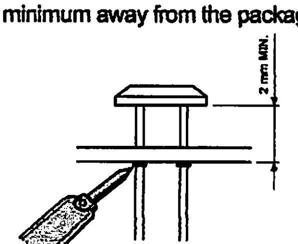
KPDC0012EA

● Lead forming

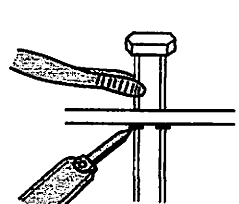
When forming leads, care should be taken to keep the recommended mechanical stress limits: 5 N pull for 5 seconds maximum, two 90 degrees bends and two twists of the leads at 6 mm minimum away from the package base.
To form the leads of plastic-molded package devices, use long-nose pliers to hold near by the root of the leads securely.

● Soldering

Since photodiodes are subject to damage by excessive heat, sufficient care must be given to soldering temperature and dwell time. As a guide, metal package devices should be soldered at 260 °C or below within 10 seconds, ceramic package devices at 260 °C within 5 seconds at 2 mm minimum away from the package base, and plastic package devices at 230 °C or below within 5 seconds at 1 mm minimum away from the package base.



Mount ceramic package types 2 mm minimum away from any surface and solder at 260 °C maximum for 5 seconds maximum time.



Use tweezers, etc. as a heatsink when soldering small photodiodes.

KPDC0013EB

● Recommended soldering condition

Package	Soldering temperature Max. (°C)	Soldering time Max. (s)	Remark
Metal	260	10	
Ceramic	260	5	2 mm or more away from package
Ceramic chip carrier	260	5	S5106, S5107 non moisture absorption
Plastic	230	5	1 mm or more away from package

● Cleaning

Use alcohol to remove solder flux. Never use other type of solvent because, in particular, plastic packages may be damaged. It is recommended that the device be dipped into alcohol for cleaning. Ultrasonic cleaning and vapor cleaning may cause fatal damage to some types of devices (especially, hollow packages and devices with filters). Confirm in advance that there is no problem with such cleaning methods, then perform cleaning.

Some caution may be needed when using the photodiode according to the particular structure. Cautions needed when using various products are listed on the next page.

Bare chip Si photodiode (S3590-19, S6337-01)

S3590-19 and S6337-01 have a windowless package and does not incorporate measures to protect the photodiode chip.

- Never touch the photodiode chip surface or wiring.
- Wear dust-proof gloves and a dust-proof mask.
- Use air-blow to remove foreign objects or objects attached to the surface.
- Do not attempt to wash.

Si photodiode with preamp

The Si photodiode with preamp is prone to damage or deterioration from static electricity in the human body, surge voltages from test equipment, leakage voltage from soldering irons, and packing materials, etc.
To eliminate the risk of damage from static electricity, the device, worker, work location, and tool jig must all be at the same electrical potential. Take the following precautions during use.

- Use items such as a wrist strap to get a high resistance (1 MΩ) between the human body and ground to prevent damage to the device from static electricity that accumulates on the worker and the worker's clothes.
- Lay a semi-conductive sheet (1 MΩ to 100 MΩ) on the floor and also on the workbench, and then connect them to ground.
- Use a soldering iron having an insulation resistance of 10 MΩ or more and connect it to ground.
- Conductive material or aluminum foil is recommended for use as a container for shipping or packing. To prevent accumulation of static charges, use material with a resistance of 0.1 MΩ/cm^2 to 1 GΩ/cm^2.

Surface mount type Si photodiode

Surface mount Si photodiodes come in ceramic or plastic package types. Sealing resin used for photodiodes was designed with light transmittance in mind and so has low resistance to moisture and heat compared to sealing resin for general-purpose IC. This means that special care is required during handling. Unexpected troubles can occur if the IC temperature profile is used in reflow soldering. Therefore keep the following points in mind.

1) Ceramic type (silicone resin coating type)
- The resin protecting the photodiode surface is soft so that applying an external force may damage the resin surface, warp the bonding wires, or break wires, so avoid touching the surface as much as possible.
- If stored for 3 months while unpacked or if more than 24 hours have elapsed after unpacking, bake for 3 to 5 hours at 150 °C in a nitrogen atmosphere, or for 12 to 15 hours at 120 °C in a nitrogen atmosphere.
  Note) Stick type shipping container material is vulnerable to heat, so do not try baking while the photodiodes are still in a stick.

2) Plastic type (epoxy resin mold type)
- Trouble during reflow is due to moisture absorption in the epoxy resin forming the package material. During soldering, the amount of moisture increases suddenly due to the heat and trouble such as peeling on the chip surface and package cracks is prone to occur.
- The packing is not usually moisture-proof so baking for 3 to 5 hours at 150 °C or for 12 to 15 hours at 120 °C in a nitrogen atmosphere is necessary before reflow soldering.
  Note) Stick type shipping container material is vulnerable to heat, so do not try baking while the photodiodes are still in a stick.
- When required, it is possible to bake photodiodes prior to shipping and pack them in a moisture-proof case.

3) Reflow soldering
- Reflow soldering conditions depend on factors such as the PC board, reflow oven and product being used. Please ask in advance, about recommended reflow conditions for a particular product.

BERITA ACARA UJIAN SKRIPSI

FAKULTAS TEKNOLOGI INDUSTRI

Nama Mahasiswa	: APRIYANTO ARIBOWO
NIM	: 00.17.160
Jurusan	: TEKNIK ELEKTRO S-1
Konsentrasi	: ELEKTRONIKA
Judul Skripsi	: PERENCANAAN DAN PEMBUATAN *TOUCH SCREEN*

Dipertahankan dihadapan majelis penguji skripsi jenjang strata satu (S-1), pada :

Hari	: Senin
Tanggal	: 23 Maret 2009
Dengan Nilai	: 76,75 (B+)

Panitia Ujian Skripsi

Ketua,

Ir. Sidik Noertjahjono, MT
NIP.Y.1028700163

Sekretaris,

Ir. F. Yudi Limpraptono, MT
NIP.Y. 1039500274

Anggota Penguji

Penguji Pertama,

Ir. Eko Nurcahyo
NIP.Y. 1028700172

Penguji Kedua,

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

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

FORMULIR PERBAIKAN SKRIPSI

Dari hasil ujian komprehensif jenjang strata satu jurusan Teknik Elektro S-1 konsentrasi elektronika yang diselenggarakan pada :

Hari : Senin

Tanggal : 23 Maret 2009

Telah dilaksanakan perbaikan skripsi oleh :

Nama : Apriyanto Aribowo

NIM : 00.17.160

Masa Bimbingan : 31 Oktober 2008 – 31 April 2009

Judul : **Perencanaan dan Pembuatan *Touch Screen***

No	Tanggal	Uraian	Paraf
1	5 April 2009	Kesimpulan diperbaiki sesuai dengan analisa	
2	5 April 2009	Setiap gambar dan tabel kutipan diberi sumbernya	
3	5 April 2009	Foto perancangan dan foto pengujian alat	
4	6 April 2009	Datasheet Infra Red dan Photodioda dilampirkan	
5	6 April 2009	Kesimpulan dibuat rincian	

Penguji I,

Ir. Eko Nurcahyo

Penguji II,

M. Ibrahim Ashari, ST, MT

Mengetahui:

Dosen Pembimbing I,

Ir. F. Yudi Limpraptono, MT

Dosen Pembimbing II,

Sotyohadi, ST

PERKUMPULAN PENGELOLA PENDIDIKAN UMUM DAN TEKNOLOGI NASIONAL MALANG

INSTITUT TEKNOLOGI NASIONAL MALANG

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

PT. BNI (PERSERO) MALANG
BANK NIAGA MALANG

Kampus I : Jl. Bendungan Sigura-gura No. 2 Telp. (0341) 551431 (Hunting), Fax. (0341) 553015 Malang 65145
Kampus II : Jl. Raya Karanglo, Km 2 Telp. (0341) 417636 Fax. (0341) 417634 Malang

Malang, 28 Pebruari 2009

Nomor : **ITN- 766/7/TA /2009**
Lampiran :
Perihal : ***Bimbingan Skripsi***

Kepada : Yth. Sdr. **SOTYOHADI, ST**
Dosen Pembimbing
Jurusan Teknik Elektro S-1
di
Malang

Dengan hormat,
Sesuai dengan permohonan dan persetujuan dalam proposal skipsi untuk mahasiswa:

Nama	: **APRIYANTO ARIBOWO**
Nim	: **00 17 160**
Fakultas	: **Teknologi Industri**
Jurusan	: **Teknik Elektro S-1**
Konsentrasi	: **Teknik Elektronika**

Maka dengan ini pembimbingan tersebut kami serahkan sepenuhnya kepada Saudara/i selama masa waktu 6 (enam) bulan, terhitung mulai tanggal:

31 OKTOBER 2008 s/d 31 APRIL 2009

Sebagai satu syarat untuk menempuh Ujian sarjana.
Demikian atas perhatian serta kerjasama yang baik kami ucapkan terima kasih

Ketua Jurusan
Teknik Elektro S-1

Ir. F. Yudi Limpraptono, MT
NIP. Y. 1039500274

Tindasan:
1. Mahasiswa yang Bersangkutan
2. Arsip

Form S-4a

Institut Teknologi Nasional Malang
Fakultas Teknologi Industri
Jurusan Teknik Elektro S1

FORMULIR BIMBINGAN SKRIPSI

Nama : Apriyanto Aribowo
Nim : 00.17.160
Masa Bimbingan : 31 Oktober 2008 s/d 31 April 2009
Judul Skripsi : Perencanaan Dan Pembuatan Touch Screen

No	Tanggal	Uraian	Paraf Pembimbing
1	19 maret	demo alat (diberi tutup); makalah seminar; Bab 3 (perhitungan & blok diagram); Bab 5	
2			
3			
4			
5			
6			
7			
8			
9			
10			

Malang,
Dosen pembimbing II,

Sotyohadi, ST
NIP Y. 1039700309

Form S-4a

PERKUMPULAN PENGELOLA PENDIDIKAN UMUM DAN TEKNOLOGI NASIONAL MALANG

INSTITUT TEKNOLOGI NASIONAL MALANG

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

T. BNI (PERSERO) MALANG
BANK NIAGA MALANG

Kampus I : Jl. Bendungan Sigura-gura No. 2 Telp. (0341) 551431 (Hunting), Fax. (0341) 553015 Malang 65145
Kampus II : Jl. Raya Karanglo, Km 2 Telp. (0341) 417636 Fax. (0341) 417634 Malang

Malang, 28 Pebruari 2009

Nomor : ITN- 765/7/TA /2009
Lampiran :
Perihal : ***Bimbingan Skripsi***

Kepada : Yth. Sdr. **IR. F. YUDI LIMPRAPTONO, MT**
Dosen Pembimbing
Jurusan Teknik Elektro S-1
di
Malang

Dengan hormat,
Sesuai dengan permohonan dan persetujuan dalam proposal skipsi untuk mahasiswa:

Nama	: **APRIYANTO ARIBOWO**
Nim	: **00 17 160**
Fakultas	: **Teknologi Industri**
Jurusan	: **Teknik Elektro S-1**
Konsentrasi	: **Teknik Elektronika**

Maka dengan ini pembimbingan tersebut kami serahkan sepenuhnya kepada Saudara/i selama masa waktu 6 (enam) bulan, terhitung mulai tanggal:

31 OKTOBER 2008 s/d 31 APRIL 2009

Sebagai satu syarat untuk menempuh Ujian sarjana.
Demikian atas perhatian serta kerjasama yang baik kami ucapkan terima kasih

Ketua Jurusan
Teknik Elektro S-1

Ir. F. Yudi Limpraptono, MT
NIP. Y. 1039500274

Tindasan:
1. Mahasiswa yang Bersangkutan
2. Arsip

Form S-4a

Institut Teknologi Nasional Malang
Fakultas Teknologi Industri
Jurusan Teknik Elektro S1

FORMULIR BIMBINGAN SKRIPSI

Nama : Apriyanto Aribowo
Nim : 00.17.160
Masa Bimbingan : 31 Oktober 2008 s/d 31 April 2009
Judul Skripsi : Perencanaan Dan Pembuatan Touch Screen

No	Tanggal	Uraian	Paraf Pembimbing
1	19/03 09	Perbaikan abstraksi makalah seminar - Perbaikan alat (diberi tutup)	
2			
3			
4			
5			
6			
7			
8			
9			
10			

Malang,

Dosen pembimbing I,

Ir. F. Yudi Limpraptono, MT
NIP Y. 1039500274

Form S-4a