PERANCANGAN DAN PEMBUATAN ALAT MEDIS *CRANIAL ELECTROTHERAPY STIMULATION* (CES) DENGAN LM555 DAN MIKROKONTROLLER AT89C2051

SKRIPSI

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

Disusun Oleh:
HASYIM ASY'ARI YUSUF
00.17.192

JURUSAN TEKNIK ELEKTRO S-1
KONSENTRASI TEKNIK ELEKTRONIKA
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LEMBAR PERSETUJUAN

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Hari	: Jum'at
Tanggal	: 26 September 2008
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KATA PENGANTAR

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Malang, Oktober 2008

Penyusun

ABSTRAK

Yusuf, Hasyim Asy'ari. 2008. *Perancangan dan Pembuatan Alat Medis Cranial Electrotherapy Stimulation (CES) dengan LM555 dan mikrokontroller AT89C2051.* Skripsi, Konsentrasi Teknik Elektronika, Jurusan Teknik Elektro S-1, Fakultas Teknologi Industri, Institut Teknologi Nasional Malang. Pembimbing : (I) I Komang Somawirata, ST. MT. (II) Sotyohadi, ST. M.Sc.

Kata kunci : depresi ringan, LM555, HEF4017B, AT89C2051

Masalah kejiwaan berkaitan erat dengan kehidupan seseorang. Setiap tahun semakin banyak orang yang mengalami gangguan kejiwaan. Jika kita mengamati di jalan-jalan dalam beberapa tahun belakangan ini semakin sering dijumpai orang dengan gangguan kejiwaan. Teknologi telah memberikan solusi atas masalah ini, diantaranya ialah CES (Cranial Electrotherapy Stimulation).

Alat ini menggunakan LM555 sebagai pembangkit pulsa, Decade Counter HEF4017B dan dua buah mikrokontroller AT89C2051. Fungsi LM555 adalah memberikan input berupa sinyal kotak sebesar 2,5 Hz ke Decade Counter HEF4017B yang kemudian akan diolah menjadi stimulus yang akan diberikan ke pasien. Output dari Decade Counter HEF4017B yang digunakan hanya dua output dari sepuluh output yang tersedia. Dari dua output tersebut dihubungkan dengan dua elektroda tempel yang akan direkatkan di kepala pasien.

Fungsi dari mikrokontroller yang digunakan ialah untuk menterjemahkan kerja alat kepada pengguna melalui LCD M1632. Data yang ditampilkan ialah lama pulsa high dan low dalam satuan[sekon], arus dalam satuan [mikroAmpere] dan frekuensi output dalam satuan [Hertz]. Sedangkan mikrokontroller yang lainnya berfungsi sebagai kontrol terhadap output stimulasi dan deteksi arus.

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BAB I

PENDAHULUAN

1.1. Latar Belakang

Masalah kejiwaan berkaitan erat dengan kehidupan seseorang. Setiap tahun semakin banyak orang yang mengalami gangguan kejiwaan. Jika kita mengamati di jalan-jalan dalam beberapa tahun belakangan ini semakin sering dijumpai orang dengan gangguan kejiwaan. Berbeda dengan pasien yang berada di rumah sakit jiwa, mereka tidak mendapatkan penanganan yang baik. Di rumah sakit jiwa mereka akan mendapat penanganan secara medis. Diantaranya dengan menggunakan *Cranial Electrotherapy Stimulation.*

Cranial Electrotherapy Stimulation (*CES*) merupakan teknik popular yang digunakan untuk merangsang kondisi psikologis pada penderita gangguan kejiwaan ringan. Semenjak pertama kali dikenalkan, teknik ini sering digunakan terutama di Amerika untuk mengobati pasien dengan gangguan masalah kejiwaan seperti rasa cemas yang berlebihan, stres, depresi ringan, insomnia, dan ketergantungan obat. Dengan memberikan stimulasi gelombang listrik pada *cranial* (tempurung kepala) diharapkan menstimulus syaraf-syaraf yang terganggu.

Sinyal yang diberikan oleh *Cranial Electrotherapy Stimulation* merupakan sinyal listrik yang mengandung gelombang kotak dengan frekuensi 0,5Hz. Dengan adanya peningkatan di bidang teknologi digital khususnya komponen *Integrated Circuit* (IC), sinyal tersebut dapat dibuat dengan lebih mudah dan presisi dengan menggunakan IC *timer* LM555.

1.2. Rumusan Masalah

Berdasarkan latar belakang tersebut, maka permasalahan yang timbul adalah bagaimana merancang dan membuat alat *Cranial Electrotherapy Stimulation* (CES) yang mampu menghasilkan frekuensi kotak dengan menggunakan IC LM555. Adapun rumusan masalah dari permasalahan tersebut adalah sebagai berikut :

a) Bagaimana sistem perangkat keras *Cranial Electrotherapy Stimulation* dengan menggunakan IC LM555.
b) Bagaimana sistem perangkat lunak *Cranial Electrotherapy Stimulation* dengan menggunakan mikrokontroler AT89C2051 untuk mendeteksi frekuensi dari LM555.

1.3. Tujuan Penulisan

Tujuan dari penulisan skripsi ini adalah untuk membuat prototipe alat *Cranial Electrotherapy Stimulation* (CES) yang menggunakan IC LM555 dan mikrokontroler AT89C2051.

1.4. Batasan Masalah

Penulis membatasi ruang lingkup dalam skripsi ini dalam batasan masalah. Adapun batasan masalah tersebut adalah sebagai berikut :

a) Frekuensi pembangkit sebesar 2,5Hz berasal dari IC LM555.

b) Frekuensi 0,5Hz didapat dari komponen pembagi Frekuensi yang berupa IC HEF4017.

c) Sumber tegangan didapat dari battery 9Vdc.

d) Besarnya tegangan untuk frekuensi 0,5Hz sebesar 9Vdc.

e) Mikrokontroler AT89C2051 hanya digunakan sebagai pengatur tampilan dan pengukur arus dan frekuensi.

f) Tidak membahas ilmu kimia dan biologi.

1.5. Metodologi Penulisan

Metodologi yang dipakai dalam pembuatan skripsi ini adalah:

1. Studi Literatur

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

2. Pengkajian

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

3. Perancangan dan Pembuatan Alat

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

4. Pengujian Alat

   Dengan melakukan pengujian per-blok rangkaian dan kerja seluruh sistem pada alat tersebut.

1.6. Sistematika Pembahasan

Agar pembaca lebih cepat memahami alur dari laporan ini maka sistematika pembahasan dalam laporan akhir perlu penulis kemukakan. Adapun sistematikanya adalah sebagai berikut:

BAB I PENDAHULUAN, yang berisikan tentang latar belakang permasalahan, tujuan, batasan masalah dan sistematika pembahasan.

BAB II TEORI PENUNJANG, yang berisikan tentang teori dasar sebagai penunjang dari permasalahan yang diambil.

BAB III PERANCANGAN ALAT, yang merupakan pembahasan dari komponen-komponen yang digunakan dan pemilihannya menurut perencanaan dan perhitungan.

BAB IV PENGUJIAN ALAT, yang berisikan tentang pembahasan dari rumusan masalah.

BAB V PENUTUP, yang berisikan kesimpulan dan saran.

BAB II
TEORI PENUNJANG

2.1. Teori Stres

Kata Stres seringkali terdengar dalam perbincangan kita sehari-hari. Mulai dari untuk menggambarkan suasana hati yang suntuk, ketegangan, kecemasan, kesedihan yang mendalam, serta segala perasaan tidak enak lainnya. Banyak kejadian yang dapat dijelaskan dengan singkat menggunakan kalimat : "Lagi stres!" Anak sekolah yang sibuk ujian, remaja yang lagi patah hati, anak yang kurang mendapat perhatian, anak yang terlalu diperhatikan, pegawai yang kebanyakan kerja, orang yang di PHK, yang sedang mencari kerja dan banyak lagi orang-orang yang mengaku sedang stres atau bahkan dituduh stres oleh lingkungannya. Perilaku orang yang mengalaminya pun beragam, mulai dari menangis seharian, melamun, tidak bisa tidur, tidak bisa makan, bahkan tidak sedikit kita temui sebagai pasien di UGD untuk percobaan bunuh diri.

Menurut Feldman stres dapat didefinisikan sebagai suatu proses menilai peristiwa sebagai sesuatu yang mengancam, menantang, membahayakan, dan individu merespon pada level fisiologis, emosional, kognitif dan perilaku[1]. Stres terbagi dalam beberapa tingkatan, diantaranya stres ringan, stres sedang dan stres berat (akut). Indikasi stres diantaranya adalah susah tidur (*insomnia*), cepat lelah, mudah terusik, kepala pusing, dan sebagainya. Secara fisiologis penderita stres memiliki tekanan darah diatas normal, rata rata sekitar 120 per 70. Dan dalam

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1. Fitri Fausiah, Julianti Widury,"Psikologi Abnormal Klinis Dewasa", UI Press, 2005

penyusunan skripsi ini penulis fokus dalam stres ringan dengan spesifik gejala susah tidur.

2.2. Cranial Electrotherapy Stimulation (CES).

2.2.1. Sejarah CES.

Pengembangan CES dilakukan Uni Soviet pada akhir tahun 1949 berdasarkan hasil riset Leduc dan Rouxeau di Perancis pada tahun 1902 tentang rangsangan otak dengan listrik arus lemah[2]. Pengambangan Uni Soviet tersebut menghasilkan alat yang disebut dengan electrosleep. Electrosleep pertamakali diciptakan untuk mengatasi gangguan tidur *(insomnia)*. Namun dalam pengembangannya electrosleep bisa juga mengatasi gelisah dan depresi.

Electrosleep mulai masuk ke dataran eropa secara luas pada tahun 1950-an. Pada akhir tahun 1960-an penelitian CES pada binatang dilakukan di University of Tennesse, sekarang dikenal University of Wisconsin Medical School, yang kemudian diteruskan penelitian pada manusia oleh University of Texas Medical Schol dan University of Mississippi Student Counseling Center. Semenjak mendapat persetujuan FDA untuk pengobatan stres, frustasi dan depresi pada tahun 1976, perkembangan CES secara komersial pada penggunaan di rumah meluas di Amerika. Namun dalam beberapa dasawarsa terakhir CES mulai turun pamornya karena munculnya teknologi terbaru pengembangan dari CES yang bernama *CESta* dan *e-stim (electro-stimulation)*.

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2. http:// www.elixa.com/CES/CESfaq.htm

2.2.2. Spesifikasi Alat.

Proses terapi dengan menggunakan CES dalam satu sesi berlangsung minimal 20 menit sampai maksimal 40 menit, dengan rata rata penggunaan paling sering dilakukan selama 30 menit dalam dua kali sesi perhari. Namun bila diperlukan proses terapi bisa juga dilakukan selama 60 menit langsung untuk satu hari. Beberapa CES yang beredar di pasaran memiliki spesifikasi, arus 10 – 600[mikroAmpere], frekuensi 0,5 - 100[Hertz], timer aktif 10 – 60[menit] dan menggunakan baterai 9Vdc.

2.3. Elektroda.

Elektroda adalah transducer yang menghubungkan peralatan medis ke tubuh pasien. Dalam proses tersebut terdapat dua jenis penghantar yang berbeda. Pada bahan logam energi dihantarkan oleh elektron, sedangkan pada zat cair energi dihantarakan oleh ion[3]. Dan elektroda tersebut ditempelkan 1[inchi] di atas pusat garis lurus antara mata dan lubang telinga.

Elektroda yang digunakan merupakan elektroda noninvasive, yaitu elektroda yang tidak menembus permukaan kulit. Bahan yang digunakan dalam pembuatan elektroda ini adalah Ag dan Cl, sehingga disebut elektroda Ag/AgCl. Ag adalah kode kimia untuk perak dan Cl adalah kode kimia untuk klorida. Mengenai elektroda tidak dibahas lebih lanjut karena telah masuk pada bidang ilmu kimia dan tidak memungkinkan dilakukan pengukuran secara biasa.

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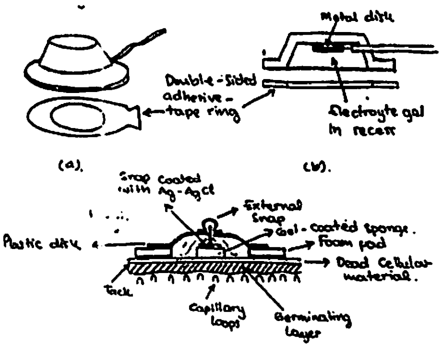
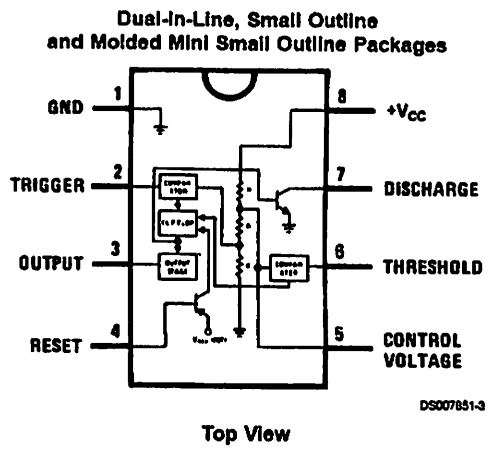
3 http:// www.nico2000.net/datasheets/How%20ISEs%20Work.htm



Gambar 2.1. Elektroda noninvasive[4]

2.4. IC Timer LM555

IC LM555 merupakan komponen yang memiliki kestabilan tinggi sebagai pembangkit waktu dan osilator. Pada mode pembangkit waktu, waktu dapat diatur secara presisi hanya dengan menggunakan satu buah resistor dan kapasitor. Sedangkan pada mode pembangkit gelombang (osilator), frekuensi dan *duty cycle* secara akurat dapat diatur dengan hanya menggunakan 2 buah resistor dan 1 buah kapasitor. Adapun susunan kaki-kaki dari IC LM555 sesuai dengan Gambar 2.2.



Gambar 2.2. Susunan kaki-kaki IC LM555[5]

4. Diktat matakuliah Instrumentasi Medika, 2006 : 3

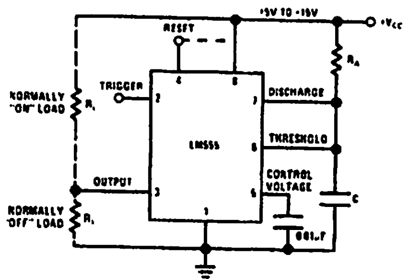
5. Datasheet LM555 : 2

2.4.1 *One-Shoot Monostable Operation*

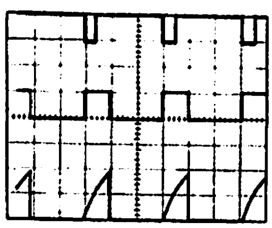
Pada jenis pengoperasian ini, IC LM555 difungsikan dengan cara memberikan pulsa negatif atau tegangan maksimal 1/3 dari Vcc (logika "0") ke kaki *trigger* (pin 2). Ketika IC ini diaktifkan, rangkaian flip-flop di dalam IC akan terhubung dengan kapasitor dan menghasilkan logika "high" di keluarannya. Tegangan yang melewati kapasitor akan meningkat selama :

$$R = \frac{T}{1{,}1.C}$$

Sampai tegangan tersebut sebesar 2/3Vcc. Setelah itu, komparator akan melakukan reset terhadap rangkaian flip-flop sehingga keluarannya berlogika "low". Rangkaian ini sesuai dengan Gambar 2.3., sedangkan gambar gelombangnya ditunjukkan pada Gambar 2.4.



Gambar 2.3. *Monostable operation* IC LM555[6]



Gambar 2.4. Bentuk gelombang *monostable* IC LM555[6]

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6. Datasheet LM555 : 7

2.4.2 Free-Running Monostable Operation

Gambar rangkain dari jenis operasi ini hampir sama dengan operasi *one-shoot monostable*, perbedaannya hanya di jalur pin 2 (*trigger*). Pada jenis pengoperasian ini, pin 2 terhubung ke pin 6. Dengan adanya hubungan ini, maka jalur *trigger* dapat berosilasi secara terus-menerus.

2.5. IC HEF4017B Counter

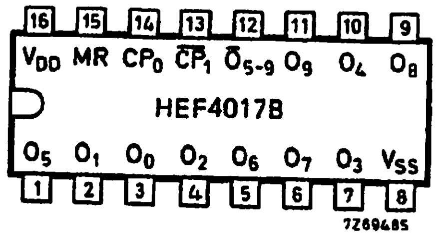
IC HEF4017 merupakan suatu jenis IC yang dilengkapi dengan rangkaian *5-stage Johnson decade counter* dengan 10 jalur keluaran akitf "high" (0_0 sampai 0_9), 1 jalur keluaran aktif "low" pada *most significant flip-flop* ($\overline{O}_{5-9}$), jalur masukkan *clock* aktif "high" dan "low" ($CP_0, \overline{CP}_1$) dan 1 jalur masukkan untuk master reset (MR).

Perhitungan pada jalur keluaran terjadi ketika terjadinya transisi logika dari "low" ke "high" pada CP_0 sementara $\overline{CP}_1$ berlogika "low" atau ketika terjadinya transisi logika dari "high" ke "low" pada $\overline{CP}_1$ sementara CP_0 berlogika "high".

Pada saat perhitungan berada di posisi 5, 6, 7, 8 dan 9, jalur keluaran $\overline{O}_{5-9}$ yang sedang berlogika "low" dapat digunakan untuk menggerakkan masukkan CP_0 untuk perhitungan berikutnya.

Logika "high" pada jalur MR akan mengakibatkan reset pada perhitungan ($O_0=\overline{O}_{5\text{-}9}$="high" ; O_1 sampai O_9="low") dan tidak terpengaruh oleh jalur clock ($CP_0, \overline{CP}_1$).

Adapun susunan kaki-kaki pada IC HEF4017 sesuai dengan Gambar 2.5.



Gambar 2.5. Susunan kaki-kaki IC HEF4017[7]

Sedangkan pengoperasian IC ini sesuai dengan Tabel 2.1. dan gambar waktu pulsa keluarannya sesuai dengan Gambar 2.6.

Tabel 2.1. Tabel Operasi IC HEF4017[8]

FUNCTION TABLE

MR	CP_0	$\overline{CP}_1$	OPERATION
H	X	X	$O_0 = \overline{O}_{5\text{-}9}$ = H; O_1 to O_9 = L
L	H	↓	Counter advances
L	↑	L	Counter advances
L	L	X	No change
L	X	H	No change
L	H	↑	No change
L	↓	L	No change

Notes

1. H = HIGH state (the more positive voltage)
2. L = LOW state (the less positive voltage)
3. X = state is immaterial
4. ↑ = positive-going transition
5. ↓ = negative-going transition

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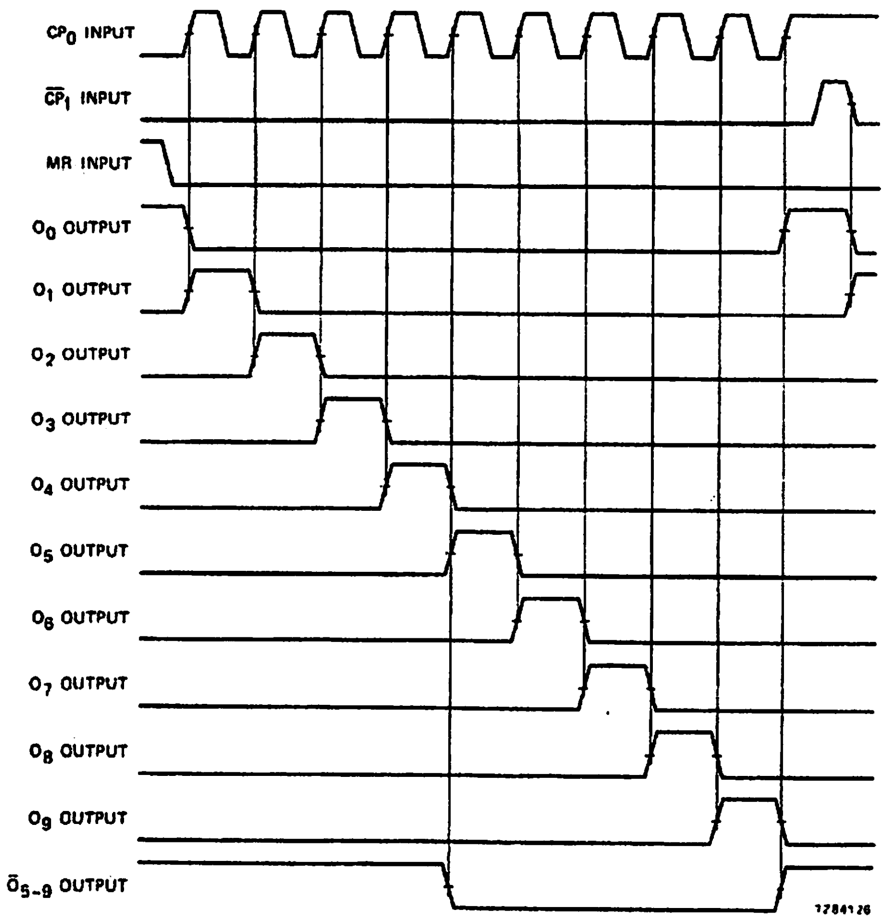
7. Datasheet HEF4017B : 2
8. Datasheet HEF4017B : 4



Gambar 2.6. Diagram waktu IC HEF4017[9]

2.6. Mikrokontroler AT89C2051

2.6.1 Sistem Mikrokontroler AT89C2051

Mikrokontroler dan AT89C2051 adalah keluarga MCS-51, membutuhkan daya yang rendah, memiliki performa yang tinggi, dan merupakan mikrokomputer 8 bit yang dilengkapi 2 Kbyte EPROM (Erasable and Programable Read Only Memory dan 128 RAM byte internal.

2.6.2 Perangkat Keras Mikrokontroler AT89C2051

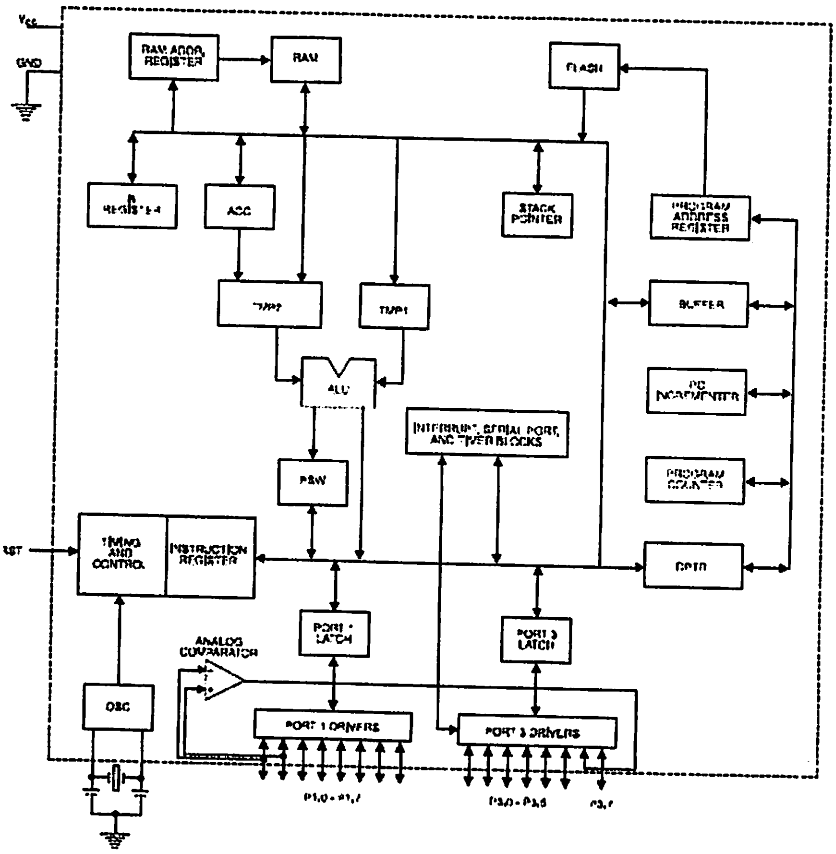
Perangkat keras mikrokontroler AT89C2051 terdiri dari :

- CPU 8-bit

---

9 Datasheet HEF4017B : 7

- Memori
- Jalur input output
- Timer dan counter
- Sumber interrupt
- Jalur serial UART
- Oscilator dan clock internal



Gambar 2.7. Diagram blok mikrokontroler AT89C2051[10]

2.6.3 Arsitektur Mikrokontroler AT89C2051

Arsitektur AT 89C2051 adalah sebagai berikut:

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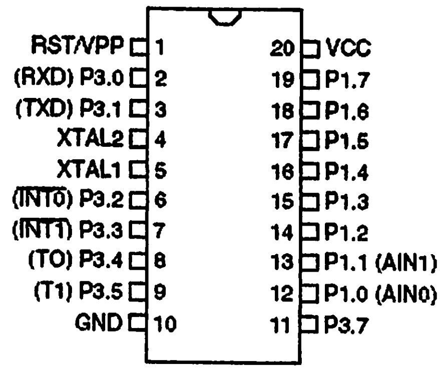
10. Datasheet AT89C2051 : 2

1. CPU (Central Processing Unit) 8bit dengan register A (Accumulator) dan B
2. 16 Bit Program Counter (PC) dan Data Pointer (DPTR)
3. 8 bit Program Status Word (PSW)
4. 8 bit stacck Pointer
5. 2Kbyte untuk iAT 89C2051 internal EPROM
6. 128 byte internal RAM
   - 4 bank register, masing – masing berisi 8 register
   - 16 byte yang dapat dialamati pada bit level
   - 80 byte general pupose memory data
7. 16 pin input output yang tersusun atas P1 dan P3, masing – masing 8 bit
8. 2 buah timer dan counter
9. Receiver / Transmiter dan serial full duplex : SBUF
10. Control Register, yaitu ; TCON, TMOD, SCON, PCON, IP dan IE
11. 5 buah sumber interupt (2 buah sumber interupt internal dan 3 buah sumber interupt external)
12. Oscillator dan Clock Internal

2.6.4 Konfigurasi Pin–pin Mikrokontroler AT89C2051

Mikrokontroler AT89C2051 terdiri dari 20 pin, dengan konfigurasi sebagai berikut :



Gambar 2.8. Konfigurasi pin-pin mikrokontroler AT89C2051[10]

Fungsi dari tiap – tiap pin adalah sebagai berikut:

1. Vcc (Supply Tegangan)
2. GND (Ground)
3. Port I adalah port I/O bidireksional 8 bit. Pin port P1.2 sampai P1.7 memberikan tarikan internal. P1.1 berperan sebagai input positif (AIN0) dan input negatif (AIN1) dari komparator analog presisi on chip. Buffer output p1 bisa diturunkan sampai 20 mA dan bisa mengarahkan diplay LED secara langsung. Jika 1 untuk pin port 1, maka dia bisa digunakan sebagai input. Jika P1.2 sampai P1.7 digunakan sebagai input diginakan secara eksternal, maka ia akan dijadikan sebagai arus sumber (I_{IL}) karena tarikan internal. Port 1 juga menerima kode selama pemrograman dan pembuktian Flash.
4. Port 3 memiliki P3.0 sampai P3.5, P3.7 dan port 3 terdiri dari tujuh pin I/O bidireksional dengan menarik internal. P3.6 memiliki ikatan keras sebagai suatu input untuk output komparator on chip dan tidak bisa

10. Datasheet AT89C2051 : 2

dijangkau sebagai pin I/O tujuan umum. Buffer output port 3 bisa diturunkan sampai 20mA. Jika ditulis untuk pin port 3, maka pin bisa ditarik ke atas engan penarikan dan bisa digunakan sebagai input. Sebagai input, pin port 3 yang ditarik ke bawah secara eksternal akan menjadikan arus sumber (I_{IL}) karena tarikan ke atas. Port 3 berperan sebagai fungsi fiture khusus dari AT 89C2051, port 3 juga menerima sinyal pengendalian dari pemrograman dan penjelasan flash.

5. RST adalah input reset.
6. X-TAL1 dan X-TAL2. Pin ini dihubungkan dengan kristal bila menggunakan occillator eksternal. X-TAL1 merupakan input inverting oscillator amplifier sedangkan X-TAL2 merupakan output inverting oscillator amplifier.

2.6.5 Organisasi Memori

Di dalam AT89C2051 ruang alamat telah dibedakan untuk program memori program dan memori data.

2.6.5.1 Program memori internal

- AT89C2051 memiliki pemrograman memory sebesar 4Kbyte dan 2Kbyte dengan ruang alamat 0000H-07FFH. Jika alamat – alamat program lebih tinggi dari pada 07FFh, yang melebihi kapasitas ROM internal menyebabkan AT 89C2051 secara otomatis mengambil kode byte dari memori ekternal. Code byte juga dapat diambil hanya dari eksternal memory dengan alamat 0000H-07FFH dengan cara menghubungkan pin ke ground.

2.6.5.2 Data Memory (RAM) Internal

Memori data (RAM) internal berkapasitas 128 byte dimulai dari 00H sampai 7FH yang terbagi atas 3 daerah, yaitu:

- Empat regiter bank

  Setiap bank terdiri dari 8 register (R0-R7) sehingga jumlah register untuk keempat bank register (bank 0- bank 3) menjadi 32 buah register yang menempati ruang alamat 00H-1FH. Mengaktifkan salah satu bank regiter dapat dilakukan dengan mengatur RS0-RS1 pada PSW (Program Status Word).

- Bit Addresable

  Terdiri dari 16 byte yang berada pada alamat 20H-2FH. Masing-masing 128 lokasi bit ini dapat dialamati secara langsung.

- Strach Pad Area

  Terdiri atas 80 byte yang secara langsung dan digunakan untuk keperluan umum (*general purpose*) misalnya digunakan untuk lokasi stack.

2.6.5.3 SFR (Register Fungsi Khusus)

Tabel 2.2. *Special Function Register* AT89C2051[11]

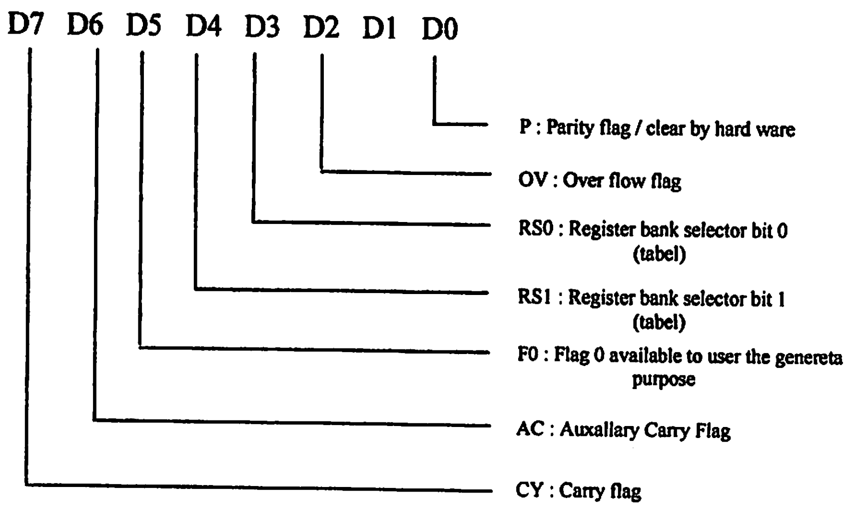
0F8H									0FFH
0F0H	B 00000000								0F7H
0E8H									0EFH
0E0H	ACC 00000000								0E7H
0D8H									0DFH
0D0H	PSW 0000000								0D7H
0C8H									0CFH
0C0H									0C7H
0B8H	IP XXX00000								0BFH
0B0H	P3 11111111								0B7H
0A8H	0XX00000								0AFH
0A0H									0A7H
98H	SCON 00000000	SBUF XXXX XXXX							9FH
90H	P1 11111111								97H
88H	TCON 00000000	TMOD 000000 00	TLO 00000000	TL1 00000000	TH0 00000000	TH1 00000000			8FH
80H		SP 000001 11	DPL 00000000	DPH 00000000				PCON 0XXX000 0	87H

11. Datasheet AT89C2051 : 5

Software dari user hendaknya tidak melakukan perubahan data pada lokasi yang tidak terdaftar, karena alamat ini mungkin akan digunakan untuk mendukung feature baru.

2.6.5.4 Program Status Word (PSW)

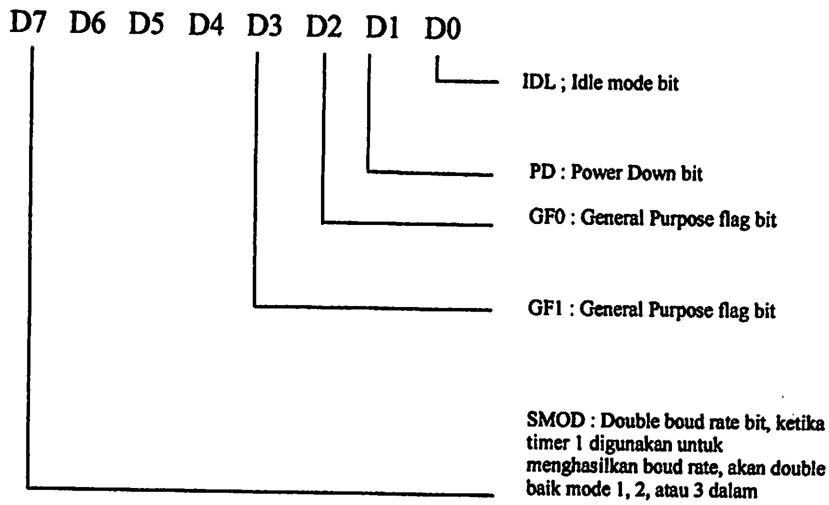
Register ini terletak di alamat D0H. Cara mendefinisikannya adalah sebagai berikut :



Gambar 2.9. Pendefinisian PSW mikrokontroler AT89C2051

2.6.5.5 PCON (Power Control)

Register ini terletak pada alamat 87H. Cara mendefinisikannya adalah sebagai berikut :



Gambar 2.10. Pendefinisian PCON mikrokontroler AT89C2051

2.6.5.6 Sistem interrupt

Mikrokontroler AT 89C2051 memiliki 5 sumber interrupt yang dapat membangkitkan permintaan yaitu :INT0, INT1, T0, T1, dan port serial.

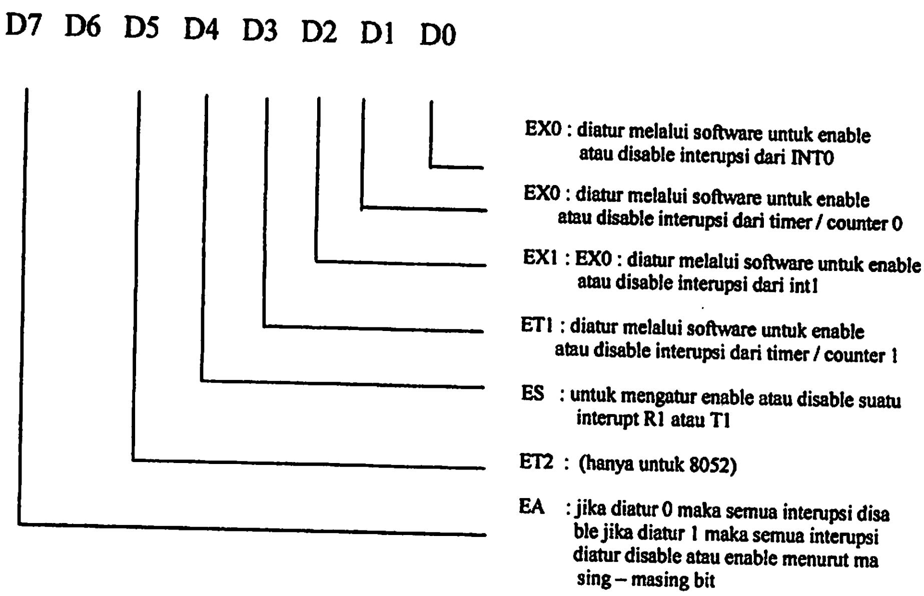
Saat terjadinya interrupt mikrokontroler secara otomatis akan menuju subrutin pada alamat tersebut. Setelah interrupt service selesai dikerjakan, mikrokontroler akan mengerjakan program semula. Dua sumber eksternal adalah INT0 dan INT1 dimana kedua interrupt eksternal akan aktif atau transisi tergantung isi IT0 dan IT1 pada register TCON. Interrupt T0 dan T1 aktif pada saat timer yang sesuai mengalami roll over. Interupsi serial dilakukan dengan melakukan oprasi OR pada R1 dan T1. Tiap – tiap sumber interupsi dapat enable atau disable secara software.

Tingkat prioritas semua sumber interupsi dapat diprogram sendiri – sendiri dengan set atau clear bit pada SFRS (Interrupsi Priority).

Tabel 2.3. Alamat Sumber Interupsi AT89C2051

Sumber Interupt	**Alamat Awal**
Interupt Luar 0 (INT0)	0003H
Pewaktu / pencacah 0 (T0)	003BH
Interupt Luar 1 (INT1)	001BH
Pewaktu / pencacah 1 (T1)	001BH
Port Serial	0023H

Register yang berperan dalam mengatur aktif tidaknya interupsi adalah input enable register (IE), berikut adalah susunan dari bit – bit beserta kegunaannya



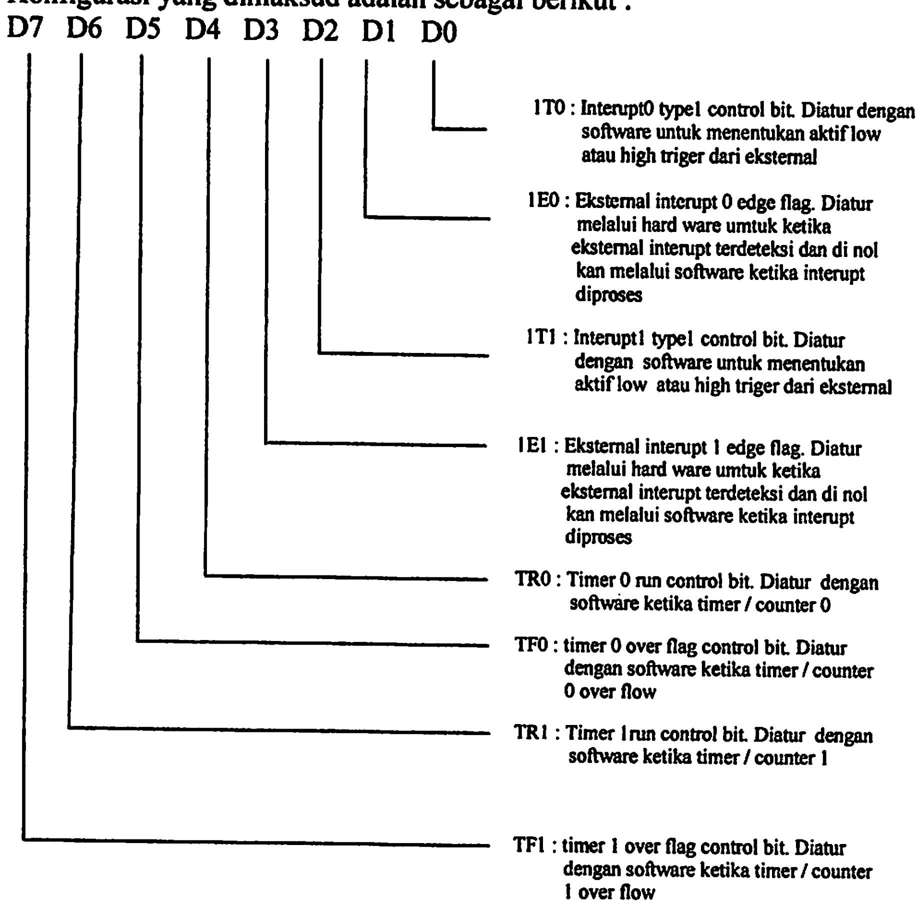
Gambar 2.11. Pendefinisian IE register mikrokontroler AT89C2051

2.6.5.7 Timer / Counter

Pengendalian kerja dari timer/counter dilakukan dengan pengaturan register yang berhubungan dengan kinerja dari timer/counter yaitu melalui sebuah timer/counter mode control.

Untuk mengaktifkan timer/counter yang meliputi penentuan fungsi sebagai timer atau sebagai counter serta pemilihan mode operasi dapat diatur melalui TMOD yang beralamat pada 98H.

Konfigurasi yang dimaksud adalah sebagai berikut :



Gambar 2.12. Pendefinisian TMOD mikrokontroler AT89C2051

Tmod : Timer / Counter Mode Control Register

GATE	C /T	M1	M0	GATE	C / T	M1	M0

TIMER 0 TIMER1

Gambar 2.13. Timer/Counter Mode Control Register

Tabel 2.4. Mode Operasi Timer/Counter

M1	M0	Oprating Mode
0	0	Timer 13 bit
0	1	Timer / Counter 16 bit
1	0	16 bir auto reload Timer / Counter
1	1	TLO dari timer adalah 8 bit timer / counter dikendalikan oleh kontrol bit timer 0. TH0 adalah timer 8 bit yang dikendalikan oleh timer 1 control bit

- *Gate*

  Bila gate = 1, Timer / Counter x enable hanya pada saat pin INTx tinggi dari Trx 1. Saat gate 0, timer / counter enable jika bit trx 1.

- *CT*

  Jika bit C /T = 0, maka timer / counter x akan berfungsi sebagai timer. Jika C /T = 1, maka counter x akan berfungsi sebagai counter.

- *M1 dan M2*

  Sebagai penentu mode Timer/Counter.

2.7. LCD M1632

LCD 1632 yang digunakan adalah LCD produksi Seiko Instrument (M1632), kelebihan dari LCD M1632 ini antara lain adalah mampu dioperasikan dalam mode 4bit, dalam arti pengolahan data dari dan ke LCD dapat dilewatkan lewat data dengan lebar 4bit saja. Ini cukup membantu menghemat port microcontroller yang dipakai.

Penjelasan pin-out pada LCD M1632 adalah sebagai berikut :

- VSS (pin 1) dan VCC (pin 2) adalah pin untuk power supply.
- VEE (pin 3), adalah pin untuk drive LCD, yaitu untuk mengatur itensitas tampilan pada LCD.
- RS (pin 4), adalah pin untuk pemilihan mode input data. Apabila RS diberi logic 0, maka data berupa data control dan bila RS diberi logic 1, maka data adalah data untuk ditampilkan di LCD.
- R/W (pin 5), pin ini merupakan pin untuk pemilihan proses pada LCD. Bila pin R/W berlogic 1, maka proses read (baca) data, kebalikannya bila pin R/W berlogic 0, proses write (tulis) data.
- E (pin 6), adalah pin enable untuk LCD. LCD akan enable bila pin ini berlogic high, kebalikannya bila pin ini berlogic 0, LCD akan disable..
- DB0-DB7 (pin 7 – pin 14), adalah pin untuk input/output data. Tetapi untuk mode pengoperasian 4 bit yang berfungsi hanya DB4 – DB7.
- V+ BL (pin15) dan V-BL (pin 16) untuk supply lampu back light.

LCD (Liquid Crystal Display) adalah komponen display yang tidak memancar (nonemissive), sehingga tidak menghasilkan sumber cahaya seperti

CRT (Cathode Ray Tube), dan berdaya sangat rendah (lebih rendah dari LED) yaitu dalam hitungan mikrowatt (LED dalam hitungan miliwatt). LCD menahan atau membiarkan cahaya yang dipantulkan dari sunber cahaya luar dan cahaya yang berasal dari belakang atau samping yang melewatinya. LCD dikontrol oleh ROM/RAM generator karakter dan RAM data display. Semua fungsi display dikontrol dengan instruksi dan LCD dapat dengan mudah diinterfacekan dengan MPU (Mikroprosessor Unit).

Karakteristik dari LCD dot-matriks adalah sebagai berikut:

- 16X2 karakter dengan 5X7 dot matriks + kursor
- ROM generator karakter dengan 8 tipe karakter (untuk program write)
- 80X8 bit RAM data display
- Dapat diinterfacekan dengan 4 atau 8 bit MPU
- RAM data dan RAM generator karakter dapat dibaca dari MPU
- +5V single power supply
- Power-on reset
- Range temperature operasi 0-60°C
- Beberapa fungsi instruksi:

  Display clear, Cursor home, Display ON/OFF, Cursor ON/OFF, Display charackter blink, Cursor Shift dan Display shift.

LCD disini dapat menampilkan karakter yang ada pada ROM generator karakter, yang sudah berisi 192 jenis karakter, dengan cara memberikan kode karakter untuk tiap-tiap karakter yang diinginkan pada pada bus data dengan menggunakan sinyal kontrol. Fungsi masing-masing pin dari LCD Dot Matriks ini dapat dilihat pada tabel 2.13 berikut ini:

Tabel 2.5. Pin-pin LCD dan Fungsinya

Nama sinyal	Jumlah terminal	I/O	Tujuan	Fungsi
DB0-DB7	8	I/O	MPU	4 bit data bus lower tristate dua arah,dapat dibaca atau ditulisi terhadap MPU melalui data tersebut. DB7 juga sebagai busy flag.
E	1	INPUT	MPU	Sinyal penanda operasi read/write
R/W	1	INPUT	MPU	0: Write 1: Read
RS	1	INPUT	MPU	Sinyal seleksi register 0: Register instruksi (write) Busy flag dan address Conter (read) 1: Data register (write dan read)
VLC	1	-	Power Supply	Power supply untuk mendrive LCD guna pengaturan contrast
VDD	1	-	Power Suipply	+5V
VSS	1	-	Power Supply	Ground
V+BL	1	-	Power Supply	4-4,2 V 50-200mA
V-BL	1	-	Power Suply	0V (GND)

2.8. Transistor Sebagai Switching

Dalam perancangan alat ini digunakan transistor C945 yang berfungsi sebagai saklar. Transistor ini merupakan transistor bipolar dengan tipe NPN.

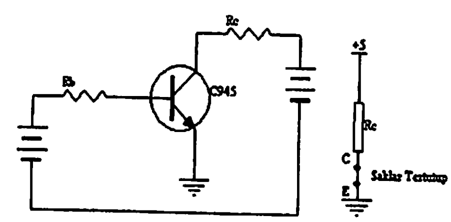
Transistor yang digunakan sebagai saklar harus dikondisikan dalam dua kondisi, yaitu :

1. Transistor dalam keadaan jenuh (saturasi).

   Transistor dalam keadaan jenuh (saturasi), maka berlaku :

   - Kuat arus (Ic) mencapai maksimum.
   - Nilai Vce sama denga 0 volt.
   - Tegangan pada beban sama dengan tegangan sumber ($V_{CC}=V_{RC}$).

   Untuk lebih jelasnya dapat dilihat pada gambar dibawah ini :



Gambar 2.14. Transistor dalam keadaan Saturasi

Untuk menghitung resistansi pada basis menggunakan rumus :

$V_{cc} - I_c.R_c - V_{ce} = 0$

Karena keadaan saturasi $V_{ce} = 0$ maka rumusnya menjadi :

$V_{ce} - I_c.R_c = 0$

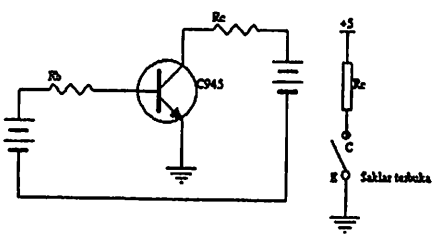
$I_c = \beta_{dc}.I_b$

$$I_b = \frac{Vcc - Vbe}{Rb}$$

2. Transistor dalam keadaan *Cut Off.*

Transistor dalam keadaan cut off (sumbat) berlaku hal – hal sebagai berikut :

- Nilai arus Ib sama dengan 0 volt.
- Nilai arus Ic sangat kecil sekali sehingga dapat dibaikan.
- Besarnya Vcc sama dengan Vce.



Gambar 2.15. Transistor dalam keadaan Cut Off (sumbat)

BAB III

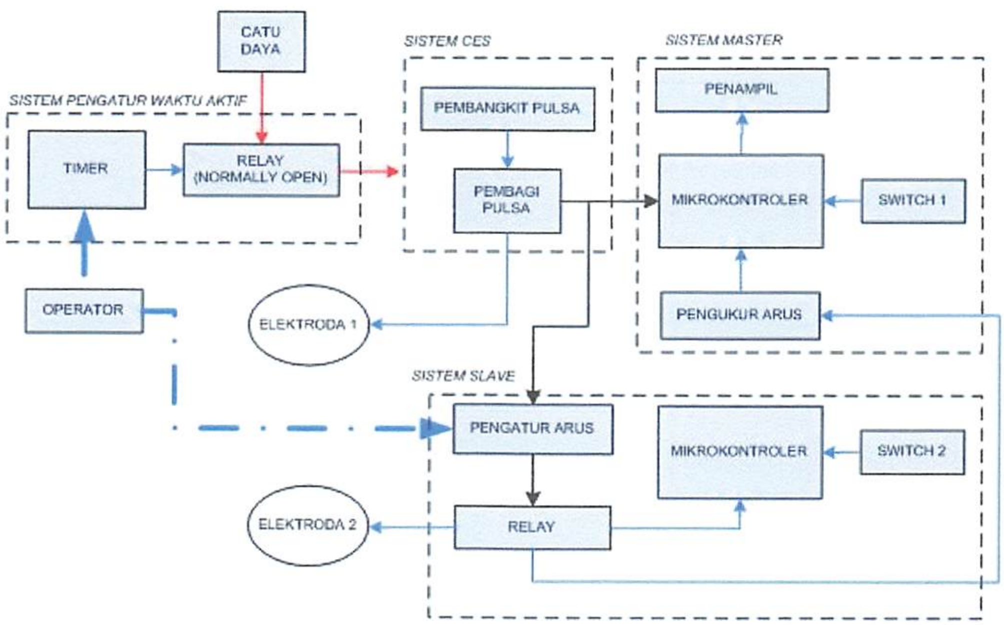
PERANCANGAN ALAT

3.1 Pendahuluan

Alat yang dirancang dalam skripsi ini adalah salah satu alat yang diadopsi dari *medical equipment* yang lebih dikenal dengan nama *Cranial Electrotherapy Stimulation* (CES) yang dikembangkan dari sebuah alat yang bernama *electrosleep*. Alat ini merupakan salah satu teknik terapi secara elektris untuk meningkatkan daya pikir, pengobatan ataupun perawatan bagi pasien penderita stres ringan, insomnia dan ketergantungan obat. Sistem CES dapat menghasilkan arus yang bervariasi (80 sampai 600 [mikroAmpere]) yang dialirkan melalui sepasang elektroda. Gelombang yang dihasilkan merupakan gelombang digital yang terdiri dari pulsa positif ("1") dan negatif ("0"). Lamanya pulsa positif yaitu sebesar 400 [ms] yang kemudian diikuti oleh pulsa negatif selama 400 [ms] dan berhenti sesaat selama 1.200 [ms]. Dengan kata lain, dalam satu gelombang terdiri dari satu pulsa positif ("1") selama 0,4 [s] dan satu pulsa negatif selama 1,6 [s]. Dari durasi gelombang tersebut, maka frekuensi yang dihasilkan oleh alat ini adalah 0,5 [Hz], hal ini dihitung berdasarkan durasi pulsa selama 2 [s].

3.2 Diagram Blok

Secara teknis, alat yang dirancang harus mampu mengeluarkan frekuensi kotak sebesar 0,5 [Hz] apabila durasi terhitung selama 2 [s], arus yang dialirkan dapat divariasikan dari 80 sampai 600 [mikroAmper], memiliki tampilan informasi besarnya frekuensi dan arus yang digunakan serta hanya bisa dioperasikan selama 30 menit. Dari deskripsi teknis tersebut, maka sistem alat dirancang dibagi menjadi 4 sistem yaitu sistem pengatur waktu aktif, CES, master dan slave. Adapun bentuk sistem yang dirancang sesuai dengan diagram blok pada Gambar 3.1.



Gambar 3.1. Diagram Blok Alat

Adapun keterangan dari setiap sistem tersebut adalah sebagai berikut:

3.2.1. Sistem pengatur waktu aktif

a) Fungsi sistem

Sistem pengatur waktu aktif berfungsi sebagai pengendali aktif atau tidaknya sistem CES. Hal ini ditujukan untuk menghemat konsumsi daya dari catu daya.

b) Cara kerja sistem

Sistem pengatur waktu aktif akan beroperasi apabila ada masukkan dari operator yang berupa penekanan *push button.* Pada proses ini rangkaian *timer* akan mulai melakukan proses perhitungan waktu selama 30 [menit]. Ketika *timer* mulai menghitung, rangkaian ini akan mengaktifkan saklar ke posisi tertutup sehingga catu daya dan sistem CES dapat terhubung. Proses penghubungan tersebut akan mengakibatkan sistem CES aktif. Setelah durasi waktu 30 [menit] tercapai, maka *timer* akan menon-aktifkan sistem CES dengan cara memutuskan saklar yang menghubungkan catu daya dengan sistem CES.

c) Perangkat keras sistem

Perangkat keras pembentuk sistem ini terdiri dari :

- Rangkaian *timer* (*one-shot monostable* IC LM555)
- Rangkaian saklar *Normally Open* (*driver relay*)

3.2.2. Sistem CES (*Cranial Electrotherapy Stimulation*)

a) Fungsi sistem

Sistem CES berfungsi sebagai penghasil stimulus yang berupa frekuensi kotak sebesar 0,5 [Hz] dalam durasi 2 [s] secara bergantian pada elektroda 1 dan elektroda 2. Pembentukan frekuensi tersebut didapat dari pulsa "high" ("1") selama 0,4 [s] dan pulsa "low" ("0") selama 1,6 [s].

b) Cara kerja sistem

Frekuensi yang terjadi pada sistem CES didapat dari rangkaian pembangkit pulsa dengan frekuensi awal sebesar 2,5 [Hz] kemudian frekuensi ini dibagi menjadi 0,5 [Hz]. Perlunya pembagian frekuensi ini dikarenakan frekuensi yang digunakan untuk terapi pasien sebesar 0,5 [Hz] dan stimulus frekuensi dibagi di bagian kiri dan kanan kepala pasien. Stimulus frekuensi ini diberikan secara bergantian di setiap bagian dan bentuk serta durasinya adalah sama.

Pada proses pengukuran besarnya durasi pulsa yang terjadi di salah satu keluaran sistem CES dipasang rangkaian transistor NPN *switching*. Hal ini dikarenakan, tegangan maksimal (logika "1") dari sistem ini sebesar 9Vdc sedangkan tegangan maksimal (logika "1") dari sistem mikrokontroler master yang akan mengukur pulsa tersebut hanya sebesar 5Vdc. Dengan adanya transistor tersebut, maka logika yang terjadi dari sistem CES dengan logika di sistem mikrokontroler master akan saling terbalik dan tegangan maksimumnya hanya sebesar 5Vdc.

c) Perangkat keras sistem

Perangkat keras pembentuk sistem ini terdiri dari :

- Rangkaian pembangkit frekuensi (*free run monostable* IC LM555)
- Rangkaian pembagi frekuensi (IC *Decade Counter* 4017)
- Rangkaian Transistor *Switching*

3.2.3. Sistem Mikrokontroler Master

a) Fungsi sistem

Sistem mikrokontroler master berfungsi sebagai pengatur jenis tampilan LCD M1632, pengukur arus dan pulsa dari sistem CES.

b) Cara kerja sistem

Pengukuran pulsa yang terjadi di sistem CES dilakukan secara terbalik, hal ini dikarenakan adanya rangkaian transistor NPN *switching* yang berfungsi sebagai pengaman tegangan sistem CES dan mikrokontroler master. Ketika sistem CES mengeluarkan logika "1" maka sistem mikrokontroler master akan menerima logika "0" pada pin P3.2, berdasarkan logika ini mikrokontroler akan mengaktifkan *timer internal* untuk menghitung durasi pulsa tersebut, demikian juga sebaliknya dengan logika "0" dari sistem CES. Hasil dari perhitungan timer mikrokontroler tersebut akan ditampilkan di layar LCD M1632.

Pengukuran arus dilakukan dengan cara mendeteksi besarnya nilai tegangan yang terjadi akibat perubahan resistasi yang melewati salah satu keluaran sistem CES. Nilai tegangan tersebut didapat dari rangkaian pembagi tegangan yang dihubungkan ke rangkaian ADC, sehingga besarnya tegangan akibat perubahan resistansi dapat dibaca oleh mikrokontroler secara digital. Oleh karena sistem mikrontroler ini hanya memiliki 15 jalur I/O dan komponen yang dikendalikan melebihi kapasitas jalur tersebut, maka digunakannya IC Latch yang berfungsi untuk menahan data komponen yang dikendalikan secara bergantian. Ketika sistem ini akan menampilkan informasi di layar LCD M1632, maka IC Latch yang terhubung dengan LCD diaktifkan dan IC Latch untuk ADC dinon-aktifkan, demikian sebaliknya apabila mikrokontroler akan membaca data dari ADC.

Indikator pergantian untuk pengukuran arus dan pulsa dari sistem CES adalah terjadinya logika "0" pada pin P1.4 akibat penekanan tombol pada salah satu jalur I/O mikrokontroler.

c) Perangkat keras sistem

Perangkat keras pembentuk sistem ini terdiri dari :

- Rangkaian minimum mikrokontroler AT89C2051
- Rangkaian IC Latch 74HC573
- Rangkaian LCD M1632
- Rangkaian ADC0804
- Rangkaian tombol *push-button*

3.2.4. Sistem Mikrokontroler Slave

a) Fungsi sistem

Sistem mikrokontroler slave berfungsi sebagai pengatur jalur tegangan keluaran sistem CES dengan elektroda dan ADC.

b) Cara kerja sistem

Sistem ini dilengkapi relay yang berfungsi sebagai pemutus dan penyambung jalur keluaran sistem CES ke rangkaian pengatur arus dengan elektroda dan rangkaian pengatur arus ke tegangan 5Vdc dengan ADC. Pada kondisi normal (relay *off*) keluaran sistem CES akan terhubung ke rangkaian pengatur arus kemudian ke elektroda dan ketika kondisi pengukuran arus, rangkaian pengatur arus akan terhubung ke rangkaian pembagi tegangan yang diteruskan ke ADC.

Indikator dari pengukuran arus keluaran sistem CES adalah terjadinya logika "0" di pin P3.2 mikrontroler slave akibat penekanan tombol *push-button.*

Adanya rangkaian relay tersebut dikarenakan tegangan maksimal yang dikeluarkan oleh sistem CES sebesar 9Vdc, sedangkan sistem pendeteksi arus yaitu ADC0804 hanya mampu mendeteksi sampai tegangan 5Vdc. Oleh karena itu diperlukannya sistem *switching* yang dapat mengendalikan keluaran sistem CES pada kondisi pengukuran arus dan pemakaian normal. Selain itu, pada sistem ini juga dilengkapi dengan rangkaian pembagi tegangan, hal ini dimaksudkan agar ADC dapat mendeteksi perubahan arus berdasarkan perubahan tegangan yang terjadi akibat perubahan resistansi yang ada pada rangkaian pengatur arus.

c) Perangkat keras sistem

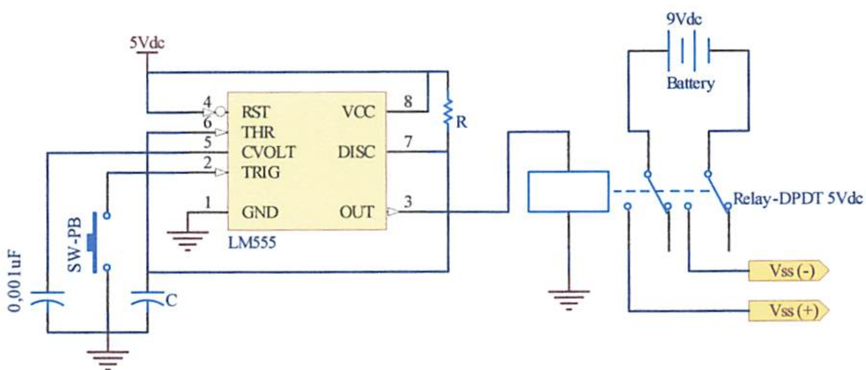
Perangkat keras pembentuk sistem ini terdiri dari :

- Rangkaian minimum mikrokontroler AT89C2051
- Rangkaian indikator led
- Rangkaian relay
- Rangkaian pengatur arus
- Rangkaian pembagi tegangan
- Rangkaian tombol *push-button*

3.3 Perencanaan Perangkat Keras

Bagian ini menguraikan perencanaan perangkat keras yang meliputi perencanaan dan perhitungan pada beberapa sistem sebagai berikut :

3.3.1. Sistem Pengatur Waktu Aktif



Gambar 3.2. Skematik sistem pengatur waktu aktif

Ketika sistem ini aktif (pin 3 LM555) mengeluarkan logika "1" maka relay DPDT akan aktif dan menghubungkan battery 9V ke seluruh sistem. Durasi aktifnya seluruh sistem yaitu selama 30 menit. Berdasarkan durasi ini maka perhitungan nilai R dan C pada komponen sistem LM555 sesuai dengan rumusan sebagai berikut :

$$t = 1{,}1.R.C$$

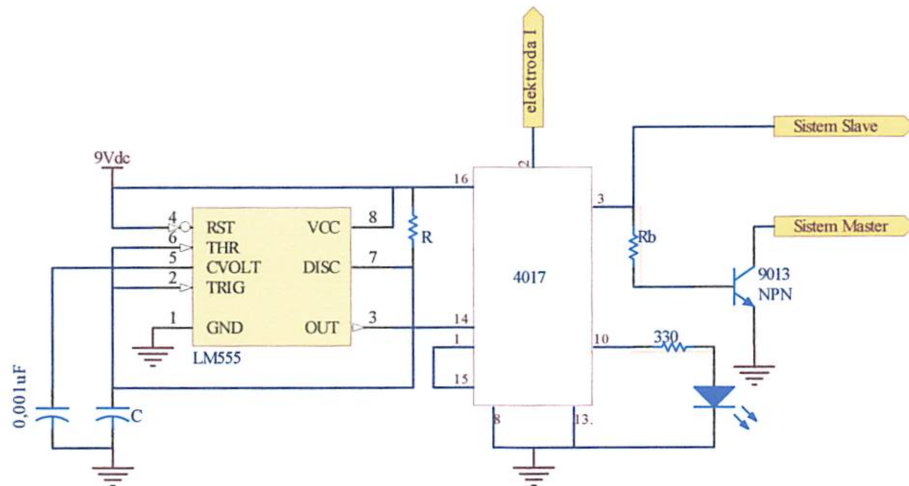
Dari rumus tersebut, maka salah satu nilai dari R atau C harus ditentukan dan berdasarkan tingkat kesulitan dalam mendapatkan komponen yang ada di pasaran maka nilai yang ditentukan yaitu nilai C sebesar 470uF. Sehingga nilai R-nya adalah sebagai berikut :

$$R_{timer} = \frac{t}{1{,}1.C}$$

$$R_{timer} = \frac{30[menit]}{1{,}1.470[uF]} = \frac{30.60[\det ik]}{1{,}1.470.10^{-6}[F]}$$

$$R_{timer} \approx 3M5$$

3.3.2. Sistem CES (*Cranial Electrotherapy Stimulation*)



Gambar 3.3. Skematik sistem CES

a) Rangkaian *free run monostable* IC LM555.

Rangkaian ini merupakan rangkain pembangkit frekuensi awal sebesar 2,5 [Hz] dan dapat beroperasi secara terus menerus (*free run*), oleh karena itu pin 2 LM555 sebagai IC penghasil frekuensi dihubungkan ke pin 6 agar pin 2 (trigger) dapat berosilasi secara otomatis.

Adapun penentuan nilai R dan C pada IC LM555 didasarkan pada kebutuhan frekuensi yang diinginkan yaitu 2,5 [Hz]. Dari frekuensi ini, maka perioda (T) yang terjadi adalah sebagai berikut :

$$T = \frac{1}{f}$$

$$T = \frac{1}{2{,}5[Hz]}$$

$$T = 0{,}4[s]$$

Sedangkan durasi pulsa (t) ketika "high" dan "low" adalah sama besar dan dapat diketahui berdasarkan perhitungan sebagai berikut :

$$t = \frac{T}{2}$$

$$t = \frac{0,4[s]}{2} = 0,2[s]$$

Dari nilai *t*, maka besarnya nilai R dan C dapat ditentukan dengan rumus sebagai berikut :

$$t = 1,1.R.C$$

Perhitungan nilai R dan C dapat dilakukan apabila salah satu nilai variabelnya ditentukan dan pada perhitungan ini nilai variabel yang ditentukan adalah nilai C sebesar 330nF, sehingga nilai R-nya adalah sebagai berikut :

$$R_{CES} = \frac{t}{1,1.C}$$

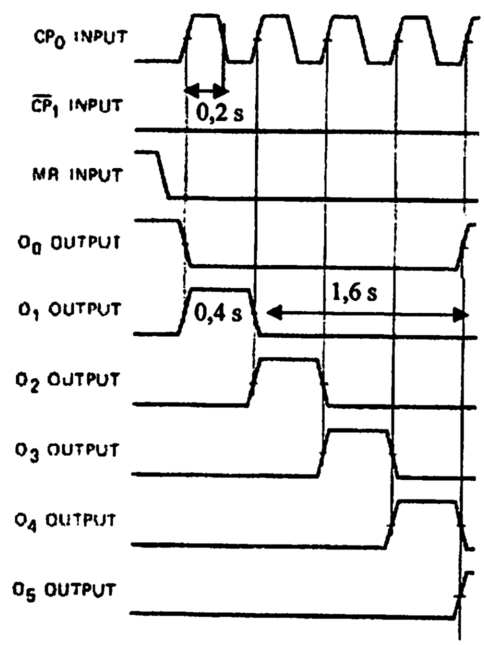
$$R_{CES} = \frac{0,2[s]}{1,1.330.10^{-9}[F]}$$

$$R_{CES} \approx 550.964\Omega$$

Dari perhitungan R, maka untuk mempermudah mencapai nilai tersebut, komponen resistansi menggunakan variable resistor sebesar 1Kohm. Keluaran dari frekuensi ini melalui pin 3 IC LM555.

b) Rangkaian *decade counter* IC 4017.

Rangkaian ini berfungsi hanya sebagai pembagi tegangan 0,5 [Hz] menjadi 2 bagian yang bentuk dan durasi pulsanya harus selalu sama. Frekuensi sumber (pin 3 LM555) yaitu 2,5 [Hz] terhubung ke pin CP0 (pin 14 IC 4017) dan pin CP_1 (pin 13 IC 4017) ke ground, dengan adanya rangkaian seperti ini, maka ketika pin CP_0 berlogika "1" (pulsa "high") secara otomatis IC ini akan melakukan pembagian pulsa "high" secara bergantian dimulai dari O_0 sampai O_5 dan kembali ke O_0. Adapun bentuk dan durasi pulsa yang terjadi di jalur output (O_n) IC 4017 adalah sebagai berikut :



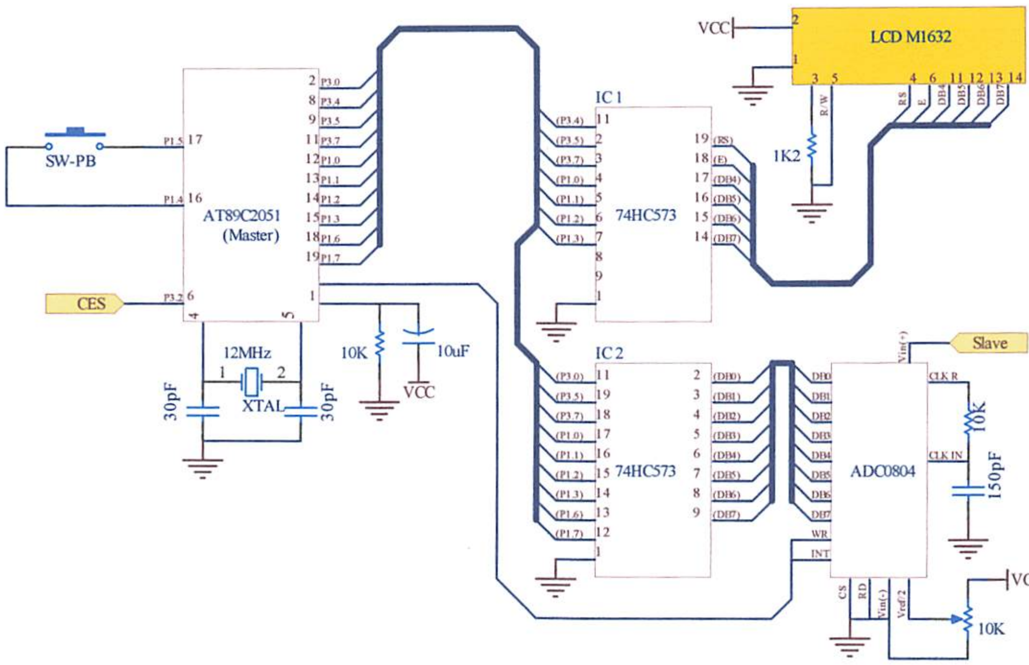
Gambar 3.4. Bentuk dan durasi pulsa keluaran IC 4017

c) Rangkaian transistor *switching.*

Rangkaian ini berfungsi sebagai pengkondisi sinyal dari sistem CES ke sistem mikrokontroler master, hal ini dikarenakan tegangan maksimum dari sistem CES sebesar 9Vdc sedangkan sistem mikrokontroler hanya sebesar 5Vdc.

Adapun perhitungan yang dilakukan adalah mencari nilai Rb dari transistor agar komponen ini dapat berada pada kondisi saturasi ketika sistem CES mengeluarkan tegangan 9V dan *cut-off* ketika tegangannya 0V.

3.3.3. Sistem Mikrokontroler Master



Gambar 3.5. Skematik sistem mikrokontroler master

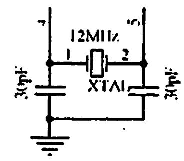
a) Rangkaian minimum mikrokontroler AT89C2051

Sub-sistem pembentuk sistem mikrokontroler ini adalah sebagai berikut :

- **Rangkaian *clock* (pin 4 dan 5)**

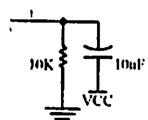
Kecepatan proses yang dilakukan oleh mikrokontroler ditentukan oleh sumber *clock* (pewaktuan) yang mengendalikan mikrokontroler tersebut. Sistem yang dirancang akan menggunakan osilator internal yang sudah tersedia di dalam chip AT89C205. Frekuensi osilator ditentukan berdasarkan *data sheet* mikrokontroler AT89C2051. *Crystal* yang digunakan adalah 12MHz dan kapasitornya sebesar 30pF.

Rangkaian *clock* (pewaktu) yang digunakan sesuai dengan Gambar 3.5.



Gambar 3.6 Rangkaian clock Mikrokontroler AT89C2051

- **Rangkaian *Reset* (pin 1)**



Gambar 3.7. Rangkaian reset Mikrokontroler AT89C2051

Rangkaian reset bertujuan agar mikrokontroler dapat menjalankan proses dari awal. Rangkaian *reset* untuk mikrokontroler dirancang agar mempunyai kemampuan *power on reset*, yaitu *reset* yang terjadi pada saat sistem dinyalakan untuk pertama kalinya.

Rangkaian *Reset* terbentuk oleh komponen R dan C. Nilai R yang dipakai adalah 10 kΩ dan C 10 μF.

Sedangkan untuk mencari frekuensi dari reset tersebut dengan menggunakan rumus sebagai berikut :

$$fo = \frac{1}{1{,}1R.C}$$

Sehingga dengan komponen resistor 10 Kohm dan kapasitor 10 uF akan dihasilkan frekuensi (f_o) sebagai berikut :

$$fo = \frac{1}{1,1.RC}$$

$$= \frac{1}{1,1.(10.10^3).(10.10^{-6})}$$

$$= 9.09Hz$$

Maka Periode Clock

$$T = \frac{1}{fo}$$

$$T = \frac{1}{9.09Hz}$$

$$= 0,11 \text{ detik} = 110\text{ms}$$

Sesuai dengan data sheet AT89C2051 telah dicantumkan bahwa $t_{reset(min)}$ adalah sebesar 2 siklus mesin. Setiap 1 siklus mesin membutuhkan 12 siklus clock, maka untuk mencapai 2 siklus mesin diperlukannya 24 siklus clock. Adapun perhitungan $t_{reset(min)}$ untuk 24 siklus clock adalah sebagai berikut :

$$t_{rst(min)} = \frac{24}{f_{crystal}}$$

$$t_{rst(min)} = \frac{24}{12.000.000[Hz]}$$

$$t_{rst(min)} = 0,000002[s]$$

$$t_{rst(min)} = 0,002[ms]$$

Berdasarkan hasil perhitungan tersebut, maka komponen resistor 10 [Kohm] dan kapasitor 10 [uF] dapat dijadikan sebagai komponen pembentuk rangkaian *power on reset.*

b) Rangkaian IC Latch 74HC573

IC 74HC573 berfungsi untuk menahan data dari jalur data masuk (pin 1D sampai 8D) ke jalur data keluar (pin 1O sampai 8O). Alasan penggunaan

IC ini dikarenakan jalur I/O mikokontroler master sangat terbatas (15 I/O) sedangkan komponen yang dikendalikan membutuhkan 16 jalur I/O dengan rincian sebagai berikut :

- 6 jalur I/O untuk komponen LCD M1632
- 9 jalur I/O untuk komponen ADC0804
- 1 jalur I/O untuk pendeteksi pulsa dari sistem CES

Dengan adanya IC 74HC573, maka jalur I/O mikrokontroler yang digunakan untuk LCD M1632 dan ADC0804 dapat diparalel sehingga hanya membutuhkan 11 jalur I/O mikrokontroler untuk mengendalikan LCD M1632 dan ADC0804. Adapun rincian dari 11 jalur I/O mikrokontroler yang terhubung dengan IC 74HC573 adalah sebagai berikut :

- 10 Jalur I/O mikrokontroler terhubung ke IC 74HC573.

Tabel 3.1 Jalur I/O AT89C2051 dengan IC 74HC573

No.	Pin AT89C2051	Pin 74HC573 (IC1)	Pin 74HC573 (IC2)
1	8(P3.4)	11 (LE)	-
2	9(P3.5)	2 (1D)	19(1O)
3	11(P3.7)	3 (2D)	18(2O)
4	12(P1.0)	4 (3D)	17(3O)
5	13(P1.1)	5 (4D)	16(4O)
6	14(P1.2)	6 (5D)	15(5O)
7	15(P1.3)	7 (6D)	14(6O)
8	18(P1.6)	-	13(7O)
9	19(P1.7)	-	14(8O
10	2(P3.0)	-	11(LE)

- 1 jalur I/O mikrokontroler (P3.1) terhubung ke pin INT dan WR ADC0804.

c) Rangkaian LCD M1632

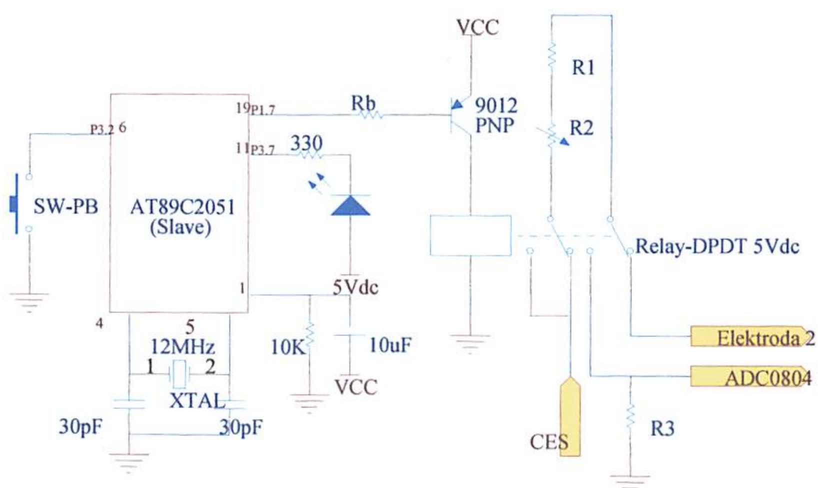
LCD M1632 difungsikan hanya pada kondisi tulis, sehingga pin R/W dihubungkan langsung ke ground (gnd).

Jalur data LCD M1632 tidak terhubung secara langsung dengan mikrokontroler akan tetapi terpisah oleh IC Latch 74HC573.

d) Rangkaian ADC0804

ADC0804 difungsikan dengan metode *free-running*, sehingga pin WR dan INT digandeng serta dihubungkan ke pin mikrokontroler (P3.1). Jalur data ADC0804 tidak terhubung secara langsung dengan mikrokontroler akan tetapi terpisah oleh IC Latch 74HC573.

3.3.4. Sistem Mikrokontroler Slave



Gambar 3.8. Skematik sistem mikrokontroler slave

a) Rangkaian minimum mikrokontroler AT89C2051

Rangkaian pembentuk sistem ini sama dengan rangkaian minimum mikrokontroler AT89C2051 master, yang membedakan hanya penggunaan jalur I/O-nya saja. Dari Gambar 3.8. terlihat bahwa pin P3.7 terhubung dengan led yang berfungsi sebagai indikator bahwa sistem ini berada pada kondisi pengukuran arus, pin P1.7 terhubung ke rangkaian transistor *switching* yang berfungsi untuk mengaktifkan relay dan pin P3.2 terhubung dengan tombol *push button.*

b) Rangkaian transistor *switching*

Rangkaian ini berfungsi sebagai pengaman mikrokontroler dengan tegangan yang disaklarkan oleh relay, apabila terjadi kerusakan relay akibat hubungan pendek pada saklarnya. Nilai komponen yang akan dihitung pada rangkaian ini adalah Rb dengan rumusan sebagai berikut :

$$R_b = \frac{V_b - V_{be(sat)}}{I_b}$$

Berdasarkan jenis transistor yang digunakan maka nilai $V_{be(sat)}$ = 0,6V sedangkan nilai I_b adalah sebagai berikut :

$$I_b = {}^{I_c}\!/_{\beta}$$

Nilai Ic disesuaikan dengan arus minimum yang dibutuhkan untuk mengaktifkan relay berdasarkan dengan nilai R_{relay} sedangkan β transistor jenis ini adalah sebesar 70. Sehingga nilai Ic dan Ib adalah :

$$I_c = {}^{V_{relay}}\!/_{R_{relay}}$$
$$I_c = {}^{5[V]}\!/_{390[\Omega]}$$
$$I_c = 0{,}013[A]$$

$$I_b = {}^{0{,}013[A]}\!/_{70}$$
$$I_b = 0{,}0002[A]$$

Maka nilai Rb adalah :

$$R_b = \frac{(5-0{,}6)[V]}{0{,}0002[A]} = 22[k\Omega]$$

Dari perhitungan Rb, maka untuk menghasilkan arus yang mampu mengaktifkan relay digunakannya Rb yang lebih kecil dari 22[kΩ] agar arus di kaki kolektor transistor 9012 semakin besar, oleh karena itu maka Rb yang ditetapkan adalah sebesar 4K7.

c) Rangkaian pengatur arus

Arus minimum yang akan diberikan ke pasien adalah sebesar 60[uA] sedangkan arus maksimumnya adalah 600[uA]. Dari kedua batasan tersebut, maka digunakannya tahanan untuk membatasi arus yang lewat.

Nilai tahanan ketika arus minimum adalah :

$$R = \frac{V}{I} = \frac{9[V]}{80[\mu A]}$$
$$R = 112.500[\Omega]$$

Sedangkan tahanan ketika arus maksimum adalah :

$$R = \frac{9[V]}{600[\mu A]}$$
$$R = 15.000[\Omega]$$

Dari hasil perhitungan tersebut, maka digunakannya 1 buah resistor tetap R1 dan 1 buah variabel resistor R2 agar arus yang dialirkan dapat divariasikan. Oleh karena nilai variabel resistor yang ada di pasaran paling besar adalah 50[kΩ] dan untuk mencapai arus maksimum dengan menggunakan R1 sebesar 15[kΩ], maka arus minimum yang mampu dialirkan oleh sistem ini adalah sebesar :

$$I = \frac{V}{R1 + R2}$$

$$I = \frac{9[V]}{(15.000 + 50.000)[\Omega]}$$

$$I = 138[\mu A]$$

Maka nilai R1 yang digunakan adalah 15[kΩ] dan R2 sebesar 50[kΩ].

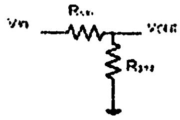
d) Rangkaian pembagi tegangan

Rangkaian ini terdiri dari rangkaian pengatur arus dan 1 buah resistor tetap yang terhubung ke ground. Tegangan yang digunakan pada rangkaian ini hanya sebesar 5V karena rangkaian ADC0804 hanya mampu menerima sinyal tegangan sebesar 5V, berbeda dengan tegangan keluaran sistem CES. Oleh karena itu diperlukannya teknik konversi data antara tegangan yang dibaca oleh ADC0804 dengan tegangan yang dikeluarkan oleh sistem CES.

Rumusan rangkaian pembagi tegangan yang sesuai dengan Gambar 3.8 adalah sebagai berikut

$$V_{out} = V_{in} \frac{R_{gnd}}{R_{gnd} + R_{Vin}}$$

Adapun skematik rangkaian ini ditunjukkan pada Gambar 3.8.



Gambar 3.8. Skematik rangkaian pembagi tegangan

Keterangan :

- $V_{in} = 9V$
- R_{Vin} = R pengatur arus

- R_{gnd} = 8K2

Penentuan nilai R_{gnd} tersebut berdasarkan metode *trial and error* dengan batasannya adalah :

- ketika R pengatur arus berada pada nilai minimal dan maksimal, tegangan $0[V]<V_{out}<9[V]$. Adapun perhitungan nilai Vout berdasarkan nilai R pengatur arus adalah sebagai berikut :

R pengatur arus minimal :

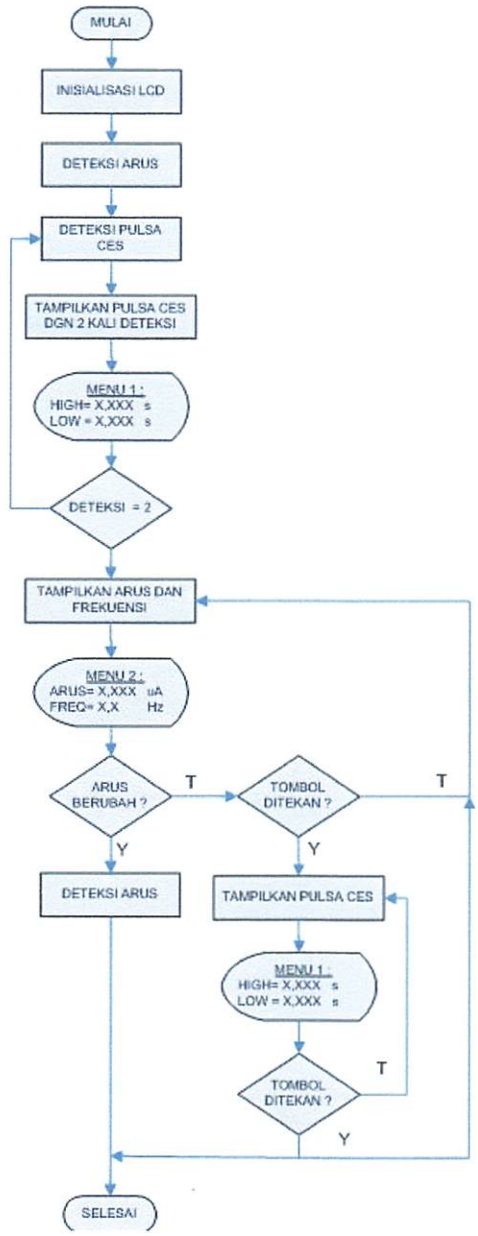
$$V_{out} = 9[V]\frac{8.200[\Omega]}{8.200[\Omega]+15.000[\Omega]}$$
$$V_{out} = 3{,}181[V]$$

R pengatur arus maksimal :

$$V_{out} = 9[V]\frac{8.200[\Omega]}{8.200[\Omega]+(15.000+50.000)[\Omega]}$$
$$V_{out} = 1[V]$$

3.4 Perencanaan Perangkat Lunak

Perencanaan perangkat lunak terdiri dari 2 sistem, sesuai dengan mikrokontroler yang digunakan (mikrokontroler master dan slave). Kedua sistem tersebut, masing-masing menggunakan mikrokontroler AT89C2051 sebagai pengatur peralatan lainnya. Jenis program yang digunakan untuk mengatur jenis perintah mikrokontroler tersebut adalah program bahasa *assembly.* Sistematika jalannya program yang dibuat didasarkan pada sistem *hardware* yang telah dirancang. Adapun urutan kerja program pada kedua sistem yang dibuat sesuai dengan Gambar 3.9. dan Gambar 3.10.



Gambar 3.10. Flowchart mikrokontroler master

Proses pendeteksian arus terdiri dari 2 tahap, yaitu proses pembacaan data ADC kemudian proses konversi data ADC ke arus (pembandingan). Adapun listing program assembly dari kedua proses tersebut adalah sebagai berikut :

- Proses pembacaan data ADC

```
BACA_ADC:
        SETB   D0
        SETB   D1
        SETB   D2
        SETB   D3
        SETB   D4
        SETB   D5
        SETB   D6
        SETB   D7
        SETB   OE1
        CLR    OE2
        CALL   DELAY_5MS
        CALL   DELAY_5MS
        CLR    A
        MOV    C,D0
        MOV    ACC.0,C
        MOV    C,D1
        MOV    ACC.1,C
        MOV    C,D2
        MOV    ACC.2,C
        MOV    C,D3
        MOV    ACC.3,C
        MOV    C,D4
        MOV    ACC.4,C
        MOV    C,D5
        MOV    ACC.5,C
        MOV    C,D6
        MOV    ACC.6,C
        MOV    C,D7
        MOV    ACC.7,C
        MOV    DATA_ADC,A
        SETB   OE1
        SETB   OE2
        CALL   DELAY_5MS
        CALL   DELAY_5MS
        RET
```

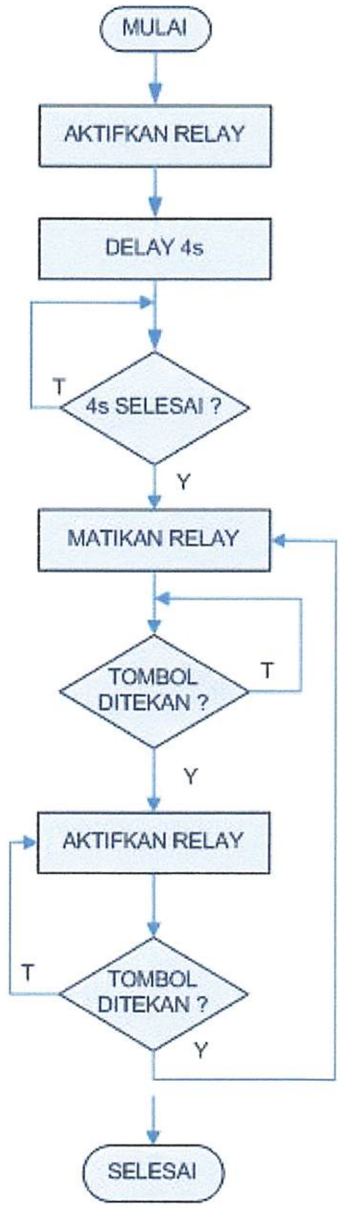
- Proses pembandingan data ADC ke arus

```
BANDING_ARUS:
        CJNE   A,#20,CEK_ARUS1
KURANG_20:
        CLR    5H
        RET
;==================================;
CEK_ARUS1:
        JC     KURANG_20
        CJNE   A,#33,CEK_ARUS2
KURANG_33:
        MOV    DIGIT_3,#31H
        MOV    DIGIT_2,#33H
        MOV    DIGIT_1,#38H
        SETB   5H
        RET
;==================================;
CEK_ARUS2:
        JC     KURANG_33
        CJNE   A,#39,CEK_ARUS3
KURANG_39:
        MOV    DIGIT_3,#31H
        MOV    DIGIT_2,#35H
        MOV    DIGIT_1,#30H
        SETB   5H
        RET
;==================================;
CEK_ARUS3:
        JC     KURANG_39
        CJNE   A,#45,CEK_ARUS4
KURANG_45:
        MOV    DIGIT_3,#31H
        MOV    DIGIT_2,#36H
        MOV    DIGIT_1,#34H
        SETB   5H
        RET
;==================================;
CEK_ARUS4:
        JC     KURANG_45
        CJNE   A,#51,CEK_ARUS5
KURANG_51:
        MOV    DIGIT_3,#31H
        MOV    DIGIT_2,#38H
        MOV    DIGIT_1,#30H
        SETB   5H
        RET
;==================================;
CEK_ARUS5:
        JC     KURANG_51
        CJNE   A,#57,CEK_ARUS6
KURANG_57:
        MOV    DIGIT_3,#32H
        MOV    DIGIT_2,#30H
        MOV    DIGIT_1,#30H
        SETB   5H
        RET
```

```
CEK_ARUS6:
        JC      KURANG_57
        CJNE    A,#63,CEK_ARUS7
KURANG_63:
        MOV     DIGIT_3,#32H
        MOV     DIGIT_2,#32H
        MOV     DIGIT_1,#35H
        SETB    5H
        RET
;==================================:
CEK_ARUS7:
        JC      KURANG_63
        CJNE    A,#69,CEK_ARUS8
KURANG_69:
        MOV     DIGIT_3,#32H
        MOV     DIGIT_2,#35H
        MOV     DIGIT_1,#37H
        SETB    5H
        RET
;==================================:
CEK_ARUS8:
        JC      KURANG_69
        CJNE    A,#75,CEK_ARUS9
KURANG_75:
        MOV     DIGIT_3,#33H
        MOV     DIGIT_2,#30H
        MOV     DIGIT_1,#30H
        SETB    5H
        RET
;==================================:
CEK_ARUS9:
        JC      KURANG_75
        CJNE    A,#81,CEK_ARUS10
KURANG_81:
        MOV     DIGIT_3,#33H
        MOV     DIGIT_2,#36H
        MOV     DIGIT_1,#30H
        SETB    5H
        RET
;==================================:
CEK_ARUS10:
        JC      KURANG_81
        CJNE    A,#87,CEK_ARUS11
KURANG_87:
        MOV     DIGIT_3,#34H
        MOV     DIGIT_2,#35H
        MOV     DIGIT_1,#30H
        SETB    5H
        RET
;==================================:
CEK_ARUS11:
        JC      KURANG_87
        MOV     DIGIT_3,#36H
        MOV     DIGIT_2,#30H
        MOV     DIGIT_1,#30H
        SETB    5H
        RET
```

Sedangkan proses pendeteksian pulsa menggunakan listing sebagai berikut :

```
CEK_PULSA:
SETB   0H
MOV    R7,#0
MOV    R6,#0
JB     P3.2,$
JNB    P3.2,$
LOOP_HIGH:
MOV    TMOD,#1
MOV    TH0,#0FCH
MOV    TL0,#18H
CLR    TF0
SETB   TR0
WAIT_HIGH:
JNB    TF0,CEK_LOGIKA
CLR    TR0
INC    R7
CJNE   R7,#100,LOOP_HIGH
MOV    R7,#0
INC    R6
JMP    LOOP_HIGH
CEK_LOGIKA:
JNB    0H,WAIT_LOW
JB     P3.2,WAIT_HIGH
CLR    TR0
MOV    HP_1,R7
MOV    HP_2,R6
MOV    R7,#0
MOV    R6,#0
CLR    0H
JMP    LOOP_HIGH
WAIT_LOW:
JNB    P3.2,WAIT_HIGH
CLR    TR0
MOV    LP_1,R7
MOV    LP_2,R6
RET
```



Gambar 3.11. Flowchart mikrokontroler slave

BAB IV

PENGUJIAN ALAT

4.1. Pendahuluan

Tujuan pengujian adalah untuk mengetahui keadaan masukan dan keluaran dari tiap blok rangkaian yang direncanakan, sehingga dapat diketahui *performance* alat yang direncanakan. Adapun pengujian yang dilakukan meliputi beberapa rangkaian sebagai berikut :

a) Pengujian rangkaian pembangkit frekuensi LM555

b) Pengujian rangkaian pembagi frekuensi HEF4017

c) Pengujian pengukuran arus

d) Pengujian pada pasien

4.2. Pengujian Rangkaian Pembangkit Frekuensi LM555

4.2.1. Tujuan Pengujian Rangkaian

1. Untuk mengetahui besarnya tegangan maksimal yang terjadi dan bentuk serta besarnya frekuensi yang dihasilkan oleh rangkaian pembangkit frekuensi LM555.

4.2.2. Peralatan Yang Digunakan

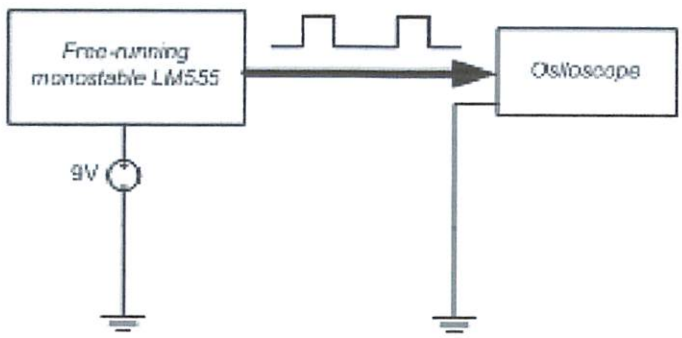
a) Rangkaian pembangkit frekuensi LM555

b) Osiloscope

c) Battery 9 volt

4.2.3. Prosedur Pengujian

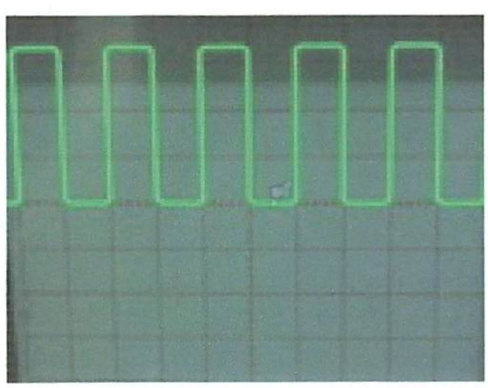
1. Merangkai peralatan yang sesuai dengan Gambar 4.1.
2. Mendokumentasi bentuk frekuensi di layar osiloscope.
3. Mencatat besarnya frekuensi dan tegangan puncak berdasarkan pembacaan di osiloscope.



Gambar 4.1. Rangkaian pengujian pembangkit frekuensi LM555

4.2.4. Hasil Pengujian dan Analisa

Hasil pengujian berupa bentuk, besarnya frekuensi dan tegangan yang terjadi di layar osiloscope. Bentuk frekuensi tersebut ditampilkan sesuai dengan Gambar 4.2.



(2v/div) (0,2ms/div)

Gambar 4.2. Foto hasil pengujian pembangkit frekuensi LM555

7,2V, sedangkan besarnya frekuensi adalah 0,5Hz. Nilai frekuensi ini sudah sesuai dengan nilai frekuensi yang diinginkan yaitu sebesar 0,5Hz.

4.4. Pengujian Pengukuran Arus

4.4.1. Tujuan Pengujian

Tujuan pengujian adalah untuk mengetahui apakah sistem pembaca arus dapat mengukur arus sesuai dengan nilai resistansi pada sistem pengatur arus.

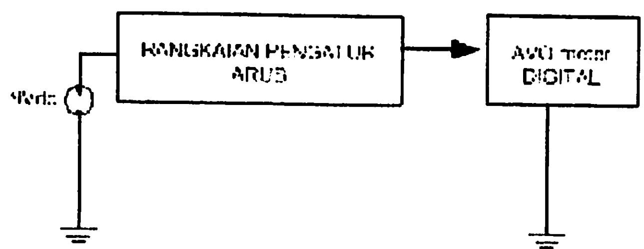
4.4.2. Peralatan Yang Digunakan

1. Rangkaian minimum sistem AT89C2051.
2. Modul ADC0804.
3. Rangkaian pembagi tegangan.
4. Rangkaian pengatur arus.
5. AVO meter digital.
6. LCD M1632.
7. Power supply 9Vdc dan 5Vdc.

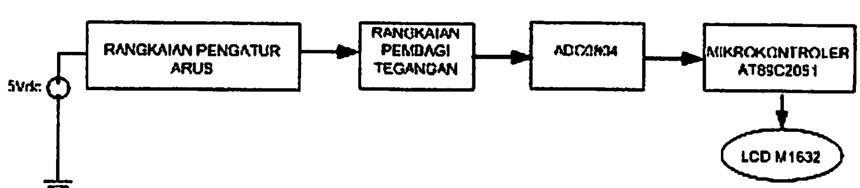
4.4.3. Prosedur Pengujian

1. Membuat program assembly dan memasukkannya ke mikrokontroler AT89C2051.
2. Merangkai peralatan sesuai dengan Gambar 4.5.
3. Menghidupkan power supply.
4. Menggeser potensio pada rangkaian pengatur arus.

5. Mendokumentasikan hasil pengukuran AVO meter digital dan mencatat hasilnya.
6. Mematikan power supply.
7. Merangkai peralatan sesuai dengan Gambar 4.6.
8. menghidupkan power supply.
9. Mendokumentasikan hasil pengukuran di layar LCD M1632 dan mencatat hasilnya.
10. Mematikan power supply.
11. Mengulangi langkah 2 sampai 9 hingga data tercatat sebanyak 11 data.



Gambar 4.5.
Rangkaian pengujian arus dengan menggunakan AVO meter



Gambar 4.6.
Rangkaian pengujian arus dengan menggunakan AT89C2051

Listing program assembly mikrokontroler AT89S8252 untuk membaca data ADC dan mengkonversikannya ke arus tegangan 9Vdc.

```
;==================================;
TAMPIL_ARUS:
        CALL  BACA_ADC
        MOV   A,DATA_ADC
        CALL  BANDING_ARUS
        CALL  TAMPILKAN_ARUS
        SETB  5H
        RET
;==============================
BACA_ADC:
        SETB  D0
        SETB  D1
        SETB  D2
        SETB  D3
        SETB  D4
        SETB  D5
        SETB  D6
        SETB  D7
        SETB  OE1
        CLR   OE2
        CALL  DELAY_5MS
        CALL  DELAY_5MS
        CLR   A
        MOV   C,D0
        MOV   ACC.0,C
        MOV   C,D1
        MOV   ACC.1,C
        MOV   C,D2
        MOV   ACC.2,C
        MOV   C,D3
        MOV   ACC.3,C
        MOV   C,D4
        MOV   ACC.4,C
        MOV   C,D5
        MOV   ACC.5,C
        MOV   C,D6
        MOV   ACC.6,C
        MOV   C,D7
        MOV   ACC.7,C
        MOV   DATA_ADC,A
        SETB  OE1
        SETB  OE2
        CALL  DELAY_5MS
        CALL  DELAY_5MS
        RET
;==============================
BANDING_ARUS:
        CJNE  A,#20,CEK_ARUS1
```

```
KURANG_20:
        CLR     5H
        RET
;====================================:
CEK_ARUS1:
        JC      KURANG_20
        CJNE    A,#33,CEK_ARUS2
KURANG_33:
        MOV     DIGIT_3,#31H
        MOV     DIGIT_2,#33H
        MOV     DIGIT_1,#38H
        SETB    5H
        RET
;====================================:
CEK_ARUS2:
        JC      KURANG_33
        CJNE    A,#39,CEK_ARUS3
KURANG_39:
        MOV     DIGIT_3,#31H
        MOV     DIGIT_2,#35H
        MOV     DIGIT_1,#30H
        SETB    5H
        RET
;====================================:
CEK_ARUS3:
        JC      KURANG_39
        CJNE    A,#45,CEK_ARUS4
KURANG_45:
        MOV     DIGIT_3,#31H
        MOV     DIGIT_2,#36H
        MOV     DIGIT_1,#34H
        SETB    5H
        RET
;====================================:
CEK_ARUS4:
        JC      KURANG_45
        CJNE    A,#51,CEK_ARUS5
KURANG_51:
        MOV     DIGIT_3,#31H
        MOV     DIGIT_2,#38H
        MOV     DIGIT_1,#30H
        SETB    5H
        RET
;====================================:
CEK_ARUS5:
        JC      KURANG_51
        CJNE    A,#57,CEK_ARUS6
KURANG_57:
        MOV     DIGIT_3,#32H
        MOV     DIGIT_2,#30H
        MOV     DIGIT_1,#30H
        SETB    5H
        RET
;====================================:
CEK_ARUS6:
```

```
        JC      KURANG_57
        CJNE    A,#63,CEK_ARUS7
KURANG_63:
        MOV     DIGIT_3,#32H
        MOV     DIGIT_2,#32H
        MOV     DIGIT_1,#35H
        SETB    5H
        RET
;======================================:
CEK_ARUS7:
        JC      KURANG_63
        CJNE    A,#69,CEK_ARUS8
KURANG_69:
        MOV     DIGIT_3,#32H
        MOV     DIGIT_2,#35H
        MOV     DIGIT_1,#37H
        SETB    5H
        RET
;======================================:
CEK_ARUS8:
        JC      KURANG_69
        CJNE    A,#75,CEK_ARUS9
KURANG_75:
        MOV     DIGIT_3,#33H
        MOV     DIGIT_2,#30H
        MOV     DIGIT_1,#30H
        SETB    5H
        RET
;======================================:
CEK_ARUS9:
        JC      KURANG_75
        CJNE    A,#81,CEK_ARUS10
KURANG_81:
        MOV     DIGIT_3,#33H
        MOV     DIGIT_2,#36H
        MOV     DIGIT_1,#30H
        SETB    5H
        RET
;======================================:
CEK_ARUS10:
        JC      KURANG_81
        CJNE    A,#87,CEK_ARUS11
KURANG_87:
        MOV     DIGIT_3,#34H
        MOV     DIGIT_2,#35H
        MOV     DIGIT_1,#30H
        SETB    5H
        RET
;======================================:
CEK_ARUS11:
        JC      KURANG_87
        MOV     DIGIT_3,#36H
        MOV     DIGIT_2,#30H
        MOV     DIGIT_1,#30H
        SETB    5H
```

```
        RET
;=========================================:
;       subroutine TAMPILAN              :
;=========================================:
TAMPILKAN_ARUS:
        MOV     A,#87H
        CALL    INTRUKSI
        MOV     A,DIGIT_3
        CALL    TULIS_DATA
        MOV     A,DIGIT_2
        CALL    TULIS_DATA
        MOV     A,DIGIT_1
        CALL    TULIS_DATA
        RET
;=========================================:
```

4.4.4. Hasil Pengujian dan Analisa

Hasil pengujian berupa data keseluruhan pada Tabel 4.1.

Gambar 4.7. Foto hasil pengujian arus dengan multimeter digital 132[mikroAmpere]

Gambar 4.8. Foto hasil pengujian arus dengan AT89C2051 138[mikroAmpere]

Gambar 4.9. Foto hasil pengujian arus dengan multimeter digital

220[mikroAmpere]

Gambar 4.10. Foto hasil pengujian arus dengan AT89C2051

225[mikroAmpere]

Gambar 4.11. Foto hasil pengujian arus dengan multimeter digital

517[mikroAmpere]

Gambar 4.12. Foto hasil pengujian arus dengan AT89C2051

600[mikroAmpere]

Tabel 4.1. Data hasil pengujian arus

No	V (volt)	ARUS (uA)		
		Range	CES	multimeter
1	9	minimum	138	132
2	9	medium	225	220
3	9	maksimum	600	517

Dari data hasil pengujian pada Tabel 4.1. terlihat bahwa arus yang terbaca oleh multimeter tidak berbeda jauh dengan arus yang telah ditentukan dan arus yang terbaca oleh alat CES juga sesuai dengan batasan maksimum arusnya.

4.5. Pengujian Pada Pasien.

4.5.1. Tujuan Pengujian

Tujuan pengujian adalah untuk mengetahui pengaruh penggunaan alat ini terhadap kondisi psikologis manusia yang diukur dengan indikasi pengukuran tekanan darah.

4.5.2. Peralatan Yang Digunakan

1. CES
2. Tensimeter

4.5.3. Prosedur Pengujian

1. Responden berjenis kelamin pria dan berusia antara 20 sampai 25 tahun dengan latar belakang pendidikan mahasiswa.
2. Responden melakukan pengukuran tekanan darah dengan menggunakan tensimeter.
3. Melakukan stimulasi dengan menggunakan CES.
4. Pengukuran tekanan darah responden setelah stimulasi.

5. Mengisi quesioner yang telah disiapkan.
6. Mengulangi langkah 2 sampai 4 untuk besaran arus lainnya yang telah ditentukan.

4.5.4. Hasil Pengujian dan Analisa

Metode pengujian ialah dengan melakukan quesioner kepada responden terhadap kondisi psikologis masing masing setelah penggunaan alat ini. Setiap rsponden melakukan stimulasi dengan arus minimal sebesar 138[mikroAmpere], arus medium sebesar 225[mikroAmpere] dan arus maksimal 600[mikroAmpere], yang hasilnya dicatat dalam tabel berikut.

Tabel 4.2. hasil quesioner (tekanan darah).

NO	RESPONDEN	TEKANAN DARAH (ARUS MINIMAL)		TEKANAN DARAH (ARUS MEDIUM)		TEKANAN DARAH (ARUS MAKSIMAL)	
		SEBELUM STIMULASI	SESUDAH STIMULASI	SEBELUM STIMULASI	SESUDAH STIMULASI	SEBELUM STIMULASI	SESUDAH STIMULASI
1	HT	120/80	120/80	120/80	120/80	120/80	110/70
2	RAP	120/90	120/90	120/90	120/80	120/90	110/80
3	HP	120/90	120/90	120/90	110/80	120/90	110/70
4	DS	130/80	130/80	130/80	130/80	130/80	120/80
5	MJ	130/90	130/90	130/90	130/90	130/90	130/90

Tabel 4.3. hasil quesioner (efek psikologis)

NO	RESPONDEN	EFEK PSIKOLOGIS(ARUS MINIMAL)	EFEK PSIKOLOGIS(ARUS MEDIUM)	EFEK PSIKOLOGIS (ARUS MAKSIMAL)
1	HT	RILEKS	RILEKS	MENGANTUK
2	RAP	TIDAK ADA	RILEKS	RILEKS
3	HP	TIDAK ADA	RILEKS	RILEKS
4	DS	TIDAK ADA	TIDAK ADA	RILEKS
5	MJ	TIDAK ADA	TIDAK ADA	TIDAK ADA

Dari tabel dapat disimpulkan bahwa alat ini tidak begitu berpengaruh terhadap sisi fisiologis, namun secara psikologis arus minimal 138[mikroAmpere] masih belum cukup untuk mendapatkan hasil efek psikologis yang diharapkan. Dengan demikian perancangan untuk keperluan komersial masih memerlukan pengkajian lebih lanjut. Namun untuk arus medium dan maksimal telah memberikan efek psikologis terhadap recepient.

4.6. Analisa Error.

Untuk menentukan error digunakan rumus :

$$error = \frac{arus\ pengukuran - arus\ perhitungan}{arus\ pengukuran}\ x\ 100\%$$

4.6.1. Error Pada Arus Minimal

Pada pengukuran arus minimal didapatkan nilai 132[mikroAmpere], sedangkan arus minimal yang direncanakan sebesar :

$$I = \frac{V}{R}$$

$$I = \frac{9[volt]}{65.000[ohm]}$$

I = 138[mikroAmpere]

Sehingga didapat error sebesar :

$$error[minimal] = \frac{132[mikroAmpere] - 138[mikroAmpere]}{132[mikroAmpere]}\ x\ 100\%$$

$$= 4{,}545\%$$

4.6.2. Error Pada Arus Medium

Pada pengukuran arus minimal didapatkan nilai 220[mikroAmpere], sedangkan arus minimal yang direncanakan sebesar :

$$I = \frac{V}{\left[\frac{R_{minimal} + R_{maksimal}}{2}\right]}$$

$$I = \frac{9[volt]}{\left[\frac{10.000[ohm] + 65.000[ohm]}{2}\right]}$$

I = 225[mikroAmpere]

Sehingga didapat error sebesar :

$$error[medium] = \frac{220[mikroAmpere] - 225[mikroAmpere]}{220[mikroAmpere]} x\ 100\%$$

$$= 2{,}272\%$$

4.6.3. Error Pada Arus Maksimal

Pada pengukuran arus maksimal didapatkan nilai 517[mikroAmpere], sedangkan arus maksimal yang direncanakan sebesar :

$$I = \frac{V}{R}$$

$$I = \frac{9[volt]}{15.000[ohm]}$$

I = 600[mikroAmpere]

Sehingga didapat error sebesar :

$$error[maksimal] = \frac{517[mikroAmpere] - 600[mikroAmpere]}{517[mikroAmpere]} x\ 100\%$$

$$= 16{,}054\%$$

4.6.4. Error Rata Rata

Berdasarkan analisa diatas maka error pada alat ini sebesar :

$$error = \frac{error[minimal] + error[medium] + error[maksimal]}{3}$$

$$= \frac{4{,}545\% + 2{,}272\% + 16{,}054\%}{3}$$

$$= 7{,}624\%$$

Tabel 4.4. Analisa Error

No	V (volt)	ARUS (uA)			error (%)
		Range	CES	multimeter	
1	9	minimum	138	132	4,545
2	9	medium	225	220	2,272
3	9	maksimum	600	517	16,054

BAB VI

PENUTUP

6.1. Kesimpulan

Dari hasil perancangan dan pembuatan alat dapat diambil kesimpulan sebagai berikut :

1. Karena tidak adanya nilai resistor 550,964 Ω yang berada di pasaran maka nilai arus minimum yang bisa di hasikan alat ini hanya sebesar 138[mikroAmpere] dengan meng-gunakan resistor variabel 1 KΩ.
2. Arus yang keluar dari CES tidak sampai 1[miliAmpere] sehingga dihindari untuk melakukan pendeteksian arus secara realtime dan melakukan percabangan jalur.
3. Penggunaan baterai 9 V non-rechargable justru mempermahal dari segi biaya operasional walaupun menguntungkan dari segi portabelitas karena hanya bisa memfungsikan alat selama 3[jam].
4. Dosis yang digunakan untuk mendapatkan efek ialah dua kali sesi, sehingga total stimulasi adalah 60[menit], dimana dosis ini melebihi batas referensinya selama 20 sampai 40[menit].
5. Arus stimulasi masih kurang cukup besar untuk mendapatkan efek psikologis yang diinginkan.

6. Elektroda merupakan sebuah materi yang kekal sifatnya, sehingga sedikit sekali kemungkinan untuk rusak. Kecuali lapisan gel elektrolit yang bisa diganti dengan yang baru.
7. Salah satu tanda gel elektrolit telah tidak dalam kondisi baik ialah perubahan kekenyalannya. Bila gel tersebut telah berubah menjadi lebih lunak maka diperlukan pergantian.
8. Error pada alat ini sebesar 7,624% dengan error pada arus maksimal 16,054 %, arus medium 2,272% dan error pada arus minimal 4,545 %.
9. Dari percobaan terhadap pasien dapat diambil kesimpulan bahwa hanya satu dari lima responden yang merasakan efeknya, dengan kata lain alat ini hanya memiliki efektifitas sebesar 20% sehingga diperlukan pengujian pada lebih banyak responden untuk mendapatkan prosentase yang lebih baik.
10. Secara umum dapat diambil kesimpulan bahwa alat ini gagal mencapai hasil seperti yang telah direncanakan.

6.2. Saran

1. Kabel pada elektroda sebaiknya tidak dipasang permanen karena semakin sering penggunaannya lapisan gel akan semakin menipis dan daya rekat berkurang.
2. Segi portabelitas bisa dikorbankan bila menginginkan penghematan dari segi baterai dengan menggunakan adaptor

3. Untuk deteksi arus secara real time bisa melalui pin 4,7,10 HEF4017 dengan menambahkan nilai resistor sebesar pada jalur output daripada memparalel jalur ke elektroda
4. Arus stimulus bisa dinaikkan menjadi diatas 600[mikroAmpere] hingga maksimal batas yang bisa ditoleransi 1500[mikroAmpere].
5. Alat ini jauh dari sempurna sehingga membutuhkan pengkajian lebih lanjut.

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LAMPIRAN

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JUDUL : PERANCANGAN DAN PEMBUATAN ALAT MEDIS *CRANIAL ELECTROTHERAPY STIMULATION* (CES) DENGAN LM555 DAN MIKROKONTROLLER AT89C2051

NO	TANGGAL	URAIAN	PARAF
1	26 September 2008	Uraian mengenai elektroda	
2	26 September 2008	Bagaimana pengujian elektroda	
3	26 September 2008	Karakteristik elektroda	
4	26 September 2008	Kesimpulan dari pengujian	
5	26 September 2008	Bagaimana erromya	

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INSTITUT TEKNOLOGI NASIONAL MALANG
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Formulir Perbaikan Ujian Skripsi

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

NAMA : Hasyim Asy'ari Y.
N I M : 0017192.
Perbaikan meliputi :

- Uraian mengenai elektroda
- Bagaimana pengujian elektroda.
- Karakteristik elektrode.
- Kesimpulan dari pengujian - bagaimana errornya?

Malang, 200

( )

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FORMULIR PERBAIKAN SKRIPSI

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JUDUL : PERANCANGAN DAN PEMBUATAN ALAT MEDIS *CRANIAL ELECTROTHERAPY STIMULATION* (CES) DENGAN LM555 DAN MIKROKONTROLLER AT89C2051

NO	TANGGAL	URAIAN	PARAF
1	26 September 2008	Elektroda	
2	26 September 2008	Referensi diperbaiki, ditambahkan tentang biologisnya, elektrodanya	
3	26 September 2008	Pengujian ditambahkan responden, dapat ditarik kesimpulan	
4	26 September 2008	Tata tulis dilihat di buku skripsi	

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Sotyohadi ST. Msc.
NIP.Y. 1039700309

INSTITUT TEKNOLOGI NASIONAL MALANG
FAKULTAS TEKNOLOGI INDUSTRI
JURUSAN TEKNIK ELEKTRO

Formulir Perbaikan Ujian Skripsi

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

NAMA : Hasyim Asy'ari
N I M : 0017192
Perbaikan meliputi :

- Elektroda.
- REFERENSI diperbaiki → ditambahkan. ttg. biologisnya ; elektrodanya.
- pengujian tambahkan responden. → dpt ditarik kesimpulan.
- tata tulis diliat dibuku skripsi

Malang, 26 Sept. 2008

( )

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, 18 Pebruari 2008

Nomor : ITN-0138/7/TA /2008
Lampiran :
Perihal : ***Bimbingan Skripsi***

Kepada : Yth. Sdr. **I KOMANG SOMAWIRATA, ST, MT**
Dosen Pembimbing
Jurusan Teknik Elektro S-1
di
Malang

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

Nama	: **HASYIM ASY'ARI YUSUF**
Nim	: **0017192**
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:

11 PEBRUARI 2008 S/D 11 AGUSTUS 2008

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

Ketua Jurusan
Teknik Elektro S-1

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

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

Tindasan:
1. Mahasiswa yang Bersangkutan
2. Arsip

Form S-4a

PERKUMPULAN PENGELOLA PENDIDIKAN UMUM DAN TEKNOLOGI NASIONAL MALANG

INSTITUT TEKNOLOGI NASIONAL MALANG

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

Malang, 25 Agustus 2008

Nomor : ITN-271/7/TA /2008
Lampiran :
Perihal : ***Bimbingan Skripsi***

Kepada :Yth. Sdr. **I KOMANG SOMAWIRATA, ST, MT** *)
Dosen Pembimbing
Jurusan Teknik Elektro S-1
di
Malang

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Nama	: **HASYIM ASY'ARI YUSUF**
Nim	: **0017192**
Fakultas	: **Teknologi Industri**
Jurusan	: **Teknik Elektro S-1**
Konsentrasi	: **Teknik Elektronika S-I**

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

11 AGUSTUS 2008 S/D 11 PEBRUARI 2009

Adapun tugas tersebut merupakan salah satu syarat untuk memperoleh gelar Sarjana Teknik, Jurusan Elektro apabila lewat dari batas waktu tsb. Maka, skripsinya akan digugurkan.
Demikian atas perhatian serta kerjasama yang baik kami ucapkan terima kasih

Ketua Jurusan
Teknik Elektro S-1

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

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

Tindasan:
3. *)Perpanjangan
4. Mahasiswa yang Bersangkutan
5. Arsip

PERKUMPULAN PENGELOLA PENDIDIKAN UMUM DAN TEKNOLOGI NASIONAL MALANG

INSTITUT TEKNOLOGI NASIONAL MALANG

FAKULTAS TEKNOLOGI INDUSTRI
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Malang, 18 Pebruari 2008

Nomor : ITN-0139/7/TA /2008
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	: **HASYIM ASY'ARI YUSUF**
Nim	: **0017192**
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:

11 PEBRUARI 2008 S/D 11 AGUSTUS 2008

Sebagai satu syarat untuk menempuh Ujian sarjana.
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Ketua Jurusan
Teknik Elektro S-1

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

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

Tindasan:
1. Mahasiswa yang Bersangkutan
2. Arsip

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
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Malang, 25 Agustus 2008

Nomor : ITN-272/7/TA /2008
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	: HASYIM ASY'ARI YUSUF
Nim	: 0017192
Fakultas	: Teknologi Industri
Jurusan	: Teknik Elektro S-1
Konsentrasi	: Teknik Elektronika S-I

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

11 AGUSTUS 2008 S/D 11 PEBRUARI 2009

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Demikian atas perhatian serta kerjasama yang baik kami ucapkan terima kasih

Ketua Jurusan
Teknik Elektro S-1

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

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

Tindasan:
3. *)Perpanjangan
4. Mahasiswa yang Bersangkutan
5. Arsip

INSTITUT TEKNOLOGI NASIONAL MALANG
JL. RAYA KARANGLO KM.2
MALANG

FORMULIR BIMBINGAN SKRIPSI

NAMA : HASYIM ASY'ARI YUSUF
NIM : 0017192
MASA BIMBINGAN : 11 FEBRUARI 2008 – 11 AGUSTUS 2008 8
JUDUL : PERANCANGAN DAN PEMBUATAN ALAT MEDIS CRANIAL ELECTROTHERAPY STIMULATION(CES) ~~DENGAN TS555CN~~ UNTUK TERAPI PASIEN DEPRESI

NO	TANGGAL	URAIAN	PARAF PEMBIMBING
1	29/08/08	Konsultasi Bab I & Bab 2. tambah teori (eeC. LCD, driver (TR), sensor arus.	[signature]
2	26/08/08	Revisi Bab III	[signature]
3	3/09/08	Acc Bab III Revisi Bab IV	[signature]
4	4/09/08	Acc Bab IV	[signature]
5	12/09/08	Konsultasi Makalah Seminar	[signature]
6	24/09/08	Acc Ujian Skripsi	[signature]
7			
8			
9			
10			

MALANG,
DOSEN PEMBIMBING I

[signature]

I KOMANG SOMAWIRATA ST. MT.
NIP.P. 1030100361

INSTITUT TEKNOLOGI NASIONAL MALANG
JL. RAYA KARANGLO KM.2
MALANG

FORMULIR BIMBINGAN SKRIPSI

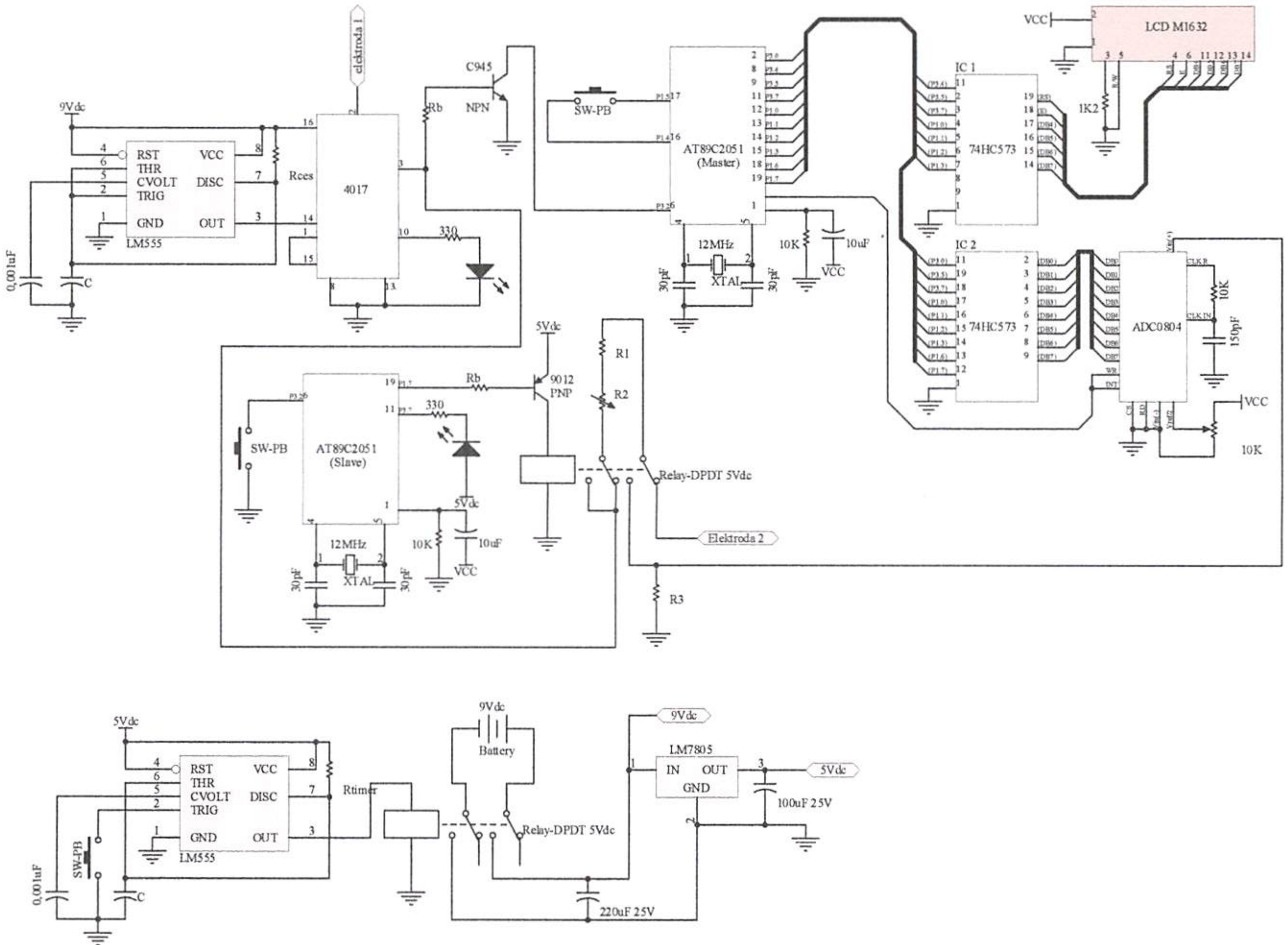
NAMA : HASYIM ASY'ARI YUSUF
NIM : 0017192
MASA BIMBINGAN : 11 FEBRUARI 2008 – 11 AGUSTUS 2008
JUDUL : PERANCANGAN DAN PEMBUATAN ALAT MEDIS CRANIAL ELECTROTHERAPY STIMULATION(CES) DENGAN TS555CN UNTUK TERAPI PASIEN DEPRESI

NO	TANGGAL	URAIAN	PARAF PEMBIMBING
1	29/03 08	Konsultasi Bab I & Bab II kurang teori depresi tambah teori oscilator & decode counter	[signature]
2	26/08 08	Revisi Bab III	[signature]
3	28/8 08	Revisi Bab IV, V	[signature]
4	3/9 08	Bab V tambah pengujian pada pasien	[signature]
5	12/9 08	ACC Seminar Hasil	[signature]
6	26/9 08	ACC ujian skripsi	[signature]
7	1/10 08	ACC jilid	[signature]
8			
9			
10			

MALANG,
DOSEN PEMBIMBING II

[signature]

SOTYOHADI ST.



Title			
Size	Number		Revision
A3			
Date:	18/10/2008	Sheet of	
File:	E:\skripsi\OOo\rangkaian lengkap.SCHDOC	Drawn By:	

LISTING PROGRAM MIKROKONTROLLER MASTER

```
MEMORI_DELAY        EQU   30H
MEMORI_DELAY_1      EQU   31H
MEMORI_DELAY_2      EQU   32H
MEM_LOOP      EQU   33H
BOUNC         EQU   34H
MEM_KONV1     EQU   35H
MEM_KONV2     EQU   36H
DIGIT_1             EQU   37H
DIGIT_2             EQU   38H
DIGIT_3             EQU   39H
DIGIT_4             EQU   3AH
HP_1          EQU   3BH
HP_2          EQU   3CH
LP_1          EQU   3DH
LP_2          EQU   3EH
DATA_ADC      EQU   3FH
M_P           EQU   40H
DIGIT_1P      EQU   41H
DIGIT_2P      EQU   42H
DIGIT_3P      EQU   43H
DIGIT_4P      EQU   44H
;~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~;
;     posisi pin MK dengan LCD      :
;~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~;
DL_7          bit   p1.3
DL_6          bit   p1.2
DL_5          bit   p1.1
DL_4          bit   p1.0
E             bit   p3.7
RS            bit   p3.5
OE1           bit   P3.4
;~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~;
;     posisi pin MK dengan ADC      :
;~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~;
D0            bit   P3.5
D1            bit   P3.7
D2            bit   P1.0
D3            bit   P1.1
D4            bit   P1.2
```

```
D5          bit   P1.3
D6          bit   P1.6
D7          bit   P1.7
OE2         bit   P3.0
ADC_ON            BIT   P3.1

pulse       BIT   P3.2
I_P1        BIT   P1.5
I_P2        BIT   P1.4

ORG   00H
JMP   MULAI

MULAI:
      SETB  OE1
      SETB  OE2
      CALL  HAPUS_MEM
      CALL  DELAY_1S
      CLR   I_P1
      CALL  INIT_LCD
      SETB  5H
REST_ARUS:
      CALL  BACA_ADC
      CALL  BANDING_ARUS
      JNB   5H, REST_ARUS
      SETB  5H
      MOV   M_P, #2
      CALL  TAMPIL_1
X_X:
      CALL  CEK_PULSA
      CALL  TAMPIL_PULSA
      DJNZ  M_P, X_X
LOOP_2:
      CALL  DISPLAY_CLEAR
      CALL  TAMPIL_2
LOOP_ARUS:
      CALL  TAMPIL_ARUS
      JB    I_P2, LOOP_ARUS
BOUNC_1:
      JNB   I_P2, $
      DJNZ  BOUNC, BOUNC_1
```

```
        MOV    BOUNC,#255
        CALL   DISPLAY_CLEAR
        CALL   TAMPIL_1
LOOP_1:
        CALL   CEK_PULSA
        CALL   TAMPIL_PULSA
        JB     I_P2,LOOP_1
BOUNC_2:
        JNB    I_P2,$
        DJNZ   BOUNC,BOUNC_2
        MOV    BOUNC,#255
        JMP    LOOP_2
;==================================:
;      subroutine CEK PULSA DAN ARUS :
;==================================:
CEK_PULSA:
        SETB   OH
        MOV    R7,#0
        MOV    R6,#0
        JB     P3.2,$
        JNB    P3.2,$
LOOP_HIGH:
        MOV    TMOD,#1
        MOV    THO,#0FCH
        MOV    TLO,#18H
        CLR    TFO
        SETB   TRO
WAIT_HIGH:
        JNB    TFO,CEK_LOGIKA
        CLR    TRO
        INC    R7
        CJNE   R7,#100,LOOP_HIGH
        MOV    R7,#0
        INC    R6
        JMP    LOOP_HIGH
CEK_LOGIKA:
        JNB    OH,WAIT_LOW
        JB     P3.2,WAIT_HIGH
        CLR    TRO
        MOV    HP_1,R7
        MOV    HP_2,R6
```

```
        MOV     R7,#0
        MOV     R6,#0
        CLR     0H
        JMP     LOOP_HIGH
WAIT_LOW:
        JNB     P3.2,WAIT_HIGH
        CLR     TR0
        MOV     LP_1,R7
        MOV     LP_2,R6
        RET
;=========================================:
;==================ADC=====================
BACA_ADC:
        SETB    D0
        SETB    D1
        SETB    D2
        SETB    D3
        SETB    D4
        SETB    D5
        SETB    D6
        SETB    D7
        SETB    OE1
        CLR     OE2
        CALL    DELAY_5MS
        CALL    DELAY_5MS
        CLR     A
        MOV     C,D0
        MOV     ACC.0,C
        MOV     C,D1
        MOV     ACC.1,C
        MOV     C,D2
        MOV     ACC.2,C
        MOV     C,D3
        MOV     ACC.3,C
        MOV     C,D4
        MOV     ACC.4,C
        MOV     C,D5
        MOV     ACC.5,C
        MOV     C,D6
        MOV     ACC.6,C
        MOV     C,D7
```

```
        MOV     ACC.7,C
        MOV     DATA_ADC,A
        SETB    OE1
        SETB    OE2
        CALL    DELAY_5MS
        CALL    DELAY_5MS
        RET
;======================================:
;=================ARUS=================:
BANDING_ARUS:
        CJNE    A,#20,CEK_ARUS1
KURANG_20:
        CLR     5H
        RET
;===================================:
CEK_ARUS1:
        JC      KURANG_20
        CJNE    A,#33,CEK_ARUS2
KURANG_33:
        MOV     DIGIT_3,#31H
        MOV     DIGIT_2,#33H
        MOV     DIGIT_1,#38H
        SETB    5H
        RET
;===================================:
CEK_ARUS2:
        JC      KURANG_33
        CJNE    A,#39,CEK_ARUS3
KURANG_39:
        MOV     DIGIT_3,#31H
        MOV     DIGIT_2,#35H
        MOV     DIGIT_1,#30H
        SETB    5H
        RET
;===================================:
CEK_ARUS3:
        JC      KURANG_39
        CJNE    A,#45,CEK_ARUS4
KURANG_45:
        MOV     DIGIT_3,#31H
        MOV     DIGIT_2,#36H
```

```
        MOV    DIGIT_1,#34H
        SETB   5H
        RET
;=================================:
CEK_ARUS4:
        JC     KURANG_45
        CJNE   A,#51,CEK_ARUS5
KURANG_51:
        MOV    DIGIT_3,#31H
        MOV    DIGIT_2,#38H
        MOV    DIGIT_1,#30H
        SETB   5H
        RET
;=================================:
CEK_ARUS5:
        JC     KURANG_51
        CJNE   A,#57,CEK_ARUS6
KURANG_57:
        MOV    DIGIT_3,#32H
        MOV    DIGIT_2,#30H
        MOV    DIGIT_1,#30H
        SETB   5H
        RET
;=================================:
CEK_ARUS6:
        JC     KURANG_57
        CJNE   A,#63,CEK_ARUS7
KURANG_63:
        MOV    DIGIT_3,#32H
        MOV    DIGIT_2,#32H
        MOV    DIGIT_1,#35H
        SETB   5H
        RET
;=================================:
CEK_ARUS7:
        JC     KURANG_63
        CJNE   A,#69,CEK_ARUS8
KURANG_69:
        MOV    DIGIT_3,#32H
        MOV    DIGIT_2,#35H
        MOV    DIGIT_1,#37H
```

```
        SETB   5H
        RET
;==================================:
CEK_ARUS8:
        JC     KURANG_69
        CJNE   A, #75, CEK_ARUS9
KURANG_75:
        MOV    DIGIT_3, #33H
        MOV    DIGIT_2, #30H
        MOV    DIGIT_1, #30H
        SETB   5H
        RET
;==================================:
CEK_ARUS9:
        JC     KURANG_75
        CJNE   A, #81, CEK_ARUS10
KURANG_81:
        MOV    DIGIT_3, #33H
        MOV    DIGIT_2, #36H
        MOV    DIGIT_1, #30H
        SETB   5H
        RET
;==================================:
CEK_ARUS10:
        JC     KURANG_81
        CJNE   A, #87, CEK_ARUS11
KURANG_87:
        MOV    DIGIT_3, #34H
        MOV    DIGIT_2, #35H
        MOV    DIGIT_1, #30H
        SETB   5H
        RET
;==================================:
CEK_ARUS11:
        JC     KURANG_87
        MOV    DIGIT_3, #36H
        MOV    DIGIT_2, #30H
        MOV    DIGIT_1, #30H
        SETB   5H
        RET
;==================================:
```

```
;     subroutine LCD                    :
;==================================:
init_lcd:
        CLR     OE1
        SETB    OE2
        CALL    DELAY_5MS
        CALL    DELAY_5MS
        MOV     A,#00101111b            ;function set1
        clr     RS
        CALL    kiriml
        CALL    DELAY_5MS
        MOV     A,#00101111b            ;function set2
        CALL    intruksi
        MOV     A,#00001000b            ;display off
        CALL    intruksi
        MOV     A,#00000001b            ;display clear
        CALL    intruksi
        MOV     A,#00000110b            ;entry mode
        CALL    intruksi
        mov     A,#00001100b            ;display on,cursor off,blink
off
        call    intruksi
        SETB    OE1
        SETB    OE2
        RET
;==================================:
kiriml:
        mov     C,Acc.7
        mov     DL_7,C
        mov     C,Acc.6
        mov     DL_6,C
        mov     C,ACC.5
        mov     DL_5,C
        mov     C,ACC.4
        mov     DL_4,C
        nop
        nop
        nop
        setb    E
        NOP
        NOP
```

```
        NOP
        NOP
        clr   E
        NOP
        NOP
        NOP
        SETB  E
        ret
;==================================:
kirim2:
        mov   C,Acc.3
        mov   DL_7,C
        mov   C,Acc.2
        mov   DL_6,C
        mov   C,ACC.1
        mov   DL_5,C
        mov   C,ACC.0
        mov   DL_4,C
        setb  E
        NOP
        NOP
        NOP
        clr   E
        CALL  DELAY_5MS
        SETB  E
        ret
;==================================:
intruksi:
        CLR   OE1
        SETB  OE2
        CALL  DELAY_5MS
        CALL  DELAY_5MS
        CLR   RS
        call  kirim1
        call  kirim2
        SETB  OE1
        SETB  OE2
        RET
;==================================:
tulis_data:
        CLR   OE1
```

```
        SETB   OE2
        CALL   DELAY_5MS
        CALL   DELAY_5MS
        SETB   RS
        call   kirim1
        call   kirim2
        SETB   OE1
        SETB   OE2
        RET
;====================================:
tampil:
        MOV    MEM_LOOP,#10H
loop1:
        MOV    A,#00H
        MOVC   A,@A+DPTR
        CALL   tulis_data                    ;ada delay 5 ms
        INC    DPTR
        DJNZ   MEM_LOOP,loop1
        RET
;====================================:
display_clear:
        mov    A,#01H
        call   intruksi
        ret
;====================================:
cursor_home:
        mov    A,#03H
        call   intruksi
        ret
;====================================:
BARIS1_posisi_00H:
        MOV    A,#080H
        CALL   intruksi
        RET
;====================================:
BARIS2_posisi_40H:
        MOV    A,#0C0H
        CALL   intruksi                      ;ada delay 5 ms
        RET
;====================================:
HAPUS_MEM:
```

```
        MOV   DIGIT_1P,#0
        MOV   DIGIT_2P,#0
        MOV   DIGIT_3P,#0
        MOV   DIGIT_4P,#0
        MOV   DIGIT_1,#0
        MOV   DIGIT_2,#0
        MOV   DIGIT_3,#0
        MOV   DIGIT_4,#0
        MOV   MEM_KONV1,#0
        MOV   MEM_KONV2,#0
        MOV   HP_1,#0
        MOV   HP_2,#0
        MOV   LP_1,#0
        MOV   LP_2,#0
        RET
;==========================================:
;     subroutine TAMPILAN                  :
;==========================================:
TAMPIL_1:
        CALL  DISPLAY_CLEAR
        MOV   DPTR,#LAYAR1_H
        CALL  TAMPIL
        CALL  BARIS2_POSISI_40H
        MOV   DPTR,#LAYAR2_L
        CALL  TAMPIL
        RET
;==========================================:
TAMPIL_PULSA:
        MOV   MEM_KONV1,HP_2
        MOV   MEM_KONV2,HP_1
        CALL  KONV_DIGIT
        MOV   A,#88H
        CALL  INTRUKSI
        MOV   A,DIGIT_1P
        CALL  TULIS_DATA
        MOV   A,#00101100B
        CALL  TULIS_DATA
        MOV   A,DIGIT_2P
        CALL  TULIS_DATA
        MOV   A,DIGIT_3P
        CALL  TULIS_DATA
```

```
        MOV   A,DIGIT_4P
        CALL  TULIS_DATA
        MOV   MEM_KONV1,LP_2
        MOV   MEM_KONV2,LP_1
        CALL  KONV_DIGIT
        MOV   A,#0C8H
        CALL  INTRUKSI
        MOV   A,DIGIT_1P
        CALL  TULIS_DATA
        MOV   A,#00101100B
        CALL  TULIS_DATA
        MOV   A,DIGIT_2P
        CALL  TULIS_DATA
        MOV   A,DIGIT_3P
        CALL  TULIS_DATA
        MOV   A,DIGIT_4P
        CALL  TULIS_DATA
        RET
;===================================:
TAMPIL_2:
        CALL  DISPLAY_CLEAR
        MOV   DPTR,#ARUS_TAMPIL
        CALL  TAMPIL
        CALL  BARIS2_POSISI_40H
        MOV   DPTR,#FREQ_TAMPIL
        CALL  TAMPIL
        RET
;===================================:
TAMPIL_ARUS:
        CALL  BACA_ADC
        MOV   A,DATA_ADC
        CALL  BANDING_ARUS
        CALL  TAMPILKAN_ARUS
        SETB  5H
        RET
;===================================:
TAMPILKAN_ARUS:
        MOV   A,#87H
        CALL  INTRUKSI
        MOV   A,DIGIT_3
        CALL  TULIS_DATA
```

```
        MOV    A,DIGIT_2
        CALL   TULIS_DATA
        MOV    A,DIGIT_1
        CALL   TULIS_DATA
        RET
;==========================================:
;       subroutine KONVERSI             :
;==========================================:
KONV_DIGIT:
        MOV    B,#10
        MOV    A,MEM_KONV2
        DIV    AB
        MOV    DIGIT_4P,B
        MOV    B,#10
        DIV    AB
        MOV    DIGIT_3P,B
        MOV    DIGIT_2P,A
        MOV    B,#10
        MOV    A,MEM_KONV1
        DIV    AB
        MOV    DIGIT_1P,A
        MOV    A,B
        ADD    A,DIGIT_2P
        MOV    B,#10
        DIV    AB
        MOV    DIGIT_2P,B
        ADD    A,DIGIT_1P
        MOV    DIGIT_1P,A
        MOV    A,#30H
        ADD    A,DIGIT_1P
        MOV    DIGIT_1P,A
        MOV    A,#30H
        ADD    A,DIGIT_2P
        MOV    DIGIT_2P,A
        MOV    A,#30H
        ADD    A,DIGIT_3P
        MOV    DIGIT_3P,A
        MOV    A,#30H
        ADD    A,DIGIT_4P
        MOV    DIGIT_4P,A
        RET
```

```
;====================================;
;====================================;
;     subroutine waktu/delay        ;
;====================================;
DELAY_2S:
      MOV   BOUNC,#2
TUNGGU_DELAY_2S:
      CALL  DELAY_1S
      DJNZ  BOUNC,TUNGGU_DELAY_2S
      RET
;------------------------------------
delay_1s:
      mov   MEMORI_DELAY,#200
tunggu_1s:
      call  delay_5ms
      djnz  MEMORI_DELAY,tunggu_1s
      ret
;------------------------------------
DELAY_05S:
      MOV   MEMORI_DELAY,#100
TUNGGU_05S:
      CALL  DELAY_5MS
      DJNZ  MEMORI_DELAY,TUNGGU_05S
      RET
;------------------------------------
DELAY_01S:
      MOV   MEMORI_DELAY,#20
TUNGGU_DELAY_01S:
      CALL  DELAY_5MS
      DJNZ  MEMORI_DELAY,TUNGGU_DELAY_01S
      RET
;------------------------------------
delay_5ms:
      mov   TMOD,#01H
      mov   TH0,#0EDH
      mov   TL0,#0FFH
      CLR   TF0
      setb  TR0
      jnb   TF0,$
      clr   TR0
```

```
        ret
;----------------------------------------
DELAY_30MS:
        MOV     MEMORI_DELAY,#6
TUNGGU_DELAY_30MS:
        CALL    DELAY_5MS
        DJNZ    MEMORI_DELAY,TUNGGU_DELAY_30MS
        RET
;----------------------------------------
DELAY_200us:
        MOV     MEMORI_DELAY_1,#10
TUNGGU_DELAY_200us:
        MOV     MEMORI_DELAY_2,#20
        DJNZ    MEMORI_DELAY_2,$
        DJNZ    MEMORI_DELAY_1,TUNGGU_DELAY_200us
        RET
LAYAR_1:
        DB      'FREK =          Hz'
LAYAR_2:
        DB      'ARUS =          uA'
LAYAR1_H:
        DB      'HIGH =           s'
LAYAR2_L:
        DB      'LOW  =           s'
ARUS_TAMPIL:
        DB      'ARUS =          uA'
FREQ_TAMPIL:
        DB      'FREQ = 0,5      Hz'
END
```

LISTING PROGRAM MIKROKONTROLLER SLAVE

```
MEMORI_DELAY        EQU   30H
MEMORI_DELAY_1      EQU   31H
MEMORI_DELAY_2      EQU   32H
MEM_LOOP      EQU   33H
BOUNC         EQU   34H
DATA_PWM      EQU   35H
HIGH_P              EQU   36H
LOW_P         EQU   37H
;~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~;
;     posisi pin MK                 ;
;~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~;
RELAY         bit   p1.7
LED           bit   P3.7
UP            BIT   P3.3
DWN           BIT   P3.2

ORG    00H
JMP    MULAI
ORG    3H
JMP    GELAP


MULAI:
       SETB  UP
       CLR   RELAY
       CLR   LED
       CALL  DELAY_2S
       CALL  DELAY_2S
       SETB  LED
       SETB  RELAY
       SETB  EA
       SETB  EX0
LOOP_MULAI:
       SETB  RELAY
       SETB  LED
       JMP   LOOP_MULAI
;=========================================
GELAP:
       CLR   EA
```

```
        CLR     LED
        CLR     RELAY
CEK_DWN:
        JNB     DWN,$
        DJNZ    BOUNC,CEK_DWN
        JB      DWN,$
CEK_DWN2:
        JNB     DWN,$
        DJNZ    BOUNC,CEK_DWN2
        SETB    EA
        RETI
;=================================================
DELAY_2S:
        MOV     BOUNC,#2
TUNGGU_DELAY_2S:
        CALL    DELAY_1S
        DJNZ    BOUNC,TUNGGU_DELAY_2S
        RET
;-------------------------------------------------
delay_1s:
        mov     MEMORI_DELAY,#200
tunggu_1s:
        call    delay_5ms
        djnz    MEMORI_DELAY,tunggu_1s
        ret
;-------------------------------------------------
delay_5ms:
        mov     TMOD,#01H
        mov     TH0,#0EDH
        mov     TL0,#0FFH
        clr     TF0
        setb    TR0
        jnb     TF0,$
        clr     TR0
        ret
END
```

National Semiconductor

July 2006

LM555
Timer

General Description

The LM555 is a highly stable device for generating accurate time delays or oscillation. Additional terminals are provided for triggering or resetting if desired. In the time delay mode of operation, the time is precisely controlled by one external resistor and capacitor. For astable operation as an oscillator, the free running frequency and duty cycle are accurately controlled with two external resistors and one capacitor. The circuit may be triggered and reset on falling waveforms, and the output circuit can source or sink up to 200mA or drive TTL circuits.

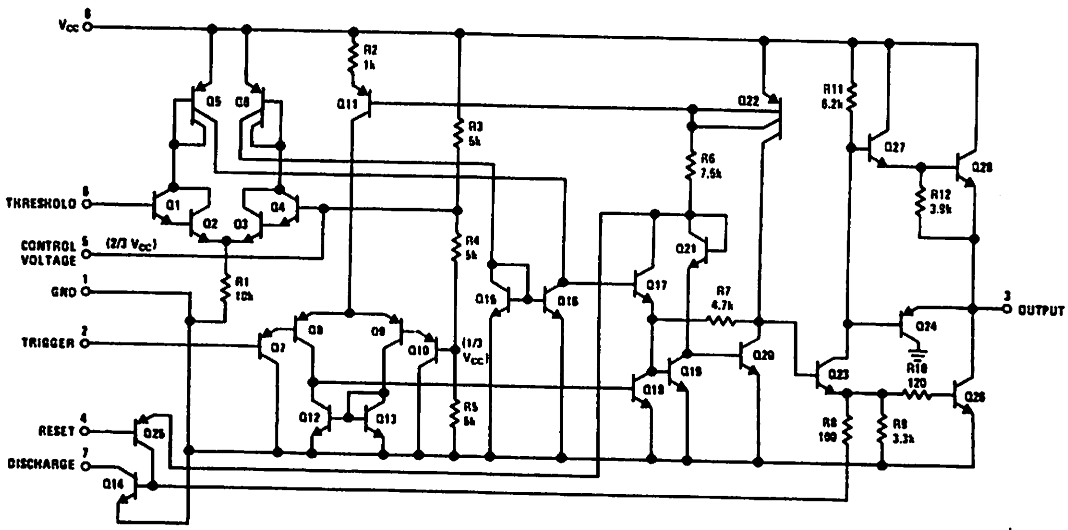
Features

- Direct replacement for SE555/NE555
- Timing from microseconds through hours
- Operates in both astable and monostable modes
- Adjustable duty cycle
- Output can source or sink 200 mA
- Output and supply TTL compatible
- Temperature stability better than 0.005% per °C
- Normally on and normally off output
- Available in 8-pin MSOP package

Applications

- Precision timing
- Pulse generation
- Sequential timing
- Time delay generation
- Pulse width modulation
- Pulse position modulation
- Linear ramp generator

Schematic Diagram



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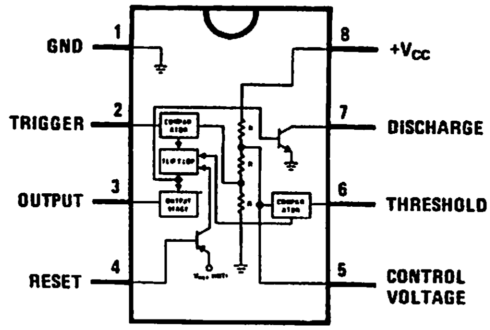
Connection Diagram

Dual-In-Line, Small Outline and Molded Mini Small Outline Packages



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Top View

Ordering Information

Package	Part Number	Package Marking	Media Transport	NSC Drawing
8-Pin SOIC	LM555CM	LM555CM	Rails	M08A
	LM555CMX	LM555CM	2.5k Units Tape and Reel	
8-Pin MSOP	LM555CMM	Z55	1k Units Tape and Reel	MUA08A
	LM555CMMX	Z55	3.5k Units Tape and Reel	
8-Pin MDIP	LM555CN	LM555CN	Rails	N08E

Absolute Maximum Ratings (Note 2)

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

Supply Voltage	+18V
Power Dissipation (Note 3)	
LM555CM, LM555CN	1180 mW
LM555CMM	613 mW
Operating Temperature Ranges	
LM555C	0°C to +70°C
Storage Temperature Range	−65°C to +150°C
Soldering Information	
Dual-In-Line Package	
Soldering (10 Seconds)	260°C
Small Outline Packages (SOIC and MSOP)	
Vapor Phase (60 Seconds)	215°C
Infrared (15 Seconds)	220°C

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

Electrical Characteristics (Notes 1, 2)

(T_A = 25°C, V_{CC} = +5V to +15V, unless othewise specified)

Parameter	Conditions	Limits LM555C Min	Typ	Max	Units
Supply Voltage		4.5		16	V
Supply Current	V_{CC} = 5V, $R_L = \infty$ V_{CC} = 15V, $R_L = \infty$ (Low State) (Note 4)		3 10	6 15	mA
Timing Error, Monostable Initial Accuracy Drift with Temperature Accuracy over Temperature Drift with Supply	R_A = 1k to 100kΩ, C = 0.1µF, (Note 5)		1 50 1.5 0.1		% ppm/°C % %/V
Timing Error, Astable Initial Accuracy Drift with Temperature Accuracy over Temperature Drift with Supply	R_A, R_B = 1k to 100kΩ, C = 0.1µF, (Note 5)		2.25 150 3.0 0.30		% ppm/°C % %/V
Threshold Voltage			0.667		x V_{CC}
Trigger Voltage	V_{CC} = 15V V_{CC} = 5V		5 1.67		V V
Trigger Current			0.5	0.9	µA
Reset Voltage		0.4	0.5	1	V
Reset Current			0.1	0.4	mA
Threshold Current	(Note 6)		0.1	0.25	µA
Control Voltage Level	V_{CC} = 15V V_{CC} = 5V	9 2.6	10 3.33	11 4	V
Pin 7 Leakage Output High			1	100	nA
Pin 7 Sat (Note 7) Output Low Output Low	 V_{CC} = 15V, I_7 = 15mA V_{CC} = 4.5V, I_7 = 4.5mA		 180 80	 200	 mV mV

Electrical Characteristics (Notes 1, 2) (Continued)

(T_A = 25°C, V_{CC} = +5V to +15V, unless othewise specified)

Parameter	Conditions	Limits LM555C Min	Limits LM555C Typ	Limits LM555C Max	Units
Output Voltage Drop (Low)	V_{CC} = 15V				
	I_{SINK} = 10mA		0.1	0.25	V
	I_{SINK} = 50mA		0.4	0.75	V
	I_{SINK} = 100mA		2	2.5	V
	I_{SINK} = 200mA		2.5		V
	V_{CC} = 5V				
	I_{SINK} = 8mA				V
	I_{SINK} = 5mA		0.25	0.35	V
Output Voltage Drop (High)	I_{SOURCE} = 200mA, V_{CC} = 15V		12.5		V
	I_{SOURCE} = 100mA, V_{CC} = 15V	12.75	13.3		V
	V_{CC} = 5V	2.75	3.3		V
Rise Time of Output			100		ns
Fall Time of Output			100		ns

Note 1: All voltages are measured with respect to the ground pin, unless otherwise specified.

Note 2: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. Electrical Characteristics state DC and AC electrical specifications under particular test conditions which guarantee specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not guaranteed for parameters where no limit is given, however, the typical value is a good indication of device performance.

Note 3: For operating at elevated temperatures the device must be derated above 25°C based on a +150°C maximum junction temperature and a thermal resistance of 106°C/W (DIP), 170°C/W (S0-8), and 204°C/W (MSOP) junction to ambient.

Note 4: Supply current when output high typically 1 mA less at V_{CC} = 5V.

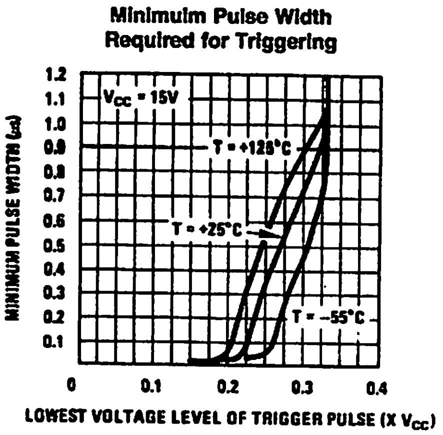
Note 5: Tested at V_{CC} = 5V and V_{CC} = 15V.

Note 6: This will determine the maximum value of $R_A + R_B$ for 15V operation. The maximum total $(R_A + R_B)$ is 20MΩ.

Note 7: No protection against excessive pin 7 current is necessary providing the package dissipation rating will not be exceeded.

Note 8: Refer to RETS555X drawing of military LM555H and LM555J versions for specifications.

Typical Performance Characteristics



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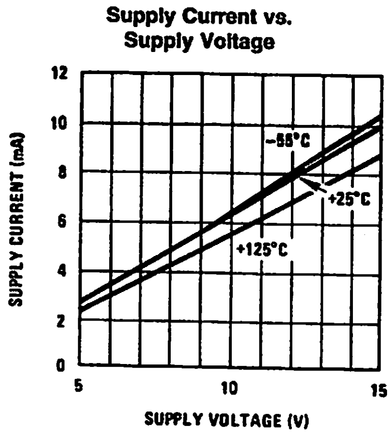

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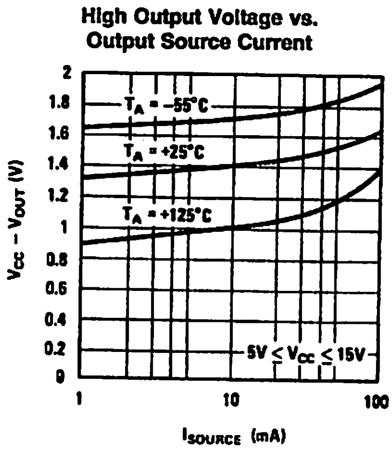

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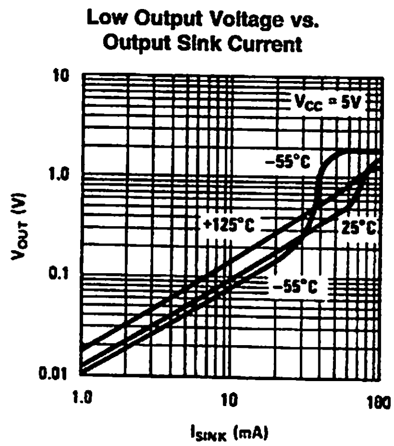

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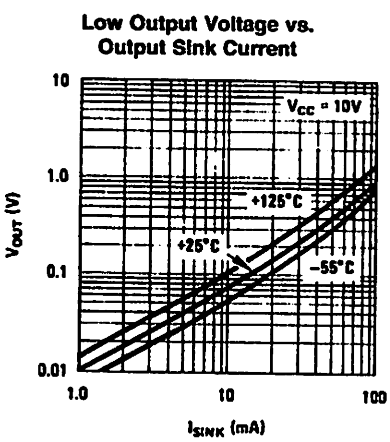

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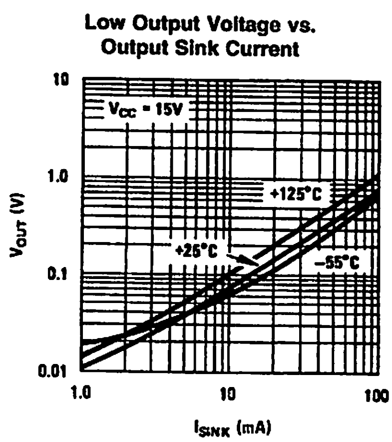

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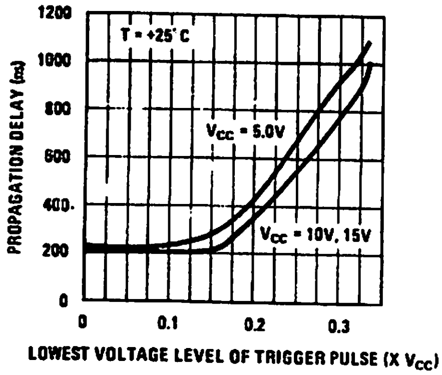
Typical Performance Characteristics (Continued)

Output Propagation Delay vs. Voltage Level of Trigger Pulse



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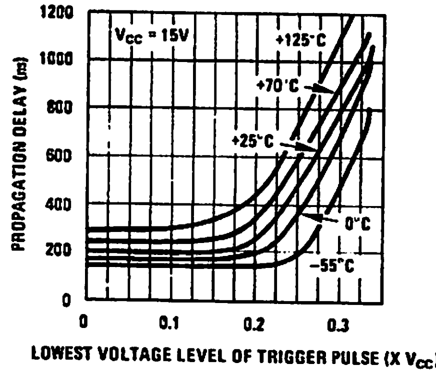
Output Propagation Delay vs. Voltage Level of Trigger Pulse



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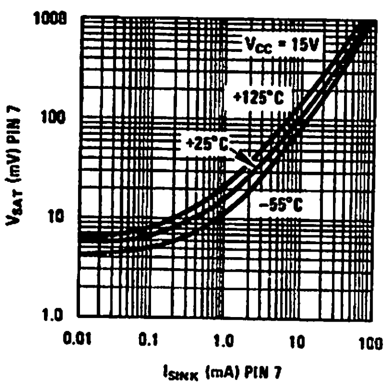
Discharge Transistor (Pin 7) Voltage vs. Sink Current



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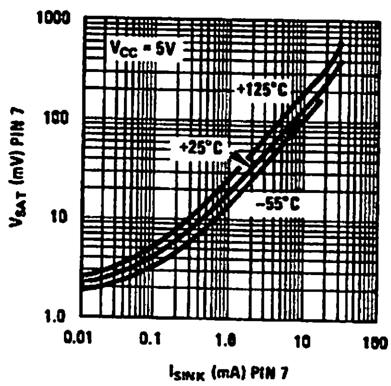
Discharge Transistor (Pin 7) Voltage vs. Sink Current

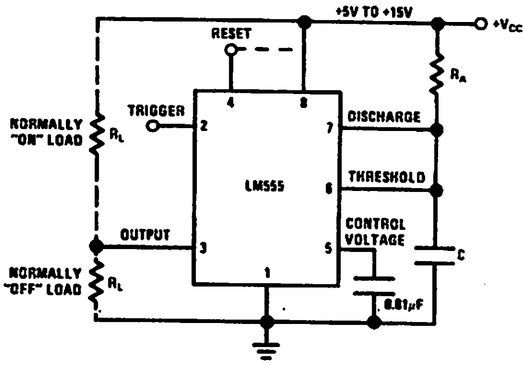


00785127

Applications Information

MONOSTABLE OPERATION

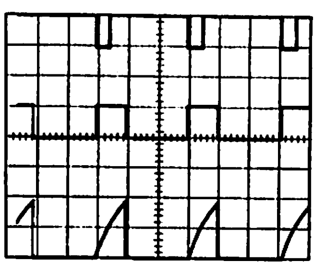
In this mode of operation, the timer functions as a one-shot (*Figure 1*). The external capacitor is initially held discharged by a transistor inside the timer. Upon application of a negative trigger pulse of less than 1/3 V_{CC} to pin 2, the flip-flop is set which both releases the short circuit across the capacitor and drives the output high.



00785105

FIGURE 1. Monostable

The voltage across the capacitor then increases exponentially for a period of $t = 1.1\ R_A\ C$, at the end of which time the voltage equals 2/3 V_{CC}. The comparator then resets the flip-flop which in turn discharges the capacitor and drives the output to its low state. *Figure 2* shows the waveforms generated in this mode of operation. Since the charge and the threshold level of the comparator are both directly proportional to supply voltage, the timing interval is independent of supply.



00785106

V_{CC} = 5V
TIME = 0.1 ms/DIV.
R_A = 9.1kΩ
C = 0.01μF

Top Trace: Input 5V/Div.
Middle Trace: Output 5V/Div.
Bottom Trace: Capacitor Voltage 2V/Div.

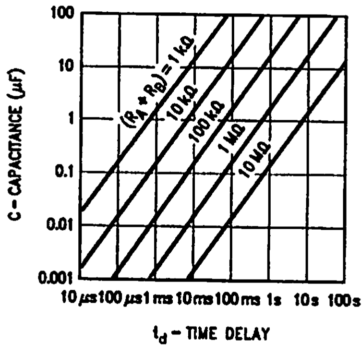
FIGURE 2. Monostable Waveforms

During the timing cycle when the output is high, the further application of a trigger pulse will not effect the circuit so long as the trigger input is returned high at least 10μs before the end of the timing interval. However the circuit can be reset during this time by the application of a negative pulse to the reset terminal (pin 4). The output will then remain in the low state until a trigger pulse is again applied.

When the reset function is not in use, it is recommended that it be connected to V_{CC} to avoid any possibility of false triggering.

Figure 3 is a nomograph for easy determination of R, C values for various time delays.

NOTE: In monostable operation, the trigger should be driven high before the end of timing cycle.

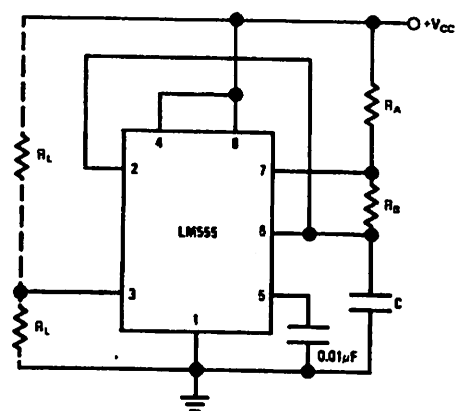


00785107

FIGURE 3. Time Delay

ASTABLE OPERATION

If the circuit is connected as shown in *Figure 4* (pins 2 and 6 connected) it will trigger itself and free run as a multivibrator. The external capacitor charges through $R_A + R_B$ and discharges through R_B. Thus the duty cycle may be precisely set by the ratio of these two resistors.



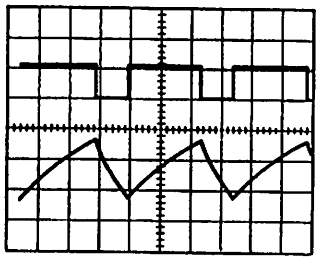
00785108

FIGURE 4. Astable

In this mode of operation, the capacitor charges and discharges between 1/3 V_{CC} and 2/3 V_{CC}. As in the triggered mode, the charge and discharge times, and therefore the frequency are independent of the supply voltage.

Applications Information (Continued)

Figure 5 shows the waveforms generated in this mode of operation.



00785109

V_{CC} = 5V
TIME = 20µs/DIV.
R_A = 3.9kΩ
R_B = 3kΩ
C = 0.01µF

Top Trace: Output 5V/Div.
Bottom Trace: Capacitor Voltage 1V/Div.

FIGURE 5. Astable Waveforms

The charge time (output high) is given by:

$$t_1 = 0.693\ (R_A + R_B)\ C$$

And the discharge time (output low) by:

$$t_2 = 0.693\ (R_B)\ C$$

Thus the total period is:

$$T = t_1 + t_2 = 0.693\ (R_A + 2R_B)\ C$$

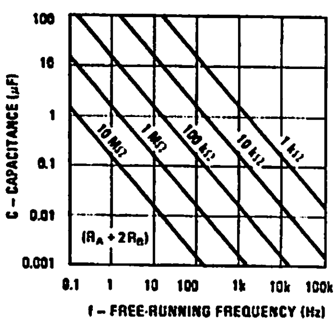
The frequency of oscillation is:

$$f = \frac{1}{T} = \frac{1.44}{(R_A + 2\,R_B)\,C}$$

Figure 6 may be used for quick determination of these RC values.

The duty cycle is:

$$D = \frac{R_B}{R_A + 2R_B}$$

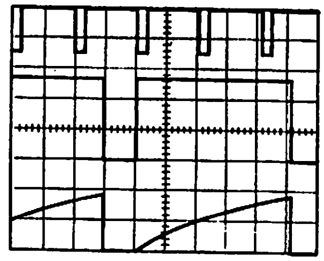


00785110

FIGURE 6. Free Running Frequency

FREQUENCY DIVIDER

The monostable circuit of *Figure 1* can be used as a frequency divider by adjusting the length of the timing cycle. *Figure 7* shows the waveforms generated in a divide by three circuit.



00785111

V_{CC} = 5V
TIME = 20µs/DIV.
R_A = 9.1kΩ
C = 0.01µF

Top Trace: Input 4V/Div.
Middle Trace: Output 2V/Div.
Bottom Trace: Capacitor 2V/Div.

FIGURE 7. Frequency Divider

PULSE WIDTH MODULATOR

When the timer is connected in the monostable mode and triggered with a continuous pulse train, the output pulse width can be modulated by a signal applied to pin 5. *Figure 8* shows the circuit, and in *Figure 9* are some waveform examples.

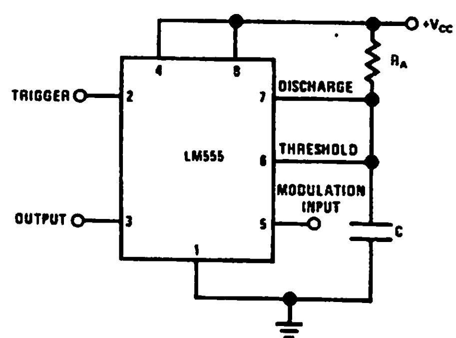


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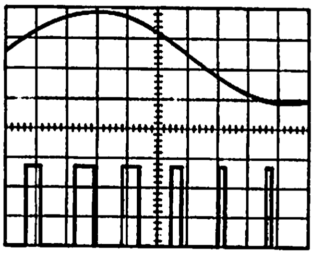
FIGURE 8. Pulse Width Modulator

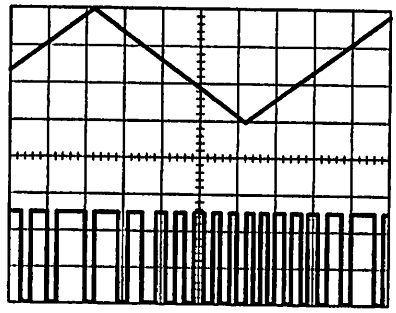
Applications Information (Continued)



00785113

V_{CC} = 5V Top Trace: Modulation 1V/Div.
TIME = 0.2 ms/DIV. Bottom Trace: Output Voltage 2V/Div.
R_A = 9.1kΩ
C = 0.01µF

FIGURE 9. Pulse Width Modulator



00785115

V_{CC} = 5V Top Trace: Modulation Input 1V/Div.
TIME = 0.1 ms/DIV. Bottom Trace: Output 2V/Div.
R_A = 3.9kΩ
R_B = 3kΩ
C = 0.01µF

FIGURE 11. Pulse Position Modulator

PULSE POSITION MODULATOR

This application uses the timer connected for astable operation, as in *Figure 10*, with a modulating signal again applied to the control voltage terminal. The pulse position varies with the modulating signal, since the threshold voltage and hence the time delay is varied. *Figure 11* shows the waveforms generated for a triangle wave modulation signal.

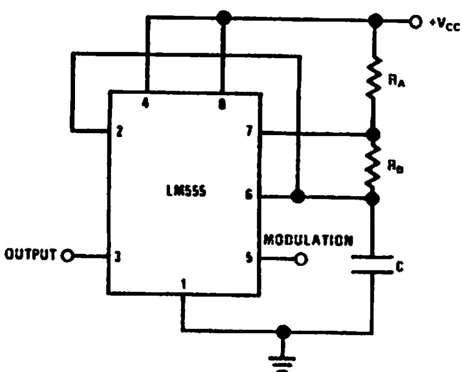


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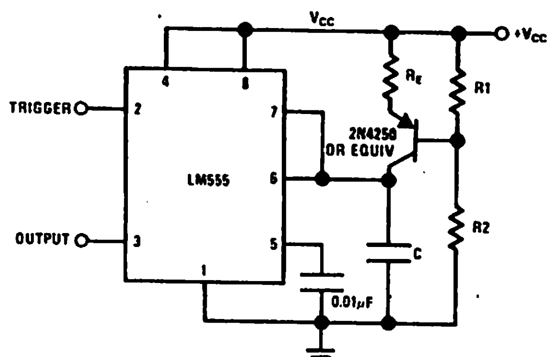
FIGURE 10. Pulse Position Modulator

LINEAR RAMP

When the pullup resistor, R_A, in the monostable circuit is replaced by a constant current source, a linear ramp is generated. *Figure 12* shows a circuit configuration that will perform this function.



00785116

FIGURE 12.

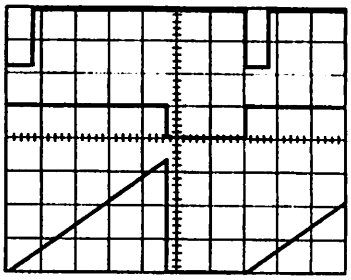
Figure 13 shows waveforms generated by the linear ramp. The time interval is given by:

$$T = \frac{2/3\, V_{CC}\, R_E\, (R_1 + R_2)\, C}{R_1 V_{CC} - V_{BE}\, (R_1 + R_2)}$$

$V_{BE} \cong 0.6V$

$V_{BE} \cong 0.6V$

Applications Information (Continued)



00785117

V_{CC} = 5V
TIME = 20µs/DIV.
R_1 = 47kΩ
R_2 = 100kΩ
R_E = 2.7 kΩ
C = 0.01 µF

Top Trace: Input 3V/Div.
Middle Trace: Output 5V/Div.
Bottom Trace: Capacitor Voltage 1V/Div.

FIGURE 13. Linear Ramp

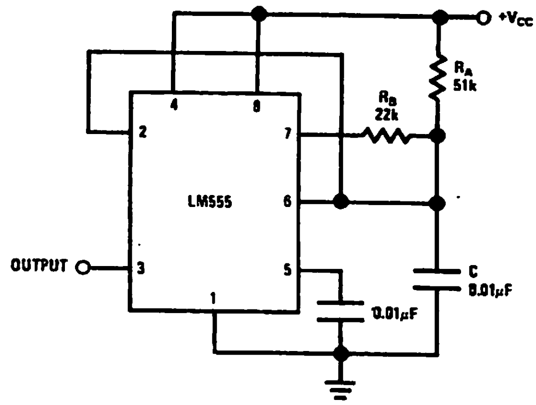
50% DUTY CYCLE OSCILLATOR

For a 50% duty cycle, the resistors R_A and R_B may be connected as in *Figure 14*. The time period for the output high is the same as previous, $t_1 = 0.693\ R_A\ C$. For the output low it is t_2 =

$$\left[(R_A R_B)/(R_A + R_B)\right] C\ ln \left[\frac{R_B - 2R_A}{2R_B - R_A}\right]$$

Thus the frequency of oscillation is

$$f = \frac{1}{t_1 + t_2}$$



00785118

FIGURE 14. 50% Duty Cycle Oscillator

Note that this circuit will not oscillate if R_B is greater than 1/2 R_A because the junction of R_A and R_B cannot bring pin 2 down to 1/3 V_{CC} and trigger the lower comparator.

ADDITIONAL INFORMATION

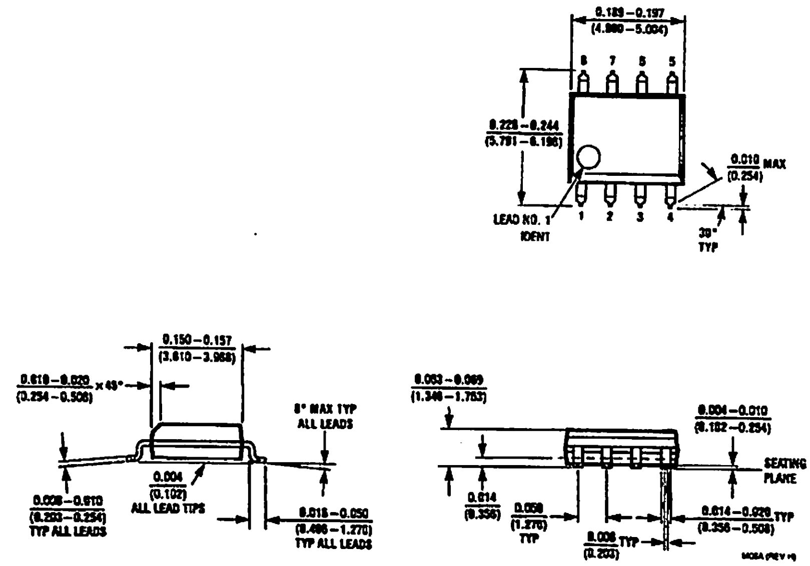
Adequate power supply bypassing is necessary to protect associated circuitry. Minimum recommended is 0.1µF in parallel with 1µF electrolytic.

Lower comparator storage time can be as long as 10µs when pin 2 is driven fully to ground for triggering. This limits the monostable pulse width to 10µs minimum.

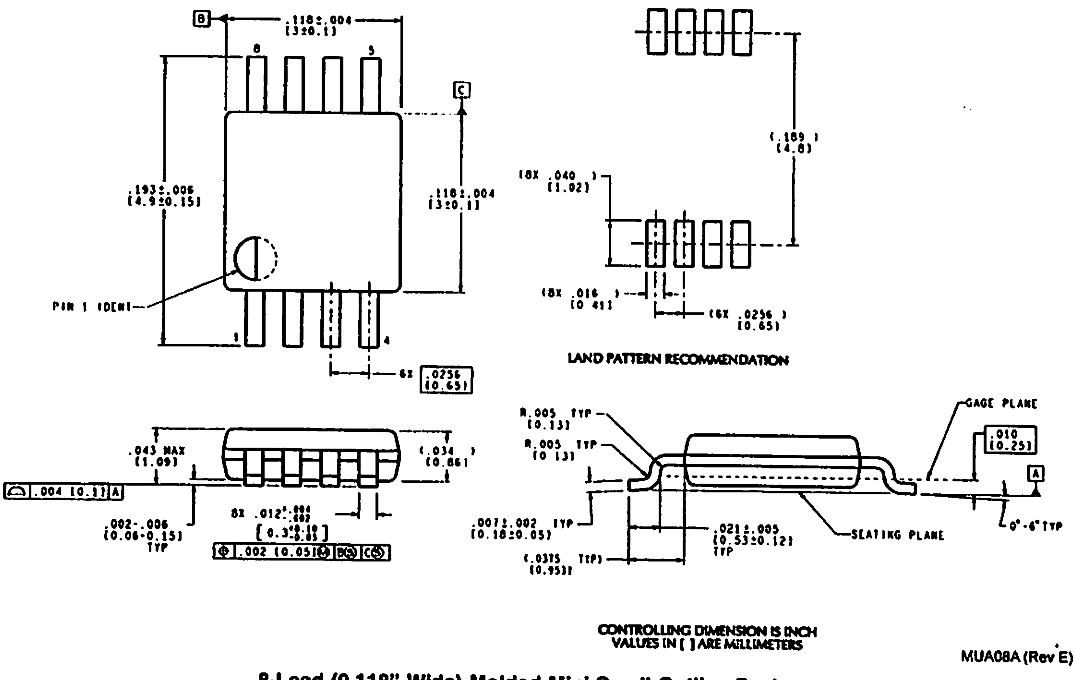
Delay time reset to output is 0.47µs typical. Minimum reset pulse width must be 0.3µs, typical.

Pin 7 current switches within 30ns of the output (pin 3) voltage.

Physical Dimensions inches (millimeters) unless otherwise noted



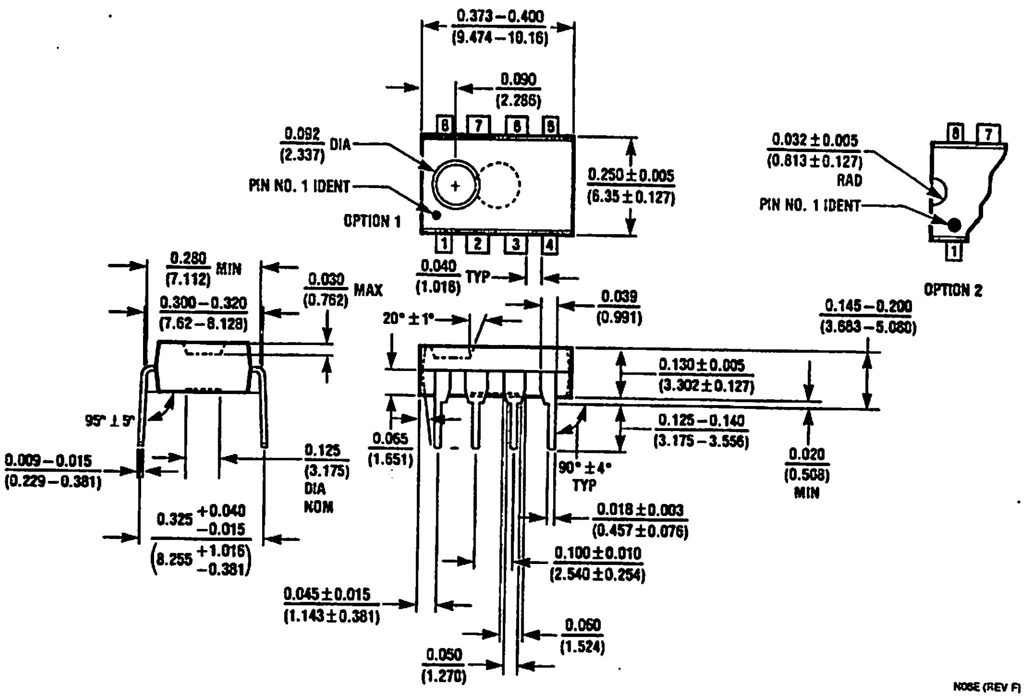
Small Outline Package (M)
NS Package Number M08A



MUA08A (Rev E)

8-Lead (0.118" Wide) Molded Mini Small Outline Package
NS Package Number MUA08A

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



Molded Dual-In-Line Package (N)
NS Package Number N08E

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DATA SHEET

For a complete data sheet, please also download:

- The IC04 LOCMOS HE4000B Logic Family Specifications HEF, HEC
- The IC04 LOCMOS HE4000B Logic Package Outlines/Information HEF, HEC

HEF4017B
MSI
5-stage Johnson counter

Product specification
File under Integrated Circuits, IC04

January 1995

Philips
Semiconductors

PHILIPS

5-stage Johnson counter

HEF4017B
MSI

DESCRIPTION

The HEF4017B is a 5-stage Johnson decade counter with ten spike-free decoded active HIGH outputs (O_0 to O_9), an active LOW output from the most significant flip-flop ($\overline{O}_{5\text{-}9}$), active HIGH and active LOW clock inputs (CP_0, $\overline{CP}_1$) and an overriding asynchronous master reset input (MR).

The counter is advanced by either a LOW to HIGH transition at CP_0 while $\overline{CP}_1$ is LOW or a HIGH to LOW transition at $\overline{CP}_1$ while CP_0 is HIGH (see also function table).

When cascading counters, the $\overline{O}_{5\text{-}9}$ output, which is LOW while the counter is in states 5, 6, 7, 8 and 9, can be used to drive the CP_0 input of the next counter.

A HIGH on MR resets the counter to zero ($O_0 = \overline{O}_{5\text{-}9}$ = HIGH; O_1 to O_9 = LOW) independent of the clock inputs (CP_0, $\overline{CP}_1$).

Automatic code correction of the counter is provided by an internal circuit: following any illegal code the counter returns to a proper counting mode within 11 clock pulses.

Schmitt-trigger action in the clock input makes the circuit highly tolerant to slower clock rise and fall times.

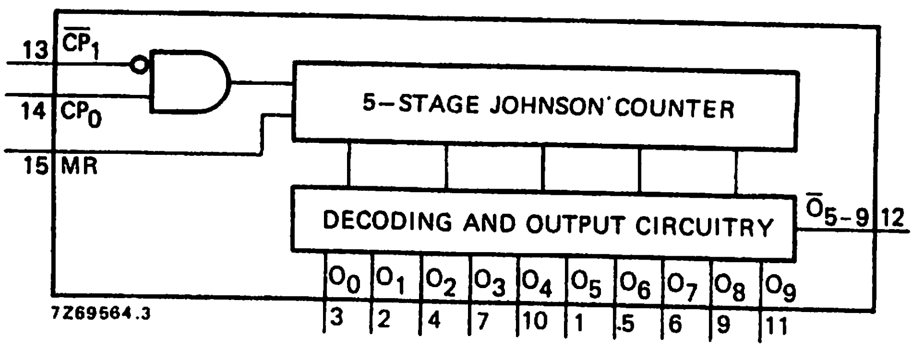


Fig.1 Functional diagram.

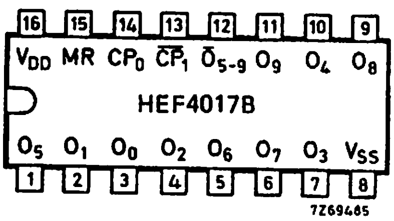


Fig.2 Pinning diagram.

PINNING

CP_0	clock input (LOW to HIGH triggered)
$\overline{CP}_1$	clock input (HIGH to LOW triggered)
MR	master reset input
O_0 to O_9	decoded outputs
$\overline{O}_{5\text{-}9}$	carry output (active LOW)

FAMILY DATA, I_{DD} LIMITS category MSI

See Family Specifications

HEF4017BP(N): 16-lead DIL; plastic (SOT38-1)
HEF4017BD(F): 16-lead DIL; ceramic (cerdip) (SOT74)
HEF4017BT(D): 16-lead SO; plastic (SOT109-1)
( ): Package Designator North America

5-stage Johnson counter

HEF4017B
MSI

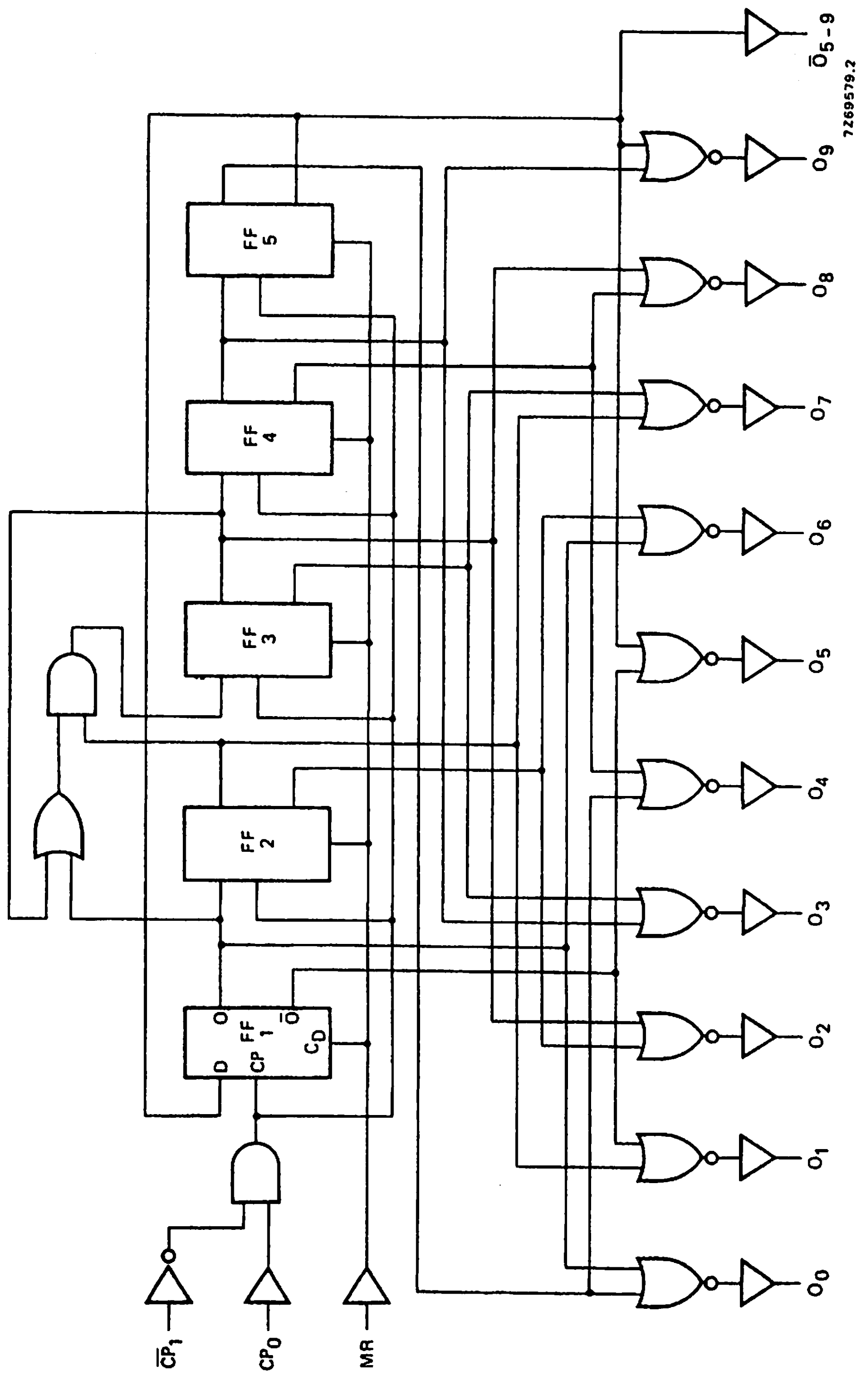


Fig.3 Logic diagram.

FUNCTION TABLE

MR	CP_0	$\overline{CP}_1$	OPERATION
H	X	X	$O_0 = \overline{O}_{5\text{-}9}$ = H; O_1 to O_9 = L
L	H	‾_	Counter advances
L	_/‾	L	Counter advances
L	L	X	No change
L	X	H	No change
L	H	_/‾	No change
L	‾_	L	No change

Notes

1. H = HIGH state (the more positive voltage)
2. L = LOW state (the less positive voltage)
3. X = state is immaterial
4. _/‾ = positive-going transition
5. ‾_ = negative-going transition

AC CHARACTERISTICS

V_{SS} = 0 V; T_{amb} = 25 °C; C_L = 50 pF; input transition times ≤ 20 ns

	V_{DD} V	SYMBOL	MIN.	TYP.	MAX.		TYPICAL EXTRAPOLATION FORMULA
Propagation delays							
CP_0, $\overline{CP}_1 \rightarrow O_0$ to O_9	5			140	280	ns	113 ns + (0,55 ns/pF) C_L
HIGH to LOW	10	t_{PHL}		55	110	ns	44 ns + (0,23 ns/pF) C_L
	15			40	80	ns	32 ns + (0,16 ns/pF) C_L
	5			125	250	ns	98 ns + (0,55 ns/pF) C_L
LOW to HIGH	10	t_{PLH}		50	100	ns	39 ns + (0,23 ns/pF) C_L
	15			40	80	ns	32 ns + (0,16 ns/pF) C_L
CP_0, $\overline{CP}_1 \rightarrow \overline{O}_{5\text{-}9}$	5			145	290	ns	118 ns + (0,55 ns/pF) C_L
HIGH to LOW	10	t_{PHL}		55	110	ns	44 ns + (0,23 ns/pF) C_L
	15			40	80	ns	32 ns + (0,16 ns/pF) C_L
	5			125	250	ns	98 ns + (0,55 ns/pF) C_L
LOW to HIGH	10	t_{PLH}		50	100	ns	39 ns + (0,23 ns/pF) C_L
	15			40	80	ns	32 ns + (0,16 ns/pF) C_L
MR $\rightarrow O_1$ to O_9	5			115	230	ns	88 ns + (0,55 ns/pF) C_L
HIGH to LOW	10	t_{PHL}		50	100	ns	39 ns + (0,23 ns/pF) C_L
	15			35	70	ns	27 ns + (0,16 ns/pF) C_L
MR $\rightarrow \overline{O}_{5\text{-}9}$	5			110	220	ns	83 ns + (0,55 ns/pF) C_L
LOW to HIGH	10	t_{PLH}		45	90	ns	34 ns + (0,23 ns/pF) C_L
	15			35	70	ns	27 ns + (0,16 ns/pF) C_L
MR $\rightarrow O_0$	5			130	260	ns	103 ns + (0,55 ns/pF) C_L
LOW to HIGH	10	t_{PLH}		55	105	ns	44 ns + (0,23 ns/pF) C_L
	15			40	75	ns	32 ns + (0,16 ns/pF) C_L

	V_{DD} V	SYMBOL	MIN.	TYP.	MAX.		TYPICAL EXTRAPOLATION FORMULA
Output transition times HIGH to LOW	5			60	120	ns	10 ns + (1,0 ns/pF) C_L
	10	t_{THL}		30	60	ns	9 ns + (0,42 ns/pF) C_L
	15			20	40	ns	6 ns + (0,28 ns/pF) C_L
LOW to HIGH	5			60	120	ns	10 ns + (1,0 ns/pF) C_L
	10	t_{TLH}		30	60	ns	9 ns + (0,42 ns/pF) C_L
	15			20	40	ns	6 ns + (0,28 ns/pF) C_L

AC CHARACTERISTICS

V_{SS} = 0 V; T_{amb} = 25 °C; C_L = 50 pF; input transition times ≤ 20 ns

	V_{DD} V	SYMBOL	MIN.	TYP.	MAX.		
Hold times $CP_0 \rightarrow \overline{CP}_1$	5		90	45		ns	see also waveforms Figs 4 and 5
	10	t_{hold}	40	20		ns	
	15		20	10		ns	
$\overline{CP}_1 \rightarrow CP_0$	5		80	40		ns	
	10	t_{hold}	40	20		ns	
	15		30	10		ns	
Minimum clock pulse width: CP_0 = LOW; $\overline{CP}_1$ = HIGH	5		80	40		ns	
	10	t_{WCPL} = t_{WCPH}	40	20		ns	
	15		30	15		ns	
Minimum MR pulse width; HIGH	5		50	25		ns	
	10	t_{WMRH}	30	15		ns	
	15		20	10		ns	
Recovery time for MR	5		60	30		ns	
	10	t_{RMR}	30	15		ns	
	15		20	10		ns	
Maximum clock pulse frequency	5		6	12		MHz	
	10	f_{max}	12	24		MHz	
	15		15	30		MHz	

	V_{DD} V	TYPICAL FORMULA FOR P (μW)	
Dynamic power dissipation per package (P)	5	$500\ f_i + \Sigma\ (f_oC_L) \times V_{DD}^2$	where
	10	$2200\ f_i + \Sigma\ (f_oC_L) \times V_{DD}^2$	f_i = input freq. (MHz)
	15	$6000\ f_i + \Sigma\ (f_oC_L) \times V_{DD}^2$	f_o = output freq. (MHz)
			C_L = load cap. (pF)
			$\Sigma\ (f_oC_L)$ = sum of outputs
			V_{DD} = supply voltage (V)

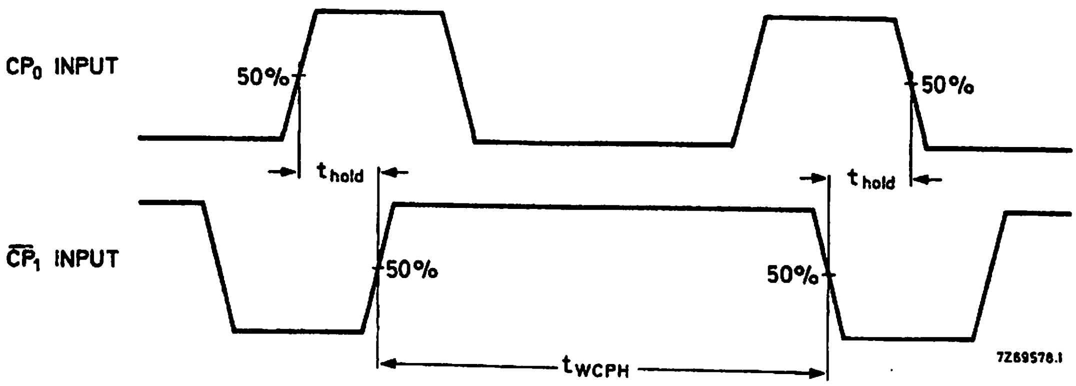
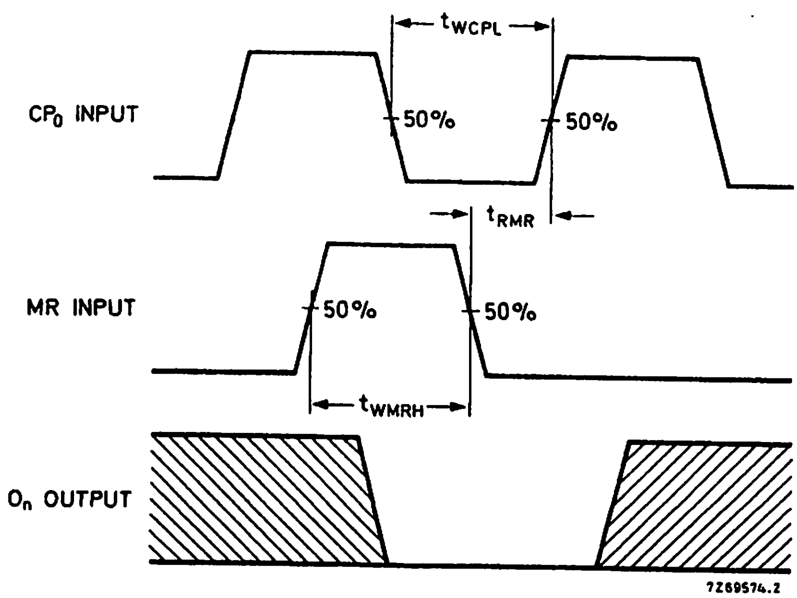


Fig.4 Waveforms showing hold times for CP_0 to $\overline{CP}_1$ and $\overline{CP}_1$ to CP_0. Hold times are shown as positive values, but may be specified as negative values.



Conditions: $\overline{CP}_1$ = LOW while CP_0 is triggered on a LOW to HIGH transition. t_{WCP} and t_{RMR} also apply when CP_0 = HIGH and $\overline{CP}_1$ is triggered on a HIGH to LOW transition.

Fig.5 Waveforms showing recovery time for MR; minimum CP_0 and MR pulse widths.

5-stage Johnson counter

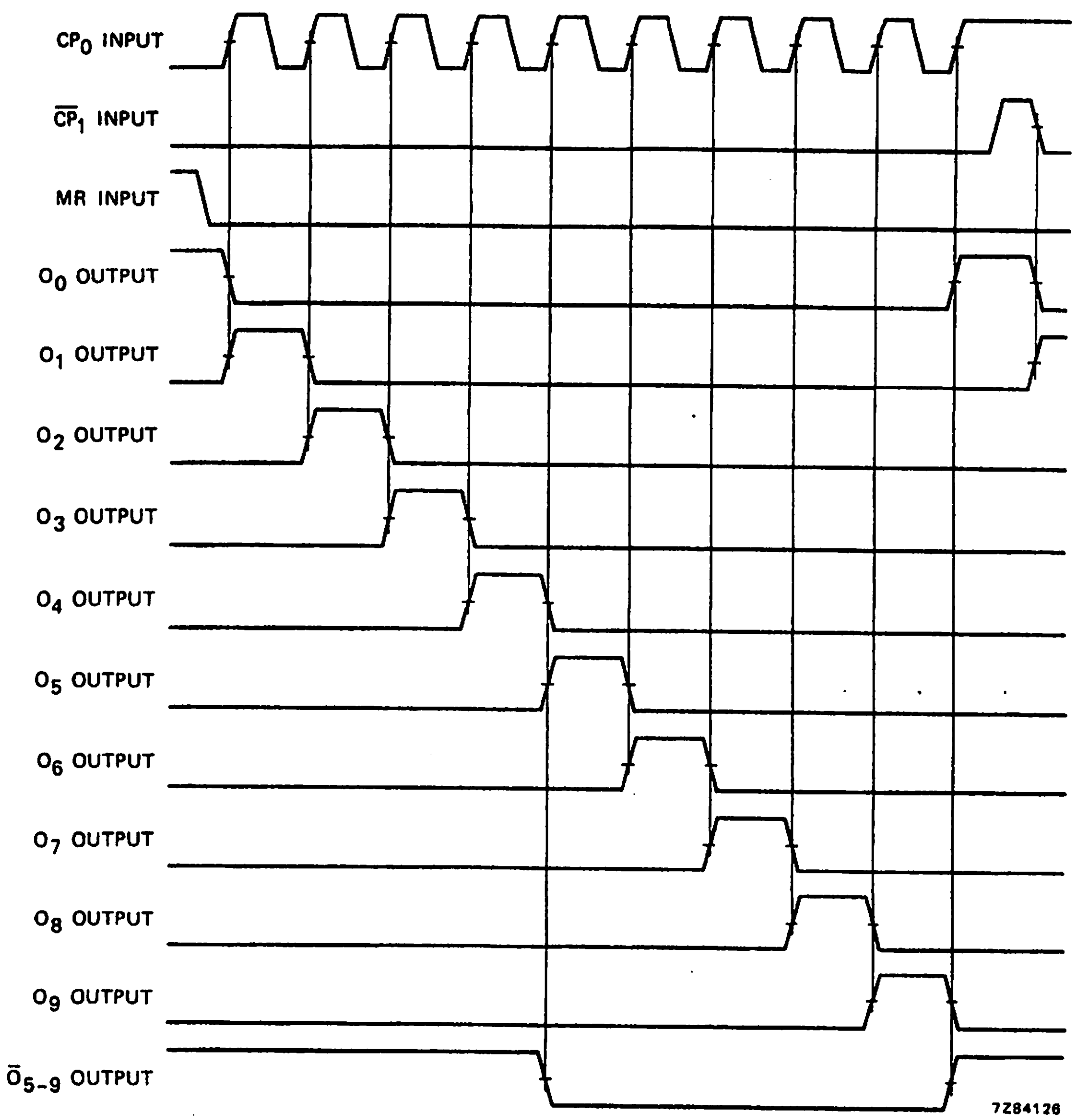


Fig.6 Timing diagram.

APPLICATION INFORMATION

Some examples of applications for the HEF4017B are:

- Decade counter with decimal decoding
- 1 out of n decoding counter (when cascaded)
- Sequential controller
- Timer.

Figure 7 shows a technique for extending the number of decoded output states for the HEF4017B. Decoded outputs are sequential within each stage and from stage to stage, with no dead time (except propagation delay).

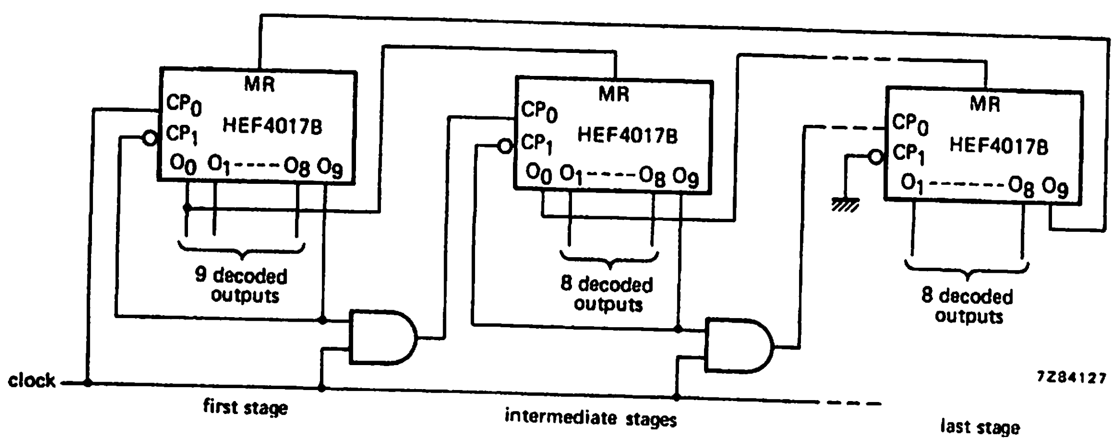


Fig.7 Counter expansion.

Note

It is essential not to enable the counter on $\overline{CP}_1$ when CP_0 is HIGH, or on CP_0 when $\overline{CP}_1$ is LOW, as the this would cause an extra count.

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- Bytes of Reprogrammable Flash Memory
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- Interrupt Sources
- grammable Serial UART Channel
- ect LED Drive Outputs
- chip Analog Comparator
- -power Idle and Power-down Modes
- en (Pb/Halide-free) Packaging Option

8-bit Microcontroller with 2K Bytes Flash

AT89C2051

Description

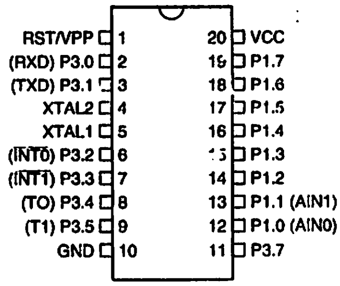
T89C2051 is a low-voltage, high-performance CMOS 8-bit microcomputer with tes of Flash programmable and erasable read-only memory (PEROM). The e is manufactured using Atmel's high-density nonvolatile memory technology compatible with the industry-standard MCS-51 instruction set. By combining a tile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C2051 is a power- crocomputer which provides a highly-flexible and cost-effective solution to many dded control applications.

T89C2051 provides the following standard features: 2K bytes of Flash, 128 of RAM, 15 I/O lines, two 16-bit timer/counters, a five vector two-level interrupt ecture, a full duplex serial port, a precision analog comparator, on-chip oscillator lock circuitry. In addition, the AT89C2051 is designed with static logic for opera- own to zero frequency and supports two software selectable power saving s. The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial nd interrupt system to continue functioning. The power-down mode saves the contents but freezes the oscillator disabling all other chip functions until the next are reset.

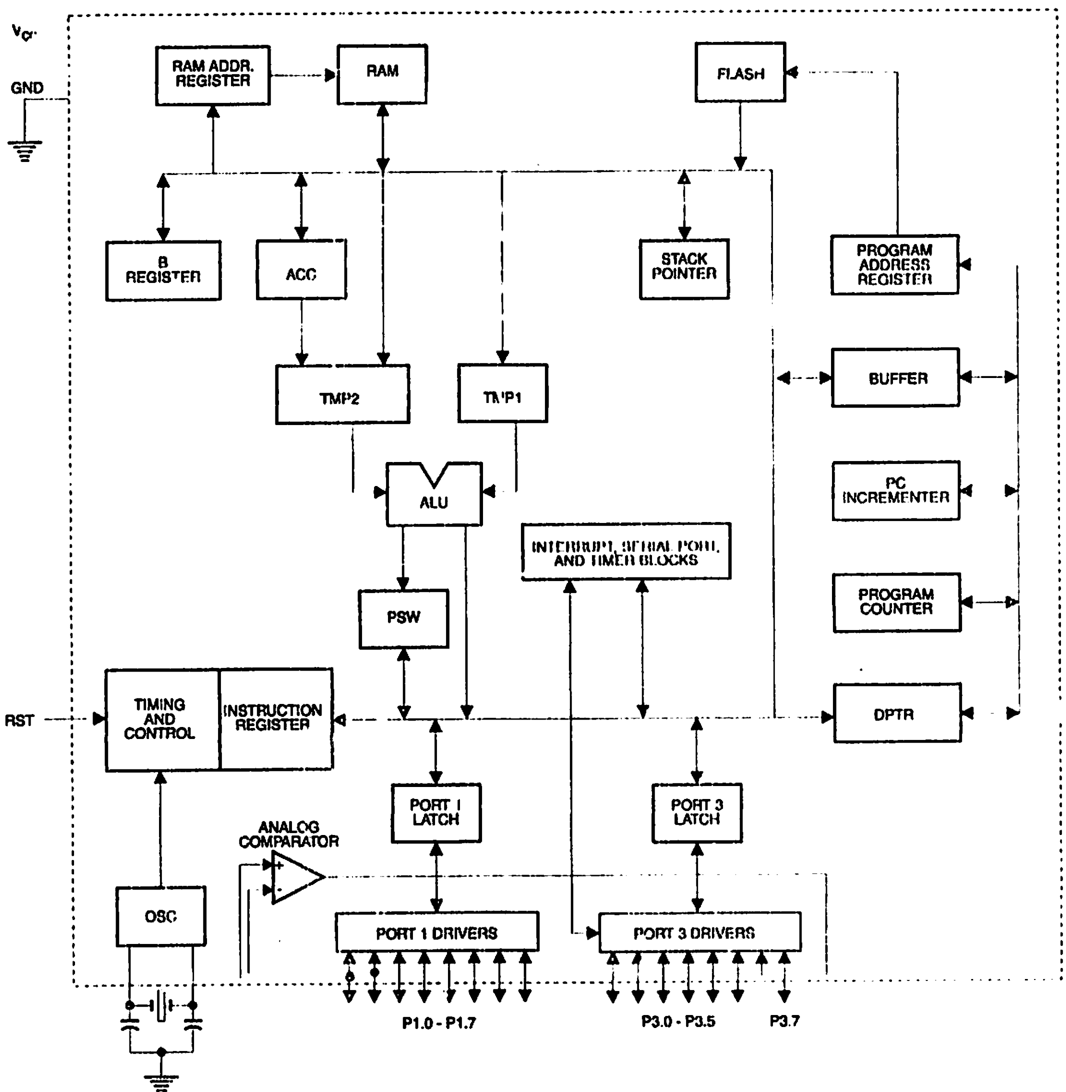
0368G–MICRO–6/05

Pin Configuration

20-lead PDIP/SOIC



Block Diagram



Pin Description

VCC

Supply voltage.

GND

Ground.

Port 1

The Port 1 is an 8-bit bi-directional I/O port. Port pins P1.2 to P1.7 provide internal pull-ups. P1.0 and P1.1 require external pull-ups. P1.0 and P1.1 also serve as the positive input (AIN0) and the negative input (AIN1), respectively, of the on-chip precision analog comparator. The Port 1 output buffers can sink 20 mA and can drive LED displays directly. When 1s are written to Port 1 pins, they can be used as inputs. When pins P1.2 to P1.7 are used as inputs and are externally pulled low, they will source current (I_{IL}) because of the internal pull-ups.

Port 1 also receives code data during Flash programming and verification.

Port 3

Port 3 pins P3.0 to P3.5, P3.7 are seven bi-directional I/O pins with internal pull-ups. P3.6 is hard-wired as an input to the output of the on-chip comparator and is not accessible as a general-purpose I/O pin. The Port 3 output buffers can sink 20 mA. 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 also serves the functions of various special features of the AT89C2051 as listed below:

Port Pin	Alternate Functions
P3.0	RXD (serial input port)
P3.1 P3.2	TXD (serial output port) $\overline{\text{INT0}}$ (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)

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

RST

Reset input. All I/O pins are reset to 1s as soon as RST goes high. Holding the RST pin high for two machine cycles while the oscillator is running resets the device.

Each machine cycle takes 12 oscillator or clock cycles.

XTAL1

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

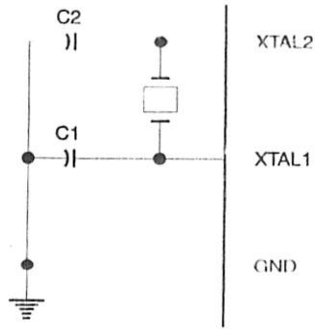
XTAL2

Output from the inverting oscillator amplifier.

Oscillator Characteristics

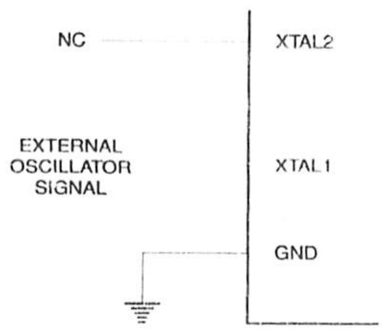
The XTAL1 and XTAL2 are the input and output, respectively, of an inverting amplifier which can be configured for use as an on-chip oscillator, as shown in Figure 5-1. Either a quartz crystal or ceramic resonator may be used. To drive the device from an external clock source, XTAL2 should be left unconnected while XTAL1 is driven as shown in Figure 5-2. There are no requirements on the duty cycle of the external clock signal, since the input to the internal clocking circuitry is through a divide-by-two flip-flop, but minimum and maximum voltage high and low time specifications must be observed.

Figure 5-1. Oscillator Connections



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

Figure 5-2. External Clock Drive Configuration



Special Function Registers

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

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.

User software should not write 1s to these unlisted locations, since they may be used in future products to invoke new features. In that case, the reset or inactive values of the new bits will always be 0.

6-1. AT89C2051 SFR Map and Reset Values

								0FFH
B 00000000								0F7H
								0EFH
ACC 00000000								0E7H
								0DFH
PSW 00000000								0D7H
								0CFH
								0C7H
IP XXX00000								0BFH
P3 11111111								0B7H
IE 0XX00000								0AFH
								0A7H
SCON 00000000	SBUF XXXXXXXX							9FH
P1 11111111								97H
TCON 00000000	TMOD 00000000	TL0 00000000	TL1 00000000	TH0 00000000	TH1 00000000			8FH
	SP 00000111	DPL 00000000	DPH 00000000				PCON 0XXX0000	87H

Restrictions on Certain Instructions

The AT89C2051 and is an economical and cost-effective member of Atmel's growing family of microcontrollers. It contains 2K bytes of Flash program memory. It is fully compatible with the MCS-51 architecture, and can be programmed using the MCS-51 instruction set. However, there are a few considerations one must keep in mind when utilizing certain instructions to program this device.

All the instructions related to jumping or branching should be restricted such that the destination address falls within the physical program memory space of the device, which is 2K for the AT89C2051. This should be the responsibility of the software programmer. For example, LJMP 7E0H would be a valid instruction for the AT89C2051 (with 2K of memory), whereas LJMP 900H would not.

Branching Instructions

LCALL, LJMP, ACALL, AJMP, SJMP, JMP @A+DPTR – These unconditional branching instructions will execute correctly as long as the programmer keeps in mind that the destination branching address must fall within the physical boundaries of the program memory size (locations 00H to 7FFH for the 89C2051). Violating the physical space limits may cause unknown program behavior.

CJNE [...], DJNZ [...], JB, JNB, JC, JNC, JBC, JZ, JNZ – With these conditional branching instructions the same rule above applies. Again, violating the memory boundaries may cause erratic execution.

For applications involving interrupts the normal interrupt service routine address locations of the 80C51 family architecture have been preserved.

MOVX-related Instructions, Data Memory

The AT89C2051 contains 128 bytes of internal data memory. Thus, in the AT89C2051 the stack depth is limited to 128 bytes, the amount of available RAM. External DATA memory access is not supported in this device, nor is external PROGRAM memory execution. Therefore, no MOVX [...] instructions should be included in the program.

A typical 80C51 assembler will still assemble instructions, even if they are written in violation of the restrictions mentioned above. It is the responsibility of the controller user to know the physical features and limitations of the device being used and adjust the instructions used correspondingly.

Program Memory Lock Bits

On the chip are two lock bits which can be left unprogrammed (U) or can be programmed (P) to obtain the additional features listed in the Table 8-1.

Table 8-1. Lock Bit Protection Modes[1]

Program Lock Bits			
	LB1	LB2	Protection Type
1	U	U	No program lock features
2	P	U	Further programming of the Flash is disabled
3	P	P	Same as mode 2, also verify is disabled

Note: 1. The Lock Bits can only be erased with the Chip Erase operation.

Idle Mode

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

The P1.0 and P1.1 should be set to "0" if no external pull-ups are used, or set to "1" if external pull-ups are used.

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

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. The only exit from power-down is a hardware reset. Reset redefines the SFRs but does not change the on-chip RAM. The reset should not be activated before V_{CC} is restored to its normal operating level and must be held active long enough to allow the oscillator to restart and stabilize.

The P1.0 and P1.1 should be set to "0" if no external pull-ups are used, or set to "1" if external pull-ups are used.

Programming The Flash

The AT89C2051 is shipped with the 2K bytes of on-chip PEROM code memory array in the erased state (i.e., contents = FFH) and ready to be programmed. The code memory array is programmed one byte at a time. *Once the array is programmed, to re-program any non-blank byte, the entire memory array needs to be erased electrically.*

Internal Address Counter: The AT89C2051 contains an internal PEROM address counter which is always reset to 000H on the rising edge of RST and is advanced by applying a positive going pulse to pin XTAL1.

Programming Algorithm: To program the AT89C2051, the following sequence is recommended.

1. Power-up sequence:
   Apply power between V_{CC} and GND pins
   Set RST and XTAL1 to GND
2. Set pin RST to "H"
   Set pin P3.2 to "H"
3. Apply the appropriate combination of "H" or "L" logic
   levels to pins P3.3, P3.4, P3.5, P3.7 to select one of the programming operations
   shown in the PEROM Programming Modes table.

To Program and Verify the Array:

4. Apply data for Code byte at location 000H to P1.0 to P1.7.
5. Raise RST to 12V to enable programming.
6. Pulse P3.2 once to program a byte in the PEROM array or the lock bits. The byte-write cycle is self-timed and typically takes 1.2 ms.
7. To verify the programmed data, lower RST from 12V to logic "H" level and set pins P3.3 to P3.7 to the appropriate levels. Output data can be read at the port P1 pins.
8. To program a byte at the next address location, pulse XTAL1 pin once to advance the internal address counter. Apply new data to the port P1 pins.
9. Repeat steps 6 through 8, changing data and advancing the address counter for the entire 2K bytes array or until the end of the object file is reached.
10. Power-off sequence:
    set XTAL1 to "L"
    set RST to "L"
    Turn V_{CC} power off

$\overline{\text{Data}}$ Polling: The AT89C2051 features $\overline{\text{Data}}$ Polling to indicate the end of a write cycle. During a write cycle, an attempted read of the last byte written will result in the complement of the written data on P1.7. Once the write cycle has been completed, true data is valid on all outputs, and the next cycle may begin. $\overline{\text{Data}}$ Polling may begin any time after a write cycle has been initiated.

Ready/$\overline{\text{Busy}}$: The Progress of byte programming can also be monitored by the RDY/$\overline{\text{BSY}}$ output signal. Pin P3.1 is pulled low after P3.2 goes High during programming to indicate BUSY. P3.1 is pulled High again when programming is done to indicate READY.

Program Verify: If lock bits LB1 and LB2 have not been programmed code data can be read back via the data lines for verification:

1. Reset the internal address counter to 000H by bringing RST from "L" to "H".
2. Apply the appropriate control signals for Read Code data and read the output data at the port P1 pins.
3. Pulse pin XTAL1 once to advance the internal address counter.
4. Read the next code data byte at the port P1 pins.
5. Repeat steps 3 and 4 until the entire array is read.

The lock bits cannot be verified directly. Verification of the lock bits is achieved by observing that their features are enabled.

Chip Erase: The entire PEROM array (2K bytes) and the two Lock Bits are erased electrically by using the proper combination of control signals and by holding P3.2 low for 10 ms. The code array is written with all "1"s in the Chip Erase operation and must be executed before any non-blank memory byte can be re-programmed.

Reading the Signature Bytes: The signature bytes are read by the same procedure as a normal verification of locations 000H, 001H, and 002H, except that P3.5 and P3.7 must be pulled to a logic low. The values returned are as follows.

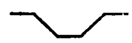
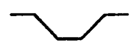
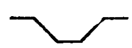
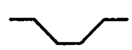
(000H) = 1EH indicates manufactured by Atmel
(001H) = 21H indicates 89C2051

Programming Interface

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

Most major worldwide programming vendors offer support for the Atmel AT89 microcontroller series. Please contact your local programming vendor for the appropriate software revision.

Flash Programming Modes

e		RST/VPP	P3.2/$\overline{\text{PROG}}$	P3.3	P3.4	P3.5	P3.7
Code Data[1][3]		12V		L	H	H	H
Code Data[1]		H	H	L	L	H	H
Lock	Bit - 1	12V		H	H	H	H
	Bit - 2	12V		H	H	L	L
Erase		12V	 (2)	H	L	L	L
Signature Byte		H	H	L	L	L	L

1. The internal PEROM address counter is reset to 000H on the rising edge of RST and is advanced by a positive pulse at XTAL1 pin.
2. Chip Erase requires a 10 ms $\overline{\text{PROG}}$ pulse.
3. P3.1 is pulled Low during programming to indicate RDY/$\overline{\text{BSY}}$.

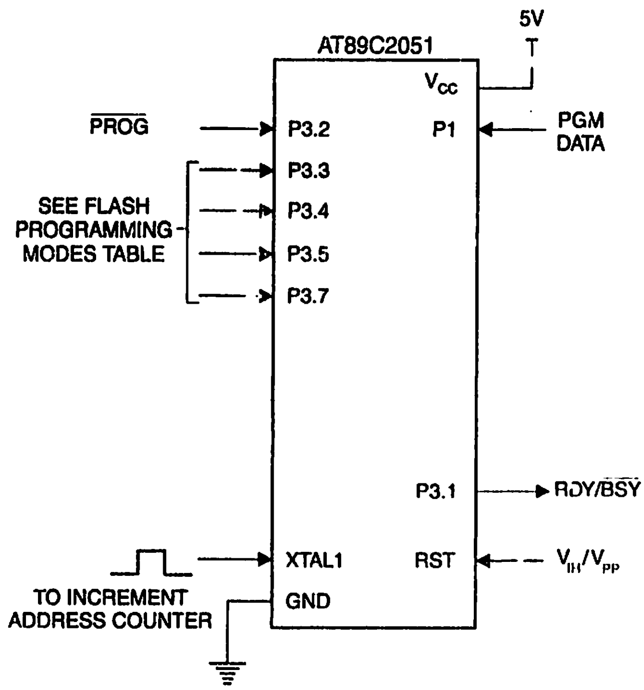


Figure 13-1. Programming the Flash Memory

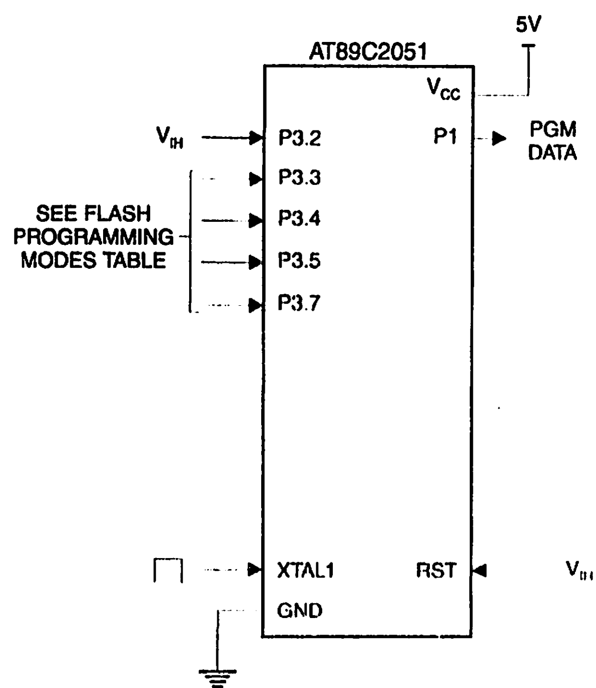


Figure 13-2. Verifying the Flash Memory

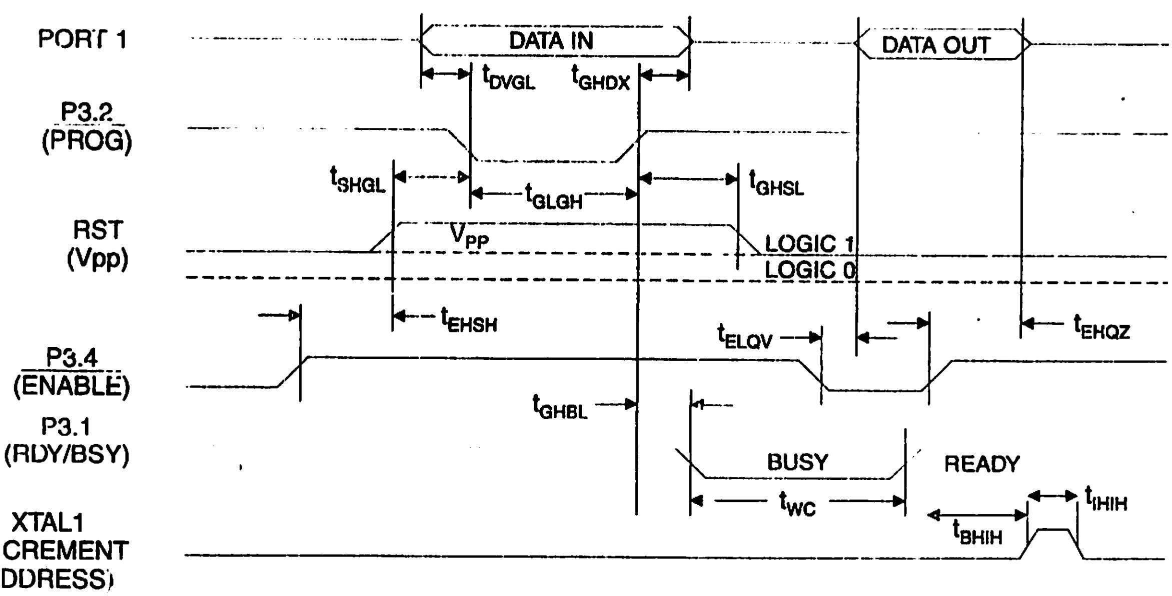
Flash Programming and Verification Characteristics

)°C to 70°C, $V_{CC} = 5.0 \pm 10\%$

bol	Parameter	Min	Max	Units
	Programming Enable Voltage	11.5	12.5	V
	Programming Enable Current		250	μA
	Data Setup to $\overline{PROG}$ Low	1.0		μs
	Data Hold after $\overline{PROG}$	1.0		μs
	P3.4 ($\overline{ENABLE}$) High to V_{PP}	1.0		μs
	V_{PP} Setup to $\overline{PROG}$ Low	10		μs
	V_{PP} Hold after $\overline{PROG}$	10		μs
	$\overline{PROG}$ Width	1	110	μs
	$\overline{ENABLE}$ Low to Data Valid		1.0	μs
	Data Float after $\overline{ENABLE}$	0	1.0	μs
	$\overline{PROG}$ High to $\overline{BUSY}$ Low		50	ns
	Byte Write Cycle Time		2.0	ms
	RDY/$\overline{BSY}$\ to Increment Clock Delay	1.0		μs
	Increment Clock High	200		ns

1. Only used in 12-volt programming mode.

Flash Programming and Verification Waveforms



Absolute Maximum Ratings*

rating Temperature	-55°C to +125°C
age Temperature	-65°C to +150°C
ago on Any Pin Respect to Ground	-1.0V to +7.0V
imum Operating Voltage	6.6V
Output Current	25.0 mA

*NOTICE: Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

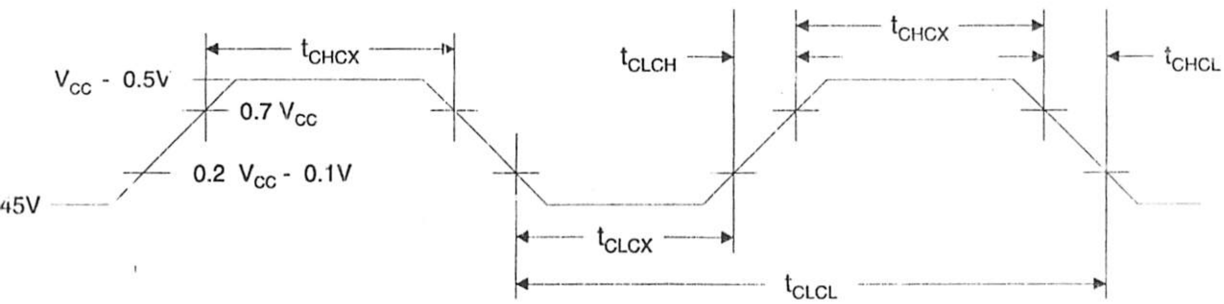
DC Characteristics

-40°C to 85°C, V_{CC} = 2.7V to 6.0V (unless otherwise noted)

ibol	Parameter	Condition	Min	Max	Units
	Input Low-voltage		-0.5	0.2 V_{CC} - 0.1	V
	Input High-voltage	(Except XTAL1, RST)	0.2 V_{CC} + 0.9	V_{CC} + 0.5	V
	Input High-voltage	(XTAL1, RST)	0.7 V_{CC}	V_{CC} + 0.5	V
	Output Low-voltage(1) (Ports 1, 3)	I_{OL} = 20 mA, V_{CC} = 5V I_{OL} = 10 mA, V_{CC} = 2.7V		0.5	V
	Output High-voltage (Ports 1, 3)	I_{OH} = -80 µA, V_{CC} = 5V ± 10%	2.4		V
		I_{OH} = -30 µA	0.75 V_{CC}		V
		I_{OH} = -12 µA	0.9 V_{CC}		V
	Logical 0 Input Current (Ports 1, 3)	V_{IN} = 0.45V		-50	µA
	Logical 1 to 0 Transition Current (Ports 1, 3)	V_{IN} = 2V, V_{CC} = 5V ± 10%		-750	µA
	Input Leakage Current (Port P1.0, P1.1)	0 < V_{IN} < V_{CC}		±10	µA
	Comparator Input Offset Voltage	V_{CC} = 5V		20	mV
	Comparator Input Common Mode Voltage		0	V_{CC}	V
T	Reset Pull-down Resistor		50	300	kΩ
	Pin Capacitance	Test Freq. = 1 MHz, T_A = 25°C		10	pF
	Power Supply Current	Active Mode, 12 MHz, V_{CC} = 6V/3V		15/5.5	mA
		Idle Mode, 12 MHz, V_{CC} = 6V/3V P1.0 & P1.1 = 0V or V_{CC}		5/1	mA
	Power-down Mode(2)	V_{CC} = 6V, P1.0 & P1.1 = 0V or V_{CC}		100	µA
		V_{CC} = 3V, P1.0 & P1.1 = 0V or V_{CC}		20	µA

1. Under steady state (non-transient) conditions, I_{OL} must be externally limited as follows:
   Maximum I_{OL} per port pin: 20 mA
   Maximum total I_{OL} for all output pins: 80 mA
   If I_{OL} exceeds the test condition, V_{OL} may exceed the related specification. Pins are not guaranteed to sink current greater than the listed test conditions.
2. Minimum V_{CC} for Power-down is 2V.

External Clock Drive Waveforms



External Clock Drive

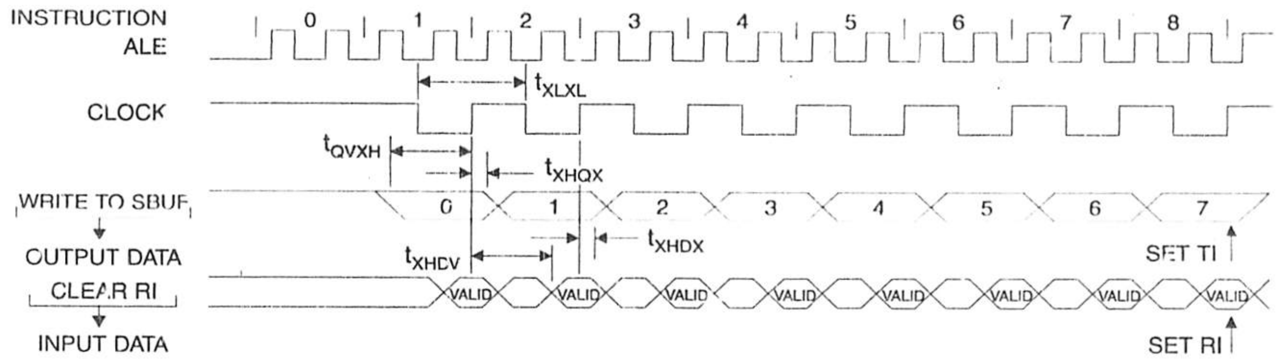
bol	Parameter	V_{CC} = 2.7V to 6.0V		V_{CC} = 4.0V to 6.0V		Units
		Min	Max	Min	Max	
CL	Oscillator Frequency	0	12	0	24	MHz
	Clock Period	83.3		41.6		ns
	High Time	30		15		ns
	Low Time	30		15		ns
	Rise Time		20		20	ns
	Fall Time		20		20	ns

Serial Port Timing: Shift Register Mode Test Conditions

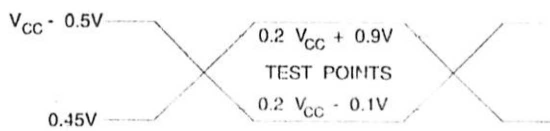
5.0V ± 20%; Load Capacitance = 80 pF

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

Shift Register Mode Timing Waveforms

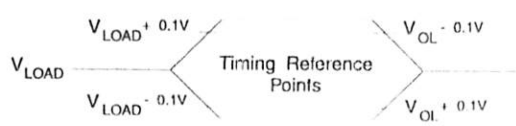


AC Testing Input/Output Waveforms(1)



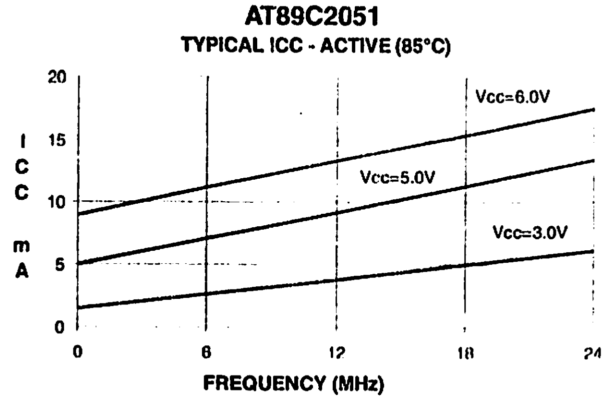
1. AC Inputs during testing are driven at V_{CC} - 0.5V for a logic 1 and 0.45V for a logic 0. Timing measurements are made at V_{IH} min. for a logic 1 and V_{IL} max. for a logic 0.

Float Waveforms(1)

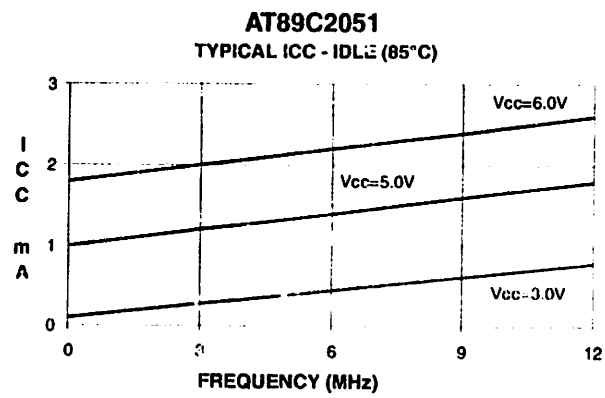


1. For timing purposes, a port pin is no longer floating when a 100 mV change from load voltage occurs. A port pin begins to float when 100 mV change from the loaded V_{OH}/V_{OL} level occurs.

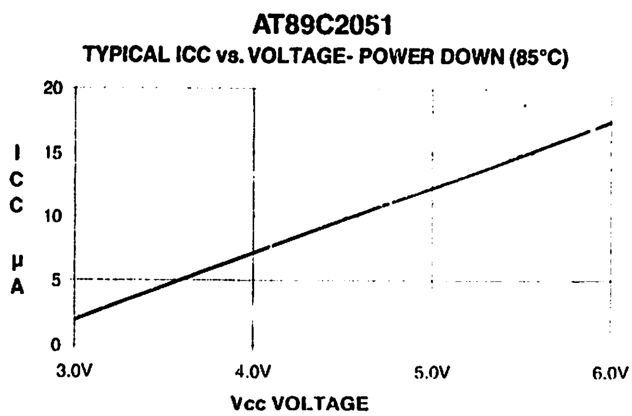
cc (Active Mode) Measurements



:c (Idle Mode) Measurements



:c (Power Down Mode) Measurements



Notes: 1. XTAL1 tied to GND
2. P.1.0 and P1.1 = V_{CC} or GND
3. Lock bits programmed

Ordering Information

1 Standard Package

Speed (MHz)	Power Supply	Ordering Code	Package	Operation Range
12	2.7V to 6.0V	AT89C2051-12PC AT89C2051-12SC	20P3 20S	Commercial (0°C to 70°C)
		AT89C2051-12PI AT89C2051-12SI	20P3 20S	Industrial (-40°C to 85°C)
24	4.0V to 6.0V	AT89C2051-24PC AT89C2051-24SC	20P3 20S	Commercial (0°C to 70°C)
		AT89C2051-24PI AT89C2051-24SI	20P3 20S	Industrial (-40°C to 85°C)

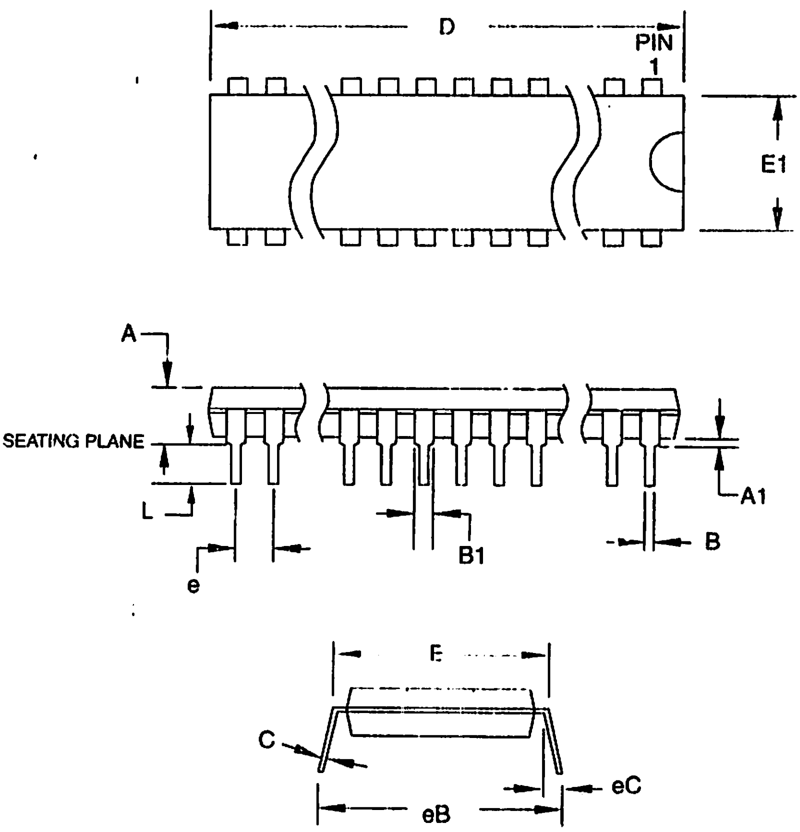
2 Green Package Option (Pb/Halide-free)

Speed (MHz)	Power Supply	Ordering Code	Package	Operation Range
12	2.7V to 6.0V	AT89C2051-12PU AT89C2051-12SU	20P3 20S	Industrial (-40°C to 85°C)
24	4.0V to 6.0V	AT89C2051-24PU AT89C2051-24SU	20P3 20S	Industrial (-40°C to 85°C)

	Package Type
3	20-lead, 0.300" Wide, Plastic Dual In-line Package (PDIP)
	20-lead, 0.300" Wide, Plastic Gull Wing Small Outline (SOIC)

. Package Information

1 20P3 – PDIP



COMMON DIMENSIONS
(Unit of Measure = mm)

SYMBOL	MIN	NOM	MAX	NOTE
A	–	–	5.334	
A1	0.381	–	–	
D	24.892	–	26.924	Note 2
E	7.620	–	8.255	
E1	6.096	–	7.112	Note 2
B	0.356	–	0.559	
B1	1.270	–	1.551	
L	2.921	–	3.810	
C	0.203	–	0.356	
eB	–	–	10.922	
eC	0.000	–	1.524	
e		2.540 TYP		

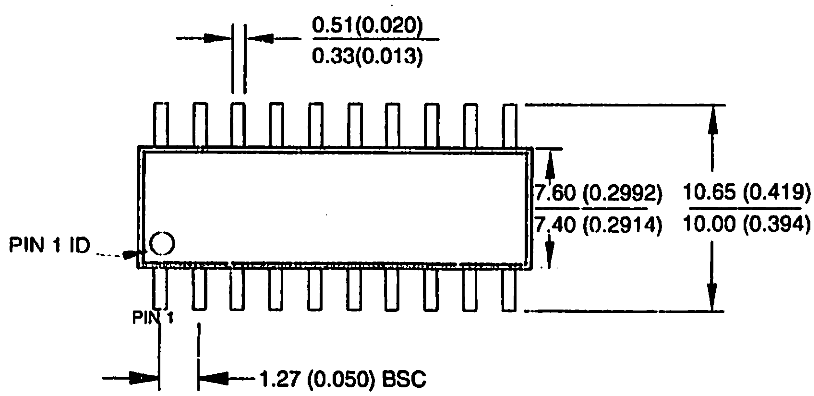
Notes: 1. This package conforms to JEDEC reference MS-001, Variation AD.
2. Dimensions D and E1 do not include mold Flash or Protrusion. Mold Flash or Protrusion shall not exceed 0.25 mm (0.010").

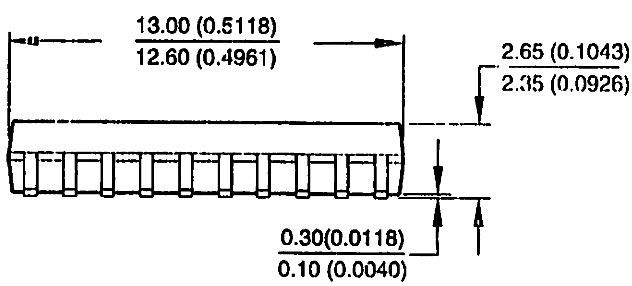
1/23/04

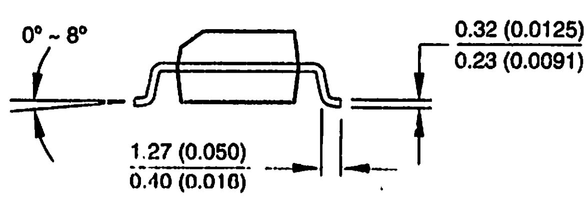
	TITLE	DRAWING NO.	REV.
2325 Orchard Parkway San Jose, CA 95131	**20P3**, 20-lead (0.300"/7.62 mm Wide) Plastic Dual Inline Package (PDIP)	20P3	D

20S – SOIC

Dimensions in Millimeters and (Inches).
Controlling dimension: Inches.
JEDEC Standard MS-013







10/23/03

	TITLE	DRAWING NO.	REV.
2325 Orchard Parkway San Jose, CA 95131	**20S**, 20-lead, 0.300" Body, Plastic Gull Wing Small Outline (SOIC)	20S	B

DATA SHEET

For a complete data sheet, please also download:

- The IC06 74HC/HCT/HCU/HCMOS Logic Family Specifications
- The IC06 74HC/HCT/HCU/HCMOS Logic Package Information
- The IC06 74HC/HCT/HCU/HCMOS Logic Package Outlines

74HC/HCT573
Octal D-type transparent latch; 3-state

Product specification
File under Integrated Circuits, IC06

December 1990

Philips
Semiconductors

PHILIPS

Octal D-type transparent latch; 3-state — 74HC/HCT573

FEATURES

- Inputs and outputs on opposite sides of package allowing easy interface with microprocessors
- Useful as input or output port for microprocessors/microcomputers
- 3-state non-inverting outputs for bus oriented applications
- Common 3-state output enable input
- Functionally identical to the "563" and "373"
- Output capability: bus driver
- I_{CC} category: MSI

GENERAL DESCRIPTION

The 74HC/HCT573 are high-speed Si-gate CMOS devices and are pin compatible with low power Schottky TTL (LSTTL). They are specified in compliance with JEDEC standard no. 7A.

The 74HC/HCT573 are octal D-type transparent latches featuring separate D-type inputs for each latch and 3-state outputs for bus oriented applications.
A latch enable (LE) input and an output enable ($\overline{OE}$) input are common to all latches.

The "573" consists of eight D-type transparent latches with 3-state true outputs. When LE is HIGH, data at the D_n inputs enter the latches. In this condition the latches are transparent, i.e. a latch output will change state each time its corresponding D-input changes.

When LE is LOW the latches store the information that was present at the D-inputs a set-up time preceding the HIGH-to-LOW transition of LE.
When $\overline{OE}$ is LOW, the contents of the 8 latches are available at the outputs.
When $\overline{OE}$ is HIGH, the outputs go to the high impedance OFF-state.
Operation of the $\overline{OE}$ input does not affect the state of the latches.

The "573" is functionally identical to the "563" and "373", but the "563" has inverted outputs and the "373" has a different pin arrangement.

QUICK REFERENCE DATA

GND = 0 V; T_{amb} = 25 °C; $t_r = t_f$ = 6 ns

SYMBOL	PARAMETER	CONDITIONS	TYPICAL		UNIT
			HC	HCT	
t_{PHL}/ t_{PLH}	propagation delay	C_L = 15 pF; V_{CC} = 5 V			
	D_n to Q_n		14	17	ns
	LE to Q_n		15	15	ns
C_I	input capacitance		3.5	3.5	pF
C_{PD}	power dissipation capacitance per latch	notes 1 and 2	26	26	pF

Notes

1. C_{PD} is used to determine the dynamic power dissipation (P_D in μW):

   $P_D = C_{PD} \times V_{CC}^2 \times f_i + \sum (C_L \times V_{CC}^2 \times f_o)$ where:

   f_i = input frequency in MHz; f_o = output frequency in MHz

   $\sum (C_L \times V_{CC}^2 \times f_o)$ = sum of outputs

   C_L = output load capacitance in pF; V_{CC} = supply voltage in V
2. For HC the condition is V_I = GND to V_{CC}; for HCT the condition is V_I = GND to V_{CC} − 1.5 V

ORDERING INFORMATION

See *"74HC/HCT/HCU/HCMOS Logic Package Information"*.

PIN DESCRIPTION

PIN NO.	SYMBOL	NAME AND FUNCTION
2, 3, 4, 5, 6, 7, 8, 9	D_0 to D_7	data inputs
11	LE	latch enable input (active HIGH)
1	$\overline{OE}$	3-state output enable input (active LOW)
10	GND	ground (0 V)
19, 18, 17, 16, 15, 14, 13, 12	Q_0 to Q_7	3-state latch outputs
20	V_{CC}	positive supply voltage

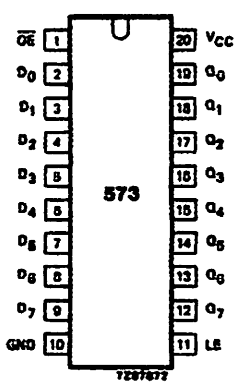


Fig.1 Pin configuration.

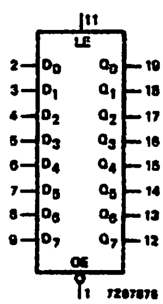


Fig.2 Logic symbol.

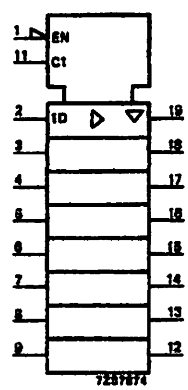


Fig.3 IEC logic symbol.

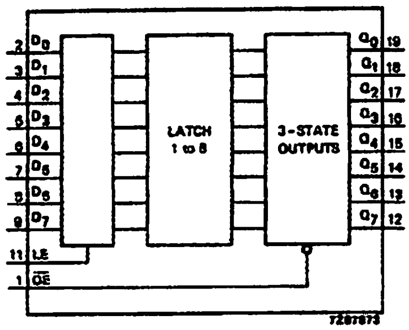


Fig.4 Functional diagram.

FUNCTION TABLE

OPERATING MODES	INPUTS			INTERNAL LATCHES	OUTPUTS
	$\overline{OE}$	LE	D_N		Q_0 to Q_7
enable and read register (transparent mode)	L L	H H	L H	L H	L H
latch and read register	L L	L L	l h	L H	L H
latch register and disable outputs	H H	L L	l h	L H	Z Z

Notes

1. H = HIGH voltage level
   h = HIGH voltage level one set-up time prior to the HIGH-to-LOW LE transition
   L = LOW voltage level
   l = LOW voltage level one set-up time prior to the HIGH-to-LOW LE transition
   Z = high impedance OFF-state

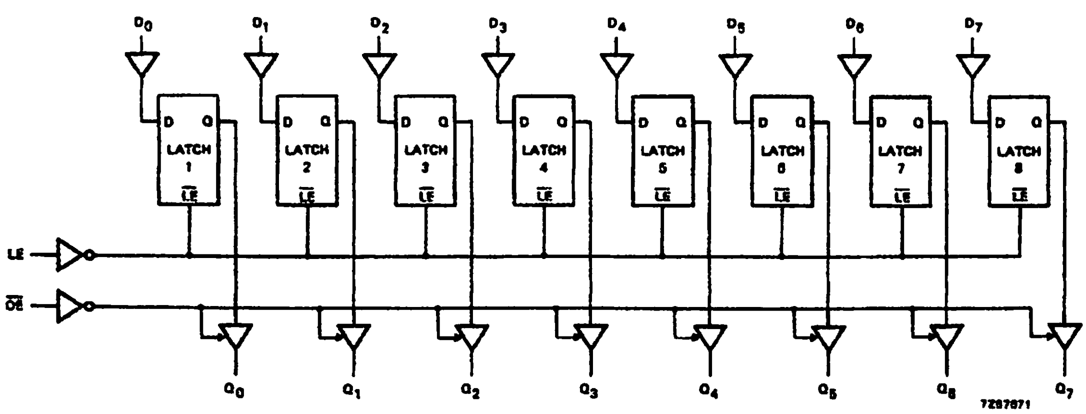


Fig.5 Logic diagram.

DC CHARACTERISTICS FOR 74HC

For the DC characteristics see *"74HC/HCT/HCU/HCMOS Logic Family Specifications"*.

Output capability: bus driver

I_{CC} category: MSI

AC CHARACTERISTICS FOR 74HC

GND = 0 V; $t_r = t_f = 6$ ns; $C_L = 50$ pF

SYMBOL	PARAMETER	T_{amb} (°C)							UNIT	TEST CONDITIONS	
		74HC								V_{CC} (V)	WAVEFORMS
		+25			−40 to +85		−40 to +125				
		min.	typ.	max.	min.	max.	min.	max.			
t_{PHL}/ t_{PLH}	propagation delay D_n to Q_n		47 17 14	150 30 26		190 38 33		225 45 38	ns	2.0 4.5 6.0	Fig.6
t_{PHL}/ t_{PLH}	propagation delay LE to Q_n		50 18 14	150 30 26		190 38 33		225 45 38	ns	2.0 4.5 6.0	Fig.7
t_{PZH}/ t_{PZL}	3-state output enable time $\overline{OE}$ to Q_n		44 16 13	140 28 24		175 35 30		210 42 36	ns	2.0 4.5 6.0	Fig.8
t_{PHZ}/ t_{PLZ}	3-state output disable time $\overline{OE}$ to Q_n		55 20 16	150 30 26		190 38 33		225 45 38	ns	2.0 4.5 6.0	Fig.8
t_{THL}/ t_{TLH}	output transition time		14 5 4	60 12 10		75 15 13		90 18 15	ns	2.0 4.5 6.0	Fig.6
t_W	enable pulse width HIGH	80 16 14	14 5 4		100 20 17		120 24 20		ns	2.0 4.5 6.0	Fig.7
t_{su}	set-up time D_n to LE	50 10 9	11 4 3		65 13 11		75 15 13		ns	2.0 4.5 6.0	Fig.9
t_h	hold time D_n to LE	5 5 5	3 1 1		5 5 5		5 5 5		ns	2.0 4.5 6.0	Fig.9

DC CHARACTERISTICS FOR 74HCT

For the DC characteristics see *"74HC/HCT/HCU/HCMOS Logic Family Specifications"*.

Output capability: bus driver

I_{CC} category: MSI

Note to HCT types

The value of additional quiescent supply current (ΔI_{CC}) for a unit load of 1 is given in the family specifications.
To determine ΔI_{CC} per input, multiply this value by the unit load coefficient shown in the table below.

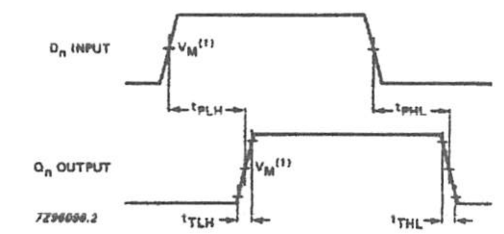
INPUT	UNIT LOAD COEFFICIENT
D_n	0.35
LE	0.65
$\overline{OE}$	1.25

AC CHARACTERISTICS FOR 74HCT

GND = 0 V; $t_r = t_f = 6$ ns; $C_L = 50$ pF

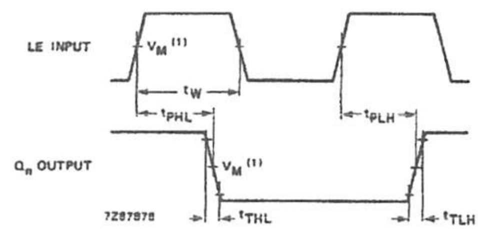
SYMBOL	PARAMETER	T_{amb} (°C)							UNIT	TEST CONDITIONS	
		74HCT								V_{CC} (V)	WAVEFORMS
		+25			−40 to +85		−40 to +125				
		min.	typ.	max.	min.	max.	min.	max.			
t_{PHL}/t_{PLH}	propagation delay D_n to Q_n		20	35		44		53	ns	4.5	Fig.6
t_{PHL}/t_{PLH}	propagation delay LE to Q_n		18	35		44		53	ns	4.5	Fig.7
t_{PZH}/t_{PZL}	3-state output enable time $\overline{OE}$ to Q_n		17	30		38		45	ns	4.5	Fig.8
t_{PHZ}/t_{PLZ}	3-state output disable time $\overline{OE}$ to Q_n		18	30		38		45	ns	4.5	Fig.8
t_{THL}/t_{TLH}	output transition time		5	12		15		18	ns	4.5	Fig.6
t_W	enable pulse width HIGH	16	5		20		24		ns	4.5	Fig.7
t_{su}	set-up time D_n to LE	13	7		16		20		ns	4.5	Fig.9
t_h	hold time D_n to LE	9	4		11		14		ns	4.5	Fig.9

AC WAVEFORMS



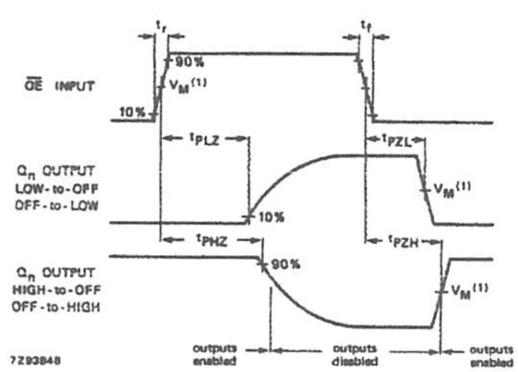
(1) HC : V_M = 50%; V_I = GND to V_{CC}.
HCT: V_M = 1.3 V; V_I = GND to 3 V.

Fig.6 Waveforms showing the data input (D_n) to output (Q_n) propagation delays and the output transition times.



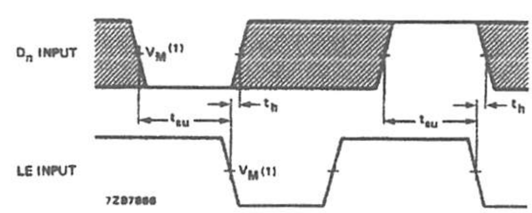
(1) HC : V_M = 50%; V_I = GND to V_{CC}.
HCT: V_M = 1.3 V; V_I = GND to 3 V.

Fig.7 Waveforms showing the latch enable input (LE) pulse width, the latch enable input to output (Q_n) propagation delays and the output transition times.



(1) HC : V_M = 50%; V_I = GND to V_{CC}.
HCT: V_M = 1.3 V; V_I = GND to 3 V.

Fig.8 Waveforms showing the 3-state enable and disable times.



The shaded areas indicate when the input is permitted to change for predictable output performance.

(1) HC : V_M = 50%; V_I = GND to V_{CC}.
HCT: V_M = 1.3 V; V_I = GND to 3 V.

Fig.9 Waveforms showing the data set-up and hold times for D_n input to LE input.

PACKAGE OUTLINES

See *"74HC/HCT/HCU/HCMOS Logic Package Outlines"*.

DATA SHEET

ADC0803/0804
CMOS 8-bit A/D converters

Product data
Supersedes data of 2001 Aug 03

2002 Oct 17

Philips
Semiconductors

PHILIPS

:SCRIPTION

ɛ ADC0803 family is a series of three CMOS 8-bit successive ɔroximation A/D converters using a resistive ladder and ɪacitive array together with an auto-zero comparator. These ıverters are designed to operate with microprocessor-controlled ;es using a minimum of external circuitry. The 3-State output data 's can be connected directly to the data bus.

ɛ differential analog voltage input allows for increased nmon-mode rejection and provides a means to adjust the o-scale offset. Additionally, the voltage reference input provides a ans of encoding small analog voltages to the full 8 bits of olution.

:ATURES

- ;ompatible with most microprocessors
-)ifferential inputs
- -State outputs
- ogic levels TTL and MOS compatible
- ;an be used with internal or external clock
- ınalog input range 0 V to V_{CC}
- ;ingle 5 V supply
- ;uaranteed specification with 1 MHz clock

PIN CONFIGURATION

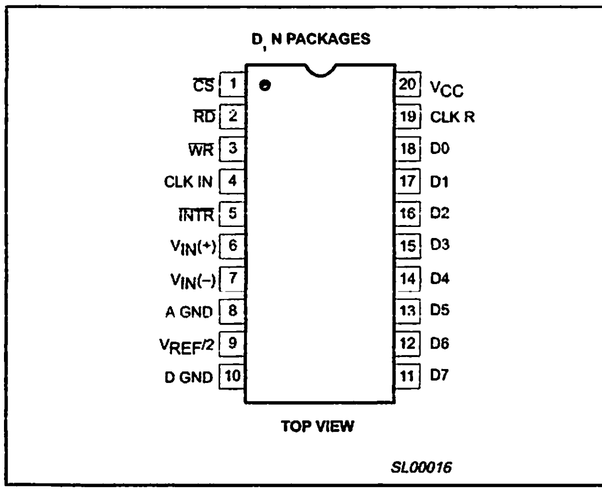


Figure 1. Pin configuration

APPLICATIONS

- Transducer-to-microprocessor interface
- Digital thermometer
- Digitally-controlled thermostat
- Microprocessor-based monitoring and control systems

ɪDERING INFORMATION

DESCRIPTION	TEMPERATURE RANGE	ORDER CODE	TOPSIDE MARKING	DWG #
-pin plastic small outline (SO) package	0 to 70 °C	ADC0803CD, ADC0804CD	ADC0803-1CD, ADC0804-1CD	SOT163-1
-pin plastic small outline (SO) package	–40 to 85 °C	ADC0803LCD, ADC0804LCD	ADC0803-1LCD, ADC0804-1LCD	SOT163-1
-pin plastic dual in-line package (DIP)	0 to 70 °C	ADC0803CN, ADC0804CN	ADC0803-1CN, ADC0804-1CN	SOT146-1
-pin plastic dual in-line package (DIP)	–40 to +85 °C	ADC0803LCN, ADC0804LCN	ADC0803-1LCN, ADC0804-1LCN	SOT146-1

;SOLUTE MAXIMUM RATINGS

YMBOL	PARAMETER	CONDITIONS	RATING	UNIT
:C	Supply voltage		6.5	V
	Logic control input voltages		–0.3 to +16	V
	All other input voltages		–0.3 to (V_{CC} +0.3)	V
nb	Operating temperature range ADC0803LCD/ADC0804LCD ADC0803LCN/ADC0804LCN ADC0803CD/ADC0804CD ADC0803CN/ADC0804CN		 –40 to +85 –40 to +85 0 to +70 0 to +70	 °C °C °C °C
g	Storage temperature		–65 to +150	°C
d	Lead soldering temperature (10 seconds)		230	°C
	Maximum power dissipation[1] N package D package	T_{amb} = 25 °C (still air)	 1690 1390	 mW mW

ΓE:
Ↄerate above 25 °C, at the following rates: N package at 13.5 mW/°C; D package at 11.1 mW/°C.

.OCK DIAGRAM

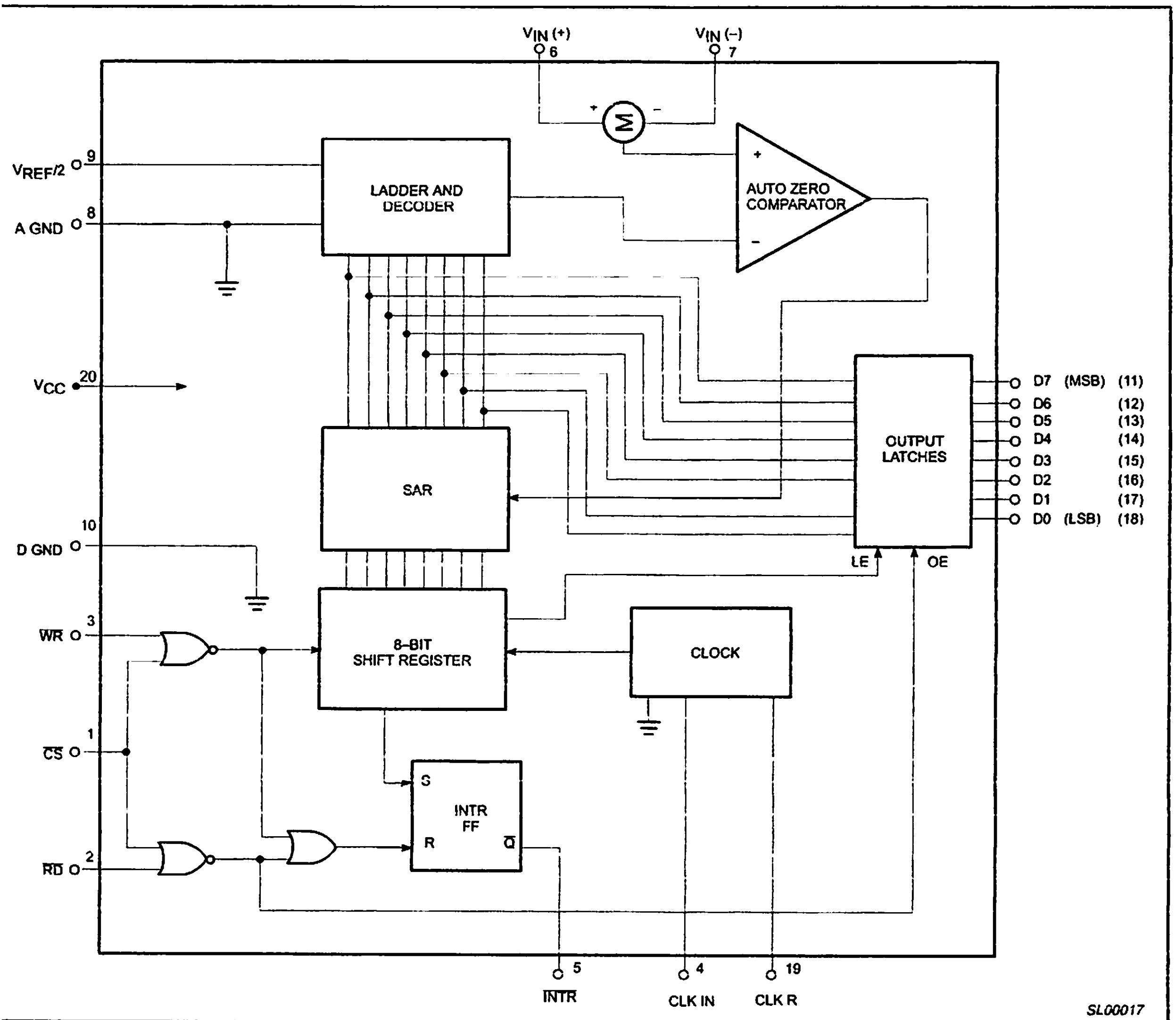


Figure 2. Block diagram

; ELECTRICAL CHARACTERISTICS

$_C$ = 5.0 V, f_{CLK} = 1 MHz, $T_{min} \leq T_{amb} \leq T_{max}$, unless otherwise specified.

YMBOL	PARAMETER	TEST CONDITIONS	LIMITS Min	Typ	Max	UNIT
	ADC0803 relative accuracy error (adjusted)	Full-Scale adjusted			0.50	LSB
	ADC0804 relative accuracy error (unadjusted)	$V_{REF}/2$ = 2.500 V_{DC}			1	LSB
N	$V_{REF}/2$ input resistance[3]	V_{CC} = 0 V[2]	400	680		Ω
	Analog input voltage range[3]		–0.05		V_{CC}+0.05	V
	DC common-mode error	Over analog input voltage range		1/16	1/8	LSB
	Power supply sensitivity	V_{CC} = 5V ±10%[1]		1/16		LSB
ontrol inputs						
H	Logical "1" input voltage	V_{CC} = 5.25 V_{DC}	2.0		15	V_{DC}
L	Logical "0" input voltage	V_{CC} = 4.75 V_{DC}			0.8	V_{DC}
I	Logical "1" input current	V_{IN} = 5 V_{DC}		0.005	1	μA_{DC}
	Logical "0" input current	V_{IN} = 0 V_{DC}	–1	–0.005		μA_{DC}
ock in and clock R						
+	Clock in positive-going threshold voltage		2.7	3.1	3.5	V_{DC}
–	Clock in negative-going threshold voltage		1.5	1.8	2.1	V_{DC}
H	Clock in hysteresis (V_T+)–(V_T–)		0.6	1.3	2.0	V_{DC}
OL	Logical "0" clock R output voltage	I_{OL} = 360 µA, V_{CC} = 4.75 V_{DC}			0.4	V_{DC}
OH	Logical "1" clock R output voltage	I_{OH} = –360 µA, V_{CC} = 4.75 V_{DC}	2.4			V_{DC}
ata output and $\overline{INTR}$						
OL	Logical "0" output voltage					
	Data outputs	I_{OL} = 1.6 mA, V_{CC} = 4.75 V_{DC}			0.4	V_{DC}
	$\overline{INTR}$ outputs	I_{OL} = 1.0 mA, V_{CC} = 4.75 V_{DC}			0.4	V_{DC}
OH	Logical "1" output voltage	I_{OH} = –360 µA, V_{CC} = 4.75 V_{DC}	2.4			V_{DC}
		I_{OH} = –10 µA, V_{CC} = 4.75 V_{DC}	4.5			
ZL	3-State output leakage	V_{OUT} = 0 V_{DC}, $\overline{CS}$ = logical "1"	–3			μA_{DC}
ZH	3-State output leakage	V_{OUT} = 5 V_{DC}, $\overline{CS}$ = logical "1"			3	μA_{DC}
C	+Output short-circuit current	V_{OUT} = 0 V, T_{amb} = 25 °C	4.5	12		mA_{DC}
C	–Output short-circuit current	V_{OUT} = V_{CC}, T_{amb} = 25 °C	9.0	30		mA_{DC}
C	Power supply current	f_{CLK} = 1 MHz, $V_{REF}/2$ = OPEN, $\overline{CS}$ = Logical "1", T_{amb} = 25 °C		3.0	3.5	mA

TES:

Analog inputs must remain within the range: $-0.05 \leq V_{IN} < V_{CC} + 0.05$ V.

See typical performance characteristics for input resistance at V_{CC} = 5 V.

$V_{REF}/2$ and V_{IN} must be applied after the V_{CC} has been turned on to prevent the possibility of latching.

: ELECTRICAL CHARACTERISTICS

;YMBOL	PARAMETER	TO	FROM	TEST CONDITIONS	LIMITS			UNIT
					Min	Typ	Max	
	Conversion time			f_{CLK} = 1 MHz[1]	66		73	µs
LK	Clock frequency[1]				0.1	1.0	3.0	MHz
	Clock duty cycle[1]				40		60	%
ʀ	Free-running conversion rate			$\overline{CS}$ = 0, f_{CLK} = 1 MHz INTR tied to WR			13690	conv/s
($\overline{WR}$)L	Start pulse width			$\overline{CS}$ = 0	30			ns
CC	Access time	Output	$\overline{RD}$	$\overline{CS}$ = 0, C_L = 100 pF		75	100	ns
ɪ, t_{0H}	3-State control	Output	$\overline{RD}$	C_L = 10 pF, R_L = 10 kΩ See 3-State test circuit		70	100	ns
ı1, t_{R1}	$\overline{INTR}$ delay	$\overline{INTR}$	$\overline{WD}$ or $\overline{RD}$			100	150	ns
N	Logic input=capacitance					5	7.5	pF
ƆUT	3-State output capacitance					5	7.5	pF

ITE:
Accuracy is guaranteed at f_{CLK} = 1 MHz. Accuracy may degrade at higher clock frequencies.

INCTIONAL DESCRIPTION

ɜse devices operate on the Successive Approximation principle. ɜlog switches are closed sequentially by successive ɔroximation logic until the input to the auto-zero comparator N(+)–V_{IN}(–)] matches the voltage from the decoder. After all bits tested and determined, the 8-bit binary code corresponding to input voltage is transferred to an output latch. Conversion begins ı the arrival of a pulse at the $\overline{WR}$ input if the CS input is low. On High-to-Low transition of the signal at the WR or the CS input, SAR is initialized, the shift register is reset, and the $\overline{INTR}$ output et high. The A/D will remain in the reset state as long as the $\overline{CS}$ ɪ $\overline{WR}$ inputs remain low. Conversion will start from one to eight ɔk periods after one or both of these inputs makes a Low-to-High ısition. After the conversion is complete, the $\overline{INTR}$ pin will make a h-to-Low transition. This can be used to interrupt a processor, or erwise signal the availability of a new conversion result. A read ᴐ) operation (with $\overline{CS}$ low) will clear the $\overline{INTR}$ line and enable the put latches. The device may be run in the free-running mode as ıcribed later. A conversion in progress can be interrupted by ɹing another start command.

ɟital Control Inputs

ı digital control inputs (CS, WR, $\overline{RD}$) are compatible with ıdard TTL logic voltage levels. The required signals at these ɹts correspond to Chip Select, START Conversion, and Output ıble control signals, respectively. They are active-Low for easy ɾface to microprocessor and microcontroller control buses. For ılications not using microprocessors, the $\overline{CS}$ input (Pin 1) can be unded and the A/D START function is achieved by a ɪative-going pulse to the $\overline{WR}$ input (Pin 3). The Output Enable ɔtion is achieved by a logic low signal at the $\overline{RD}$ input (Pin 2), ch may be grounded to constantly have the latest conversion sent at the output.

ANALOG OPERATION

Analog Input Current

The analog comparisons are performed by a capacitive charge summing circuit. The input capacitor is switched between $V_{IN(+)}$4 and $V_{IN(-)}$, while reference capacitors are switched between taps on the reference voltage divider string. The net charge corresponds to the weighted difference between the input and the most recent total value set by the successive approximation register.

The internal switching action causes displacement currents to flow at the analog inputs. The voltage on the on-chip capacitance is switched through the analog differential input voltage, resulting in proportional currents entering the $V_{IN(+)}$ input and leaving the $V_{IN(-)}$ input. These transient currents occur at the leading edge of the internal clock pulses. They decay rapidly so do not inherently cause errors as the on-chip comparator is strobed at the end of the clock period.

Input Bypass Capacitors and Source Resistance

Bypass capacitors at the input will average the charges mentioned above, causing a DC and an AC current to flow through the output resistance of the analog signal sources. This charge pumping action is worse for continuous conversions with the $V_{IN(+)}$ input at full scale. This current can be a few microamps, so bypass capacitors should NOT be used at the analog inputs of the V_{REF}/2 input for high resistance sources (> 1 kΩ). If input bypass capacitors are desired for noise filtering and a high source resistance is desired to minimize capacitor size, detrimental effects of the voltage drop across the input resistance can be eliminated by adjusting the full scale with both the input resistance and the input bypass capacitor in place. This is possible because the magnitude of the input current is a precise linear function of the differential voltage.

'ge values of source resistance where an input bypass capacitor ıot used will not cause errors as the input currents settle out prior :he comparison time. If a low pass filter is required in the system, ɜ a low valued series resistor (< 1 kΩ) for a passive RC section or ɟ an op amp active filter (low pass). For applications with source istances at or below 1 kΩ, a 0.1 μF bypass capacitor at the inputs l prevent pickup due to series lead inductance or a long wire. A) Ω series resistor can be used to isolate this capacitor (both the ;istor and capacitor should be placed out of the feedback loop) m the output of the op amp, if used.

ıalog Differential Voltage Inputs and ɔmmon-Mode Rejection

ɜse A/D converters have additional flexibility due to the analog erential voltage input. The $V_{IN(-)}$ input (Pin 7) can be used to ɔtract a fixed voltage from the input reading (tare correction). This ılso useful in a 4/20 mA current loop conversion. Common-mode se can also be reduced by the use of the differential input.

ɜ time interval between sampling $V_{IN(+)}$ and $V_{IN(-)}$ is 4.5 clock 'iods. The maximum error due to this time difference is given by:

/(max) = $(V_P)\ (2f_{CM})\ (4.5/f_{CLK})$,

ere:

/ = error voltage due to sampling delay

$/_P$ = peak value of common-mode voltage

$_{CM}$ = common mode frequency

· example, with a 60 Hz common-mode frequency, f_{cm}, and a 1Hz A/D clock, f_{CLK}, keeping this error to 1/4 LSB (about 5 mV) uld allow a common-mode voltage, V_P, which is given by:

$$'_P = \frac{[V(max)\ (f_{CLK})}{(2f_{CM})(4.5)}$$

$$'_P = \frac{(5 \times 10^{-3})\ (10^4)}{(6.28)\ (60)\ (4.5)} = 2.95V$$

ɜ allowed range of analog input voltages usually places more 'ere restrictions on input common-mode voltage levels than this, vever.

analog input span less than the full 5 V capability of the device, ether with a relatively large zero offset, can be easily handled by ɩ of the differential input. (See Reference Voltage Span Adjust).

ɩise and Stray Pickup

ɜ leads of the analog inputs (Pins 6 and 7) should be kept as ırt as possible to minimize input noise coupling and stray signal ‹-up. Both EMI and undesired digital signal coupling to these uts can cause system errors. The source resistance for these uts should generally be below 5 kΩ to help avoid undesired noise ‹up. Input bypass capacitors at the analog inputs can create ɔrs as described previously. Full scale adjustment with any input ıass capacitors in place will eliminate these errors.

'ference Voltage

application flexibility, these A/D converters have been designed ıccommodate fixed reference voltages of 5V to Pin 20 or 2.5 V to 9, or an adjusted reference voltage at Pin 9. The reference can set by forcing it at $V_{REF}/2$ input, or can be determined by the ply voltage (Pin 20). Figure 6 indicates how this is accomplished.

Reference Voltage Span Adjust

Note that the Pin 9 ($V_{REF}/2$) voltage is either 1/2 the voltage applied to the V_{CC} supply pin, or is equal to the voltage which is externally forced at the $V_{REF}/2$ pin. In addition to allowing for flexible references and full span voltages, this also allows for a ratiometric voltage reference. The internal gain of the $V_{REF}/2$ input is 2, making the full-scale differential input voltage twice the voltage at Pin 9.

For example, a dynamic voltage range of the analog input voltage that extends from 0 to 4 V gives a span of 4 V (4–0), so the $V_{REF}/2$ voltage can be made equal to 2 V (half of the 4 V span) and full scale output would correspond to 4 V at the input.

On the other hand, if the dynamic input voltage had a range of 0.5 to 3.5 V, the span or dynamic input range is 3 V (3.5–0.5). To encode this 3 V span with 0.5 V yielding a code of zero, the minimum expected input (0.5 V, in this case) is applied to the $V_{IN}(-)$ pin to account for the offset, and the $V_{REF}/2$ pin is set to 1/2 the 3 V span, or 1.5 V. The A/D converter will now encode the $V_{IN}(+)$ signal between 0.5 and 3.5 V with 0.5 V at the input corresponding to a code of zero and 3.5 V at the input producing a full scale output code. The full 8 bits of resolution are thus applied over this reduced input voltage range. The required connections are shown in Figure 7.

Operating Mode

These converters can be operated in two modes:

1) absolute mode
2) ratiometric mode

In absolute mode applications, both the initial accuracy and the temperature stability of the reference voltage are important factors in the accuracy of the conversion. For $V_{REF}/2$ voltages of 2.5 V, initial errors of ±10 mV will cause conversion errors of ±1 LSB due to the gain of 2 at the $V_{REF}/2$ input. In reduced span applications, the initial value and stability of the $V_{REF}/2$ input voltage become even more important as the same error is a larger percentage of the $V_{REF}/2$ nominal value. See Figure 8.

In ratiometric converter applications, the magnitude of the reference voltage is a factor in both the output of the source transducer and the output of the A/D converter, and, therefore, cancels out in the final digital code. See Figure 9.

Generally, the reference voltage will require an initial adjustment. Errors due to an improper reference voltage value appear as full-scale errors in the A/D transfer function.

ERRORS AND INPUT SPAN ADJUSTMENTS

There are many sources of error in any data converter, some of which can be adjusted out. Inherent errors, such as relative accuracy, cannot be eliminated, but such errors as full-scale and zero scale offset errors can be eliminated quite easily. See Figure 7.

Zero Scale Error

Zero scale error of an A/D is the difference of potential between the ideal 1/2 LSB value (9.8 mV for $V_{REF}/2$=2.500 V) and that input voltage which just causes an output transition from code 0000 0000 to a code of 0000 0001.

If the minimum input value is not ground potential, a zero offset can be made. The converter can be made to output a digital code of 0000 0000 for the minimum expected input voltage by biasing the $V_{IN}(-)$ input to that minimum value expected at the $V_{IN}(-)$ input to that minimum value expected at the $V_{IN}(+)$ input. This uses the differential mode of the converter. Any offset adjustment should be done prior to full scale adjustment.

ll Scale Adjustment

l scale gain is adjusted by applying any desired offset voltage to (–), then applying the $V_{IN}(+)$ a voltage that is 1-1/2 LSB less than desired analog full-scale voltage range and then adjusting the gnitude of $V_{REF}/2$ input voltage (or the V_{CC} supply if there is no $_{EF}/2$ input connection) for a digital output code which just inges from 1111 1110 to 1111 1111. The ideal $V_{IN}(+)$ voltage for full-scale adjustment is given by:

$$_{IN}(+) = V_{IN}(-) - 1.5 \times \frac{V_{MAX} - V_{MIN}}{255}$$

ere:

$_{MAX}$ = high end of analog input range (ground referenced)

$_{MIN}$ = low end (zero offset) of analog input (ground referenced)

.OCKING OPTION

clock signal for these A/Ds can be derived from external irces, such as a system clock, or self-clocking can be omplished by adding an external resistor and capacitor, as wn in Figure 11.

ivy capacitive or DC loading of the CLK R pin should be avoided his will disturb normal converter operation. Loads less than 50pF allowed. This permits driving up to seven A/D converter CLK IN of this family from a single CLK R pin of one converter. For er loading of the clock line, a CMOS or low power TTL buffer or input logic should be used to minimize the loading on the CLK in.

start During a Conversion

onversion in process can be halted and a new conversion began oringing the $\overline{CS}$ and $\overline{WR}$ inputs low and allowing at least one of n to go high again. The output data latch is not updated if the version in progress is not completed; the data from the viously completed conversion will remain in the output data hes until a subsequent conversion is completed.

ntinuous Conversion

provide continuous conversion of input data, the $\overline{CS}$ and $\overline{RD}$ its are grounded and $\overline{INTR}$ output is tied to the $\overline{WR}$ input. This $\overline{R}/\overline{WR}$ connection should be momentarily forced to a logic low n power-up to insure circuit operation. See Figure 10 for one to accomplish this.

DRIVING THE DATA BUS

This CMOS A/D converter, like MOS microprocessors and memories, will require a bus driver when the total capacitance of the data bus gets large. Other circuitry tied to the data bus will add to the total capacitive loading, even in the high impedance mode.

There are alternatives in handling this problem. The capacitive loading of the data bus slows down the response time, although DC specifications are still met. For systems with a relatively low CPU clock frequency, more time is available in which to establish proper logic levels on the bus, allowing higher capacitive loads to be driven (see Typical Performance Characteristics).

At higher CPU clock frequencies, time can be extended for I/O reads (and/or writes) by inserting wait states (8880) or using clock-extending circuits (6800, 8035).

Finally, if time is critical and capacitive loading is high, external bus drivers must be used. These can be 3-State buffers (low power Schottky is recommended, such as the N74LS240 series) or special higher current drive products designed as bus drivers. High current bipolar bus drivers with PNP inputs are recommended as the PNP input offers low loading of the A/D output, allowing better response time.

POWER SUPPLIES

Noise spikes on the V_{CC} line can cause conversion errors as the internal comparator will respond to them. A low inductance filter capacitor should be used close to the converter V_{CC} pin and values of 1 µF or greater are recommended. A separate 5 V regulator for the converter (and other 5 V linear circuitry) will greatly reduce digital noise on the V_{CC} supply and the attendant problems.

WIRING AND LAYOUT PRECAUTIONS

Digital wire-wrap sockets and connections are not satisfactory for breadboarding this (or any) A/D converter. Sockets on PC boards can be used. All logic signal wires and leads should be grouped or kept as far as possible from the analog signal leads. Single wire analog input leads may pick up undesired hum and noise, requiring the use of shielded leads to the analog inputs in many applications.

A single-point analog ground separate from the logic or digital ground points should be used. The power supply bypass capacitor and the self-clocking capacitor, if used, should be returned to digital ground. Any $V_{REF}/2$ bypass capacitor, analog input filter capacitors, and any input shielding should be returned to the analog ground point. Proper grounding will minimize zero-scale errors which are present in every code. Zero-scale errors can usually be traced to improper board layout and wiring.

›PLICATIONS

croprocessor Interfacing

s family of A/D converters was designed for easy microprocessor ›rfacing. These converters can be memory mapped with ›ropriate memory address decoding for $\overline{CS}$ (read) input. The ive-Low write pulse from the processor is then connected to the ₹ input of the A/D converter, while the processor active-Low read se is fed to the converter $\overline{RD}$ input to read the converted data. If clock signal is derived from the microprocessor system clock, designer/programmer should be sure that there is no attempt to ıd the converter until 74 converter clock pulses after the start se goes high. Alternatively, the $\overline{INTR}$ pin may be used to interrupt processor to cause reading of the converted data. Of course, the ıverter can be connected and addressed as a peripheral (in I/O ıce), as shown in Figure 12. A bus driver should be used as a fer to the A/D output in large microprocessor systems where the a leaves the PC board and/or must drive capacitive loads in ›ess of 100 pF. See Figure 14.

›rfacing the SCN8048 microcomputer family is pretty simple, as ›wn in Figure 13. Since the SCN8048 family has 24 I/O lines, one hese (shown here as bit 0 or port 1) can be used as the chip ect signal to the converter, eliminating the need for an address ›oder. The $\overline{RD}$ and $\overline{WR}$ signals are generated by reading from ı writing to a dummy address.

gitizing a Transducer Interface Output

cuit Description

ure 15 shows an example of digitizing transducer interface output ıage. In this case, the transducer interface is the NE5521, an)T (Linear Variable Differential Transformer) Signal Conditioner. ı diode at the A/D input is used to insure that the input to the A/D ›s not go excessively beyond the supply voltage of the A/D. See the NE5521 data sheet for a complete description of the operation of that part.

Circuit Adjustment

To adjust the full scale and zero scale of the A/D, determine the range of voltages that the transducer interface output will take on. Set the LVDT core for null and set the Zero Scale Scale Adjust Potentiometer for a digital output from the A/D of 1000 000. Set the LVDT core for maximum voltage from the interface and set the Full Scale Adjust potentiometer so the A/D output is just barely 1111 1111.

A Digital Thermostat

Circuit Description

The schematic of a Digital Thermostat is shown in Figure 16. The A/D digitizes the output of the LM35, a temperature transducer IC with an output of 10 mV per °C. With $V_{REF}/2$ set for 2.56 V, this 10 mV corresponds to 1/2 LSB and the circuit resolution is 2 °C. Reducing $V_{REF}/2$ to 1.28 yields a resolution of 1 °C. Of course, the lower $V_{REF}/2$ is, the more sensitive the A/D will be to noise.

The desired temperature is set by holding either of the set buttons closed. The SCC80C451 programming could cause the desired (set) temperature to be displayed while either button is depressed and for a short time after it is released. At other times the ambient temperature could be displayed.

The set temperature is stored in an SCN8051 internal register. The A/D conversion is started by writing anything at all to the A/D with port pin P10 set high. The desired temperature is compared with the digitized actual temperature, and the heater is turned on or off by clearing setting port pin P12. If desired, another port pin could be used to turn on or off an air conditioner.

The display drivers are NE587s if common anode LED displays are used. Of course, it is possible to interface to LCD displays as well.

PICAL PERFORMANCE CHARACTERISTICS

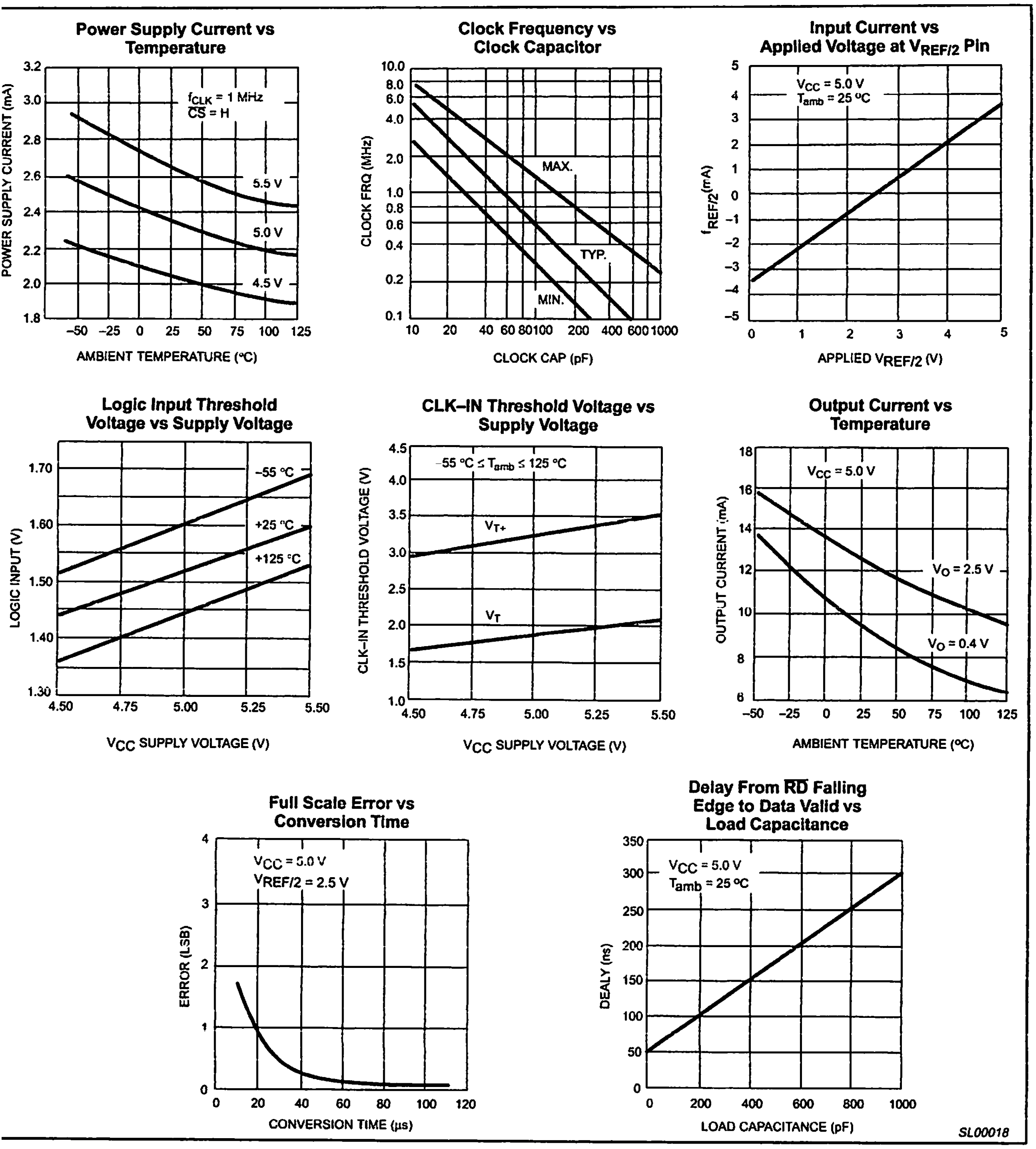


Figure 3. Typical Performance Characteristics

TATE TEST CIRCUITS AND WAVEFORMS (ADC0801-1)

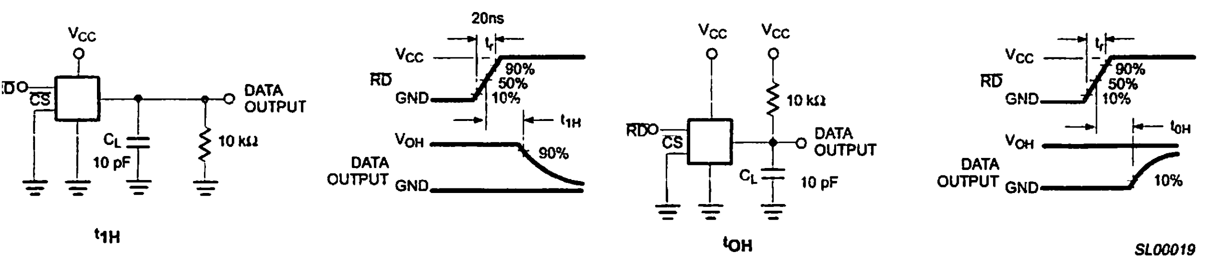
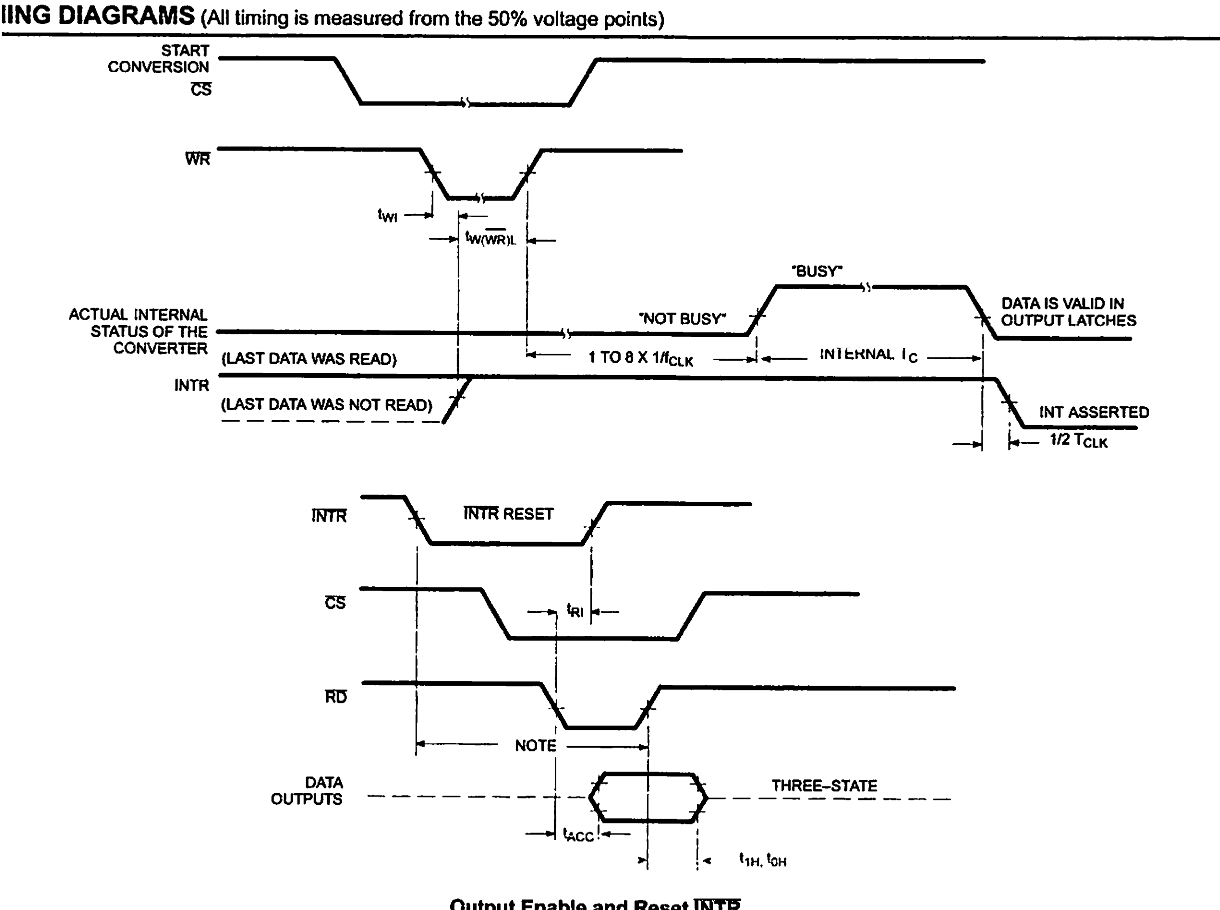


Figure 4. 3-State Test Circuits and Waveforms (ADC0801-1)

IING DIAGRAMS (All timing is measured from the 50% voltage points)



TE:

ad strobe must occur 8 clock periods ($8/f_{CLK}$) after assertion of interrupt to guarantee reset of INTR.

SL00020

Figure 5. Timing Diagrams

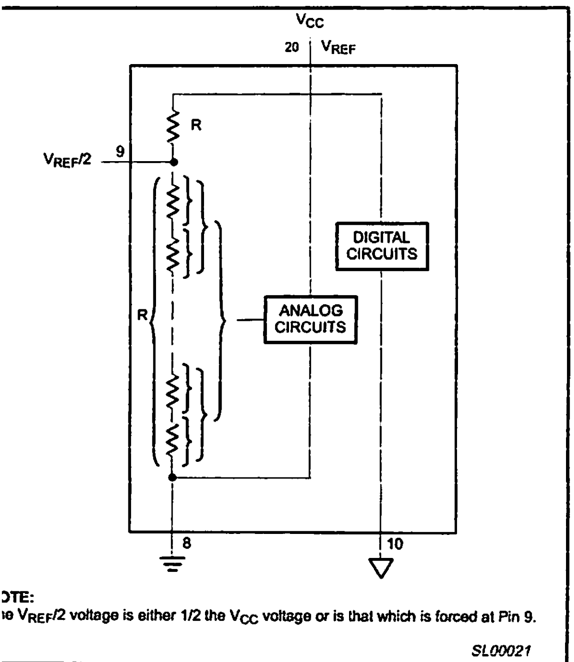


Figure 6. Internal Reference Design

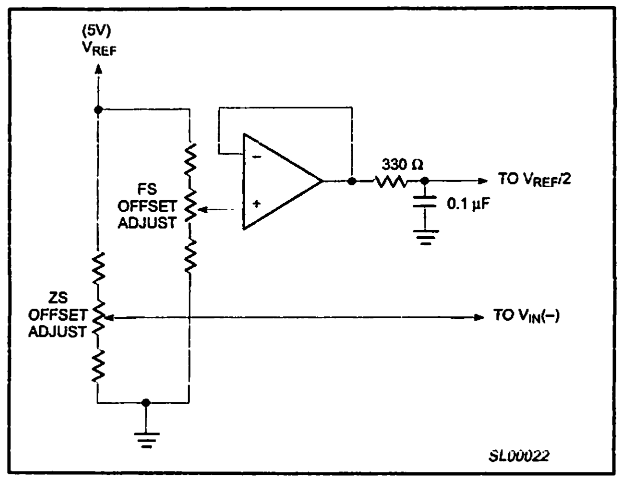


Figure 7. Offsetting the Zero Scale and Adjusting the Input Range (Span)

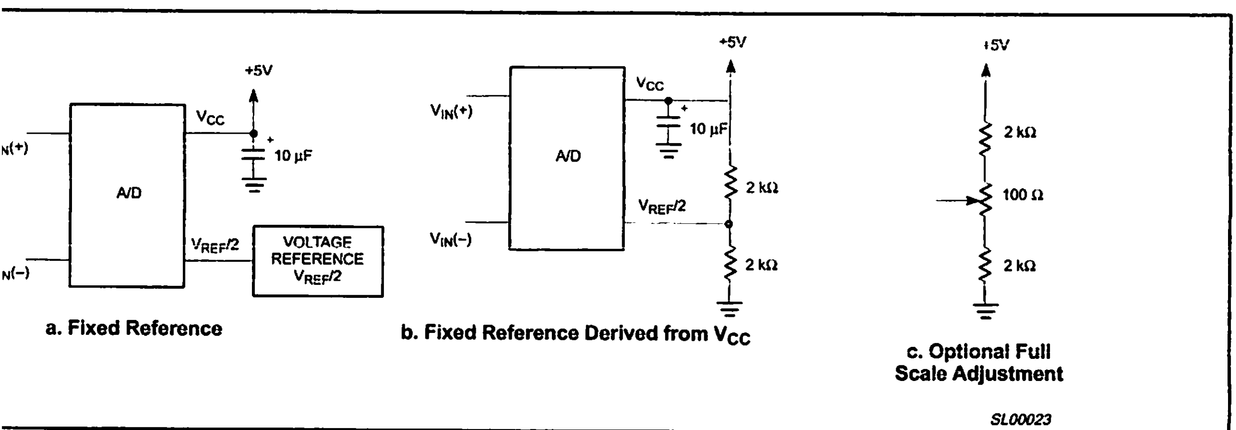
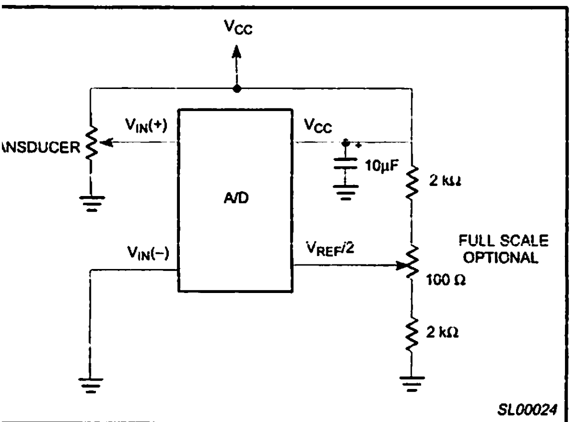


Figure 8. Absolute Mode of Operation



igure 9. Ratiometric Mode of Operation with Optional Full Scale Adjustment

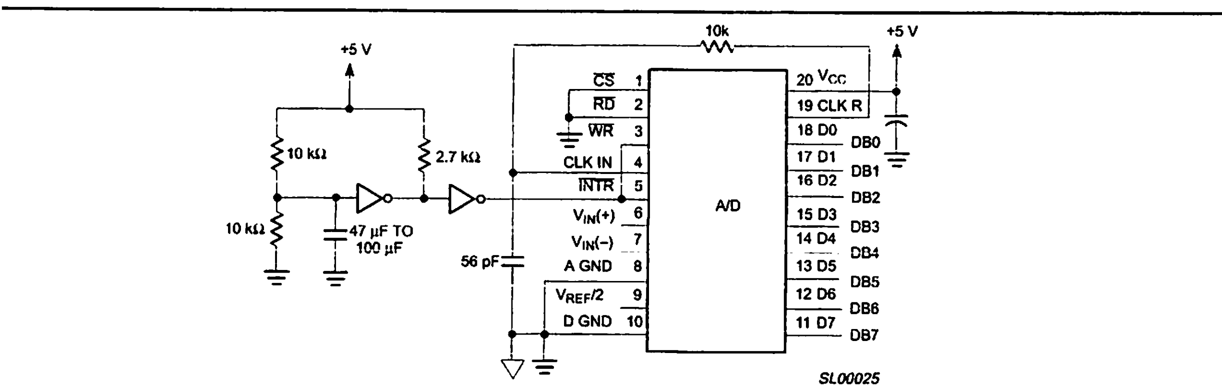


Figure 10. Connection for Continuous Conversion

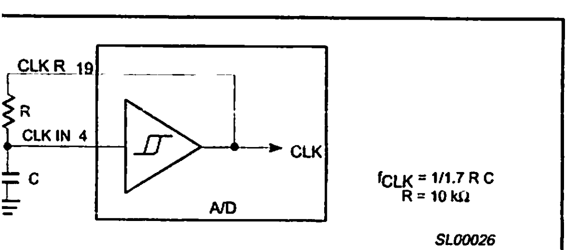


Figure 11. Self-Clocking the Converter

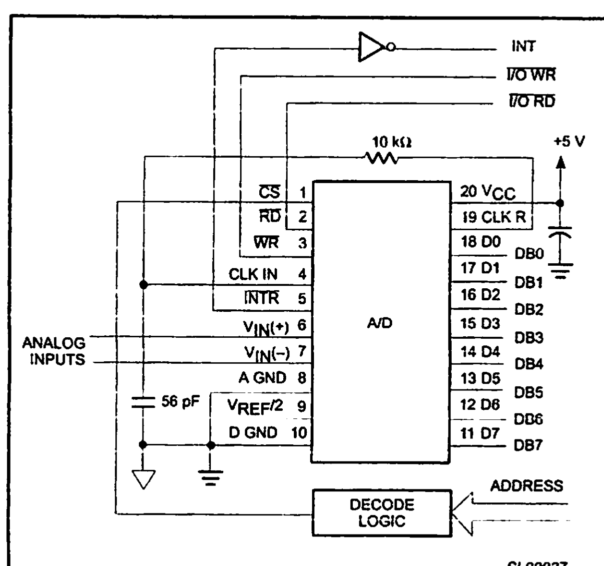


Figure 12. Interfacing to 8080A Microprocessor

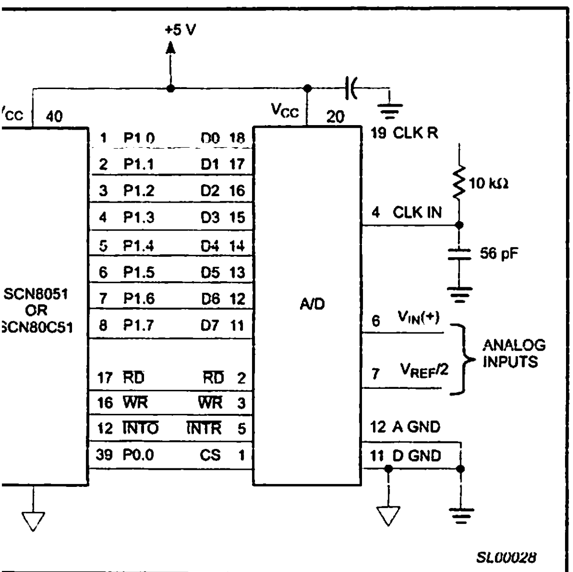


Figure 13. SCN8051 Interfacing

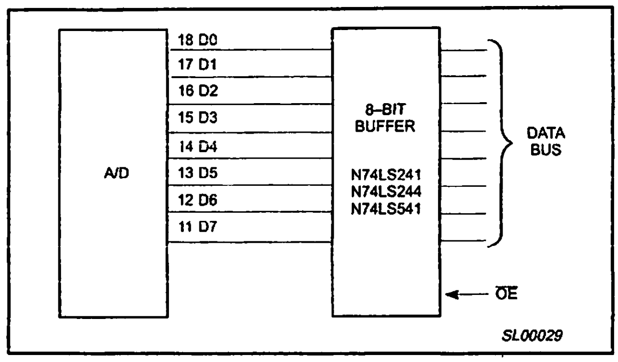


Figure 14. Buffering the A/D Output to Drive High Capacitance Loads and for Driving Off-Board Loads

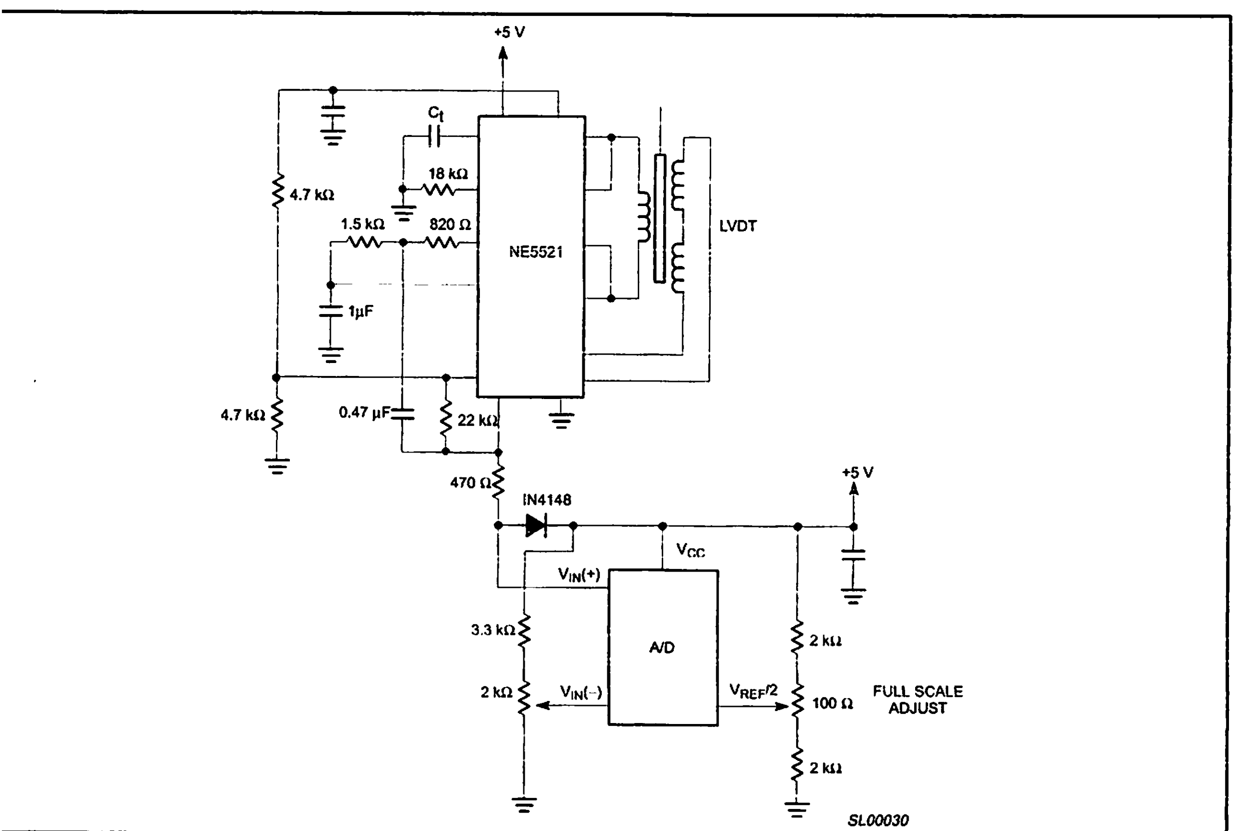


Figure 15. Digitizing a Transducer Interface Output

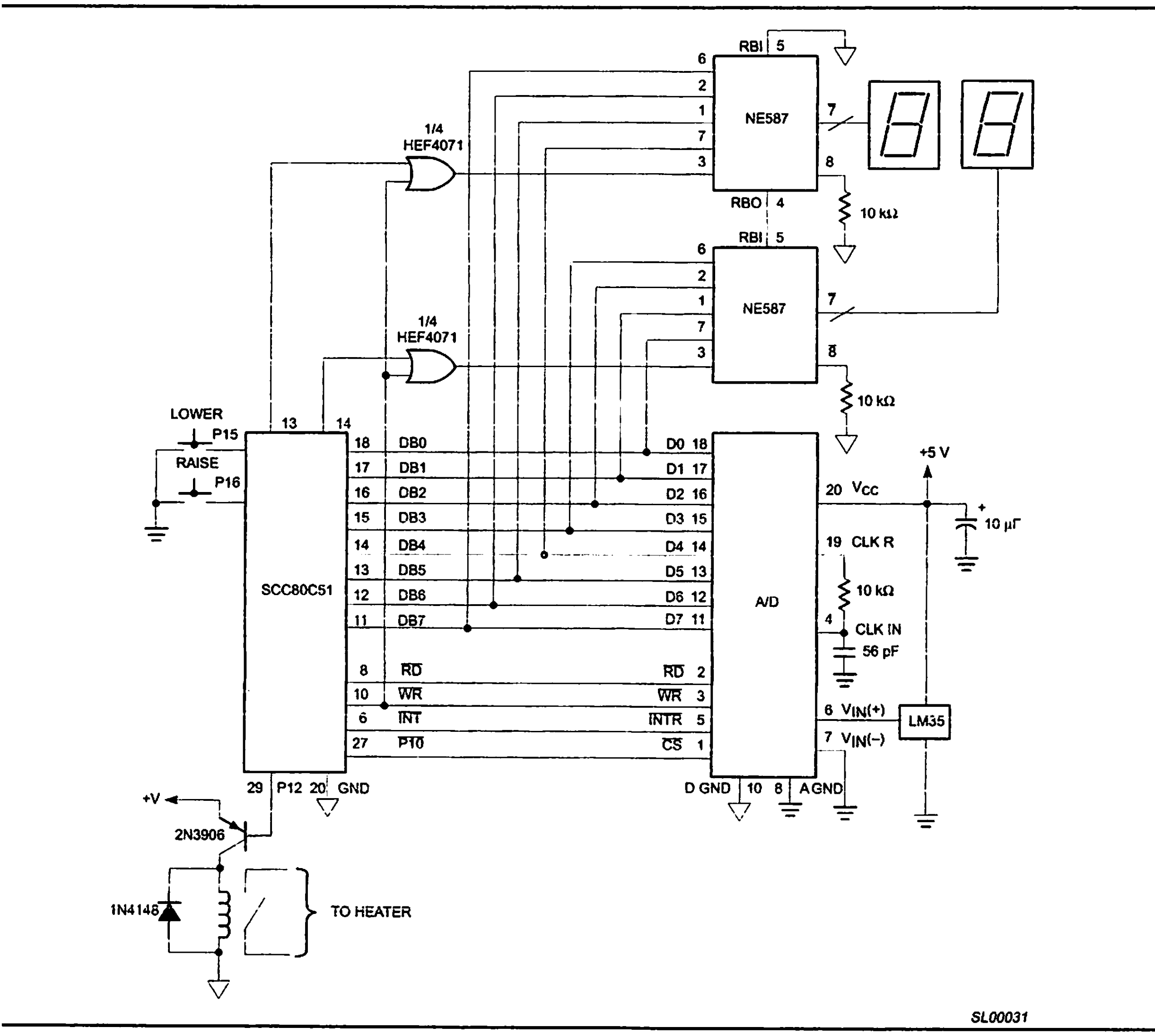
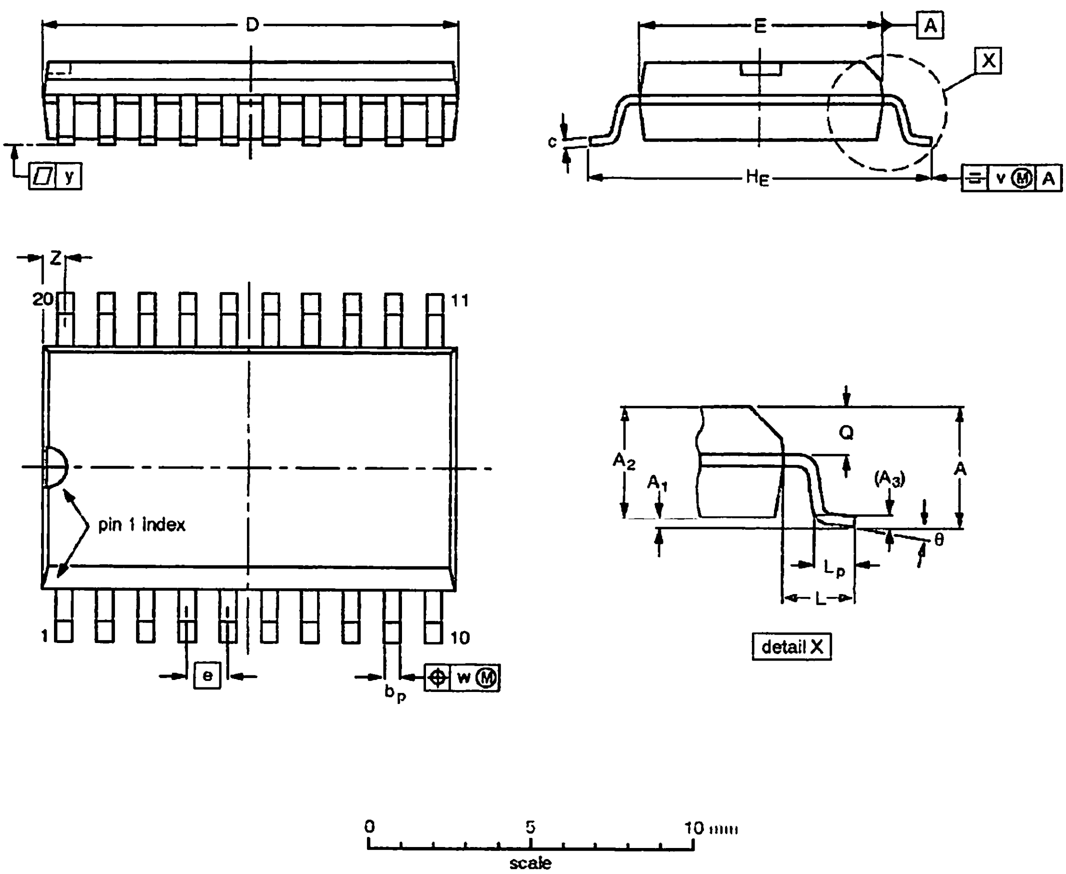


Figure 16. Digital Thermostat

20: plastic small outline package; 20 leads; body width 7.5 mm **SOT163-1**



DIMENSIONS (inch dimensions are derived from the original mm dimensions)

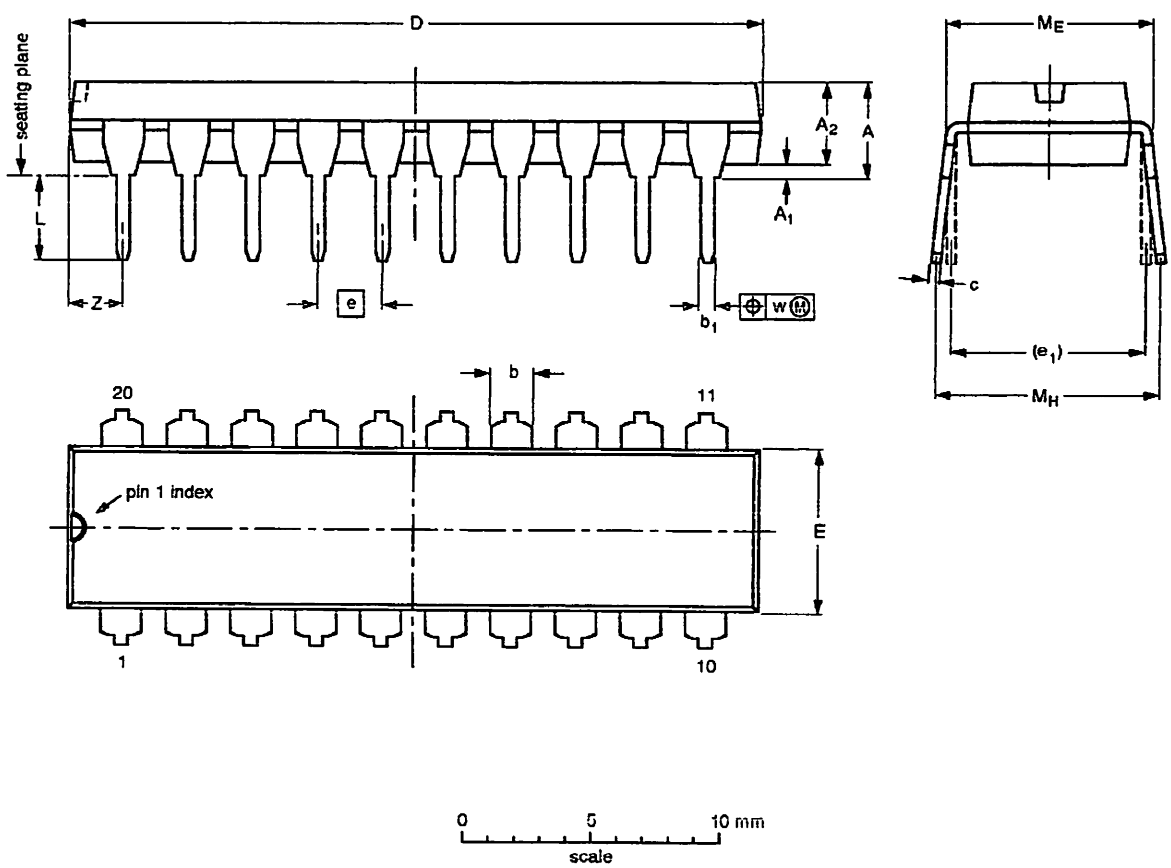
UNIT	A max.	A_1	A_2	A_3	b_p	c	D[(1)]	E[(1)]	e	H_E	L	L_p	Q	v	w	y	Z[(1)]	θ
mm	2.65	0.30 0.10	2.45 2.25	0.25	0.49 0.36	0.32 0.23	13.0 12.6	7.6 7.4	1.27	10.65 10.00	1.4	1.1 0.4	1.1 1.0	0.25	0.25	0.1	0.9 0.4	8° 0°
inches	0.10	0.012 0.004	0.096 0.089	0.01	0.019 0.014	0.013 0.009	0.51 0.49	0.30 0.29	0.050	0.419 0.394	0.055	0.043 0.016	0.043 0.039	0.01	0.01	0.004	0.035 0.016	

Note

1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT163-1	075E04	MS-013				~~97-05-22~~ 99-12-27

P20: plastic dual in-line package; 20 leads (300 mil) **SOT146-1**



IMENSIONS (inch dimensions are derived from the original mm dimensions)

UNIT	A max.	A_1 min.	A_2 max.	b	b_1	c	D (1)	E (1)	e	e_1	L	M_E	M_H	w	Z (1) max.
mm	4.2	0.51	3.2	1.73 1.30	0.53 0.38	0.36 0.23	26.92 26.54	6.40 6.22	2.54	7.62	3.60 3.05	8.25 7.80	10.0 8.3	0.254	2.0
inches	0.17	0.020	0.13	0.068 0.051	0.021 0.015	0.014 0.009	1.060 1.045	0.25 0.24	0.10	0.30	0.14 0.12	0.32 0.31	0.39 0.33	0.01	0.078

ote

Plastic or metal protrusions of 0.25 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT146-1		MS-001	SC-603			~~95-05-24~~ 99-12-27

VISION HISTORY

v	Date	Description
	20021017	**Product data; third version; supersedes data of 2001 Aug 03.** Engineering Change Notice 853–0034 28949 (date: 20020916). **Modifications:** • Add "Topside Marking" column to Ordering Information table.
	20010803	**Product data; second version (9397 750 08926).** Engineering Change Notice 853–0034 26832 (date: 20010803).
	19940831	**Product data; initial version.** Engineering Change Notice 853–0034 13721 (date: 19940831).

a sheet status

rel	Data sheet status [1]	Product status [2] [3]	Definitions
	Objective data	Development	This data sheet contains data from the objective specification for product development. Philips Semiconductors reserves the right to change the specification in any manner without notice.
	Preliminary data	Qualification	This data sheet contains data from the preliminary specification. Supplementary data will be published at a later date. Philips Semiconductors reserves the right to change the specification without notice, in order to improve the design and supply the best possible product.
	Product data	Production	This data sheet contains data from the product specification. Philips Semiconductors reserves the right to make changes at any time in order to improve the design, manufacturing and supply. Relevant changes will be communicated via a Customer Product/Process Change Notification (CPCN).

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For data sheets describing multiple type numbers, the highest-level product status determines the data sheet status.

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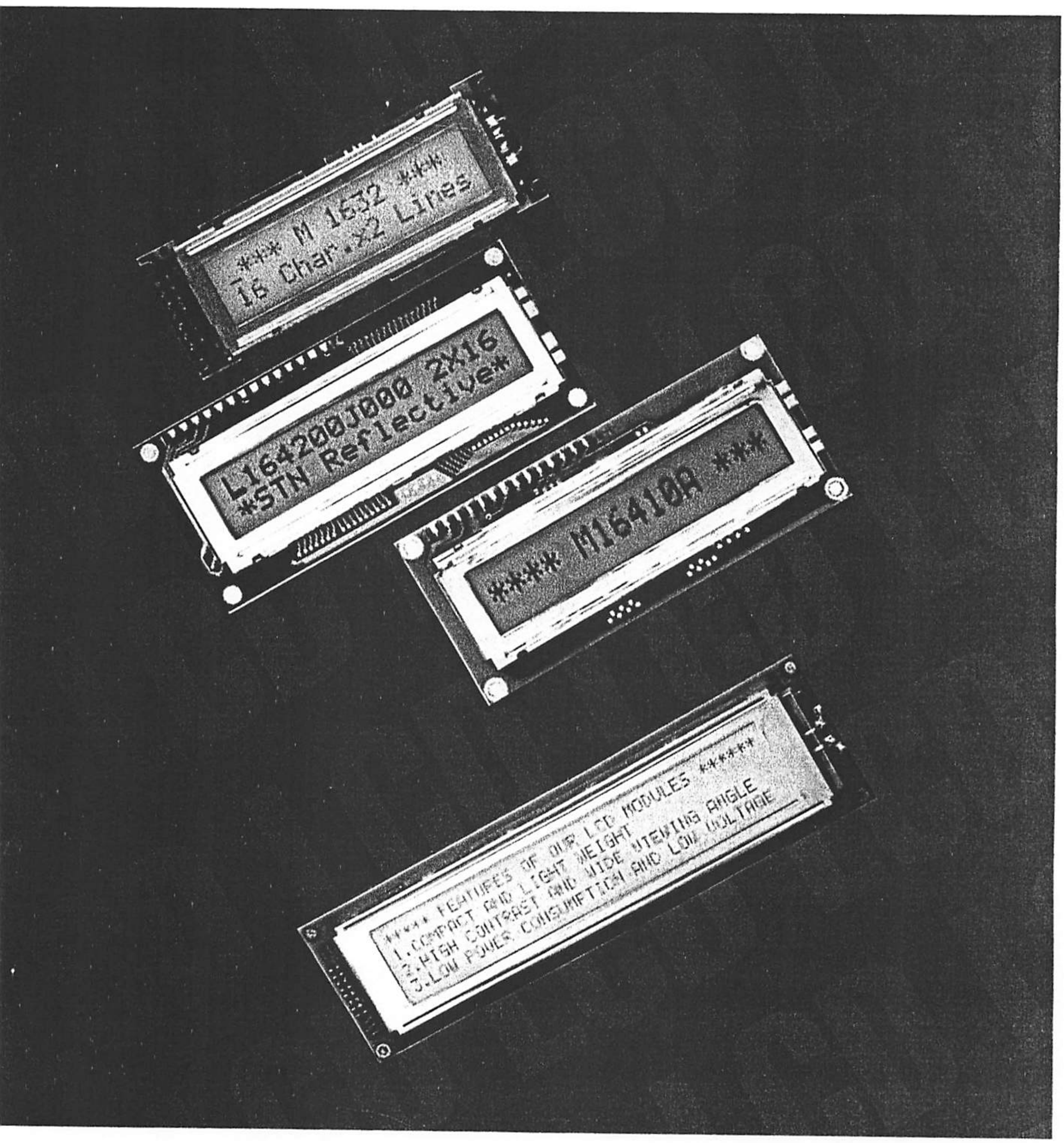
Date of release: 10-02

Document order number: 9397 750 10538

LCM

Liquid Crystal Display Modules

Seiko Instruments GmbH



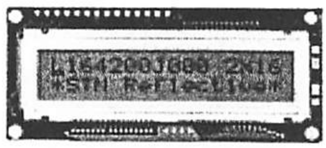
Dot Matrix Liquid Crystal Display Modules

CHARACTER TYPE

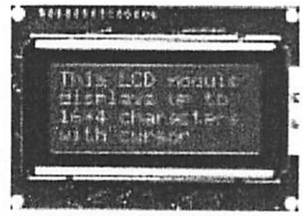
• FEATURES :

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

M1641



L1642



L1614

M1632

L1652

L2012

• SPECIFICATIONS :

[shaded box]: Standard products [white box]: Products of optional specification

Character Format (character x line)		16 x 1	16 x 2	16 x 2	16 x 2	16 x 4	20 x 2
Model		M1641	M1632	L1642	L1652	L1614	L2012
Reflective		M16410AS	M16320AS	L164200J000S	L165200J200S	L161400J000S	L201200J000S
EL backlight		M16419DWS	M16329DWS	L164221J000S	L165221J200S	L161421J000S	L201221J000S
LED backlight		M16417DYS	M16327DYS	L1642B1J000S	L1652B1J200S	L1614B1J000S	L2012B1J000S
Reflective (wide temp)		M16410CS	M16320CS	L164200L000S	L165200L200S	L161400L000S	L201200L000S
LED backlight (wide temp)		M16417JYS	M16327JYS	L1642B1L000S	L1652B1L200S	L1614B1L000S	L2012B1L000S
Character font		5x7 dots + cursor	5x7 dots + cursor	5x7 dots + cursor	5x7 dots + cursor	5x7 dots + cursor	5x7 dots + cursor
Module size (HxVxT) mm	Reflective	80,0 x 36,0 x 11,3	85,0 x 30,0 x 10,1	80,0 x 36,0 x 11,3	122,0 x 44,0 x 11,3	87,0 x 60,0 x 11,6	116,0 x 37,0 x 11,3
	EL backlight	80,0 x 36,0 x 11,3	85,0 x 30,0 x 10,1	80,0 x 36,0 x 11,3	122,0 x 44,0 x 11,3	87,0 x 60,0 x 11,6	116,0 x 37,0 x 11,3
	LED backlight	80,0 x 36,0 x 15,8	80,0 x 30,0 x 15,8	80,0 x 36,0 x 15,8	122,0 x 44,0 x 15,8	87,0 x 60,0 x 15,8	116,0 x 37,0 x 15,8
Viewing area (HxV) mm		64,5 x 13,8	62,0 x 16,0	64,5 x 13,8	99,0 x 24,0	61,8 x 25,2	83,0 x 18,6
Character size (HxV) mm *1		3,07 x 5,73	2,78 x 4,27	2,95 x 3,80	4,84 x 8,06	2,95 x 4,15	3,20 x 4,85
Dot size (HxV) mm		0,55 x 0,75	0,50 x 0,55	0,50 x 0,55	0,92 x 1,10	0,55 x 0,55	0,60 x 0,65
Power supply voltage (VDD-VSS) V		+ 5 V	+ 5 V	+ 5 V	+ 5 V	+ 5 V	+ 5 V
Current consumption (mA,typ)	IDD	1,5	2,0	1,6	2,0	2,7	2,0
	ILC *4	0,2	0,2	0,3	0,4	1,1	0,4
Driving method (duty)		1/16	1/16	1/16	1/16	1/16	1/16
Built-in LSI		KS0066 or equivalent	KS0066 MSM5839 or equivalent	KS0066 MSM5839 or equivalent	KS0066 MSM5839 or equivalent	KS0066 KS0063 or equivalent	KS0066 KS0063 or equivalent
Operating temperature (°C)	normal temp.	0 to + 50	0 to + 50	0 to + 50	0 to + 50	0 to + 50	0 to + 50
	wide temp. *2	- 20 to + 70	- 20 to + 70	- 20 to + 70	- 20 to + 70	- 20 to + 70	- 20 to + 70
Storage temperature (°C)	normal temp.	- 20 to + 60	- 20 to + 60	- 20 to + 60	- 20 to + 60	- 20 to + 60	- 20 to + 60
	wide temp.	- 30 to + 80	- 30 to + 80	- 30 to + 80	- 30 to + 80	- 30 to + 80	- 30 to + 80
Weight (g, typ.)	Reflective	25	25	25	50	50	40
	EL backlight	30	30	30	55	55	45
	LED backlight	35	40	35	65	65	60
Inverters for EL	Model	5S	5S	5S	5C	5A	5A
	Power supply (V)	+ 5.0	+ 5,0	+ 5.0	+ 5.0	+ 5.0	+ 5.0
	current consumption (mA) *3	10	10	10	35	45	45
LED backlight	Forward current consumption (mA)	100	112	100	240	200	154
	Forward input voltage (V,typ.)	+ 4,1	+ 4,1	+ 4,1	+ 4,1	+ 4,1	+ 4,1

*1 : Excluding cursor

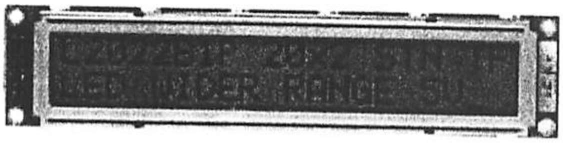
H : Horizontal V : Vertical T : Thickness (max)

*2 : With external temperature compensation

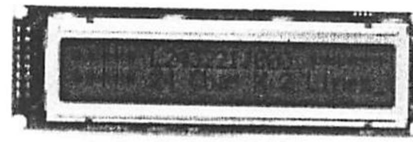
*3 : Including EL backlight

*4 : Based on normal temperature range

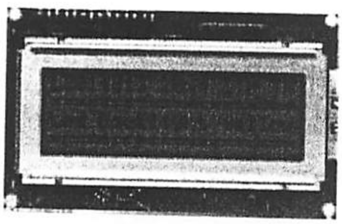
Since our policy is one of continues improvements we reserve the right to change the specifications for the products in the catalogue without notice.



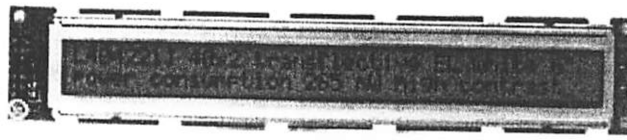
L2022



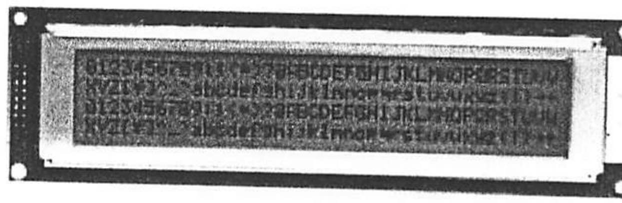
L2432



L2014



L4042



M4024

• SPECIFICATIONS :

[ ] : Standard products [ ] : Products of optional specification

Character Format (character x line)		20 x 2	20 x 4	24 x 2	40 x 2	40 x 4
Model		L2022	L2014	L2432	L4042	M4024
Reflective		-	L201400J000S	L243200J000S	L404200J000S	M40240AS
EL backlight		-	L201421J000S	L243221J000S	L404221J000S	M40249DWS
LED backlight		-	L2014B1J000S	L2432B1J000S	L4042B1J000S	M40247DYS
Reflective (wide temp)		L202200P000S	L201400L000S	L243200L000S	L404200L000S	M40240CS
LED backlight (wide temp)		L2022B1P000S	L2014B1L000S	L2432B1L000S	L4042B1L000S	M40247JYS
Character font		5x7 dots + cursor	5x7 dots + cursor	5x7 dots + cursor	5x7 dots + cursor	5x7 dots + cursor
Module size (HxVxT) mm	Reflective	180,0 x 40,0 x 10,5	98,0 x 60,0 x 11,6	118,0 x 36,0 x 11,3	182,0 x 33,5 x 11,3	190,0 x 54,0 x 10,1
	EL backlight	180,0 x 40,0 x 10,5	98,0 x 60,0 x 11,6	118,0 x 36,0 x 11,3	182,0 x 33,5 x 11,3	190,0 x 54,0 x 10,1
	LED backlight	180,0 x 40,0 x 14,8	98,0 x 60,0 x 15,8	118,0 x 36,0 x 15,8	182,0 x 33,5 x 16,3	190,0 x 54,0 x 16,3
Viewing area (HxV) mm		149,0 x 23,0	76,0 x 25,2	94,5 x 17,8	154,4 x 15,8	147,0 x 29,5
Character size (HxV) mm *1		6,00 x 9,66	2,95 x 4,15	3,20 x 4,85	3,20 x 4,85	2,78 x 4,27
Dot size (HxV) mm		1,12 x 1,12	0,55 x 0,55	0,60 x 0,65	0,60 x 0,65	0,50 x 0,55
Power supply voltage (VDD-VSS) V		+ 5 V	+ 5 V	+ 5 V	+ 5 V	+ 5 V
Current consumption (mA,typ)	IDD	4,2	2,9	2,5	3,0	8,0
	ILC *4	2,6	1,2	0,5	1,0	3,0
Driving method (duty)		1/16	1/16	1/16	1/16	1/16
Built-in LSI		KS0066 KS0063 or equivalent	KS0066 MSM5839 or equivalent	KS0066 KS0063 or equivalent	KS0066 KS0063 or equivalent	KS0066 MSM5839 or equivalent
Operating temperature (°C)	normal temp.	-	0 to + 50	0 to + 50	0 to + 50	0 to + 50
	wide temp. *2	- 20 to + 70	- 20 to + 70	- 20 to + 70	- 20 to + 70	- 20 to + 70
Storage temperature (°C)	normal temp.	-	- 20 to + 60	- 20 to + 60	- 20 to + 60	- 20 to + 60
	wide temp.	- 30 to + 80	- 30 to + 80	- 30 to + 80	- 30 to + 80	- 30 to + 80
Weight (g, typ.)	Reflective	80	55	40	70	90
	EL backlight	-	60	45	75	105
	LED backlight	110	70	60	95	140
Inverters for EL	Model	-	5A	5A	5C	5D
	Power supply (V)	+ 5.0	+ 5.0	+ 5.0	+ 5.0	+ 5.0
	current consumption (mA) *3	-	45	45	25	80
LED backlight	Forward current consumption (mA)	320	240	150	260	480
	Forward input voltage (V,typ.)	+ 4,1	+ 4,1	+ 4,1	+ 4,1	+ 4,1

*1 : Excluding cursor
*2 : With external temperature compensation
*3 : Including EL backlight
*4 : Based on normal temperature range

H : Horizontal V : Vertical T : Thickness (max)

Dot Matrix Liquid Crystal Display Modules

GRAPHIC TYPE

• FEATURES :

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

• SPECIFICATIONS :

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

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

*2 : Use with external temperature compensation circuit

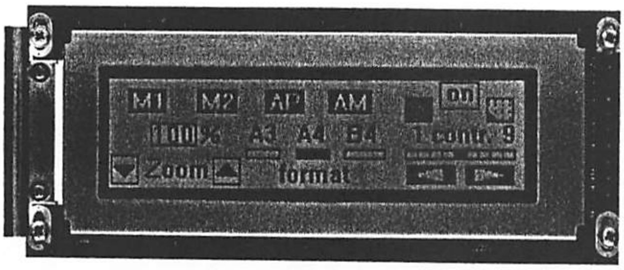
Since our policy is one of continues improvements we reserve the right to change the specifications of the products in the catalogue without notice.

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

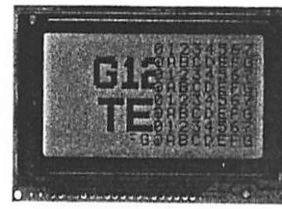
*1 : built-in DC/DC converter (single power source)

*2 : Use with external temperature compensation

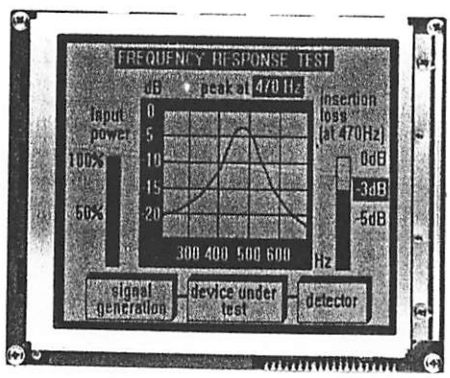
Since our policy is one of continous improvemets, we reserve the right to change the specifications of the products in the catalogue without notice.



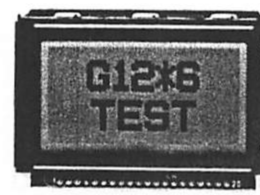
G2446



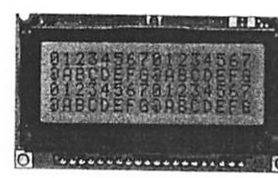
G1226



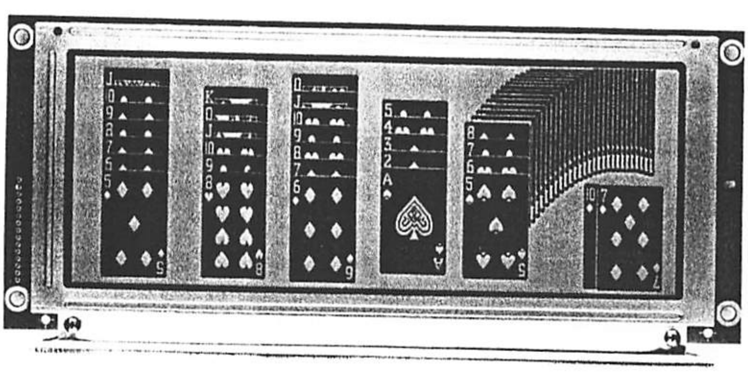
G321D



G1216

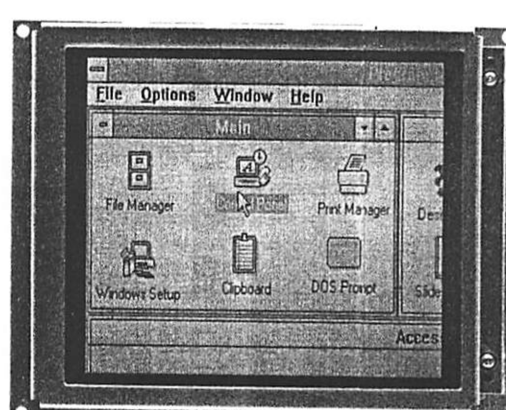


G1213



G649D

G242C



G324E

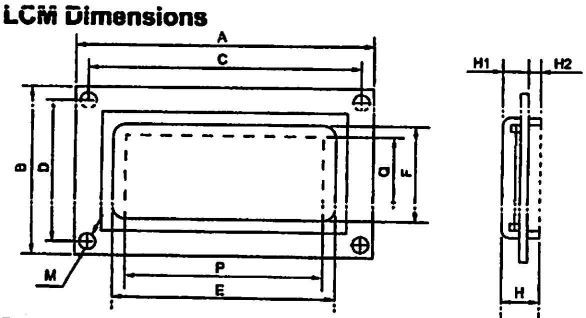
CHECK LIST FOR CUSTOM DESIGNED LCD MODULE

1. Company__________ **2. Application**__________ **3. Customer Specified Part No.**__________

4. Design

- ☐ New ☐ Modified : Manufacturer__________, Part No.__________, Remarks __________
- ☐ Equivalent: Manufacturer__________, Part No.__________, Remarks __________

5. LCM Dimensions



- A x B : Module size______ x ______mm
- E x F : Viewing area______ x ______mm
- P x Q : Active display area______ x ______mm
- C : Length between mounting holes______mm
- D : Length between mounting holes______mm
- M : Diameter of mounting hole______mm
- H : Total thickness______mm
- H1 : Upper thickness______mm
- H2 : Lower thickness______mm

6. Display Contents

☐ Character type:______characters______lines
Character font______ x ______dots + cursor
Character pitch______ x ______mm
Dot pitch______ x ______mm
Dot size______ x ______mm
☐ Graphics (Full dot) type:______ x ______dots
Dot pitch______ x ______mm
Dot size______ x ______mm
☐ Segment type: ______digits ______lines
☐ Others__________

7. LCD Panel

Viewing angle: ☐ 6 o'clock ☐ 12 o'clock ☐ ____o'clock
Type: ☐ TN ☐ FSTN (Black and white)
☐ STN (☐ Yellow green ☐ Gray ☐ Blue)
Chromaticity coordinates
(___ ≤ x ≤ ___ , ___ ≤ y ≤ ___)
☐ Positive type ☐ Negative type
☐ Reflective ☐ Transflective ☐ Transmissive
☐ Others__________
Gray scale: ☐ Yes______gray scale ☐ No
Preferential specifications:
☐ Response time t_{on} ____ms (____°C) t_{off} ____ms (____°C)
☐ Viewing angle____deg. (____°C) ☐ Contrast____ (____°C)
☐ Others__________
LCD surface finishing:
☐ Normal ☐ Anti-glare ☐ ______
Polarizer color: ☐ Normal (neutral gray) ☐ Red
☐ Green ☐ Blue ☐ ______

8. Driving Method

Multiplexing:1/______duty, 1/______bias
Frame frequency: ______Hz

9. IC

LCD driver: ☐ Specified ☐ Unspecified
Segment driver______(Manufacturer______)
Common driver______(Manufacturer______)
Controller: ☐ Internal ☐ External
Type No______(Manufacturer______)
MPU: ☐ Internal ☐ External
Type No.______(Manufacturer______)
RAM: ☐ Internal ☐ External
Type No. /Memory size______(Kbit) (Manufacturer______)

10. Power Supply

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

11. Temperature Compensation Circuit

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

12. Current Consumption

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

13. Contrast Adjustment

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

14. Temperature Range

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

15. Input/Output Terminals

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

16. Weight

typ. ____g, max. ____g

17. Connector

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

18. Backlight

☐ Internal ☐ External ☐ Unnecessary
☐ EL: ☐ Green ☐ White ☐ ______
☐ LED: ☐ Yellow green ☐ Amber ☐ ______
☐ CFL: ☐ White ☐ ______
☐ Incandescent lamp ☐ Others______
☐ Backlight type ☐ Edge backlight type
Brightness:______cd/m²
Inverter: ☐ Internal ☐ External ☐ Unnecessary
Power supply voltage______V
Current consumption (backlight included)______mA
Brightness control: ☐ Yes ☐ No

19. Others

____
____
____

20. Schedule

Estimate: ______
Sample: Delivery______, Quantity:______pcs
Mass production: Target price: ______
Delivery ______, Total quantity: ______pcs
Quantity per month______pcs

CHECK LIST FOR CUSTOM DESIGNED LCD

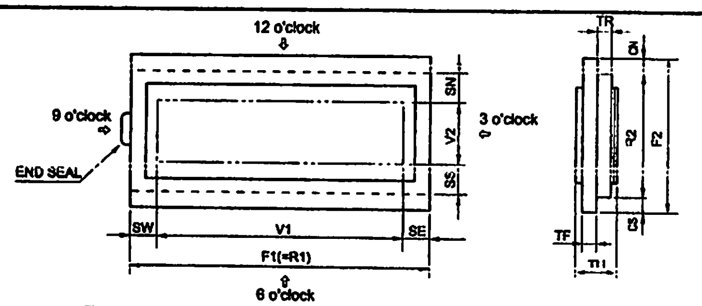
1. Company__________ 2. Application__________ 3. Customer Specified Part No.__________

4. Design

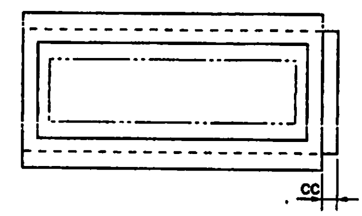
☐New ☐Modified: Manufacturer ________, Part No. ________, Remarks ________

☐Equivalent: Manufacturer ________, Part No. ________, Remarks ________

5. Panel Dimensions



- Type A (connection through conductive material) -



- Type B (direct common) -

F1: Horizontal length of upper glass ________ mm

F2: Vertical length of upper glass ________ mm

R1: Horizontal length of lower glass ____ the same as F1

R2*: Vertical length of lower glass ________ mm

*R2 is generally longer than F2 when terminals are with pin.

TF, TR***: Thickness of glass ________ mm

***Standard type: 1.1 mm or 0.7 mm

TU: Thickness of LCD ________ mm

End seal: ☐Right ☐Left ☐Right or Left

V1 :Horizontal length of viewing area ________ mm

V2 :Vertical length of viewing area ________ mm

CN**: Terminal length ________ mm

CS**:Terminal length ________ mm

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

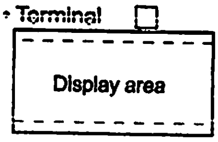
CC: Terminal length ________ mm

SE,SW,SN,SS : Seal width

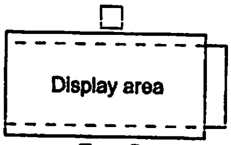
(According to design or manufacturing condition: about 2.0 mm to 4.0 mm)

6. Panel Form

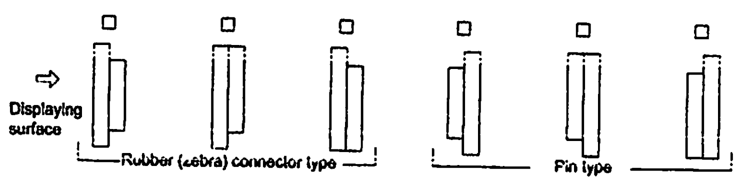
• Terminal

☐ 

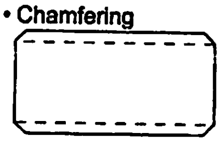
- Type A -

☐ 

- Type B -

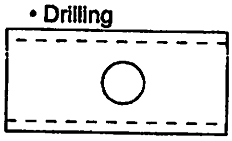


• Chamfering



☐ Yes ☐ No

• Drilling



☐ Yes ☐ No

7. Display Mode

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

Type: ☐TN ☐FSTN (Black and white)

☐STN: (☐ Yellow green ☐ Gray ☐ Blue)

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

☐Positive type ☐Negative type

☐Reflective ☐Transflective ☐Transmissive

Preferential specifications:

☐Response time t_{on} ___ ms (___ °C) t_{off} ___ ms (___ °C)

☐Viewing angle ___ deg. (___ °C) ☐Contrast ___ (___ °C)

☐Others

8. Polarizer

Surface finishing: ☐Normal ☐Anti-glare ☐________

Color: ☐Normal (neutral gray) ☐Red ☐Green ☐Blue ☐________

Front polarizer : ☐ Attached type ☐ Separate type

Rear polarizer : ☐ Attached type ☐ Separate type

9. Driving Method

☐Static ☐Multiplexing: (1/_____duty, 1/_____bias)

Operating voltage (V_{opr}) : ________ V

Frame frequency: ________ Hz

Driving IC: ________ (Manufacturer ________)

Current consumption: ________ µA

10. Temperature Range

Operating temperature range

☐With temperature compensation circuit (or volume)

(☐ 0°C to 50°C ☐______°C to______°C)

☐Without temperature compensation circuit

(☐ 0°C to 50°C ☐______°C to______°C)

Storage temperature range

(☐ - 20°C to 60°C ☐______°C to______°C)

11. Terminal Connecting Method

☐Rubber connector (Zebra rubber)

☐Pin: ☐DIL ☐SIL ☐________

Pitch (☐2.54 ☐______mm) Length (______mm)

☐Heat seal: ☐Equipped ☐Unnecessary

12. Others

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

Protective film:

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

Chamfering (for heat-seal connector) :

☐Yes (Position:_______)

(Quantity:_______)

☐No

13. Schedule

Estimate :________

Sample : Delivery________, Quantity :________ pcs

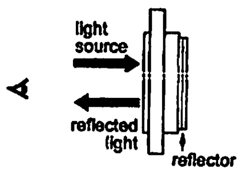
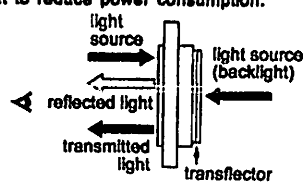
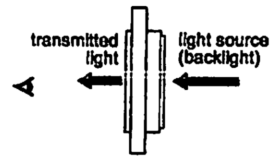
Mass production : Target price : ________

Delivery ________, Total quantity:________ pcs

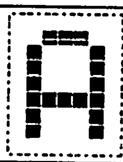
Quantity per month:________ pcs

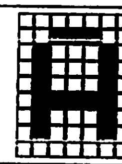
Liquid Crystal Display Modules

■ REFLECTIVE/TRANSFLECTIVE/TRANSMISSIVE LCD

❶ Reflective LCD	❷ Transflective LCD	❸ Transmissive LCD
Reflector bonded to the rear polarizer reflects the incoming ambient light. Low power consumption because no backlight is required. 	Transflector bonded to the rear polarizer reflects light from the front as well as enabling lights to pass through the back. Used with backlight off in bright light and with it on in low light to reduce power consumption. 	Without reflector or transflector bonded to the rear polarizer. Backlight required. Most common is transmissive negative image. 

■ POSITIVE/NEGATIVE MODE

Positive type	

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

■ TN TYPE/STN TYPE/FSTN TYPE

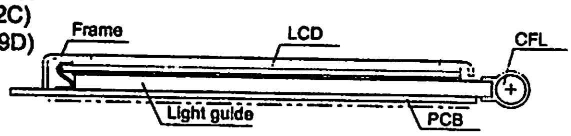
TN	(Background/dot color) Gray/Black	TN(Twisted Nematic) type is most conventional and economical. It is used for static drive LCD and low-duty drive LCD (watch,calculator, etc.)
STN	Yellowgreen/Dark blue Gray/Dark blue White/Blue	STN (Super Twisted Nematic) type has a higher twist angle, and thus provides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

■ STRUCTURE AND FEATURE OF LCD MODULE WITH BACKLIGHT

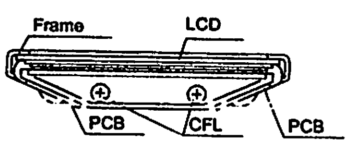
CFL (Cold Cathode Fluorescent Lamp) backlight

Features: high brightness, long service life, inverter requjred

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

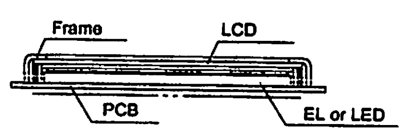


- Backlight type



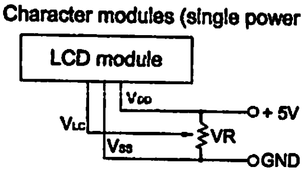
EL (Electroluminescent Lamp) backlight
LED (Light Emitting Diode) backlight

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

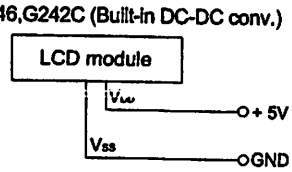


■ POWER SUPPLY

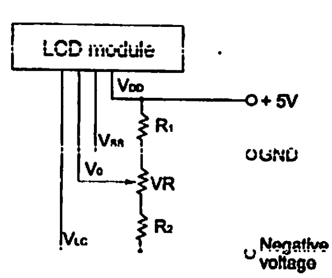
- Character modules (single power supply)



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

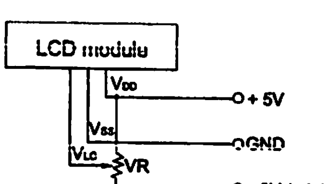


- G321D, G324E and G649D

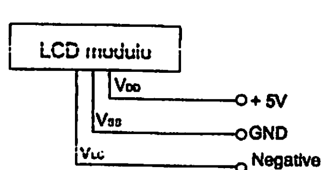


Note 1:Contrast can be adjusted by VR.
Note 2:For module with backlight, power supply for backlight is necessary.

- Character Modules(Dual power supply)



- Y1206 and G1226



*Negative voltage should be variable for contrast adjustment.

Precautions

Safety Instructions

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

Handling Precautions

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

Mounting and Designing

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

Cleaning

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

Storing

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

On This Brochure

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Notes :

Cranial Electrostim

Home | Up | Diagnosis | Causes
Genetics | Omega-3 | Exercise | Vitamins, Minerals
Bright Light | Medications | Diet | Other Therapies
Geriatric | Children & Teens | Minor Depression | Harm of Depression
Cranial Electrostim | rTMS & ECT

Pain Studies

I just became aware of this research in January, 2006, although I had seen mention of it very early in my career under the name of electro-sleep. Although it has been available for many years, Cranial Electrotherapy Stimulation (CES) is certainly not very popular, since I have never come across a single patient in my 30 year career using it in the four different states in which I have worked. However, the research looks acceptable and positive, although larger, higher quality studies would certainly help. It is true that many of the review articles and some of the published research are by the manufacturer. However, most of the depression double-blind studies appear independent of the manufacturer and the manufacturer has a sensible policy of assisting research by providing devices and a double-blinding apparatus to researchers totally independent from the manufacturer. The device costs $495 and operating costs add another $10 per month. I have bought five devices to try out as loaners to patients, but don't yet have any impression on patient reception.

TENS is somewhat similar to CES, although at somewhat higher levels of electricity. Electroacupuncture is also included here, since it appears much more effective than acupuncture, is quite different from acupuncture, and appears to be very similar to CES. In fact, the research findings on traditional acupuncture in high quality studies find that it is virtually worthless. For more, see acupuncture.

CES has been used for aggression, anxiety, depression, closed head injury, headache, fibromyalgia, and pain.

Cranial Electrostimulation Manufacturer Information: The manufacturer says that with the Alpha-Stim stimulator one out of 506 people will experience a mild headache, and one out of 910 will have a skin reaction at the electrode site. Usually a minor self-limiting reddening of the skin. There are no other significant side effects reported in over 55 research studies, or in 24 years of clinical and home use. The Alpha-Stim 100, Alpha-Stim PPM or Alpha-Stim SCS may effect the operation of cardiac pacemakers (particularly demand type pacemakers). Do not stimulate directly on the eyes, or over the carotid sinus (on the neck beside the larynx). Federal Law (USA only) restricts these devices to sale by, or on the order of a licensed health care practitioner. The Alpha Stim cost is $895. The Alpha-Stim SCS Stress Control System is $495. It is promoted for anxiety, depression, and insomnia. http://www.alpha-stim.com/Merchant2/merchant.mv Most CES devices limit the stimulus intensity to less than 1.0 milliampere at 0.5 or 100 Hz from a 9 volt source. Over the past three decades, at least eight medical device companies have applied for and received FDA clearance to market CES devices. They use a different waveform at a much lower current level than TENS units. The current up to a comfortable or subsensory level and leaves it at that level for 20 minutes to one hour for the treatment. Longer duration may be used to make up for lower current level. A note elsewhere states that it is contraindicated in pregnancy.

Cranial Electrotherapy Stimulation: Manufacturer's Review: According to the manufacturer, there are 26 published studies of patients with depression and measured physiological and/or psychological changes after CES treatment. Twenty-one of the 26 (81%) studies reported positive results for depression. The five CES studies which reported negative or indeterminate results were from the 1970s with CES devices that are no longer commercially available. Three studies showed both actual treatment and sham treated groups to improve significantly, most likely because both groups were also taking medications (Levitt, James, & Flavell, 1975; Marshall & Izard, 1974; Passini, Watson, & Herder, 1976). One study reported no significant change on anxiety or depression scales, but subjective insomnia improved (P < .05) during active treatment (Moore, Mellor, Standage, & Strong, 1975). Only one early CES study published over 30 years ago conducted on a population of insomniacs with an average duration of symptoms of nearly 20 years did not show any significant change at all in any parameters (Frankel, Buchbinder, & Snyder, 1973). In 22 CES studies from a meta-analyzes of 1,075 patients, the treatment effect size was 57% improvement when corrected for sample size (Kirsch & Smith, 2004). The mean effectiveness of CES above that of the placebo controls in the CES studies was 63%, vs. 23% for 8 DB PC studies using anti-depressant medication. Gilula, Marshall F, Kirsch, Daniel L Cranial electrotherapy stimulation review: a safer alternative to psychopharmaceuticals in the treatment of depression. *Journal of Neurotherapy*, 9(2):63-77, 2005.

Adverse Effects, According to Manufacturer: Adverse effects are usually mild and self-limiting. Adverse effects seen in approximately 4,541 patients in controlled, open, uncontrolled conditions, and by physician survey and reasonably associated with the use of CES are dizziness (6 cases, 0.13%), skin irritation/electrode burns (5 cases, 0.11%), and headaches (9 cases, 0.20%). Prolonged CES treatment at higher than necessary currents may cause dizziness or nausea that can last for hours to days. Treatment immediately prior to going to sleep may cause difficulty sleeping due to increased alertness. It is recommended that CES be used at least 3 hours before going to sleep. Paradoxical reactions such as hyperexcited states, increased anxiety, and sleep disturbances may occur. If the Alpha-Stim SCS does not control your anxiety, depression and/or insomnia within 3 weeks, discontinue use. While pregnancy is not a contraindication, safety during pregnancy has not been established.

Aggression: Cranial Electrotherapy Stimulation Might Help: Nine aggressive, retarded patients refractory to conventional care at a maximum security hospital were given a 3-month course of cranial electrotherapy stimulation, usually 45-60 minutes twice a day. Aggressive episodes declined 59% from baseline; seclusions were down 72%; restraints were down 58%; and use of prescribed-as-needed sedative medications decreased 53%. No patients discontinued cranial electrotherapy stimulation (CES) because of side effects. Cranial electrotherapy stimulation reduces aggression in a violent retarded population: a preliminary report. Childs A. North Texas State Hospital, Vernon, TX. allen.childs@dshs.state.tx.us. *J Neuropsychiatry Clin NeuroSci* 2005 Fall;17(4):548-51. Ed: This is a clinical, not a research report, since there were no controls, and no blinding.

Alcoholism: CES Helped Mood in Alcoholics, But Not Drinking: A recent controlled study in the treatment of opiate withdrawal has been positive. In a 4-week DB study of 64 alcoholic males, 30 minutes/day of cerebral electrical stimulation resulted in less weekend drinking and less depression and anxiety but no change in general drinking behavior when compared to a sham stimulation. Effects of cerebral electrical stimulation on alcoholism: a pilot study. Padjen AL, et al. Alcohol Research Program, Verdun, Que, Canada. *Alc Clin Exp Res* 1995 Aug;19(4):1004-10.

Alzheimer's: Cranial Electrostimulation No Benefit in 6 Week Study: In one study, behavioral disorders of patients with vascular dementia reacted positively to cranial electrostimulation (CES). In this DB sham controlled study of 18 probable Alzheimer's disease patients, 30 min per day, 5 days a week, for 6 weeks resulted in no improvements in cognition and (affective) behavior were found after CES. Cranial electrostimulation (CES) in patients with probable Alzheimer's disease. Scherder EJ, et al. Vrije Universiteit, Amsterdam, The Netherlands. eja.scherder@psy.vu.nl. *Behav Brain Res* 2002 Jan 22;128(2):215-7.

Anxiety: Cranial Electrotherapy Stimulation: Reported to Help During Dental Procedures: In a DB PC study of 33 dental patients, the active CES treatment group was significantly less anxious than the placebo group at the conclusion of various dental procedures. CES was used starting 5 minutes before the procedure and continued during the procedure. Cranial electrotherapy stimulation (CES): a safe and effective low cost means of anxiety control in a dental practice. Winick RL. *Gen Dent* 1999 Jan-Feb;47 (1):50-5.

Anxiety in Substance Abusers: Cranial Electrostimulation Reported to Helped: In a DB sham-controlled study of 40 inpatient alcohol and/or polydrug users with an additional 20 patients serving as normal hospital routine controls, CES-treated patients showed significantly greater improvement on all anxiety measures than did either control group. Cranial electrotherapy stimulation as a treatment for anxiety in chemically dependent persons. Schmitt R, et al. *Alcohol Clin Exp Res* 1986 Mar-Apr;10(2):158-60.

Closed Head Injury: Cranial Electrostimulation Claimed of Benefit: In an unreliable manufacter's DB sham controlled study of 15 closed-head-injured patients, cranial electrostimulation for 45 min daily, 4 days a week for 3 weeks, responded significantly on all negative mood factors of the Profile Of Mood States. While the majority of the patients were known seizure cases, no patient suffered a seizure during CES therapy. No placebo effects were found, nor were any negative effects from CES treatment seen. The use of cranial electrotherapy stimulation in the treatment of closed-head-injured patients. Smith RB, Tiberi A, Marshall J. MedTec 2000, Inc, Fort Worth, Texas. *Brain Inj* 1994 May-Jun;8(4):357-61. The manufacturer also separately reported that 5 multiple sclerosis patients had sent back manufacturer warranty cards reporting benefit.

Depression: Cranial Electrostimulation May Help But Manual Acupuncture Does Not: Seven randomized comparative trials involving 509 patients were analyzed. The evidence is inconsistent on whether manual acupuncture is superior to sham, and suggests that acupuncture was not superior to waiting list. Evidence suggests that the effect of electroacupuncture may not be significantly different from antidepressant medication, weighted mean difference -0.43(95% CI -5.61 to 4.76). There is inconclusive evidence on whether acupuncture has an additive effect when given as an adjunct to antidepressant drugs. The effectiveness of acupuncture for depression--a systematic review of randomised controlled trials. Mukaino Y, et al. Peninsula Medical School, Exeter, UK. mukaino@fukuoka-u.ac.jp. *Acupunc Med* 2005 Jun;23(2):70-6.

Depression and Fatigue: Electroacupunture and Acupuncture Reported to Help Hemodialysis Patients: In a 1-month random assignment study of 106 hemodialysis patients, acupressure 3 times per week led to significantly less fatigue, better sleep, and less depression as did Transcutaneous Electrical Acupoint Stimulation compared to controls with no difference between the two. Acupressure and Transcutaneous Electrical Acupoint Stimulation in improving fatigue, sleep quality and depression in hemodialysis patients. Tsay SL, et al. National Taipei College of Nursing, Taiwan, R.O.C. sltsay@ntcn.edu.tw. *Am J Chin Med* 2004;32(3):407-16.

Depression: Electroacupuncture Did as Well as Amitriptyline and Better for Anxiety: Electroacupuncture (EA) stimulation influences brain norepinephrine metabolism in experimental animals. Preliminary clinical research found that EA treatment is as effective as amitriptyline for patients with depression. In a 6-week DB PC study of 29 depressed inpatients with three groups: EA + placebo; amitriptyline; and EA + amitriptyline and in a following DB PC multicenter study of 241 inpatients with depression comparing electroacupuncture + placebo to amitriptyline, the results from both studies showed that the therapeutic efficacy of EA was equal to that of amitriptyline for depressive disorders ($P > 0.05$). Electro-acupuncture had a better therapeutic effect for anxiety somatization and cognitive process disturbance of depressed patients than amitriptyline ($P < 0.05$). The side effects of EA were much less ($P < 0.001$). Clinical research on the therapeutic effect of the electro-acupuncture treatment in patients with depression. Luo H, et al. Beijing Medical University, PR China. *Psychiatry Clin Neurosci* 1998 Dec;52 Suppl:S338-40.

Depression Studies: Cranial Electrotherapy Stimulation: CES studies reporting a significant reductions in clinical depression: Cox, A., & Heath, R. G. (1975). Neurotone therapy: A preliminary report of its effect on electrical activity of forebrain structures. *Diseases of the Nervous System, 36*, 245-247; Bianco, F., Jr. (1994). The efficacy of cranial electrotherapy stimulation (CES) for the relief of anxiety and depression among polysubstance abusers in chemical dependency treatment. Unpublished doctoral dissertation, The University of Tulsa; Philip, P., Demotes-Mainard, J., Bourgeois, M., & Vincent, J. D. (1991). Efficiency of transcranial electrostimulation on anxiety and insomnia symptoms during a washout period in depressed patients: A double-blind study. *Biological Psychiatry, 29*, 451-456; Rosenthal, S. H. (1972). Electrosleep: A double-blind clinical study. *Biological Psychiatry, 4*, 179-185; Feighner, J. P., Brown, S. L.,&Olivier, J. E. (1973). Electrosleep therapy: A controlled double-blind study. *Journal of Nervous and Mental Disorders, 157*, 121; McKenzie, R. E., Rosenthal, S. H., & Driessner, J. S. (1976). Some psychophysiologic effects of electrical transcranial stimulation (electrosleep). In N. L. Wulfsohn & A. Sances (Eds.), *The nervous system and electric currents* (pp. 163-167). New York:Plenum; Matteson, M. T., & Ivancevich, J. M. (1986). An exploratory investigation of CES as an employee stress management technique. *Journal of Health and Human Resource Administration, 9*, 93-109; Rosenthal, S. H., & Wulfsohn, N. L. (1970a). Studies of electrosleep with active and simulated treatment. *Current Therapeutic Research, 12* (3), 126-130. Rosenthal, S. H.,&Wulfsohn, N. L. (1970b). Electrosleep: A preliminary communication. *Journal of Nervous and Mental Disease, 151*, 146-151; Rosenthal, S. H. (1972). Electrosleep: A double-blind clinical study. *Biological Psychiatry, 4*, 179-185; Shealy, C. N., Cady, R. K., Wilkie, R. G., Cox, R., Liss, S., & Clossen,W. (1989). Depression: A diagnostic, neurochemical profile and therapy with cranial electrical stimulation (CES). *Journal of Neurological and Orthopaedic Medicine and Surgery, 10* (4), 319-321; Smith, R. B. (1999). Cranial electrotherapy stimulation in the treatment of stress related cognitive dysfunction with an eighteen month follow-up. *Journal of Cognitive Rehabilitation, 17* (6), 14-18. Smith, R. B.,&O'Neill, L. (1975). Electrosleep in the management of alcoholism. *Biological Psychiatry, 10* (6), 675-680).

Depression: Electroacupuncture Equal to Maprotiline in Poorly Controlled Study: In a randomized study of 61 depressed patients, electro-acupuncture on Baihui (GV20), Yintang (EX-HN3) and the differential points was compared to maprotiline. HAMD scores decreased for both groups without significant between-group differences ($P > 0.05$). Side-effects were higher for the anti-depressant. Clinical study on electro-acupuncture treatment for 30 cases of mental depression. Han C, et al. Beijing University of Traditional Chinese Medicine. *J Trad Chin Med* 2004 Sep;24(3):172-6.

Fibromyalgia: Cranial Electrotherapy Stimulation Reported to Help: in a double-blind crossover study examining the effect of cranial electrotherapy stimulation (CES) on the pain associated with fibromyalgia. Initially, 39 patients were randomly allocated to CES and 35 patients were allocated to a sham group. Measurements taken at baseline and after three weeks included pain intensity, McGill Pain Score, tenderpoint score, profile of mood states, and Oswestry Score. Three weeks after crossover, measurements were repeated. Significant CES effects were identified, revealing an improvement in pain intensity, McGill Score, tenderpoint score, and profile of mood states ($p<0.05$). The Effect of Cranial Electrotherapy Stimulation (CES) on Pain Associated with Fibromyalgia. Cook RC, et al. Louisiana State Univ. *Internet J Anesthesiol* 2004.

Headache: Cranial Electrostimulation Reportedly Helped Tension Headaches: In a DB sham controlled study a single 20 minute treatment of 100 patients with tension headaches with scores just before and after treatments, those using the Pain Suppressor Unit, a cranial electrotherapy stimulator using extremely low level, high frequency current applied transcranially, reported an average reduction in pain intensity of approximately 35%. Placebo patients reported a reduction of approximately 18% ($p = 0.01$). Both physicians and patients rated the stimulator as more effective than placebo ($p = 0.004$). Safety and effectiveness of cranial electrotherapy in the treatment of tension headache. Solomon S, et al. *Headache* 1989 Jul;29(7):445-50.

Mild Cognitive Impairment: TENS Reported Helped: Transcutaneous electrical nerve stimulation (TENS) has been applied to patients with either Alzheimer's disease (AD) or incipient dementia, resulting in an enhancement in memory and verbal fluency. Moreover, affective behavior was shown to improve. In a study of nondemented elderly with mild cognitive impairment living in a residential home, TENS resulted a mild improvement in self-efficacy and mood, while the placebo group showed a considerable reduction in self-efficacy and an increase in depression. Effects of transcutaneous electrical nerve stimulation (TENS) on self-efficacy and mood in elderly with mild cognitive impairment. Luijpen MW, et al. Vrije Universiteit, Amsterdam, the Netherlands. mw.luijpen@psy.vu.nl. *Neurorehabil Neural Repair* 2004 Sep;18(3):166-75.

Pain: Spinal Cord Injury Central Pain Helped: Using a very safe technique of non-invasive brain stimulation - transcranial direct current stimulation (tDCS) - on pain control in patients with central pain due to traumatic spinal cord injury, patients were randomized to receive sham or active motor tDCS (2mA, 20min for 5 consecutive days). There was a significant pain improvement after active anodal stimulation of the motor cortex, but not after sham stimulation. These results were not confounded by depression or anxiety changes. Cognitive performance was not significantly changed throughout the trial in both treatment groups. A sham-controlled, phase II trial of transcranial direct current stimulation for the treatment of central pain in traumatic spinal cord injury. Fregni F, et al. Harvard. *Pain* 2006 Mar 23.

Substance Abuse: Cranial Electrostimulation No Benefit: In a DB sham controlled study of 101 smokers trying to stop, cranial electrical stimulation on 5 consecutive days had no significant benefit on daily cigarettes smoked, exhaled carbon monoxide, urinary cotinine levels, treatment retention, smoking urges, or total tobacco withdrawal scores, although subjects in the CES group had less cigarette craving and anxiety during the first 2 experimental days. The ineffectiveness of CES to reduce withdrawal symptoms and facilitate smoking cessation are similar to results of other clinical studies of CES in drug dependence, although positive effects of CES in animal studies have been reported. Evaluation of cranial electrostimulation therapy on short-term smoking cessation. Pickworth WB, et al. National Institute on Drug Abuse, Addiction Research Center, Baltimore, Maryland. *Biol Psychiatry* 1997 Jul 15;42(2):116-21.

Schizophrenia: Electroacupuncture as an Add-On: In a DB study of 90 schizophrenia patients, electroacupuncture was added to clozapine and clozapine alone. The total effective rate was 75% with added electroacupunture and 73% with clozapine alone. However, somatic complaint was lower and compliance was higher in the EA group. Short-term curative effect of electroacupuncture as an adjunctive treatment on schizophrenia. Feng-Ju Y, et al. Second Affiliated Hospital of Xinxiang Medical College, Henan, China. yingyang@126.com. *Zhongguo Zhong Xi Yi He Za Zhi* 2006 Mar;26(3):253-5. Ed: Electroacupunture is very similar to Cranial Electrostimulation. It is easy and harmless. However, I can't tell if it had any beneficial effect in this study. It has been found helpful by itself for depression.

OBJECTIVE: To study effects of electroacupuncture at Jiaji (EX-B2) on protracted withdrawl syndrome of the patient of heroin dependence. METHODS: One hundred and twenty cases of heroin dependence were randomly divided into 4 groups: acupuncture group I (Jianji and Shenshu acupoints), acupuncture group II (acupoints at limbs), simulation group and control group. Protracted withdrawl syndrome scale, Hamilton anxiety scale (HAMA) and self-rating depression scale (SDS) were used to observe changes of the scores before and after treatment of 4, 8, 10 weeks. RESULTS: In the treatment of

4, 8, 10 weeks, the cumulative scores for protracted withdrawl syndrome, HAMA and SDS in the acupuncture group I and II decreased significantly as compared with those in the control group ($P < 0.01$). CONCLUSION: Electroacupuncture can significantly improve protracted withdrawl syndrome, alleviate anxiety and depression, and electroacupuncture at Jiaji (EX-B2) being better than at the acupoints of the limbs. Clinical study on electroacupuncture at Jiaji (EX-B2) for interfering protracted withdrawal syndrome in the patient of heroin dependence. Mu JP, et al. Yunyang Medical College, Hubei, China. mjpll@sohu.com. *Zhongguo Zhen Jiu* 2005 Sep;25(9):599-602.

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Frequently Asked Questions About CES (cranial electrical stimulation)

Q. What is CES?
CES, or cranial electrotherapy stimulation, is a non-pharmacologic approach using gentle electrical impulses for the prevention and treatment of depression, anxiety, and insomnia.

Q. How does it work?
The exact physiological mechanism by which CES works is not fully understood and is still the subject of research study. It is hypothesized, however, that CES acts by indirectly stimulating brain tissue in the hypothalamic area, causing the brain to manufacture various neurohormones and restoring them to pre-stress homeostasis.

Q. Is CES safe?
CES has an unblemished safety record. A broad reading of published literature on the subject shows no negative effects or major contraindications from its use, either in the U.S. or in other parts of the world. The National Research Council has deemed CES a non-significant risk modality.

The unit's sole source of current is a common nine volt battery. Its intensity is limited to 1.5 milliamps—no more than is required to run a small toy or a penlight. Even when turned to maximum intensity, it is not harmful. It is suggested, however, that until you become fully acclimated to the unit, you maintain the amplitude at a lower setting.

Q. How is the current transmitted?
The CES Ultra is powered by a nine volt battery. It utilizes pre-gelled electrodes that sit below each ear and snap on or attach to the end of a lead-wire that plugs into the jack of the unit. Another option is ear-clips fitted with felt or conductive rubber electrodes which attach to each earlobe.

Q. What is it like?
Most people find CES a pleasurable experience. The most you will ever feel is a gentle tingling sensation with the higher frequencies and a light-headedness with frequencies less than one hertz. If the sensation proves too strong, you can simply reduce it by a simple turn of the knob.

Increasing or decreasing the amplitude does not impair the efficacy of the treatment. Research shows CES to operate effectively at both lower and higher levels of stimulation as well as below the sensate threshold. A common approach is to turn the amplitude to the point of sensation, turn it down slightly below that point, and leave it there for the remainder of the session. Your own comfort level always dictates the amplitude.

Q. Is CES user-friendly?
Most CES units are easy to employ: (1.) Attach either the electrodes or the ear-clips. (2.) Insert the lead-wire into the jack. (3.) Turn the unit on. (4.) Set the timer and amplitude.

Q. Does CES work for everyone?
Nothing works for everyone. But CES is effective for most people.

Q. What immediate results can I expect?
Most people experience a response almost immediately after treatment, others, after several days. This relaxed but alert state will usually remain for an average of 12 to 72 hours after the first few sessions. With regular use it is possible for the patient to habituate to this preferred state of consciousness.

Q. How does CES affect sleep?
CES is positively indicated in the treatment of insomnia. Sleep patterns begin to normalize within the first day or two, with less and shorter periods of awakening during the night, faster onset of sleep after going to bed, and a greater feeling of being rested upon awakening in the morning. CES users often report an increase in vivid dreaming, resulting from compensation for lost REM sleep. As sleep patterns normalize-within the next two or three nights—it should become less frequent.

Q. What additional long-range changes should I expect?
Depression and mood swings become less frequent, as do irrational anger, irritability, and poor impulse control. Mental confusion due to stress begins to subside. The ability to focus and concentrate on work becomes easier and more efficient. Cognitive processing is visibly enhanced. As concentration and memory improve, recalling information and learning in an accelerated manner return to normal pre-stress levels.

Q. When should CES be used?
CES may be used on waking in the morning and/or on going to bed at night and/or during the day in particular situations. It can be used both as an adjunct to meditation each morning or during stressor moments occurring unexpectedly in the course of a day—those times when you "lose it." Using the unit in those situations—even for as little as ten minutes—can help curb that anxiety. In addition to activating actual bio-electrical changes, it serves as a reminder that you can be with yourself in a different way—a positive affirmation that you have the power to change your emotional state and are willing to create the time and the space to do so. Ultimately, each person finds for themselves how to best incorporate CES into their daily routine.

Q. Where can it be used?
Most CES units are portable, allowing its use just about anywhere and under a variety of circumstances, except those noted under the contraindications. You can use it at home while watching TV, doing the dishes, or at the office while poring over a report. But CES should be treated as more than an aside—one more task, squeezed in between others. It is an important reminder of the need for inner quiet. Though you need not interrupt your usual activity for CES, its results are generally enhanced by setting aside a special time for its use alone.

beta.google.com/group/Monroe-Institute-Hemi-Sync-Users

Q. What is the suggested length and frequency of treatment?
The recommended usage is 30-45 minutes once or twice daily for the first month. Once symptoms are reduced or eliminated entirely, the frequency may be reduced to two or three times weekly. Individuals undergoing psychiatric treatment or suffering from severe anxiety and extremes of compulsive behavior often benefit from more frequent and prolonged application.

When symptoms of depression or anxiety have lessened or disappeared, it is important to have continuous access to the unit as a tool for relapse prevention on an as-needed basis. It is helpful that you work closely with your physician/healthcare professional to determine the role CES plays in your overall treatment program.

Q. What is the difference between the two CES Ultra frequencies?
The CES Ultra has two different electrical frequencies: 100 Hz and 0.35 Hz. The frequency of choice is the 100 Hz which has the largest body of evidence as to efficacy. It may be used while engaging in other activities, providing a gentle and calming tingling sensation.

The 0.35 Hz setting operates at a lesser amplitude, generating very little actual sensation, but with a more subtle impact. The 100 Hz has so far proved to be the most effective configuration. Micro-frequencies, such as the 0.35 Hz, should be used after having first tried the 100 Hz and primarily when meditating or in a resting state.

Q. Are there any contraindications for its use?
There are no known contraindications for use of CES. There are, however, circumstances in which its safety has not been tested. CES should not be used without on-going clinical supervision by severe depressives, epileptics, those known to be pregnant, or by individuals with implanted electronic devices such as cardiac pacemakers or insulin pumps. The induced relaxation response, resulting from use of CES does not in any way impair reaction time. It is recommended, however, that CES not be used while operating dangerous or complex equipment or while driving.

Less than three percent of CES users report a slight headache. This is usually alleviated by simply down turning the current. If the headache recurs during ordinary use, cease using the unit and consult with your physician.

As with the use of any medical device, the physician/licensed practitioner should be informed of any medication or neurotransmitter blockers the patient is taking as well as the employment of cardiac pacemakers or other electronic devices as mentioned above.

CES is not a substitute for professional counseling, meditation, or constructive relationships. Used in conjunction with those efforts, CES assists you in attaining a balanced emotional state.

Q. What is the history of CES?
Research on what is now referred to as CES began in the former Soviet Union during the 1950's, its primary focus being the treatment of sleep disorders, hence its initial designation as "electro-sleep." Treatment of insomnia was soon overshadowed, however, by psychiatric application for depression and anxiety. Since then, it has been referred to by many other names, the most popular being "transcranial electrotherapy" (TCET) and "neuroelectric therapy" (NET).

East European nations soon picked up CES as a treatment modality, and its use spread worldwide. By the late 1960's, animal studies of CES had begun in the United States at the University of Tennessee and what is now the University of Wisconsin Medical school. These were soon followed by human clinical trials at the University of Texas Medical school in San Antonio and the University of Wisconsin Medical School. More studies followed.

CES has been an international treatment modality for more than 50 years. Thousands of people worldwide continue to receive its benefits. The most extensive work on CES is presently being conducted at the Pavlov Institute in St. Petersburg, Russia. But by no means is its use restricted to that part of the world. Current estimates are that there are between 50-100,000 units in use globally.

Q. What research is there as to its effectiveness?
There are approximately 1,000 articles on CES therapy many of which are listed in four reviews put out by the Foreign Service Bulletin of the United States Library of Congress. This is in addition to the wealth of physiological and bio-engineering data on electro-sleep and electro-anesthesia, including 18 experimental animal studies. Human research studies on CES currently number more than 100. Its efficacy has been clinically confirmed through 28 established psychometric tests s, computerized EEGs and topographical brain-mapping. Meta-analyses yielding positive results from the use of CES have been conducted at the University of Tulsa and at the Harvard University School of Public Health.

Q. What is the current legal status of CES?
CES is an over-the-counter device, available without a prescription and with few restrictions everywhere in the world except for the United States. There it may be secured only on the order of a licensed health care practitioner (M.D., N.D., D.O., PhD. Psychologist, or Chiropractor, depending on a given state's regulations).

Q. Why haven't I heard more about CES?
CES has been a relative unknown and under-deployed technology due to the fundamental Western bias on behalf of pharmaceuticals. Within the last ten years, we have come to better understand the connection between brain function, neurotransmitters, and electrical stimulation. As our knowledge of this area grows and new research findings emerge, so too will the popularity and increased usage of CES.

Q. What distinguishes the CES Ultra from other CES units?
The most significant research on CES is based on the traditional 100Hz; a much smaller portion on micro frequencies—those less than one Hz. The CES Ultra is currently the only unit on the market featuring both. Other units may claim to carry the 100Hz. but do not have an accurate rendition of the configuration on which most of the research is based.

There are also certain "underground" instruments on the market, many of which can be found on the Internet. Contrary to their oft-stated anecdotal claims, most have no scientific evidence behind them. Many are nothing more than low-cost pulse generators of dubious quality, and have not been fully evaluated for either efficacy or safety. They are not registered with the FDA. Often billing themselves as "for research purposes only," they do not have permission to present themselves as "medical devices" or make any medical claims.

[v] Make

US residents $300

CES Ultra Home Page | CES Ultra RX Form | FAQs
CES Ultra Professional Use | Users Manual & Articles About CES | CES Ultra Complete System & Specs.

Mental Fitness
Detailed Info on how to succeed with neurotechnology

? **Electrical-Stimulation** Info on CES (Cranial Electrical Stimulation for mood, IQ, addictions), TENS (for pain), Blood Purification, etc.

? **Magnetan** Pocket-sized pulsed magnetic field for pain, mood, sleep, and more

? **CES Ultra:** Multi-use CES, TENS and more. Enhances Relaxed Awareness, Cognitive Functioning, Memory, I.Q.

? **BT7 BioTuner:** The famous Beck Black Box for addictions, depression, IQ

? **NeuroTrek:** Advanced Digital CES. The ultimate in Cranial Electrical Stimulation, More control of frequencies for neurotransmitter balancing, endorphin release, deep relaxation, sleep, IQ gains, and more.

? **Oasis:** Miniature multipurpose microcurrent CES synchronized to pulsing lights and sounds!

? **Zappers:** Electrical and magnetic stimulation for parasite elimination thru blood purification.

Light & Sound Mind Machines
Instant meditation, stress reduction, accelerated learning:

? **PROTEUS: All the Orion programs and features with advanced PC link and BiColor lights!**

? **A.D.D. & Learning Disorders**

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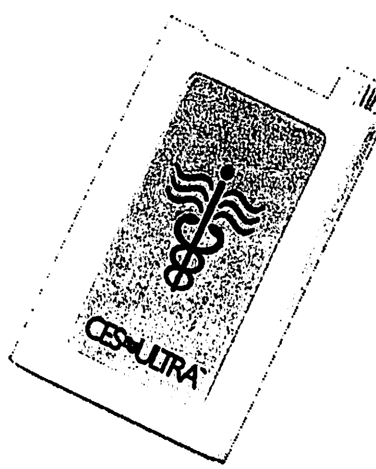
CES Ultra: Useful for Anxiety, Depression, Insomnia, Addiction.

Enhances Relaxed Awareness, Cognitive Function, Mental Performance, Memory, I.Q.
Reduces tension
Elevates mood
Normalizes sleep patterns
No serious negative side effects
Easy to use, compact, and portable
A fraction of the cost of prescription drugs



Stress is our nation?s #1 health problem. It is the source of the anxiety, depression, and insomnia plaguing millions of Americans. Stress accounts for more than two-thirds of family doctor visits and is an important risk factor in all major illnesses. Left unchecked, it is a killer.

There are many ways to manage stress. Among the most popular is altering brain chemistry through the use of pharmaceuticals. This approach is not without its problems however, including negative side effects and cost.

Now there is CES, (cranial electrotherapy stimulation). Employing mild electrical stimulation, CES helps restore emotional balance, for optimum pre-stress functioning in a safe, non-addictive, and affordable manner.

We have found a wonderful estim device that can perform many functions at a great price:

- CES for relaxation, anxiety, meditation (similar to Brain Tuner/Black Box using a high frequency carrier wave for rich harmonics)
- BioTuning (balancing neurotransmitters like acupuncture)
- Relieve tension and promote healing of other areas

It comes with a carrying case, earclips and reusable electrodes, instructions, and 9 volt battery.

The CES Ultra has FDA registration as a cranial electrotherapy stimulator, a device that applies electrical current to the head to treat insomnia, depression, or anxiety.
See FDA Part 882—Neurological Devices Subpart F—Neurological Therapeutic Devices Sec. 882.5800

CES Ultra Cranial Electrical Stimulator

The CES Ultra is a CES instrument (cranial electrotherapy stimulator) that offers a non-drug therapy for the treatment of ANXIETY, DEPRESSION and INSOMNIA. CES has been used in numerous countries around the world for over 30 years. It involves the application of mild microcurrent electrical impulses to the head via electrodes applied behind the ears or by means of ear-clip electrodes

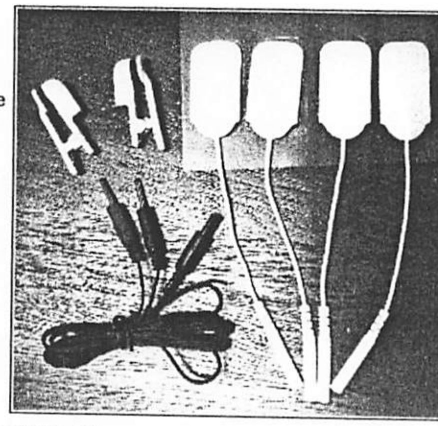
CES should be used under direction of a licensed health care practitioner. Individual results will vary, but many patients report significant improvement of their Stress-Related Symptoms over a period of 2 to 3 weeks daily use. Following the initial series of CES Ultra applications, the device may be used on occasion as needed to maintain the achieved level of improvements. Normally, CES is used Once or Twice Daily for 30 minutes per session, or longer if desired.

Electrode Selection

The CES Ultra offers three types of electrodes: a pair of comfortable Ear Clip Electrodes, a set of Self-Adhesive electrodes and a pin-connector leadwire for use with variable size electrodes. Most CES applications will use the earclip electrodes.

CES Ultra includes:

- Pulse repetition rate - 100 Hz.
- Timers - 30 min., 45 min. or continuous
- Battery - 9v. alkaline approx. 20 hours use
- Low Battery indicator Led
- Convenient ear-clip electrodes
- 4 Self-adhesive electrodes (wet to reuse)
- 2 cable sets with 2mm pin connectors suitable for a variety of electrodes
- Sturdy carrying and storage case
- One year warranty for repair or replacement
- 30 day return privilege (less 15% restock fee).



BUY NOW CES Ultra $295. *Free S&H in US and Canada*
Call or email for specials and/or used
BUY NOW 4 Adhesive electrodes $10. **(for 2mm pins)**
BUY NOW Earclip set $10. **(for 2mm pins)**
BUY NOW Cables $10. **(with 2mm pins)**

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The suggested retail of the CES Ultra is below that of other popular C.E.S. machines, such as the Alpl Stim and Brain Tuner. Unlike The Brain Tuner, the CES Ultra is backed by extensive scientific researc fact, the CES Ultra is the only unit on the market that has the original 100 Hz. configuration upon whi most of this research is based.

Braverman, E, Smith, R., Smayda, R, and Blum, K. Modification of P300 amplitude and other electrophysiological parameters of drug abuse by cranial electrical stimulation. Current Therapeutic Research. 48(4):586596, 1990.

Device: 100 Hz, 20% duty cycle, 1.0 mA, no dc bias, square waves, electrodes at left wrist and forehead

Electrophysiological abnormalities are said to be hallmarks of the high risk individual for drug abuse and the drug abuser. P300 waves occur 300 mS after a cognitive auditory potential and have been shown to have a reduced amplitude in many alcoholics, which does not revert to normal even after continued abstinence. Earlier research has concluded that the need to modify these electrophysiological parameters could be of critical importance in the treatment and possibly the prevention of drug abuse. In this study 13 alcohol and/or drug abusers (9 - 81 years old, mean of 43.44) and 2 staff controls were selected as they entered the clinic for brain electrical activity mapping (BEAM, a computerized EEG). After providing informed consent, all were given 40 minutes of CES between preand postCES BEAM scans. There was no significant changes in the controls. Following CES the pts P300 amplitude increased significantly ($P<.05$) as analyzed by Fisher test of probability which compared the differences between the means and variances. The time went from a pretreatment of 308 24 to 317 26 msec post treatment. The amplitude (dV) went from pretreatment of 7.0 4.1 to 9.9 6.0 post treatment. Also, there were significant positive shifts in alpha, delta, theta and beta spectra in patients who were abnormal in one or more of these areas prior to CES treatment. It was concluded that CES might be a significant nondrug treatment for the underlying electrophysiological disorder of the drug abuser, because the normalization of these electrophysiological parameters are characteristic of pharmaceutical treatment. The authors concluded that they believe the future is bright for prescriptive electricity, and that the electrophysiological changes that occur as a result of CES have the greatest implication for American's # 1 health problem, drug abuse. No side effects were reported.

CES Ultra Primary Specifications

Frequency: 100 Hz.

Power Source: 9V Battery (Incl.)

Amplitude: 10-1500 micro amps (continuously adjustable)

Wave Shape: Modified Sinusoidal

Waveform: Bipolar asymmetric rectangular

Duty Cycle: 50%

Pulse Duration: 2 milliseconds (20% duty cycle)

Timer Control: 30 min. & 45 min.

Complete Kit Contains:

CES Ultra control unit

Battery – 9v. alkaline approx. 20 hours use

Low Battery indicator Led

Convenient ear-clip electrodes

Self-adhesive electrodes

2 cable sets with 2mm pin connectors suitable for a variety of electrodes

Sturdy carrying and storage case

E-Stim
NeuroTrek Digital CES

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Alpha-Stim® 100 Product Information

Alpha-Stim® 100
MICROCURRENT STIMULATOR

FREEDOM FROM PAIN... OF THE BODY & MIND

Nothing relieves pain and enhances the quality of your life as easily, effectively, and safely as the Alpha-Stim 100; a sophisticated bioelectric therapy device. Alpha-Stim 100 represents a revolution in the treatment of the body & mind based on recent advances in our understanding of biophysics.

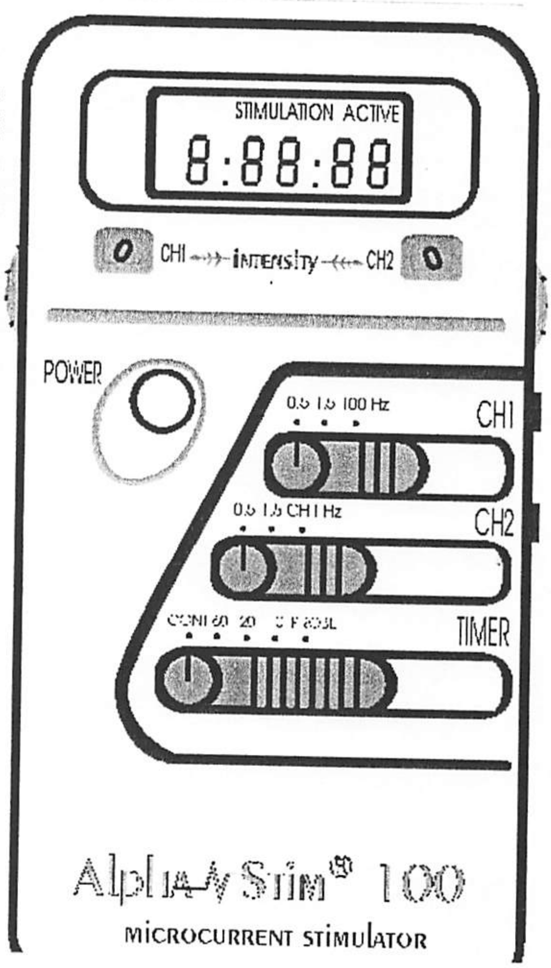
"Without exception, in every case there was a positive effect in decreasing pain... the longevity of the results was especially encouraging."
William Bauer, M.D.
Archives of Otolaryngology

"The ten minute treatment brings immediate, dramatic relief that lasts at least eight hours. And unlike morphine, Alpha-Stim leaves the patient alert."
Eric Mishara
Omni Magazine

THERE ARE OTHER WAYS TO RELIEVE PAIN, BUT THERE ARE NO BETTER WAYS.

ALPHA-STIM TECHNOLOGY

The Alpha-Stim 100 is a microcurrent electromedical device classified as a transcutaneous electrical nerve stimulator (TENS). Results in electromedicine are based on the design and quality of the waveform, the intensity of current used, the time it is applied and the location of the electrodes. The Alpha-Stim 100 is a precision medical instrument which generates low intensity electrical currents up to 600 millionths of an ampere (600 microAmperes) in modified square waves of variable frequencies and current levels. It is the fourth generation of Alpha-Stim technology which was first introduced in 1981. The Alpha-Stim 100 actually has four waveform generators; two for each channel to provide a unique blend of therapeutic frequencies and to add random factors to avoid accomodation by the nervous system. The Alpha-Stim 100 is a microcomputer incorporating the latest advances in solid state electronics. All components are of the highest quality available to assure the ultimate in reliable and trouble-free performance. The output is accurate within 1% under all operating conditions. The instrument's design assures electrical safety by the use of readily available 9 volt batteries.



The Alpha-Stim 100 is attractively designed. Although it is compact and light-weight it offers many of the features found in clinical units costing thousands of dollars more. An adjustable interval timer assures the prescribed treatment time even for those who are distracted or fall asleep. The amount of current can be easily modified for maximum comfort and effectiveness. The frequencies can be selected at either the standard recommendation of 0.5 Hz, or 1.5 Hz or 100 Hz. One of the most important features found in the Alpha-Stim 100 is an electronic circuit that operates to maintain a nearly constant current to the electrodes, minimizing the effects of electrode resistance variations due to poor electrode-to-skin contact and environmental factors.

ELECTROMEDICINE: THE OTHER SIDE OF PHYSIOLOGY

Western drug medicine limits itself to our understanding of chemistry to heal and control pain. Microcurrent electrical therapy (MET) is distinct in that it is based on the concept that the biophysics underlying the chemistry also plays a significant role in regulating all of life's processes. Using waveforms at a level of current similar to the body's own, MET bridges cellular communications reestablishing the normal electrical flow. The concept of a bioelectrical control system is common to every form of healing ever developed in recorded history except drug medicine. The Chinese named bioelectricity *ch'i*, the Japanese called it *ki*, and the Indians referred to it as *prana*. The Russians spoke of the same thing under the name *bioplasma*. All doctors in every discipline are taught that there are about *75 trillion* cells in a human body, each one having an electrical potential across its cell membrane, just like a battery. It is amazing that Western physiology books do not even bother to speculate on the staggering significance of these facts. Western medicine acknowledges a limited concept of *homeostasis*, defined as a tendency to uniformity or stability. Unfortunately it does not yet fully appreciate the natural healing powers of the body or the bioelectrical systems that control them. In our most rudimentary education we were taught that chemicals can be broken down into elements, then atoms and subatomic particles such as electrons. The Alpha-Stim 100 works by moving electrons through the body at a variety of frequencies. By using two frequency generators per channel the Alpha-Stim 100 actually uses a very broad band of frequencies collectively know as *harmonic resonance*. This insures that the right frequency will be delivered to reestablish homeostasis within the bioelectrical system. The other frequencies pass harmlessly.

Two contemporary scientists have proposed new comprehensive models to explain how our physiology is controlled by bioelectrical control systems. Robert O. Becker, M.D. of New York has done over 30 years of research and concluded that all biological systems have a primitive direct current electrical extraneuronal analog data transmission and control system to regulate all life's processes. Dr. Becker was able to test his theories by studying regeneration. Using low level electrical currents, he completely regenerated frogs limbs and achieved partial regeneration in rats. His book, *The Body Electric: Electromagnetism and the Foundation of Life* (William Morrow and Co., New York, 1985) is the most important book in electromedicine. It includes a fascinating history of the development of science as it relates to the constant struggle between those who prefer to believe we have a "*vital*" life force and those who insist that we are just a collection of chemicals without a soul. Bjorn Nordenstrom, M.D. is another leading pioneer in electromedicine. Dr. Nordenstrom who recently served as Chairman of the Nobel Assembly, proposed a theory that a controlling bioelectrical system is closely integrated both structurally and functionally with the circulatory system. Dr. Nordenstrom successfully treated terminal patients at the prestigious Karolinska Institute in Sweden to prove his theories. His complete paradigm, including the experimental proof is published in his book, *Biologically Closed Electrical Circuits: Clinical, Experimental and Theoretical Evidence for an Additional Circulatory System* (Nordic Medical Publishers, Stockholm, 1983).

WHAT TO EXPECT

Many people will experience results during or directly following the very first treatment. Some will not achieve an effect until the morning following treatment. Others may require five to seven or more sessions before the effects will be noticed. If there is no change after ten treatments, and several electrode placement sites have been tried, the use of the Alpha-Stim 100 should be reevaluated. Although a slight tingling sensation is sometimes felt under the electrodes, it is not necessary to feel this in order to achieve results. Most people feel nothing at all except positive results. The current should never be raised to a level that is uncomfortable. Alpha-Stim treatment often leaves the user feeling relaxed, but, unlike with drugs, the mind remains alert. Frequently people report an increase in their energy level. For people who are having trouble falling asleep, Alpha-Stim should be used at least three hours before going to bed or the increased alertness may prevent sleep.

INDICATIONS

Microcurrent electrical therapy (MET) is continuously being subjected to rigorous study and evaluation by the international medical community. Findings to date indicate that the Alpha-Stim 100 is an effective treatment with broad applications for a variety of syndromes involving pain. In many cases it is the sole therapeutic method required. Effective results have been seen during and/or subsequent to stimulation over effected body parts, adjacent areas, and even areas removed from those in pain. As with any therapeutic intervention, not all patients will respond to the Alpha-Stim 100. The degree of efficacy will vary with the nature of the problem being treated and with the method of treatment. Accordingly, a trial evaluation is recommended on each patient to determine the best possible electrode location and to ascertain the long-term benefits of treatment.

The risk/reward ratio for the Alpha-Stim 100 ranks exceedingly high when compared to pharmacological management and other brands of TENS. Typically, one 10 to 20 minute treatment session *every other day* is sufficient to manage the conditions for the Alpha-Stim 100 is prescribed. However, some people will benefit from more (or less) treatment time. The Alpha-Stim 100 is safe enough to be used continuously if necessary

CONTRAINDICATIONS

No contraindications have been established.

PRECAUTIONS

For external use only. The Alpha-Stim 100 may affect the operation of cardiac pacemakers particularly demand type pacemakers; it is not recommended for use by these patients. Do not stimulate directly on the eyes. Do not stimulate directly over the carotid sinus (upper side of neck). Do not allow children to use or handle this device without adult supervision. Do not operate potentially dangerous machinery or motor vehicles during periods of stimulation. Safety of stimulation has not been established during pregnancy. Caution is advised in cases where other forms of analgesia would not be used; such as to retain the beneficial aspects of pain for diagnosis or in cases where patients may overuse pain-controlled areas. Use only for the purpose for which it is prescribed.

ADVERSE EFFECTS

No clear documentation of adverse effects exists to date. No death or serious injury has ever been reported following the use of the Alpha-Stim or any other TENS. The most common area of concern is skin reactions at the electrode sites. To minimize this problem, clean the skin prior to use. Cleaning the skin will also assure better electrode contact. If skin irritation occurs, consult your physician.

!!! CAUTION !!!

The United States Food and Drug Administration (FDA) restricts this device to sale by or on the order of a licensed health care practitioner. The Alpha-Stim 100 is available throughout the rest of the free world without a prescription.

TECHNICAL SPECIFICATIONS

Alpha-Stim 100

Height	5.3 inches
Width	2.5 inches
Depth	1.3 in. with belt clip
Weight	5.5 oz. with battery

Carrying Case (included) Height 8.2 inches Width 10.6 inches Depth 1.8 inches Weight 2.0 lbs. complete

ELECTRICAL

Power Source:
One 9 volt battery
Timer Settings:
Probe: 10 seconds on alternating with 2 seconds off; 10, 20 & 60 minutes; & continuous
Current (intensity):
10 to 600 microAmperes continuously adjustable.
Frequency:
0.5, 1.5, & 100 Hz

ONE BUTTON OPERATION FEATURE

The Alpha-Stim 100 is extremely user friendly. Once set, it can be used at the touch of one button. Details in Owner's Manual.

ACCESSORIES

The Alpha-Stim 100 is packaged complete with one set of 4 self-adhesive silver/silver-chloride electrodes (good for approximately one month of use), electrode wires, one probe, a 9 volt alkaline battery and illustrated Owner's Manual. This is everything necessary to begin to use the Alpha-Stim 100 right away.

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How Ion-Selective Electrodes Work

Click here for a printer-friendly **MS Word 97** version

Some Basics

There are two different types of Electrical Conductivity:

1) In **Metals** the electric current is carried by **Electrons**.

2) In **Liquids** the electric current is carried by **Ions**

Every Electrochemical Process (Galvanic Cell, Electrolysis, Electro-Analysis) involves both these types of conductivity. The junctions where they meet and transfer the electrical charge are referred to as Metal-Liquid Interfaces. These interfaces were originally called Electrodes, but now this term is also used for various other devices such as welding electrodes or electro-cardiogram electrodes.

At the Metal-Liquid interface there is an exchange of Electrons in one or other direction (details can be found in standard chemistry text books, in sections on Galvanic or Electrolytic Cells.

(NB: Galvanic [Voltaic] Cells generate electricity; Electrolytic Cells consume electricity).

For example, in a Copper-Silver Galvanic Cell, on one electrode an Oxidation reaction takes place:

Cu (metallic) → Cu 2+ (ionic, in solution) +2 e-

on the other electrode a Reduction reaction takes place:

Ag+ (ionic, from solution) + e- → Ag (metallic - deposited on electrode surface)

This explains how the electric current in the wire (Electrons) becomes a current in the liquid (Ions).

The Electrochemical Circuit for an Ion Selective Electrode measurement.

An ISE (with its own internal reference electrode - more details later) is immersed in an aqueous solution containing the ions to be measured, together with a separate, external reference electrode. (NB: this external reference can be completely separate or incorporated in the body of the ISE to form a Combination Electrode.) The electrochemical circuit is completed by connecting the electrodes to a sensitive milli-volt meter using special low-noise cables and connectors. A potential difference is developed across the ISE membrane when the target ions diffuse through from the high concentration side to the lower concentration side (a detailed description follows later).

Figure adapted from that by Wojciech Wroblewski at CSRG, University of Warsaw, Poland.

(Copied from http://www.ch.pw.edu.pl/~dybko/csrg/tutorials/ise/index.html)

General principle of ISE analysis

At equilibrium, the membrane potential is mainly dependent on the concentration of the target ion outside the membrane and is described by the Nernst equation (see Glossary at www.nico2000.net). Briefly, the measured voltage is proportional to the Logarithm of the concentration, and the sensitivity of the electrode is expressed as the electrode Slope - in millivolts per decade of concentration. Thus the electrodes can be calibrated by measuring the voltage in solutions containing, for example, 10ppm and 100ppm of the target ion, and the Slope will be the slope of the (straight) calibration line drawn on a graph of mV versus Log concentration.
i.e. S = [mV(100ppm) - mV(10ppm)] / [Log100 - Log10]
Thus the slope simply equals the difference in the voltages - since Log100-Log10 = 1.
Unknown samples can then be determined by measuring the voltage and plotting the result on the calibration graph.

The exact value of the slope can be used as an indication of the proper functioning of an ISE and the following are typical values:
Monovalent: Cations +55 ± 5, Anions -55 ± 5. Divalent: Cations +26 ± 3, Anions -26 ± 3.

The Function of the Reference Electrode

The membrane potential cannot be measured directly. It needs a Metal-Liquid interface (or a metal-solid solution interface in modern "all-solid-state" ISEs) on both sides of the membrane. Theoretically these could just be metal wires immersed in the solutions. But the electrical potential on many simple metal-liquid junctions is not stable; thus the need for a so-called reference system on both sides of the ISE membrane, with a particular metal-liquid interface which is known to have a stable potential. The magnitude of this potential need not be known because it is the same for all measurements of standards and samples and is thus eliminated during the calibration process.

Nevertheless, it must be noted that this potential, plus any others that may be generated at any or all of the metal-liquid or liquid-liquid junctions in the circuit, is the value which is seen when the electrodes are immersed in pure water or any other solution which does not contain the target ion. This explains why the measured voltage is not expected to be zero when no target ion is present and also why it is not necessarily always positive when the target ion is present - it all depends on the difference between the ISE voltage and the sum of all the other voltages in the circuit. For example, for a monovalent positive ion, the voltage could be -25 mV in 10ppm and +30mV in 100ppm (or even -60 mV in 10ppm and -5mV in 100ppm) but this still gives a slope of +55mV per decade of concentration and indicates that the ISE is functioning correctly. Reversing the charges above would describe the situation for a monovalent negative ion.

It should be noted here that immersion in pure water should be avoided because it tends to leach out the target ion from the ISE membrane. This, together with the inherent instability of the liquid junction potential of the reference electrode, will cause an unstable voltage to be measured in pure water and require the ISE membrane to be re-equilibrated in a high concentration "pre-conditioning" solution before it will give stable readings again.

In practice, the most common reference system is a silver wire coated with solid silver chloride and immersed in a concentrated solution (known as the "filling solution") of potassium chloride saturated with silver chloride. The reference electrode is a half-cell that provides a constant potential which is dependent only on the concentration of chloride ions in the filling solution. The reversible Redox reaction involves the chloride atoms in the solid silver chloride (plated on the silver wire) receiving an electron and the chloride ion going into solution, and vice versa. This electrode will give a constant potential of +205 mV (relative to the Standard Hydrogen Electrode) with a saturated KCl/AgCl solution at 25°C.

Electrochemical Processes in the Membrane of an ISE

There are various different charge-transfer processes, both outside and inside the membrane for the various different membrane types, and many of these are highly complex and poorly understood in detail. For example, even the apparently simple glass membrane of a pH electrode, which has traditionally been thought of as involving the passage of Hydrogen (H+), or possibly hydroxonium (H_3O+) ions, has recently been shown, by radioactive tagging experiments, to involve only the movement of Sodium (Na+) ions !

The following descriptions of the Calcium and Fluoride ISEs are typical examples of the basic principles of ion-selective membrane processes. Nevertheless, it must be noted that these processes may be far more complex than those described and may involve several layers of ions at each phase junction.

Principle of Operation of the Calcium ISE

A Calcium ISE has a PVC membrane which is impregnated with an organic molecule which selectively binds and transports Ca2+ ions, and contains an internal solution with a fixed concentration of calcium chloride - added to the KCl / AgCl solution of the internal reference system. (Note that in modern all-solid-state ISEs the internal "solution" is in a solid form). Initially when this electrode is immersed in a sample solution containing Ca2+ ions, the potential difference across the membrane is zero - because there are, on both sides of the membrane, solutions where the electrical charges are balanced (i.e. they contain equal numbers of cations and anions). But very soon after immersion, calcium ions will start to diffuse across the membrane, from the side with the higher calcium concentration to the side with the lower calcium concentration. (NB: for the purposes of this explanation it is convenient to assume that the flow of ions is from the test solution into the ISE.)

As the positive calcium ions are transported across the membrane by the diffusion pressure, there is a build up of positive charge (cations) on the inside of the membrane and a corresponding increase in negative charge (anions) outside. These charges on the membrane surface mean that an electrical potential difference is established across the membrane. This potential difference causes the calcium ion migration to slow down and finally stop when the diffusion pressure due to the difference in concentration is exactly balanced by the electric field effects due to the fact that similarly charged particles repel one another. The potential difference at equilibrium is called the membrane potential.

Inside the ISE, the build up of positive charge at the membrane surface causes silver ions in the internal reference system to lose their charge (by receiving electrons from the silver wire) and be deposited on the wire. Thus electrons are drawn through the external wiring from the meter and thence from the external reference electrode. Here, chloride ions are attracted to the silver chloride-coated wire and give up their electrons by combining with silver atoms in the wire, and potassium ions flow out into the sample solution through the porous frit (labelled liquid junction in the diagram) to compensate for the positive charge deficiency caused by the loss of calcium.

At equilibrium, the electron flow ceases, i.e. there is no current, - but there are residual voltage differences at each metal-liquid, solid-liquid, solid-solid and liquid-liquid junction - in addition to the membrane potential and the reference electrode stable voltage. The measured potential difference, (in millivolts) is the sum of all these potentials. In theory, during calibration with standard solutions of known concentration, and during sample measurement, only the membrane potential is changed so that the other voltages can be ignored. In practice some of these vary a little - particularly at the porous frit (liquid junction) of the reference electrode - and are one of the sources of error in ISE measurements.

Principle of Operation of the Fluoride ISE.

In the case of the F ISE, the ion-selective membrane is a single crystal of Lanthanum Fluoride (LaF_3) doped with Europium Fluoride (EuF_2) which produces holes in the crystal lattice through which F ions can pass. When immersed in a fluoride solution and connected via a voltmeter to an AgCl/KCl external reference electrode immersed in the same solution, the negative F ions in the solution pass through the crystal membrane by normal diffusion from high concentration to low concentration until there is an equilibrium between the force of diffusion and the reverse electrostatic force due to repulsion between particles of similar charge. On the other side of the membrane there is a corresponding build-up of positive ions.

The build up of negative F ions on the inside of the membrane is compensated for by Cl ions in the internal reference solution becoming neutralised by combining with the Ag/AgCl wire, and electrons are thus forced through the external wire to the voltage measuring device (ion meter or computer interface). The other terminal of the voltmeter is connected to the Ag/AgCl wire of the external reference electrode. Here, the influx of electrons causes Ag ions in the filling solution to accept electrons and deposit on the silver wire and, consequently, Cl ions to flow out into the sample solution.

Note that, in general, depending on the concentrations inside and outside the membrane and which ion is being measured, all the reactions described above could occur in the opposite direction.

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BEHAVIOUR OF Ag/AgCl ELECTRODES IN SOLUTIONS CONTAINING BOTH Cl^- AND I^-

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Abstract: Potentials of Ag/AgCl electrodes exposed to solutions containing Cl^- and I^- were recorded. Solutions contained halide concentrations arranged in matrix form, such that (pCl = 3 - 1, pI = 6 - 3). In the region pl 6 to 4, the potentials rapidly reached steady-state values. Within this range, the potentials decreased linearly with pi, the slope being related to pCl. In the range pI 4 to 3, potentials E initially decreased linearly with time t, the magnitude of the rate of change [d*E*/dt], increasing with diminishing pI. Eventually, at any particular pI value less than 4, |d*E*/dt| began to increase rapidly, reached a maximum, then diminished as the electrode potential approached the theoretical potential of the Ag/AgI electrode. This S-shaped relation of potential with time, defined as transformation, marks the functional transition of the electrode from the Ag/AgCl type to the Ag/AgI type. Electrodes removed from solutions during transformation were analysed by mass spectrometric and X-ray diffraction techniques. These studies revealed that AgI replaces AgCl in the electrode film without the formation of solid solution. It is concluded that the potential of the silver/silver-halide electrode is determined by the halides in both solution and crystalline phases.

INTRODUCTION

The potential of the Ag/AgCl electrode is determined by the silver-ion activity in solution, which is inversely related to chloride activity through the solubility product. Any additional ion present in sufficient concentration to form an insoluble silver salt, such as may be found in solutions of biological origin, will contribute to the resultant potential. For example, in thyroid, the I^- present is expected to interfere with the electrochemical determination of [Cl^-]. It has been shown that the potential of the Ag/AgCl electrode exposed to high concentrations of I^- or Br^- (0.1 N) is determined exclusively by the activity of iodide or bromide.[1] On the other hand, small amounts of I^- or Br^- contaminating Cl^- solutions cause relatively small deviations from Cl^- equilibrium potentials.[2] The time course of the transformation of Ag/Agcl electrodes to Ag/AgBr and Ag/AgI electrodes has also been studied.[3] This paper shows the general characteristics of the interaction between the Ag/AgCl electrode and solutions containing both chloride and iodide. A preliminary report of this work has appeared elsewhere.[4]

EXPERIMENTAL PROCEDURE

Notation

Solutions are identified as follows: a solution containing 10^{-3} m chloride and 10^{-4} m iodide is identified as (pCl 3, pI 4), where pCl = -log [Cl^-]. Unless otherwise noted, pCl and pI refer to molal concentrations of electrolytes. The notation E(Cl, 1) refers to electrode potentials measured in solutions containing both Cl^- and I^-. The units of the electrical potential E(Cl, I) are always expressed in mV(sce), where sce is the saturated KCl calomel half-cell. The precision of a measurement or calculation is indicated by the number of significant figures in the numerical result.

Electrodes

The Ag/AgCl electrodes were manufactured by electrodeposition of AgCl onto chemically polished silver wire. The nominal purity of the commercially acquired silver was 0-999+. The wire diameter was 0-0508 cm. The silver wires were sealed into glass capillaries with epoxy resin, with varying lengths of wire protruding from the insulated region. The silver was anodized in 1-0 m KCl solution stirred continuously at 25°C in conditions of room light for 60 min at 93 uA. Assuming 100% coulombic efficiency, each electrode was calculated to have 0.50 mg AgCl (3-5 micromol) in the deposited film. The surface area for each electrode was calculated from the length of the cylindrical wire exposed to anodizing solutions. Measurements of length were accurate to 0.02 cm. Electrode areas ranged from 0.06 to 0.13 cm^2 and computed film thicknesses ranged from 6-8 to 13,um. Computed cds ranged from 0.7 to 1.4 mA/cm^2. The colour of electrodes anodized in this way was dark brownish-grey. Electrodes were soaked, unshorted, in solutions of 0.01 m KCl for 3-7 d prior to their use in the experiments. Potentials were determined for each electrode to 0.1 mV precision, and the standard error of the mean among the electrodes used was never more than 0.2 mV when measured in solutions of nominally pure KCl.

Solutions

Solutions were made from reagent grade chemicals and redistilled water. The KCl used was "Baker Analyzed" (J. T. Baker Chemical Co., Phillipsburg, N.J., U.S.A.) containing 0.001% iodide by weight. Contamination by Br- was 0.005%. Where required to maintain an ionic strength of 0.10 m, KNO_3 was added to the solutions. The pH of all solutions was adjusted to 4.2 by the addition of $HN0_3$. The solutions were unbuffered. No attempt was made to exclude oxygen from the solutions.

Electrical recording

Potentials were measured against a commercially acquired saturated KCl calomel half-cell with fibre liquid junction. Since KCl was found to diffuse from the tip of the reference electrode at a rate of the order of 1 micromol/min, the reference electrode was left in solution only as long as required for the periodic potential measurements. In some experiments for which continuous records were required, the reference cell was connected to the solution through a KNO3 salt bridge.

Potentials were measured directly by analogue and digital recorders. The input of the recording apparatus was a field-effect-transistor probe compensated for leakage current. The input resistance of the probe was 10^{10} ohm and the leakage current was $< 10^{-13}$ A. Two such channels were used for the recordings. Potentials from as many as 8 electrodes and the ground reference level were led in pairs to the input probes by means of relays with gold-plated contacts which could be operated either manually or automatically. The total series junction potential in the system was not known. Drift in the direct-coupled recording apparatus was corrected by referring to ground for each set of electrode measurements.

Potentials were measured by integrating digital voltmeters with gate durations of 100 ms. Usually, potential samples were measured for each pair of electrodes once per second for 5 s, and the average was computed. Electrodes were electrically floated between measurement intervals.

Mass spectrometric analysis

The relative I/Cl ratio in the electrode film was studied by a mass spectrographic technique. Ions were generated by a spark source in a spectrometer, Type 21-110 (Consolidated Electrodynamics Corp., Pasadena, California, U.S.A.). The I/Cl atomic ratio on the spectrographic plates was determined by a computer-controlled microdensitometer. The efficiency of transmission and detection of chlorine and iodine are unknown, but it is assumed that within the reported range, the relative ratio on the spectrographic plates was proportional to the ratio in the electrode film.[5]

X-ray diffraction

The electrodes were well suited geometrically for analysis in a Debye-Scherrer powder camera. Samples were irradiated by X-rays of wavelength 1-54 Angstroms from a copper source. Measurement of the diffraction lines was facilitated by use of a microdensitometer. Systematic errors in the method were corrected and lattice constants for the fcc structure of AgCl were computed by linear extrapolation to 180° (2Ø) against the function[8]

$$f(Ø) = ½(\cos Ø \cot Ø + Ø^{-1} \cos^2 Ø). \quad (1)$$

The accuracy of the method is considered to be 0-01 Angstrom. Diffraction lines for the hexagonal structure of AgI were identified by comparison of the measured values for 20 to values computed from cell constants of pure AgI.

Procedure

Experiments were performed with solutions in 150-ml open beakers in a water bath maintained at 25.0°C. Both the solutions and the water bath were stirred by Teflon covered magnetic bars driven from below by a common magnet rotated by an air motor.

The concentrations of I^- and Cl^- varied over wide ranges in the experiments. Electrode potentials were measured in solutions, initially 100.0 ml in volume, having pCl values of 1, 2, or 3. For each solution, the pI value was varied by the addition of known quantities of a solution containing KI, KCl and KNO, such that pCl and ionic strength remained constant and pI could be computed. Initial pI was calculated allowing for I^- contamination of KCl. The time of each introduction of I^- was recorded, and the electrode potential was measured at regular intervals.

RESULTS

Potentials and physical composition were determined for electrodes exposed to solutions containing Cl^- and I^-. For convenience, the potential data will be subdivided into two parts, pre-transformation and transformation.

Pre-transformation

In solutions containing Cl^- and I^-, electrode potentials E(Cl, I) were always negative to those in pure Cl^- solutions, and decreased with increasing $[I^-]$. Figure 1 is a plot of E(Cl, 1) versus pI. Each value for potential is the average for 10-16 electrodes, each determined 10 min after the addition of I^-. Since the ionic strength of all solutions was maintained at a constant value, the activity coefficients for I^-, Cl^-, N03- and K+ should be nearly the same according to the Debye-Huckel equation. The molal concentrations given in this report may be converted to activities by adding 0.12 to the pI or pCl values. Each of the 3 sets of points plotted in Fig. 1 represents measurements made in solutions of the specified pCl. Included in each set of points are both time-dependent and time-invariant data. In the range pI 6—pI 4, E(Cl, I) reached a time-invariant value within 2 min after the time of introduction of I^-. Potentials were stable to within 0.1 mV from about 2 to at least 20 min. The lines shown in Fig. 1 are fitted to the time-invariant data by the method of least squares.

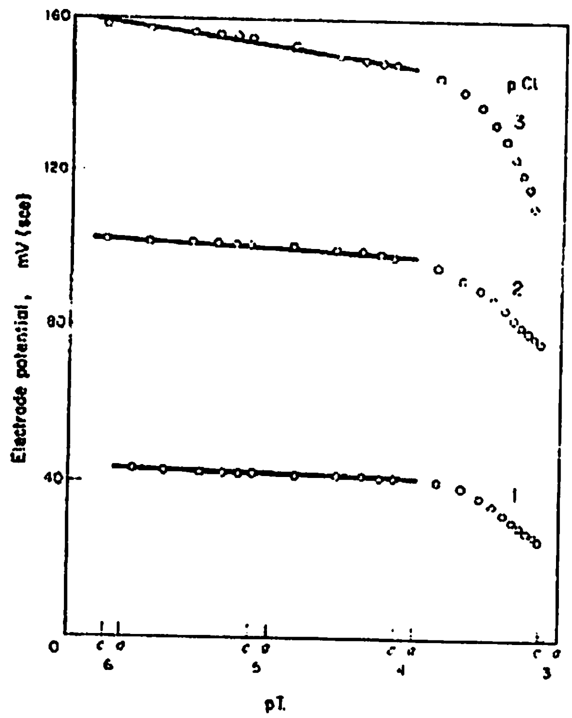

FIG. 1. Relations of electrode potential to pI for 3 pCl values. Each set of points is identified by its pCl value. Both concentration (*c*) and activity (*a*) are represented on the abscissa. The straight lines drawn are fitted by the least squares method to the data included in their length, and have slopes of 5·37, 1·93, and 0·93 for pCl 3, 2 and 1 respectively.

In the range pI 4—pI 3, the potentials departed from the linear approximation of the time-invariant data; moreover, E(Cl, I) varied linearly with time, and the slope of the relation (deldt) increased with diminishing pI (Fig. 2).

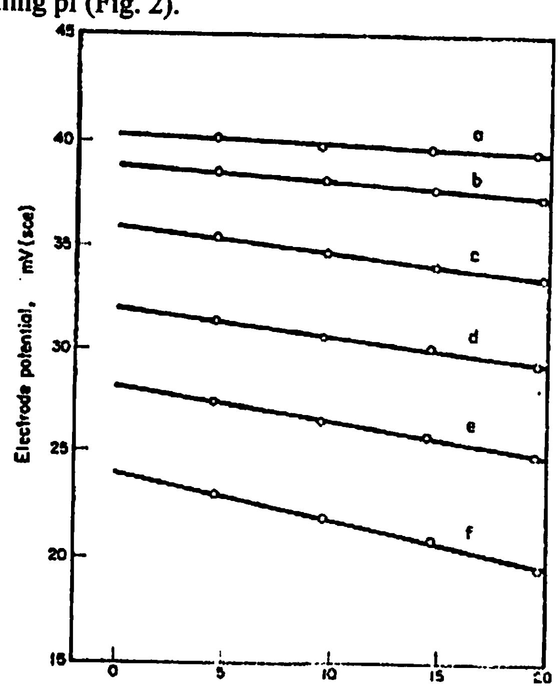

FIG. 2. Relations of electrode potential to time in solutions of pCl 1 and six values of pI. The straight lines drawn are least squares fit to the data. The pI values and slopes (mV/min) for each curve are: a, 3·54, −0·04; b, 3·42, −0·07; c, 3·26, −0·12; d, 3·14, −0·13; e, 3·05, −0·16; f, 2·98, −0·22. Each point represents the average of potentials of 8 electrodes.

The points in Fig. 2, reading from left to right and top to bottom, represent potentials sampled consecutively at 5-min intervals. The pI value was changed every 20 min during the experiment. There are too few points to characterize completely the relation between dE/dt and pI; however, the slope of the linear approximation is observed to increase with increasing pCl. In other words, high concentrations of Cl^- tend to diminish the dependence of dE/dt on pI.

Transformation

As the I^- concentration was increased the potentials developed increasingly prominent, slow, irregular oscillations. In the range of pI 4-pI 3 the peak to peak amplitude of these variations was of the order of 1-2 mV, and the period was of the order of 3-5 s. In Fig. 3, the analogue record of a single electrode potential plotted against time, the irregular oscillations can be seen superimposed upon the potential, which is linearly related to time for the first part of the record. The latter part of the record illustrates an increasingly negative dE/dt.

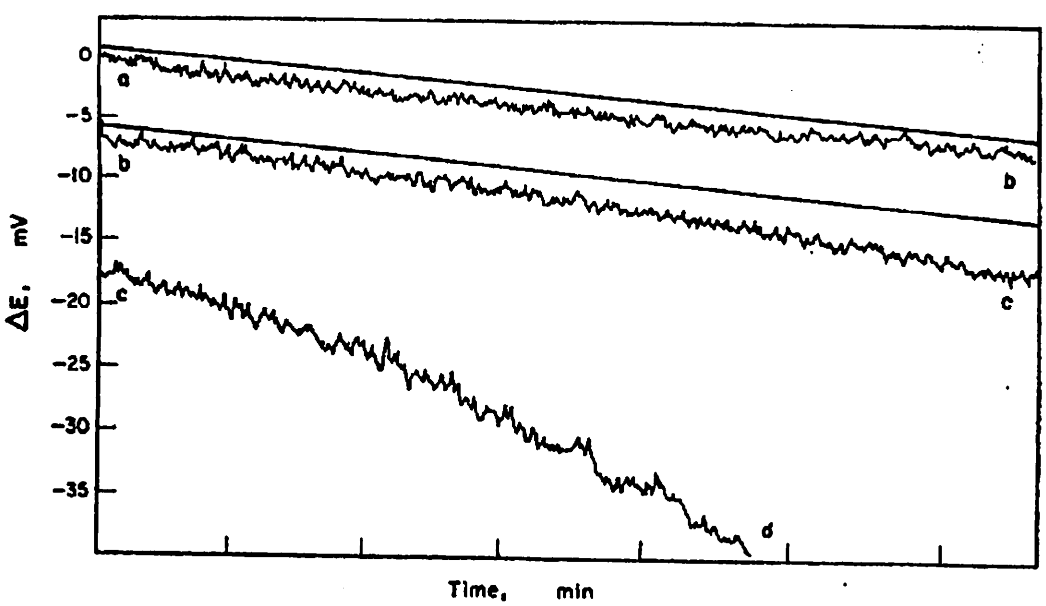

FIG. 3. Analogue record of a single electrode potential change with time, illustrating oscillation of the potential.
The solution pCl was 2, and the pI was changed to 3 at point (a), designated as the beginning of the time period. Three segments of the continuous record are shown horizontally displaced at (b)-(b) and (c)-(c). Total elapsed times at (b), (c) and (d) are 6·6, 13·2 and 18·0 min respectively. The parallel straight lines are drawn for reference.

Figure 4 is a plot of digital potential measurements for the same electrode extended over a longer time. The coefficients of the equation plotted on the graph were empirically derived from the data. The computed values of the exponential term of the equation with the coefficients given were less than 1 mV for times from 0 to 6.6 min. The S-shaped character of the plot is typical of the electrical event hereafter referred to as *transformation*. The step seen near the end of the transformation curve is a typical part of the overall potential/time relationship. The electrode of Figs. 3 and 4 had been exposed to solutions (pCl 2, pI < 4) for 100 min prior to the interval shown on the graph.

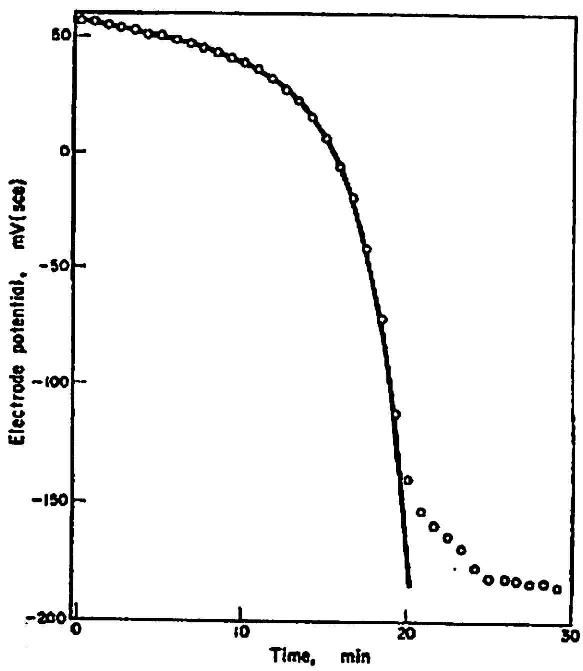

FIG. 4. Electrochemical transformation of the same electrode as in Fig. 3. The circles are potentials determined by digital voltmeter every 50 s during the interval shown. The solid line is a plot of

$$E = (56{\cdot}6 - 1{\cdot}37t) - 0{\cdot}094 \exp(0{\cdot}38t),$$

where E is potential (mV) and t is time (min).

Transformation marks the transition from one to another set of functional characteristics. Before the onset of transformation the characteristics of the electrodes approach those of the ideal Ag/AgCl electrode when measured in pure KCl solutions. By contrast, fully transformed electrodes exhibit the functional characteristics of Ag/AgI electrodes; their potentials are reproducible to within 0-5 mV and vary linearly with pI with a slope of -59 mV per 10-fold increase in [I^-].

One way to observe the effect of transformation on electrodes is illustrated in Fig. 5. Potentials of pre-transformed and transformed electrodes were compared with those of a nominally pure Ag/AgCl electrode in KCl solutions containing no I^-. It can be seen that pretransformed electrodes are identical to the Ag/AgCl electrode despite their prior exposure to solutions containing I^-. By comparison, the potentials of the transformed electrodes deviate substantially from those of the Ag/AgCl electrode.

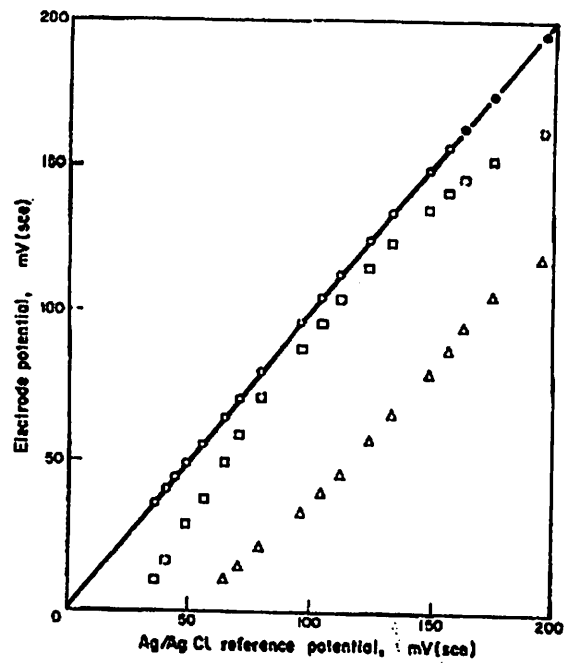

FIG. 5. Comparison of potentials of electrodes which had been exposed to I^- with those of a nominally pure Ag/AgCl electrode.
Potentials were measured in solutions of pure KCl. Circles represent the averages of potentials of 4 electrodes that had not transformed, 3 of which were yellow. Open circles, O, denote ranges of less than 0·5 mV, and closed circles, ●, represent ranges of between 0·5 and 1·0 mV. The two sets of potentials represented by squares, □, and triangles, △, were recorded from 2 transformed electrodes.

In solutions of pI 4-pI 3, each electrode potential varied linearly with time for a distinct interval prior to the onset of the transformation curve. The period of electrode exposure to these solutions terminating with the inflexion of the transformation curve is defined as the latent period of transformation, or latency. Electrodes exposed to the same experimental conditions exhibiting small variances in E(Cl, I) during the pre-transformation studies nonetheless showed wide variability in their latencies. One physical parameter found to correlate fairly well with the latent period for transformation, however, was the surface area. In Fig. 6, latency is plotted against the reciprocal of area for each of the three pCl values. As the area increased, the latent period of transformation decreased. Since the initial film volume was the same for all electrodes, the latency may also be interpreted as being directly related to film thickness.

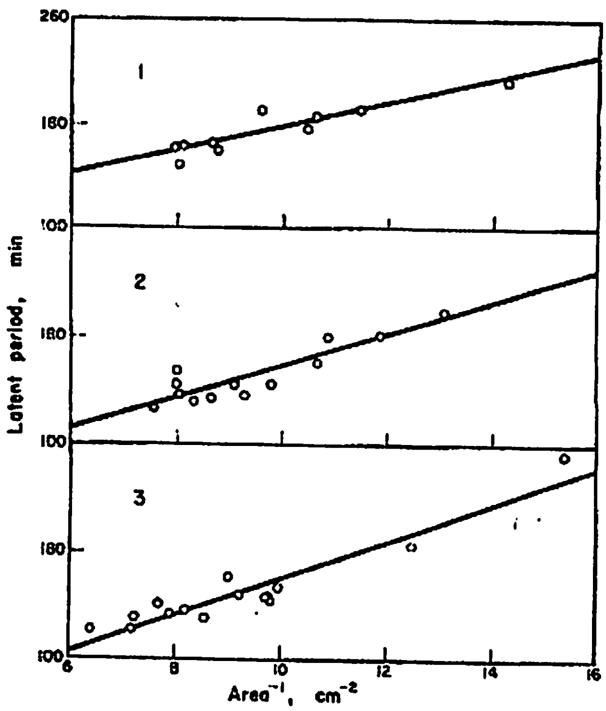

FIG. 6. Relation of the latent period of transformation to the reciprocal of electrode area. Each point represents data for a single electrode. The numbers 1, 2 and 3 correspond to the pCl values for each set of points. The straight lines were fitted by the least squares method to the data, hand have slopes of 9·0, 11·8, and 13·8 min . cm^2 for pCl values of 1, 2 and 3 respectively.

Electrode composition

As the exposure of electrodes to I^- proceeded, the original brownish grey colour of the silver chloride electrode was replaced by an increasingly vivid yellow. Electrodes began to turn yellow within 5 min when exposed to solutions containing pI < 4. On electrodes that had been completely transformed, the yellow coating was very thick, of the order of 0-5 mm, and was sufficiently friable to be brushed off easily. Microscopic study of the yellow powder brushed from electrodes revealed polycrystalline aggregates of hexagonal prisms. The maximum crystalline dimensions ranged up to 50 micrometer.

Identification of AgCl and AgI in the electrodes was made by X-ray diffraction, and the relative amounts of I and Cl were determined by mass spectrometry. The change in electrode composition during transformation is summarized in Table 1. It can be seen from the table that the relative I/Cl ratio increased by about 100-fold within the period of transformation. The X-ray diffraction studies indicated that the $I^-$and Cl^- in the electrode were present as their silver salts.

TABLE 1. ELECTRODE COMPOSITION DURING TRANSFORMATION. ELECTRODES a-d WERE REMOVED FROM SOLUTION FOR ANALYSES AT SUCCESSIVE STAGES OF TRANSFORMATION; c WAS REMOVED AT THE INFLEXION POINT OF THE TRANSFORMATION CURVE. I/Cl REFERS TO THE ATOMIC RATIO ON THE SPECTROGRAPHIC PLATES. AgCl AND AgI WERE IDENTIFIED BY THEIR CHARACTERISTIC X-RAY DIFFRACTION PATTERNS.

Electrode	I/Cl	Crystal structure
a	0·115	AgCl, AgI
b	0·215	AgCl, AgI
c	1·94	AgI
d	8·85	AgI

The lattice constant of the AgCl crystal was computed for each of 9 electrodes to discover whether there was evidence of Ag(Cl, 1) homogeneous solid solution formation. The electrodes studied included those with no AgI present as well as those with mixed AgCl and Agl crystalline structures. The AgCl lattice constant was 5.55 A for each electrode; thus, there was no evidence of lattice distortion despite the presence of AgI.

DISCUSSION

From consideration of the solubility products of AgCl and Agl, which are about 10^{-10} and 10^{-11}, respectively, it is apparent that in solutions in which $[I^-]/[Cl^-] > 10^{-6}$, the solubility of AgCl exceeds that of Agl. In the case of the Ag/AgCl electrode, if the solution is maintained such that pI - pCl < 6, the net result will be Agl precipitation at the expense of AgCl. This process will be referred to hereafter as iodide-chloride exchange. In these experiments, virtually no current is drawn from the electrode by the input circuitry; therefore, it is assumed that Ag^+ is conserved and that iodide-chloride exchange is on a one-for-one basis.

It was recognized early in the course of the experiments that the electrode potential is affected by several physical variables in addition to pCl and pI. Preliminary results suggested that these variables include ionic strength, temperature, pH, stirring rate, and electrode area. In addition, time was regarded as a parameter in all experiments. In this set of experiments, temperature, pH and ionic strength were held constant. The effect of stirring could not be determined quantitatively, but experiments with unstirred solutions demonstrated that the qualitative effects described here were not altered by stirring. Although it was not possible to maintain constant stirring conditions for all electrodes, stirred solutions were used because it was observed that the time-dependent effects of interest were enhanced. Electrode surface areas were allowed to vary by a factor of two. As a result, the inverse relation between the latent period of transformation and area was observed.

Silver/silver-chloride electrodes exposed to solutions containing Cl^- and I^- (pI < 4) become transformed to Ag/Agl electrodes after variable latent periods. The electrode potentials accompanying this process are sufficiently reproducible to substantiate the conclusion that they are functions of pCl, pI and time. The definition of time-invariant potentials depended upon the resolution of the experimental method. The minimum detectable [d*E*/dt] was 0.005 mV/min. Therefore, time-invariant potentials are defined as those having [d*E*/dtl less than this value. Potentials were time-invariant within the range of pI 6-pI 4, and decreased linearly with pI for each of three pCl values, the slopes increasing with increasing pCl.

Potentials having detectable time-dependence were observed in solutions of pI 4 - pI 3. Typically, in solutions of unchanging pCl and pI, [d*E*/dt] was constant initially; hence during this period, [d*E*/dtl was determined by pI and pCl. Later, [d*E*/dtl increased, reached a maximum, then decreased to zero. In this interval, the potential was S-shaped with time and the electrode was transformed from a Ag/AgCl electrode to a Ag/AgI electrode, as defined on a functional basis. The lattice constant for AgCl was determined by X-ray diffraction to discover whether there was any evidence of solid solution formation in the process of iodide-chloride exchange. Since the lattice constant was 5.55 A whether or not AgI was present, it is concluded that iodine does not appreciably enter a homogeneous solid solution phase with AgCl. The AgI structure identified by X-ray diffraction was hexagonal, and AgCl was fcc. Under certain conditions of precipitation AgI can assume a fcc structure having a lattice constant of 6.48 Angstrom, but there was no evidence of this structure in the X-ray diffraction patterns studied. Hexagonal prism crystals, presumably AgI, were observed with a compound microscope in the yellow powdery coating surrounding the transformed electrodes. Evidently AgI is formed in the solution phase from Ag+ made available by the solution of AgCl.

In solutions ranging from pI 4 - pI 3, prominent oscillations were observed superimposed upon the electrode potentials during the latent period. These oscillations disappeared after transformation. It is suggested that the fluctuations in potential reflect cyclic precipitation of AgI, resulting in variation of [Ag+] and [I^-] between the limits of the metastable saturation region for AgI. It is unlikely that the fluctuations are related to those reported under conditions of anodizing of Ag/AgCl electrodes in KCl solutions,[7] since no current passed through the electrodes.

The experimental evidence reported in this paper has been interpreted qualitatively. It is concluded that electrode potentials are related to chloride and iodide abundances, in both solution and crystalline phases. The quantitative description of the potential in terms of its physical variables will depend upon experimental resolution of processes at the solution/solid interface.

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QUESIONER PROTOTIPE CES
(CRANIAL ELECTROTHERAPY STIMULATION)

NAMA RESPONDEN : Hary Tans[illegible]
JENIS KELAMIN : [illegible]
USIA : 29

PENDIDIKAN TERAKHIR : [illegible]
PEKERJAAN :
SUKU : [illegible]

** berikan tanda cawang pada pilihan*

ARUS MINIMAL

ATRIBUT	KONDISI PSIKOLOGIS
NORMAL	✓
SUSAH TIDUR	✓
STRES	✓
DEPRESI RINGAN	✓

ATRIBUT	REAKSI STIMULASI
TIDAK ADA	✓
RILEKS	✓
MENGANTUK	✓
TERTIDUR	✓

Komentar : [illegible]

ARUS SEDANG

ATRIBUT	KONDISI PSIKOLOGIS
NORMAL	✓
SUSAH TIDUR	✓
STRES	✓
DEPRESI RINGAN	✓

ATRIBUT	REAKSI STIMULASI
TIDAK ADA	✓
RILEKS	
MENGANTUK	✓
TERTIDUR	✓

ARUS MAKSIMAL

ATRIBUT	KONDISI PSIKOLOGIS
NORMAL	✓
SUSAH TIDUR	✓
STRES	✓
DEPRESI RINGAN	

ATRIBUT	REAKSI STIMULASI
TIDAK ADA	✓
RILEKS	✓
MENGANTUK	✓
TERTIDUR	✓

QUESIONER PROTOTIPE CES
(CRANIAL ELECTROTHERAPY STIMULATION)

NAMA RESPONDEN : RADITYA A. P
JENIS KELAMIN : P
USIA : 26
PENDIDIKAN TERAKHIR : STM
PEKERJAAN : KULIAH
SUKU : JAWA

** berikan tanda cawang pada pilihan*

ARUS MINIMAL

ATRIBUT	KONDISI PSIKOLOGIS
NORMAL	X
SUSAH TIDUR	
STRES	X
DEPRESI RINGAN	X

ATRIBUT	REAKSI STIMULASI
TIDAK ADA	
RILEKS	X
MENGANTUK	X
TERTIDUR	X

ARUS SEDANG

ATRIBUT	KONDISI PSIKOLOGIS
NORMAL	X
SUSAH TIDUR	
STRES	X
DEPRESI RINGAN	X

ATRIBUT	REAKSI STIMULASI
TIDAK ADA	X
RILEKS	
MENGANTUK	X
TERTIDUR	X

ARUS MAKSIMAL

ATRIBUT	KONDISI PSIKOLOGIS
NORMAL	X
SUSAH TIDUR	
STRES	X
DEPRESI RINGAN	X

ATRIBUT	REAKSI STIMULASI
TIDAK ADA	X
RILEKS	
MENGANTUK	X
TERTIDUR	X

Komentar :

QUESIONER PROTOTIPE CES
(CRANIAL ELECTROTHERAPY STIMULATION)

NAMA RESPONDEN : Hijrah Saputra
JENIS KELAMIN : L
USIA : 25

PENDIDIKAN TERAKHIR : SMU
PEKERJAAN : mahasiswa
SUKU : Jawa

berikan tanda cawang pada pilihan

ARUS MINIMAL

ATRIBUT	KONDISI PSIKOLOGIS
NORMAL	
SUSAH TIDUR	* 120/90
STRES	
DEPRESI RINGAN	

ATRIBUT	REAKSI STIMULASI
TIDAK ADA	* 120/90
RILEKS	
MENGANTUK	
TERTIDUR	

ARUS SEDANG

ATRIBUT	KONDISI PSIKOLOGIS
NORMAL	
SUSAH TIDUR	* 120/90
STRES	
DEPRESI RINGAN	

ATRIBUT	REAKSI STIMULASI
TIDAK ADA	
RILEKS	110/80 * 120/90
MENGANTUK	
TERTIDUR	

ARUS MAKSIMAL

ATRIBUT	KONDISI PSIKOLOGIS
NORMAL	
SUSAH TIDUR	* 120/90
STRES	
DEPRESI RINGAN	

ATRIBUT	REAKSI STIMULASI
TIDAK ADA	
RILEKS	* 110/70
MENGANTUK	
TERTIDUR	

Komentar :

QUESIONER PROTOTIPE CES
(CRANIAL ELECTROTHERAPY STIMULATION)

NAMA RESPONDEN : Deni Sugiarto
JENIS KELAMIN : L
USIA : 2-

PENDIDIKAN TERAKHIR : SMU
PEKERJAAN : Mahasiswa
SUKU : Banjar

** berikan tanda cawang pada pilihan*

ARUS MINIMAL

ATRIBUT	KONDISI PSIKOLOGIS
NORMAL	–
SUSAH TIDUR	130/80
STRES	
DEPRESI RINGAN	–

ATRIBUT	REAKSI STIMULASI
TIDAK ADA	130/80
RILEKS	–
MENGANTUK	–
TERTIDUR	–

ARUS SEDANG

ATRIBUT	KONDISI PSIKOLOGIS
NORMAL	–
SUSAH TIDUR	130/80
STRES	
DEPRESI RINGAN	–

ATRIBUT	REAKSI STIMULASI
TIDAK ADA	130/80
RILEKS	–
MENGANTUK	–
TERTIDUR	–

ARUS MAKSIMAL

ATRIBUT	KONDISI PSIKOLOGIS
NORMAL	–
SUSAH TIDUR	130/80
STRES	
DEPRESI RINGAN	–

ATRIBUT	REAKSI STIMULASI
TIDAK ADA	–
RILEKS	120/80
MENGANTUK	–
TERTIDUR	–

Komentar :

QUESIONER PROTOTIPE CES
(CRANIAL ELECTROTHERAPY STIMULATION)

NAMA RESPONDEN : M Juliansyah
JENIS KELAMIN : L
USIA : 23
* berikan tanda cawang pada pilihan

PENDIDIKAN TERAKHIR : SMU
PEKERJAAN : Mahasiswa
SUKU : Banjar

ARUS MINIMAL

ATRIBUT	KONDISI PSIKOLOGIS
NORMAL	–
SUSAH TIDUR	130/90
STRES	–
DEPRESI RINGAN	–

ATRIBUT	REAKSI STIMULASI
TIDAK ADA	130/90
RILEKS	–
MENGANTUK	–
TERTIDUR	–

ARUS SEDANG

ATRIBUT	KONDISI PSIKOLOGIS
NORMAL	–
SUSAH TIDUR	130/90
STRES	–
DEPRESI RINGAN	–

ATRIBUT	REAKSI STIMULASI
TIDAK ADA	130/90
RILEKS	–
MENGANTUK	–
TERTIDUR	–

ARUS MAKSIMAL

ATRIBUT	KONDISI PSIKOLOGIS
NORMAL	–
SUSAH TIDUR	130/90
STRES	–
DEPRESI RINGAN	–

ATRIBUT	REAKSI STIMULASI
TIDAK ADA	130/90
RILEKS	–
MENGANTUK	–
TERTIDUR	–

Komentar :

The 555 Monostable Circuit

By Tim Surtell

ELECTRONICS in MECCANO

In the previous article in this series we looked at the astable - a circuit in which the output has no stable state. In this article we discuss the monostable circuit which has one stable state.

The waveforms in figure 1 illustrate the operation of a monostable. A monostable circuit produces one pulse of a set length (time period T) in response to a trigger input such as a push button. The output of the circuit stays in the low state until there is a trigger input, hence the name "monostable" meaning "one stable state".

This type of circuit is ideal for use in a "push to operate" system for a model displayed at exhibitions. A visitor can push a button to start a model's mechanism moving, and the mechanism will automatically switch off after a set time. Another use for the circuit is to 'de-bounce' a push button input to a digital IC - this application is explained later in this article.

Related Articles

- The 555 Timer - Background information about the 555
- The 555 Astable Circuit - Includes an introduction to waveform terminology
- The 555 Bistable Circuit

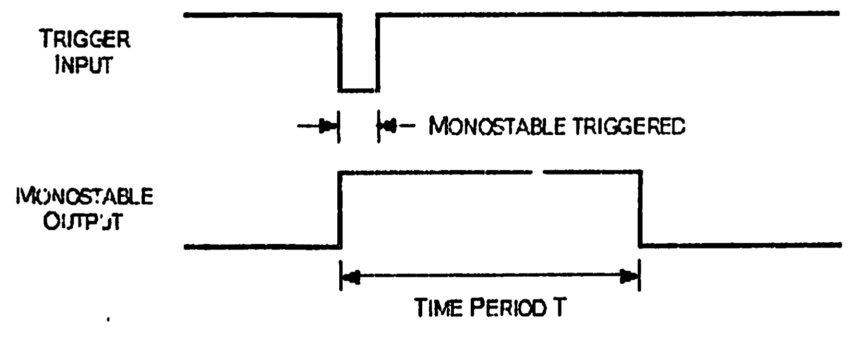

Figure 1: The monostable input and output waveforms

The 555 Monostable Circuit

The circuit diagram of the 555 monostable circuit is given in figure 2. Notice that the resistor value R and the capacitor value C are unspecified. The values of these components determine the length of time that the monostable output is in the high state, and they may be calculated using the equation below...

$$T = 1.1RC$$

...where T is the time period in seconds, and R and C are the component values in Ohms (Ω) and Farads (F).

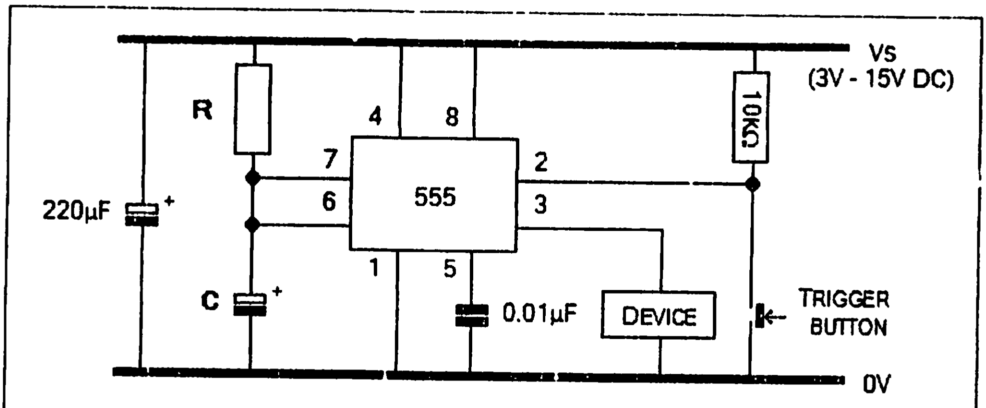

Figure 2: The 555 monostable circuit

Doing the Calculations

Here is a step-by-step guide to calculating the value of resistor R - an example is given in curly braces {}.

1. Firstly, decide the time period T that you require. This can be very small (milliseconds) or large (minutes), but it must be expressed in seconds. {I choose T = 10 seconds}
2. Next, guess a value for the capacitor C, expressed in Farads. For starters, try 100µF. {I choose C = 100µF}
3. Put the values of T and C into the equation below and calculator resistor R...

$$R = \frac{T}{1.1C} \qquad \left\{ R = \frac{10s}{1.1 \times 100\mu F} = 90k\Omega \right\}$$

If the resistor value you calculated is smaller than 1kΩ or larger than 1MΩ, you should re-do the calculation with a different value for capacitor C until you get a resistor value within the acceptable range.

Varying the Time Period

If you will need to adjust the time period of the monostable circuit in use, you can use a linear variable resistor for R, as shown in figure 3.

Because the resistance of a variable resistor goes down to around 0Ω at one end of its range, a 1kΩ resistor is placed in series with it so that the value of R will never fall below 1kΩ. As the shaft of the variable resistor is turned from its lowest setting to its highest, T will become longer.

If your chosen variable resistor has three connections, it is a potentiometer, and you should connect to the centre connection and either of the end connections.

Further Information ▶ Resistors - Includes information about variable resistors

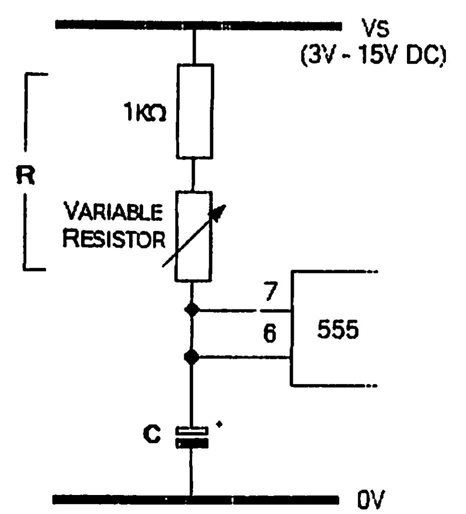

Figure 3: Varying the time period with a variable resistor

The Trigger Input

As you can see from figure 1, the 555's Trigger input must be taken low to trigger the monostable. This is achieved in figure 2 by placing a button in series with a resistor across the power supply. Normally, the 10kΩ resistor keeps the Trigger input high, at the voltage Vs, and the monostable is in its steady state. When the button is pushed, the Trigger input is directly connected to 0V and the time period T starts.

The Reset Input

If you want to make the monostable output go low before the time period has elapsed, simply take the 555's Reset input briefly low. This can be achieved with a push button in exactly the same way as with the Trigger input.

De-bouncing

When a push button is pressed or released, the contacts will bounce between the on and off states for a fraction of a second. If the button is connected to the input of a digital IC, then the IC will think the button is being pressed several times rather than once. While this may not matter in some circuits like the monostable, to others it will produce erratic behaviour.

For example, if the button is connected to the Clock input of a digital counter IC, the counter output should increment once every time the button is pressed. Instead it will count perhaps 5 times due to the contact bounce in the button.

To solve the problem, the push button must be 'de-bounced' by placing a small delay between it and the digital input - an ideal application for a monostable. Figure 4 shows a block diagram of this arrangement. Obviously, there is a need to get the length of the delay (the time period) correct - too short and some of the bounce will get through, too long and you will prevent quick successions of button presses having an effect on the digital input. A suitable time period for most applications would be around 100ms. To make a 555 monostable with this time period you would need to make R = 91kΩ and C = 1μF.

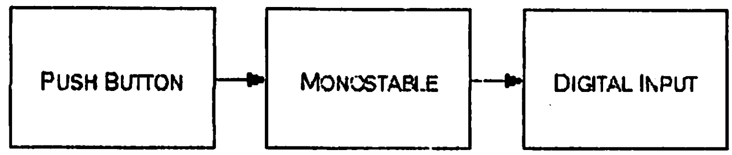

Figure 4: De-bouncing a push button

Building the Circuit

A stripboard layout for the 555 monostable circuit is given in figure 5. It provides a direct output from the 555 (pin 3), but if you want the monostable to control another device, such as a motor, you will probably want to leave some extra board space for any extra components required. Some suggestions are given in "Using the 555 output" from part 1 of this series, The 555 Timer.

The 220μF capacitor is included to smooth the power supply, and can be omitted if you are using a regulated supply or the circuit functions correctly without it.

Construction

1. Cut a piece of stripboard to 12 tracks x 21 columns + extra columns for any extra components required.
2. Fit the 5 wire links.
3. Fit the 10KΩ resistor and the resistor R.
4. Fit the 8-pin IC socket, taking care to align the notch as shown in the layout. Do not insert the 555 at this time.
5. Fit the 0.01μF, 220μF capacitors and timing capacitor C. Ensure that the polarity of the 220μF capacitor is correct. The leads will be marked with '+' or '-'. The timing capacitor you have chosen could also be polarised, and should also be carefully placed.
6. Fit the components associated with the device that the 555 is controlling.
7. Insert the 555 into its socket, taking care to align the notch with the notch in the socket.
8. Cut the copper tracks where an X is shown.
9. Connect up a 3V - 15V DC power supply and test the circuit.

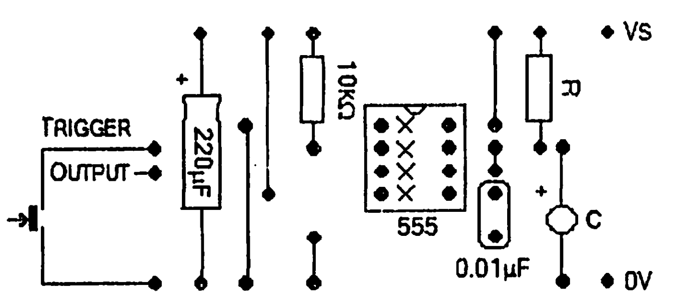

Figure 5: A stripboard layout for the 555 monostable circuit

Shopping List

Here is a list of the parts required to build the 555 monostable circuit on stripboard as shown in figure 5. You will also need the timing resistor and capacitor you have calculated (see text), plus components to drive the device you wish to control.

Part Description	Quantity Required	Maplin Code	Unit Price	Total Price