SKRIPSI

PERANCANGAN DAN PEMBUATAN ALAT PENGUKUR KETINGGIAN TEMPAT DARI PERMUKAAN AIR LAUT BERBASIS MIKROKONTROLLER AT89C4051 (ALTIMETER DIGITAL)

Disusun Oleh:

MUHAMAD ARIFIN

NIM : 04.12.259

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

OKTOBER 2009

LEMBAR PERSETUJUAN

PERANCANGAN DAN PEMBUATAN PENGUKUR KETINGGIAN TEMPAT DARI PERMUKAAN AIR LAUT BERBASIS MIKROKONTROLLER AT89C4051 (ALTIMETER DIGITAL)

SKRIPSI

Disusun dan Diajukan Sebagai Salah Satu Syarat Untuk Memperoleh Gelar Sarjana Teknik Elektronika Strata Satu (S-1)

Disusun Oleh :

MUHAMAD ARIFIN
NIM : 04.12.259

MILIK PERPUSTAKAAN ITN MALANG

Diperiksa dan Disetujui

Dosen Pembimbing I	Dosen Pembimbing II
M. Ibrahim Ashari, ST. MT.	**Irmalia S. Faradisa, ST. MT**
NIP.P. 1030100358	**NIP.P. 1030000365**

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

Mengetahui
Ketua Jurusan Teknik Elektro S-1

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

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

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

BERITA ACARA UJIAN SKRIPSI

FAKULTAS TEKNOLOGI INDUSTRI

Nama	: Muhammad Arifin
NIM	: 04.12.259
Jurusan	: Teknik Elektro S-1
Konsentrasi	: Teknik Elektronika
Judul Skripsi	: PERANCANGAN DAN PEMBUATAN ALAT PENGUKUR KETINGGIAN TEMPAT DARI PERMUKAAN AIR LAUT BERBASIS MIKROKONTROLER AT89C4051 (ALTIMETER DIGITAL)

Dipertahankan di hadapan majelis penguji Skripsi jenjang Strata satu (S-1) pada :

Hari	: Selasa
Tanggal	: 06 oktober 2009
Dengan Nilai	: 83,7 (A)

Ketua Majelis Penguji

(Ir. H. Sidik Noertjahjono, MT)
NIP.Y.1028700163

Sekretaris Majelis Penguji

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

Penguji I

(Sotyohadi, ST, MSc)
NIP.Y.1039700309

Penguji II

(Joseph Dedy Irawan, ST, MT)
NIP.132315178

LEMBAR PERSEMBAHAN

Terima kasihku untuk:

1. اللهatas nyawa yang telah engkau berikan kepadaku, serta semua karuniamu kepadaku sehingga hambamu ini dapat menyelesaikan skripsi ini. Dan telah aku sampaikan semua ilmu yang aku tahu dan aku mengerti untuk kehidupanku, dan untuk semua yang hidup dan mati karena – *Mu*. Dimana hamba sebagai manusia yang tak pernah puas, maka ampunilah semua kekhilafanku ya *Rabb*.
2. Yang Tercinta dan yang Terindu *Baginda Rasulullah Muhammad.* Karena beliaulah hambamu ini dapat memeluk islam ya *Rabb*, yang merupakan rahmat sekalian alam. Salam dan salawat selalu tertasbih untukmu…
3. Abah dan Umi yang tiada henti memberikan doanya, semangatnya, serta dukungan baik secara moril maupun materiil. Bapak semoga engkau selalu diberikan kesehatan dan karunia yang tak terhingga. Umi semoga Umi dapat terus memberikan kasih sayangmu kepadaku."Sayangilah kedua orangtuaku seperti engkau menyayangi aku pada waktu kecil".
4. Mbak Eli sebagai kakakku yang tersayang terima kasih atas semua dukungan dan "kemarahanmu" kepadaku yang akhirnya membawaku menjadi orang yang lebih baik.
5. Buat oktaviantri anjani terima kasih banyak buat dukungan dan doanya tanpa ada dukungan darimu mungkin aq tidak bisa menyelesaikan skripsiku…I love you bun….
6. Temanku seperjuangan di Lab. Analog ITN Malang, andi (Po), nanang, oki, gofur, agung, tika. Dan juga buat P.komang yang sudah sabar membimbing teman-teman di lab.
7. Bapak M.Ibrahim Ashari ,ST.MT, dan Ibu Irmalia S.Faradisa,ST.MT terima kasih sudah bimbing saya ya bu terutama "Cerewetnya" tapi dengan itu insyallah saya dapat bertahan dari kerasnya gelombang kehidupan. *AMMIIINNNN*…… terimakasih banyak ya pak bu atas kesabarannya.
8. Seluruh dosen Elektro di ITN Malang yang saya cintai dan saya kagumi, terima kasih sudah memberikan ilmu kepada saya dan semoga ilmu ini selalu berguna bagi saya dan khalayak umum.
9. Teman – teman seperjuangan teknik elektronika angkatan 2004 yang tidak dapat saya sebutkan satu – persatu.

10. Toko "Gajayana" elektronik, Delta , Digiware, Digizer, Bedak 8, dan semua toko yang telah saya datangi dan saya beli produknya, Kampus ITN Malang, , kota Malang, Thanks for jasamu.
11. Semua Teman dan Saudaraku yang tak bisa kusebut satu – persatu terima kasih, matur sembah nuwun dan Allah akan membalas semua perbuatan baik kalian kepadaku.

ABSTRAK

PERANCANGAN DAN PEMBUATAN ALAT PENGUKUR KETINGGIAN TEMPAT DARI PERMUKAAN AIR LAUT BERBASIS MIKROKONTROLLER AT89C4051 (ALTIMETER DIGITAL)

Muhammad Arifin
04.12.259
Jurusan Teknik Elektronika – Institut Teknologi Nasional Malang
Jln. Raya Karanglo Km 2 Malang
Arif_okt@yahoo.com
Dosen Pembimbing : I. M. Ibrahim Ashari, ST. MT.
II. Irmalia S. Faradisa, ST. MT.

Sejalan dengan perkembangan ilmu pengetahuan dan teknologi, sistem pengukuran ketinggian suatu tempat semakin berperan penting dalam kehidupan manusia. Sistem tersebut amat membantu manusia dalam melakukan aktivitasnya baik dalam melengkapi kegemaran mereka seperti naik gunung (*hiking*), sepeda gunung (*biking*), atau dalam bekerja seperti pengukuran ketinggian bangunan, pengukuran suatu wilayah kota dan dalam bidang pertanian. Seorang arsitek yang ingin mengetahui tinggi bangunan dengan waktu yang relatif cepat, petani yang ingin mengetahui pada ketinggian berapa mereka harus menanam tanaman yang cocok di daerahnya, pendaki gunung yang ingin mengetahui ketinggian yang telah mereka daki dimana pada ketinggian tertentu mereka bisa menderita hipoksia apabila mereka terlambat mengantisipasinya dan seorang penerjun payung yang ingin mengetahui informasi pada ketinggian berapa meter mereka harus membuka parasut, merupakan sebagian contoh pentingnya informasi ketinggian bagi mereka. Mahalnya peralatan pengukuran ketinggian yang ada sekarang juga merupakan kendala mereka.

Oleh karena itu perlu adanya suatu alat yang dapat mengukur ketinggian tempat dari permukaan air laut dengan harga relatif murah di banding dengan alat yang ada dipasaran, alat ini dapat memberikan informasi ketinggian tempat secara cepat dan akurat dengan hanya membaca tampilan pada alat tersebut, sehingga dengan alat ini diharapkan memberikan kemudahan bagi masyarakat dalam beraktifitas.

Alat ini terdiri dari sensor tekanan udara (*intgrated silicon pressure sensor*) sebagai tranduser yang menghasilkan tegangan keluaran yang proporsional dengan tekanan udara. Rangkaian ADC sebagai pengubah masukan analog menjadi data-data digital dan alat ini dikontrol dengan mikrokontroller dengan display LCD 16x2 sebagai penunjuk informasi ketinggian tempat.

Alat ukur yang dibuat memiliki bentuk portabel dan mampu mengukur ketinggian tempat dari permukaan air laut pada 350 hingga 464 Meter dengan range tekanan udara yang diukur antara 95kPa hingga 97kPa. Alat ini didesain mampu mengukur ketinggian hingga 4095 Meter pada level tekanan udara sebesar 60kPa.

Secara keseluruhan alat ukur yang dibuat memiliki tingkat kesalahan pembaca rata-rata sebesar 9,36%.
Kata kunci: *Alat ukur, Altimeter digital, Ketinggian tempat, Tekanan udara,* AT89C4051.

KATA PENGANTAR

Dengan memanjatkan puji syukur kepada Tuhan Yang Maha Esa, atas berkat rahmat dan karunia-Nya sehingga dapat menyelesaikan skripsi yang berjudul "Perancangan Dan Pembuatan Alat Pengukur Ketinggian Tempat Dari Permukaan Air Laut Berbasis Mikrokontroler AT89C4051" ini dengan lancar. Skripsi ini merupakan persyaratan kelulusan studi di jurusan Teknik Elektro S-1 konsentrasi Teknik Elektronika ITN Malang dan untuk mencapai gelar sarjana teknik.

Keberhasilan penyelesaian laporan skripsi ini tidak lepas dari dukungan dan bantuan berbagai pihak. Untuk itu penyusun menyampaikan terimakasih kepada:

1. Bapak Prof. DR. Ir. Abraham Lomi, MSME selaku Rektor ITN Malang.
2. Bapak Ir. Sidik Noertjahjono, MT selaku Dekan Fakultas Teknologi Industri.
3. Bapak Ir. F. Yudi Limpraptono, MT selaku Ketua Jurusan Teknik Elektro S-1.
4. Bapak Ir. Yusuf Ismail Nakhoda, MT selaku Sekretaris Jurusan Teknik Elektro S-1.
5. Bapak M. Ibrahim Ashari,ST,MT Selaku Dosen Pembimbing I.
6. Ibu Irmalia Suryani Faradisa,ST,MT Selaku Dosen Pembimbing II.

Akan keterbatasan pengetahuan dalam menyelesaikan laporan ini, untuk itu penyusun mengharapkan saran dan kritik yang membangun dari pembaca demi kesempuranaan laporan ini.

Harapan penyusun semoga laporan ini memberikan manfaat bagi perkembangan ilmu pengetahuan dan pembaca

Malang, Oktober 2009

Penulis

DAFTAR ISI

DAFTAR GAMBAR

DAFTAR TABEL

BAB I
PENDAHULUAN

1.1. Latar Belakang Masalah

Perkembangan teknologi saat ini mendorong lapisan masyarakat untuk mendapatkan kemudahan-kemudahan dalam bekerja atau beraktivitas. Hal ini menyebabkan semakin banyak orang yang menciptakan inovasi-inovasi baru untuk memuaskan para konsumen diantaranya terciptanya instrument yang dapat digunakan sehari-hari misalnya dalam bidang pertanian dan pembangunan. Dalam pelaksanaannya mereka sering kali mengalami kesulitan yang pada akhirnya dapat memperlambat bahkan menghambat pekerjaan mereka. Sebagai contoh untuk seorang arsitek yang ingin mengetahui ketinggian bangunan dengan waktu yang relatif cepat. Atau bagi seorang petani yang ingin mengetahui ketinggian berapa meter yang cocok untuk dapat menanam tanaman yang akan ditanam.

Masyarakat tidak hanya menggunakan instrument tersebut dalam bekerja namun juga untuk melengkapi kegemaran dalam menikmati hobby mereka atau dalam hal berolahraga misalnya tamasya, naik gunung (*Hiking*), sepeda gunung (*Biking*), terjun payung, paragliding, gantole dan masih banyak yang lainnya. Sebagai contoh pecinta *hiking* sering mengalami kesulitan untuk mengetahui ketinggian yang telah mereka daki, dimana pada ketinggian tertentu mereka bisa menderita hipoksida apabila mereka terlambat mengantisipasinya. Penerjun payung juga mengalami kesulitan untuk mengetahui informasi pada ketinggian berapa meter mereka harus membuka parasut, pada ketinggian berapa meter seorang paragliding dapat mengembangkan parasutnya. mahalnya peralatan yang digunakan juga merupakan kendala bagi mereka.

Salah satu komponen elektronika yang sering digunakan dalam instrumentasi elektronika digital yaitu Mikrokontroller sebagai suatu terobosan teknologi mikroprosessor dan mikrokontroller, hadir memenuhi kebutuhan pasar dan teknologi baru. Sebagai teknologi baru yaitu teknologi yang ada didalamnya dapat dikatakan sebagai komputer dalam chip, membutuhkan ruang yang kecil sedangkan fungsinya hampir sama dengan komputer. Selain itu dapat diproduksi dalam jumlah yang banyak membuat harganya menjadi lebih murah dibandingkan dengan mikroprosessor. Dengan menambah beberapa rangkaian sensor dan memadukannya dengan perangkat penampil (*Liqud Crystal Display* (LCD), *Seven Segment*, dan lain-lain),sebuah mikrokontroller sebagai pengolah datanya dapat menjadi perangkat yang aplikatif sesuai dengan fungsi rangkaian-rangkaian pendukungnya.

Untuk melengkapi aktifitas mereka dalam bekerja atau dalam berolahraga dan merujuk pada kendala dan permasalahan yang mereka hadapi, perlu dibuat instrument dengan memanfaatkan fungsi dari mikrokontroller. Alat ini memiliki ukuran yang relatif kecil, harga yang relatif murah namun memiliki fungsi dan manfaat dalam hal pemberian informasi tentang ketinggian tempat, memungkinkan untuk dibawa kemanapun (*Portable*) dan dimanapun mampu memberikan informasi ketinggian tempat secara tepat dan akurat hanya dengan membaca tampilan pada alat tersebut tanpa harus mengartikan atau menghitung terlebih dahulu. Dengan dibuatnya alat ini diharapkan akan memberikan kemudahan bagi masyarakat dalam beraktifitas atau menikmati kegemaran mereka.

1.2. Rumusan Masalah

Mengacu pada latar belakang di atas berkaitan dengan proses pembuatan alat pengukur ketinggian tempat dari permukaan laut (*Altimeter*) dapat disusun rumusan masalah sebagai berikut.

1) Bagaimana membuat alat yang berfungsi sebagai alat ukur yang dapat digunakan untuk mengukur ketinggian suatu tempat dari permukaan air laut dalam bentuk yang *portabel*;
2) Bagaimana merancang dan membuat rangkaian *detector* perubahan tekanan udara;
3) Bagaimana membuat prangkat lunak untuk memvisualisasikan ketinggian suatu tempat berupa angka-angka decimal pada *display* LCD;

1.3. Batasan Masalah

Untuk menjaga agar tidak melebarnya masalah yang dibahas dalam penulisan ini, maka akan dibatasi pembahasan permasalahan yang ada. Adapun yang akan dibahas adalah:

1) Masalah perangkat keras yang meliputi mikrokontroller sebagai pengolah data, sensor tekanan udara, ADC (*Analog To Digital Converter*) sebagai pengkonversi data analog dari sensor menjadi data digital dan tampilan berupa LCD yang akan memberikan informasi ketinggian tempat yang diukur.

2) Masalah perangkat lunak yang meliputi diagram alur (*Flow Chart*) dan bahasa pemrograman.

1.4. Tujuan

Tujuan dari pembuatan alat pengukur ketinggian dari permukaan air laut (*Altimeter Digital*) ini adalah:

Merancang dan membuat suatu alat dengan ukuran yang relatif kecil, harga yang relatif murah dibanding dengan alat yang yang asli (beredar di pasaran), memungkinkan untuk dibawa kemanapun (*Portable*) dan dapat memberikan informasi ketinggian secara cepat dan akurat.

1.5. Sistematika Penulisan

Sistematika penulisan yang digunakan dalam penyusunan skripsi ini adalah sebagai berikut:

BAB I : Menjelaskan tentang latar belakang permasalahan, Rumusan dan pembatasan masalah, serta tujuan dan kegunaan kajian.

BAB II : Menjelaskan tentang teori dasar yang berisi tentang penjelasan hubungan antara ketinggian dan tekanan udara, prinsip dasar sensor tekanan, ADC, Mikrokontroller AT89C4051, dan *display* LCD.

BAB III : Menjelaskan tentang metodologi penelitian Menjelaskan tentang blok diagram perancangan dan pembuatan alat yang meliputi prinsip kerja, dan perancangan *hardware*.

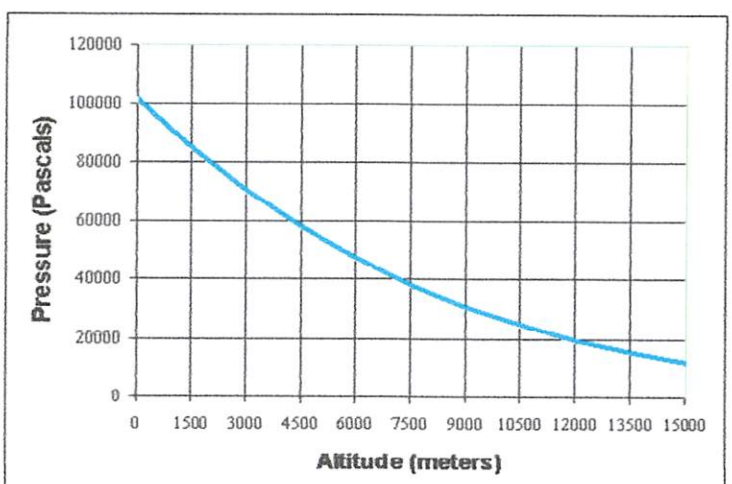
BAB IV : Menjelaskan tentang spesifikasi alat, pengujian dan analisis yang meliputi pengujian tiap-tiap bagian dan pengujian secara keseluruhan.

BAB V : Memberikan kesimpulan dan saran

BAB II
TINJAUAN PUSTAKA

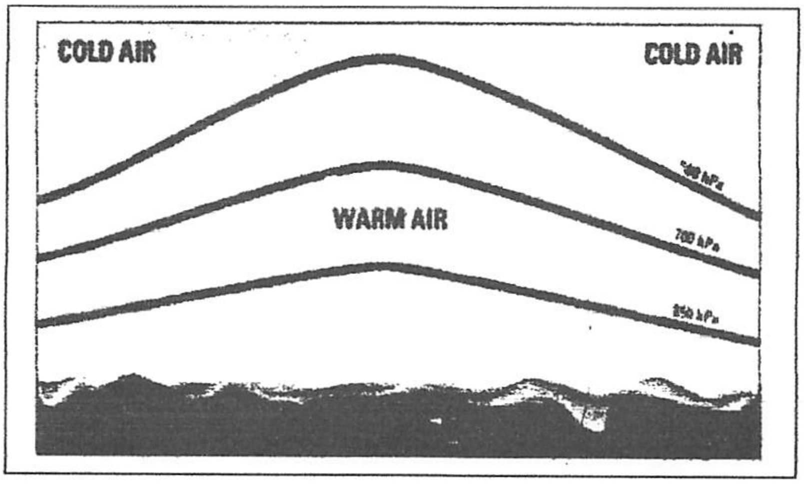
2.1 Konsep Ketinggian

Dalam pembuatan alat ukur ketinggian dari permukaan air laut digunakan sebuah metode untuk menentukan ketinggian yaitu dengan mengunakan tekanan udara di permukaan air laut, tekanan udara berkisar pada 1013,25 milibar (1013hpa). Perbedaan ketinggian dan temperatur akan menyebabkan tekanan turun. Para ahli telah menetapkan bahwa setiap terjadi perubahan ketinggian sebesar 1000m, tekanan udara akan mengalami penurunan sekitar 100mb (100hpa). Hal ini terjadi karena semakin tinggi permukaan semakin tipis pula tingkat kerapatan udara, sehingga menyebabkan penurunan tekanan udara yang besarnya sekitar 100mb (100hpa) per 1000m. (priyono,2003:2). Hal tersebut dapat digambarkan dengan menggunakan sebuah grafik seperti yang ditunjukkan dalam Gambar 2.1;



Gambar 2.1 Grafik hubungan antara tekanan udara dan ketinggian
Sumber : halliday,1985:560

Variasi tingkat ketinggian juga dipengaruhi oleh temperatur dan fluktuasi tekanan dari lapisan udara yaitu udara hangat (*warm air*) dan udara dingin (*cold air*). Karena udara terdingin lokasinya dekat kutub, level tekanan disana umumnya lebih rendah dibandingkan level tekanan diatas garis katulistiwa. (lane,2004:8). Tekanan suatu gas dengan massa tertentu berbanding lurus dengan temperatur mutlak, bila volume tak berubah (Keenan dkk,1992:258). Seperti terlihat dalam Gambar 2.2 berikut:



Gambar 2.2 Efek temperatur dari level perubahan tekanan
Sumber: Lane,2004:8

Dari gambar terlihat bahwa semakin besar tekanan udara, udara disekitarnya akan semakin hangat. Demikian pula sebaliknya makin kecil tekanan udara, udara disekitarnya juga akan semakin dingin. Fenomena ini sesuai dengan hokum gas ideal yang menyatakan bahwa

$$PV = T \quad \text{...(2.1)}$$

Sumber: Kleinfelter,1992:263

Dimana P = Tekanan dari gas, V = Volume yang ditempati, dan T = tempereatur.

Dalam bentuk sederhana, jika volume konstan, peningkatan pada temperatur sebanding dengan peningkatan pada tekanan. Jika tekanan konstan, peningkatan pada temperatur juga sebanding dengan peningkatan pada volume. Sebaliknya, jika volume menurun dan tekanan tetap konstan, temperatur juga ikut menurun. Hal terpenting adalah perubahan tekanan dan volume sebanding dengan perubahan temperatur.

Dari ilustrasi di atas dapat diambil kesimpulan bahwa dalam menentukan ketinggian tempat hal-hal yang perlu diperhatikan adalah perubahan tekanan udara dan suhu (*temperature*) pada tempat tersebut. Semakin meningkatnya ketinggian dari permukaan air laut maka tekanan udara dan suhu akan semakin menurun, demikian pula sebaliknya tekanan udara dan suhu semakin meningkat jika ketinggian menurun.

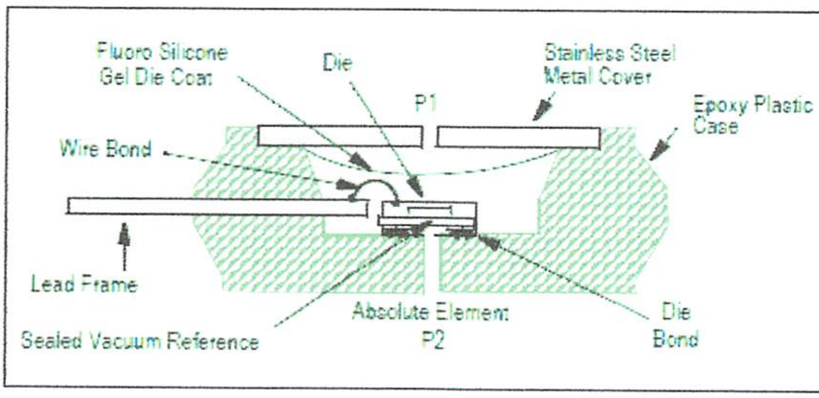
Untuk selanjutnya pada bagian ini membahas tentang sensor tekanan yang mengacu pada *datasheet* yang telah ada, ADC, mikrokontroller sebagai pengolah datanya dan *display* LCD.

2.2 Sensor Tekanan (*pressure sensor*)

Bagian pertama dan paling penting dari system ini adalah sensor yang digunakan untuk mendeteksi perubahan tekanan udara adalah sensor tekanan (*integrated silicon pressure sensor*) dengan type MPX4115AP yang diproduksi oleh Motorola Inc. sensor ini dipilh karena dapat menghasilkan sinyal keluaran analog berupa tegangan apabila terjadi perubahan tekanan udara pada suatu tempat. Menurut *datasheet* yang ada, keluaran yang dihasilkan sensor ini berada pada range 0.2 volt – 4.8 volt dengan range tekanan 15 Kpa – 115 Kpa dan memiliki sensitivitas sebesar 45.9mV/Kpa.

Cara kerja sensor MPX4115AP sama dengan cara kerja sensor-sensor lainnya dimana bila terdeteksi perubahan besaran fisik yaitu perubahan tekanan udara, maka sensor akan bekerja dan menghasilkan tegangan. Besaran fisik yang dapat dideteksi sensor MPX4115AP dinyatakan dalam satuan hpa (*hectopascal*). Hpa disebut juga seratus pascal (*newton per square meter*) dan merupakan standart pengukuran tekanan satu atmosfir yaitu 1013.25hpa (101.325 kPa) (Halliday,1985:560). Sebagai perbandingan pada permukaan laut memiliki tekanan udara sekitar 76mHg atau setara dengan satu atmosfir (101.325kPa).

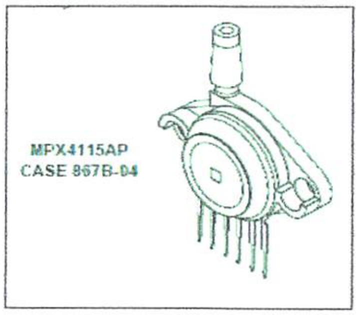
Secara garis besar sensor tekanan udara ini memiliki prinsip kerja sebagai berikut seperti ditunjukkan dalam Gambar 2.3;



Gambar 2.3 Bagian-Bagian Dari Sensor Tekanan
Sumber: datasheet, 2006:4

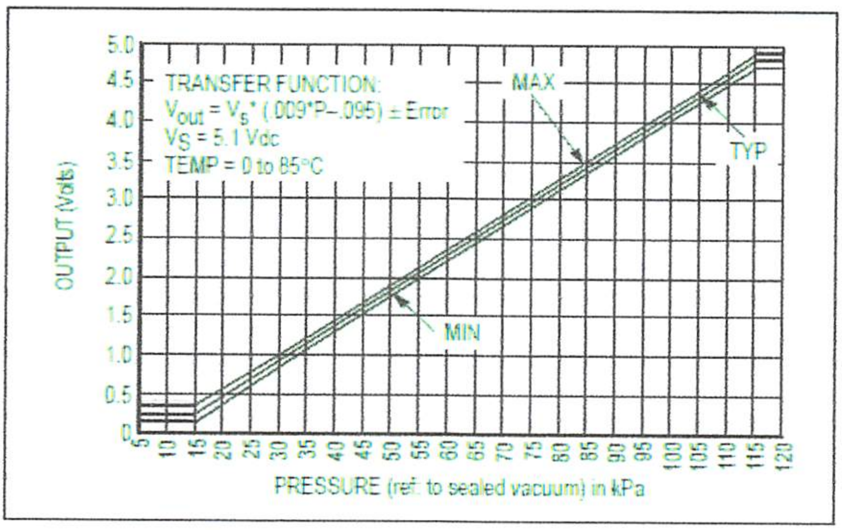
Apabila ada tekanan udara yang masuk melalui lubang P, dimana tekanan tersebut lebih besar dari tekanan vacuum yang dipergunakan sebagai tekanan referensi, maka membrane *fluoro silicon* akan melengkung kebawah, dimana besar lengkungan ini sebanding dengan besar tekanan yang diterima. Lengkungan ini yang kemudian diolah untuk kemudian dijadikan tegangan analog sebagai keluaran dari sensor melalui pin keluaran tegangan.

Sensor MPX4115AP memiliki bentuk yang kecil dengan kehandalan yang tinggi sehingga cocok dan ekonomis untuk digunakan seperti terlihat dalam Gambar 2.4:



Gambar 2.4 Sensor MPX4115AP
Sumber: datasheet, 2006:1

Keluaran sensor yang berupa tegangan (volt) memiliki hubungan yang linier terhadap tekanan (kPa) dimana keluaran tegangan akan berubah dengan perubahan tekanan udara, apabila tekanan semakin tinggi maka tegangan keluaran yang dihasilkan juga akan bertambah seperti terlihat dalam Gambar 2.5;



Gambar 2.5 Garfik Hubungan Antara Output Terhadap Tekanan
Sumber: datasheet, 2006:4

Dari gambar 2.5 terlihat bahwa pada tekanan 100kPa (1 atm), *pressure sensor* MPX4115AP akan menghasilkan tegangan keluaran sebesar 4.03 volt. Demikian pula untuk tekanan-tekanan berikutnya. Untuk mendapatkan perhitungan ketinggian digunakan persamaan

$$Z = -26126 * \ln\left(\frac{P(kPa)}{101.304}\right) \ldots\ldots\ldots (2.2)$$

Sumber: kerckhoff, 2001:1

Dimana Z = ketinggian (feet)

P = Tekanan (kPa)

Berdasarkan *Datasheet* sensor MPX4115AP, range tekanan 15kPa-115kPa dapat Di peridiksikan ketinggian dengan perhitungan sebagai berikut:

1. 15kPa

$$Z = -26126 \times \ln\left(\frac{15}{101.304}\right) = 49902 feet$$

Dengan nilai 1 feet (ft) = 0.3048*meter* maka

Z = 49902*0.3048 = 14970 meter

2. 115kPa

$$Z = -26126 * \ln\left(\frac{115}{101.304}\right) = -3313 feet$$

$$= -994.11 meter$$

Sehingga sensor MPX4115AP memiliki jangkauan 3313 feet (994.11m) dibawah permukaan air laut.

Sedangkan perhitungan untuk mendapatkan tegangan keluaran sensor adalah:

$$Vout = Vs * (0.009 * P(kPa) - 0.095) \pm error(datasheet) \ldots\ldots\ldots (2.3)$$

Dimana Vout = Tegangan keluaran yang dihasilkan sensor (volt)

P = Tekanan (kPa)

Vs = Tegangan supply sensor tekanan (volt)

Dari spesifikasi altimeter digital ini dirancang agar dapat mengukur ketinggian 0m hingga 4095m dengan range tekanan udara 60kPa hingga 101.3kPa. Berdasarkan datasheet sensor MPX4115AP pada range tekanan udara tersebut,sensor MPX4115AP dapat menghasilkan tegangan keluaran kisaran 2,25Volt hingga 4.08Volt. berikut perhitungannya:

3. 60kPa

$Vout = Vs*(0.009*P(kPa) - 0.095)$

$=5*((0.009*60) -0.095) = 2.25 volt$

4. 101.3kPa

$Vout = Vs*(0.009*P(kPa) - 0.095)$

$= 5*((0.009*101.3) - 0.095) = 4.08 volt$

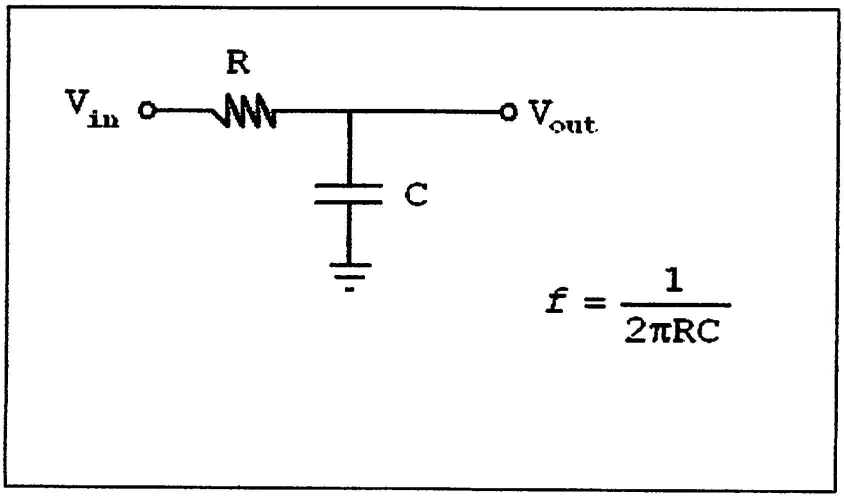
Jadi pada range tekanan sebesar 60kPa hingga101.3kPa, sensor MPX4115AP akan menghasilkan jangkauan tegangan 2.25 volt hingga 4.08 volt.

2.3 *Filter*

Filter adalah adalah sebuah rangkaian yang dirancang agar melewatkan suatu pita frekuensi tertentu seraya memperlemah semua isyarat di luar pita ini. Pengertian lain dari *filter* adalah rangkaian pemilih frekuensi agar dapat melewatkan frekuensi yang diinginkan dan menahan (*couple*) / membuang (*by pass*) frekuensi lainnya.

Rangkaian filter akti tersebut dapat *low pass filter,band pass filter*,dan *high pass filter*.

Filter dalam sistem ini menggunakan *Low Pass Filter*, *Low Pass Filter* adalah jenis *filter* yang melewatkan frekuensi rendah serta meredam/menahan frekuensi tinggi. Bentuk rangkaian LPF seperti ditunjukkan gambar Gambar 2.6 ;



Gambar 2.6 Rangkaian low pass filter
Sumber: Anonymous,2009:1

Pemberian Rangkaian *filter* diatas pada outputan dari sensor yaitu Bertujuan untuk menghilangkan sinyal *noise* yang tidak diinginkan dengan menahan/ mengeblok kisaran frekuensi tertentu.

2.4 *Analog to Digital Converter* (ADC)

Dalam sebuah pengukuran suatu variable fisik yang pada umumnya bersifat analog dengan menggunakan piranti digital, diperlukan adanya pengubahan variable digital yang nilainya proporsional dengan nilai variable yang akan diukur. Hal-hal yang perlu diperhatikan dalam penggunaan ADC ini adalah metode pengubah sinyal analog ke sinyal digital yang digunakan, tegangan maksimum yang dapat dikonversikan oleh ADC dari Sensor, resolusi, pewaktu eksternal ADC, type keluaran, ketepatan dan waktu konvesinya.

Resolusi ADC adalah perubahan terkecil yang terjadi pada keluaran analog sebagai suatu hasil dari perubahan masukan digital. Resolusi selalu sama dengan bobot dari LSB atau disebut juga '*step size*' karena step size merupakan besarnya perubahan tegangan keluaran pada saat kode masukan berubah dari satu step kestep berikutnya. Adapun perhitungan resolusi ADC adalah sebagai berikut:

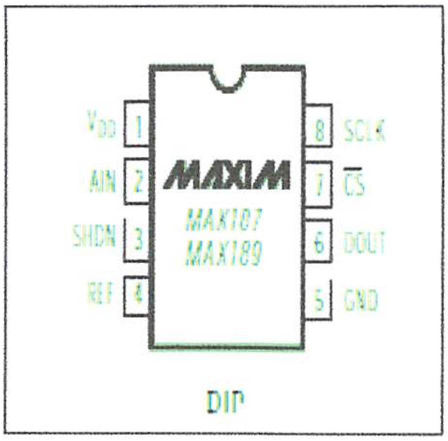
$$\Delta Vout = \frac{V_R}{2^n - 1} \qquad (2.4)$$

Sumber: Malvino, 1996:337

Dimana ΔVout menyatakan perubahan tegangan terkecil pada keluaran analog (resolusi), V_R menyatakan tegangan referensi dan n menyatakan jumlah bit keluaran biner IC *analog to digital converter.*

Spesifikasi lain untuk ADC adalah waktu konversi (*conversion time*). Waktu konversi suatu ADC adalah waktu yang diperlukan ADC untuk menghasilkan kode biner yang valid untuk tegangan masukan yang diberikan. Sebuah *converter* disebut berkecepatan tinggi jika memiliki waktu konversi yang pendek.

Dalam perencanaan dan pembuatan skripsi ini digunakan ADC MAX187 yang diproduksi oleh MAXIM semiconductor. ADC ini digunakan untuk mengubah tegangan analog menjadi besaran digital 12-bit. Max187 merupakan ADC yang memiliki keluaran serial 12-bit dengan konsumsi daya rendah dan beroperasi dengan menggunakan catu daya ±5 volt. Adapun konfigurasi pin ADC serial 12-bit MAX187 ditunjukkan dalam Gambar 2.7;



Gambar 2.7 konfigurasi pin ADC serial 12-bit MAX187
Sumber: Datasheet, 1993:1

Fungsi dari masing-masing pin pada ADC serial 12-bit MAX187 dapat dilihat pada Tabel 2.1 dibawah ini;

Tabel 2.1 Fungsi Pin ADC Serial 12-Bit

PIN	NAMA	FUNGSI
1	VDD	Tegangan supply 5 volt
2	AIN	Input analog
3	$\overline{\text{SHDN}}$	Input *shutdown* dimana untuk MAX187 SHDN high maka enable
4	REF	Tegangan referensi
5	GND	Ground digital dan analog
6	DOUT	Output data serial
7	$\overline{\text{CS}}$	*Chip select* aktif *low* yang akan memulai pengkonversian saat aktif
8	SCLK	Input serial *clock*

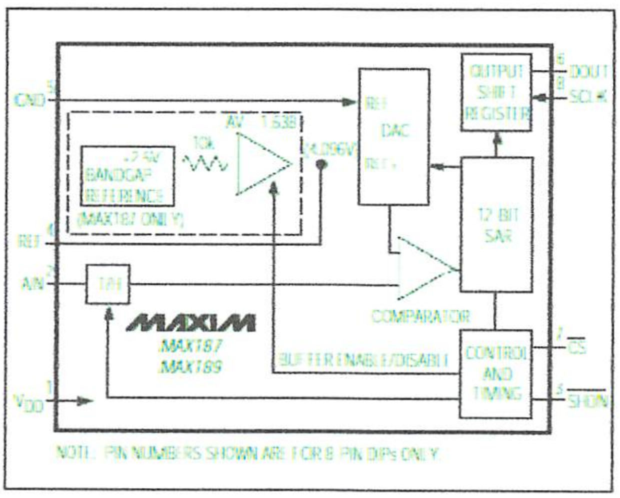
ADC serial 12-bit ini memiliki beberapa karakteristik, yaitu:

1. Input analog yakni AIN. ADC ini beroperasi dengan tegangan Vcc = +5 volt dan input analognya mempunyai variasi range 0 sampai 5 volt.
2. Dapat mengkonversi tegangan masukan analog menjadi 12 bit tegangan keluaran digital, apabila meggunakan *referensi eksternal* sebesar 5 volt maka

resolusinya adalah $\frac{5V}{2^{12}-1} = \frac{5V}{4095}$ = 1.22mV dan apabila menggunakan *referensi internal* sebesar 4.096 volt maka resolusinya adalah $\frac{4.096}{2^{12}-1} = \frac{4.096V}{4095} = 1mV$

3. MAX187 merupakan *successive-approximation* ADC dengan waktu konversi (*conversion time*) 805µs
4. Memiliki *referensi internal* Vref = 4.096V dan dapat pula menggunakan *referensi eksternal* serta memiliki fasilitas clock f_{CLK} = 4.0 MHz.

Blok diagram dari ADC MAX187 ditunjukkan dalam Gambar 2.8;

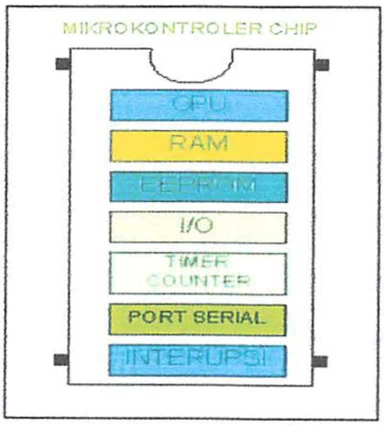


Gambar 2.8 Blok diagram ADC 12-bit MAX187
Sumber: Datasheet, 1993:1

2.5 Mikrokontroller

2.5.1 Umum

Secara umum mikrokontroller berfungsi sama dengan *personal computer* (PC). Bedanya adalah mikrokontroller terdapat di hampir semua peralatan elektronik, di dalam tape, TV, radio, telepon genggam (*handphone*) dan lain-lain. Mikrokontroller memiliki kemampuan yang diperlukan untuk membuat keputusan berdasarkan masukan yang diberikan dari luar dengan kata lain mikrokontroller merupakan otak dari sebuah perangkat elektronik. Mikrokontroller terdiri atas empat unsur yaitu processor (*central processing unit*), memori, perangkat I/O dan perangkat lain. Seperti ditunjukkan dalam Gambar 2.9;



Gambar 2.9 unit-unit mikrokontroller
Sumber: Anonymous,2009:1

Blok CPU, memori dan I/O merupakan blok utama sebuah mikrokontroller. Setiap mikrokontroller pasti memiliki blok tersebut. Selain tiga blok utama tersebut terdapat perangkat (*peripheral*) lain. Ketersediaan *peripheral-peripheral* dalam mikrokontroller tersebut dapat mengurangi adanya perangkat eksternal sehingga memperkecil ukuran alat elektronik secara keseluruhan.

Mikrokontroller didesain dengan instruksi-instruksi lebih luas dan 8 bit instruksi yang digunakan membaca data instruksi dari internal memori ke *arithmetic logic unit* (ALU). Banyak instruksi yang digabung dengan pin-pin *Chip*nya. Pin tersebut yaitu pin yang dapat diprogram (*programmable*) yang mempunyai beberapa fungsi yang berbeda tergantung pada kehendak *programmer*. Untuk memprogram sebuah *chip* mikrokontroller dibutuhkan sebuah alat pengisi kode mesin (*emulator*).

Microprocessor didesain sangat fleksibel dan mempunyai banyak byte instruksi. Semua instruksi bekerja dalam sebuah konfigurasi perangkat keras yang membutuhkan ruang memori dan perangkat I/O dihubungkan ke alamat dan pin-pin bus data pada *Chip*.

2.5.2 Perangkat keras Mikrokontroler keluarga MCS-51

Mikrokontroller keluarga MCS-51 seperti ditunjukkan pada tabel dibawah, semua berbasis pada arsitektur MCS-51. Untuk tipe 8032 dan 8052 memiliki jumlah *memory* yang lebih banyak dan ditambah dengan 1 kanal 16 bit *counter/timer*, serta memiliki jalur interupsi 6 buah. Untuk lebih jelasnya dapat dilihat pada Tabel 2.2 berikut:

Tabel 2.2 keluarga MCS-51

Device	***Internal memory***		***Timer counter***	***Interrupt***
	Program	**data**		
8052AH	8k x 8 ROM	256 x 8 RAM	3 x 16 bit	6
8051AH	4k x 8 ROM	128 x 8 RAM	2 x 16 bit	5
8051	4k x 8 ROM	128 x 8 RAM	2 x 16 bit	5
8032AH	None	256 x 8 RAM	3 x 16 bit	6
8031AH	None	128 x 8 RAM	2 x 16 bit	5
8031	None	128 x 8 RAM	2 x 16 bit	5
8751AH	4k x 8 ROM	128 x 8 RAM	2 x 16 bit	5
8751H-12	4k x 8 ROM	128 x 8 RAM	2 x 16 bit	5
8751H-88	4k x 8 ROM	128 x 8 RAM	2 x 16 bit	5
AT89C51	4k x 8 EEPROM	128 x 8 RAM	2 x 16 bit	5
AT89C4051	4k x 8 PEROM	128 x 8 RAM	2 x 16 bit	5

Semua jenis mikrokontroller yang ada pada tabel diatas memiliki arsitektur dasar yang sama, serta memiliki instruksi yang sama, yang membedakan adalah tipe bahan semikonduktor, kapasitas *memory* dan jenis *memory* ROM *internal*nya. Khusus untuk tipe AT89C51 adalah produksi atmel tetapi tetap berbasis pada arsitektur MCS-51, mikrokontroller tipe ini menggunakan *on-chip memory* program jenis EEPROM/*flash* ROM yang mudah cara menghapusnya serta memiliki harga relatif murah dibandingkan dengan tipe EPROM. Untuk tipe 8031 dan 8032 tidak memiliki ROM *internal*, sehingga harus selalu dipergunakan *eksternal* ROM.

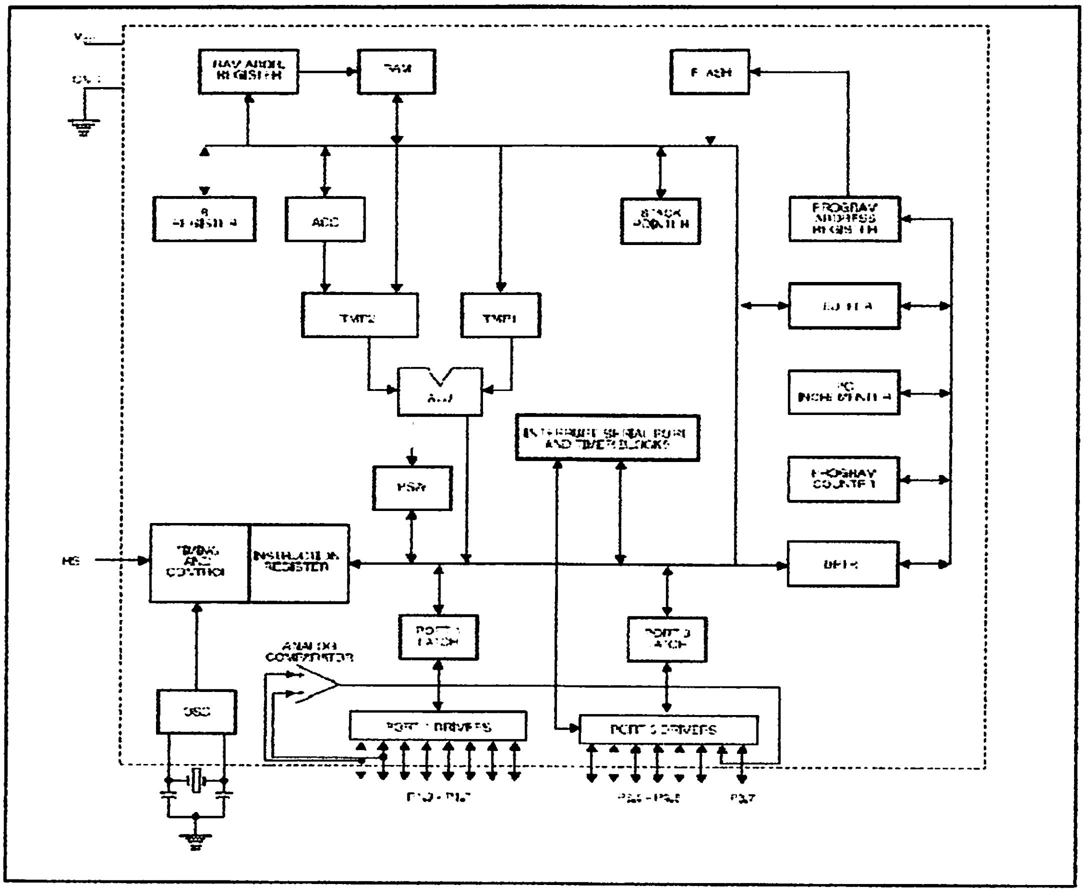
2.5.3 Arsitektur mikrokontroller AT89C4051

Mikrokontroller AT894051 adalah mikrokontroller buatan ATMEL yang didesain untuk compatible dengan produk MCS – 51™. Mikrokontroller ini berdaya rendah, untuk kerja tinggi dengan teknologi mikrokomputer CMOS 8 bit dengan 4K byte *flash programmable* dan *erasable read only memory* (PEROM).

Mikrokontroller AT89C4051 mempunyai arsitektur sebagai berikut:

1. 4k Byte Internal PEROM (*programmable and Eraseable* ROM)
2. 128 x 8 bit internal RAM
3. 15 *programable* I/O *lines*
4. 2 buah *Timer/Counter* 16-bit
5. 5 sumber *interrupt* dengan 2 level prioritas
6. *Programmable Serial* UART *channel*
7. *On-chip comparator analog* dan on-chip oscillator dan rangkaian clock

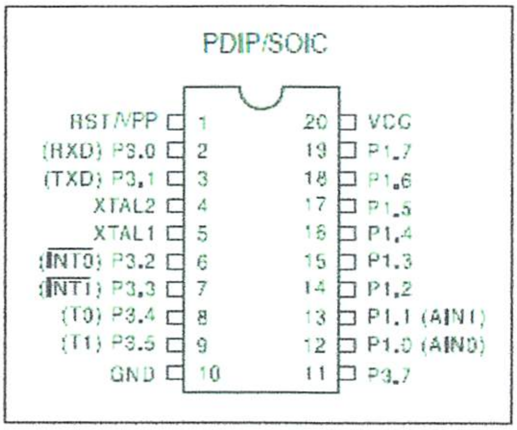
Mikrokontroller AT89C4051 mempunyai bentuk arsitektur seperti dalam Gambar 2.10;



Gambar 2.10 Arsitektur AT89C4051
Sumber: Datasheet, 1998:2

2.5.4 Konfigurasi Pin-pin AT89C4051

Mikrokontroller AT89C4051 memiliki jumlah pin 20 dimana masing-masing pinnya memiliki fungsi yang berbeda, seperti ditunjukkan dalam Gambar 2.11;



Gambar 2.11 Konfigurasi Pin AT89C4051
Sumber: Datasheet: 1998:1

Fungsi dari pin-pin MCU AT89C4051

1. VCC

   Dihubungkan dengan sumber tegangan

2. GND

   Dihubungkan dengan *ground* rangkaian

3. Port 1

   Port 1 merupakan port I/O 8 bit *bi-directional*. Pin P1.2 sampai P1.7 dengan *pull-up internal*, sedanglan pada pin P1.0 dan P1.1 membutuhkan *pull-up eksternal*. Pin P1.0 dan P1.1 juga dapat berfungsi sebagai positif input (AINA) dan negative input (AINI), secara berturut-turut ia terlatek pada *chip precision analog comparator*. Bila port 1 akan difungsikan sebagai input, maka logika 1 harus ditulis pada masing-masing bit. Dengan demikian rangkaian *pull-up internal* akan menyebabkan pin berlogika tinggi. Maka rangkaian input eksternal dapat megubah pin ke logika 1 ataupun 0. Hal ini berbeda jika logika 0 ditulis pada port. Rangkaian input eksternal tidak akan bisa mengubah pin ke logika 1. bila port difungsikan sebagai output, maka saat penulisan logika 1 ke port maka pin port tersebut akan berlogika mengambang.

4. Port 3

   Pada port 3 ada 7 pin yaitu P3.0 sampai P3,7 ketujuh pin tersebut adalah pin I/O parallel dengan *pull-up internal.* Khusus pada pin P3.6 sebagai output dari komparator dan bukan sebagai pengakses seperti pada fungsi pin I/O *general purpose*. Port 3 juga menerima beberapa sinyal *control* untuk pemrogaman dan verifikasinya. Port 3 juga mempunyai fungsi lain seperti ditunjukkan pada Tabel berikut ini:

Tabel 2.3 Fungsi Alternatif Port 3

Port Pin	Fungsi
P3.0	RXD (serial input port)
P3.1	TXD (serial output port)
P3.2	INT0 (external interrupt 0)
P3.3	INT1 (external interrupt 1)
P3.4	T0 (timer 0 external input)
P3.5	T1 (timer 1 external input)
P3.7	I/O parallel port

5. RST, pin ini merupakan input reset. Semua pin I/O akan reset selama 1s ketika pin ini menuju logika tinggi. Kondisi tinggi dari pin selama dua siklus mesin akan menyebabkan *device* ini reset
6. XTAL 1, pin ini merupakan *inverting oscillator amplifier* dan input pada operasi internal clock
7. XTAL 2, pin ini merupakan output dari *inverting oscillator amplifier*

2.5.5 Organisasi Memory

Mikrokontroller AT89C4051 memilki *address* yag terpisah antara Program memory(ROM) dan data Memory(RAM). Program memory memiliki kapasitas 4k byte berada dalam *chip*. Data memory memiliki kapasitas 128 byte dan ditambah dengan SFR (*Special Function Register*).

2.5.5.1 Program memory (ROM)

Mikrokontroller AT89C4051 hanya memiliki program memory internal sebesar 4Kbyte EEPROM dan tidak bisa menggunakan program memori eksternal.

2.5.5.2 Data memory (RAM)

Mikrokontroller AT89C4051 memiliki memori data berupa RAM internal sebesar 128 byte ditambah dengan jumlah *Special Function Register* (SFR). 128 Byte RAM internal dapat diakses secara langsung (*direct*) atau tidak langsung (*indirect*). RAM internal 128 Byte dapat dibagi menjadi 3 areal, yaitu:

1. 32 Byte dari *address* 00H-1FH merupakan areal *register* kerja yang dibagi menjadi 4 bank *register* yang duberi nomor bank 0, Bank 1, Bank 2 dan Bank 3. Tiap-tiap bank *register* yang terdiri dari 8 buah *register* dengan nama masing-masing R0, R1, R2, ...R7. Tiap-tiap *register* dapat dialamati dengan menyebutkan namanya. Untuk menyeleksi bank *register* bank dapat dilakukan melalui *Program Status Word* (PSW) pada bit RS1 dan RS0. Jika *Programmer* tidak dapat melakukan seleksi maka secara alamiah setelah kondisi reset yang diseleksi adalah *Register* Bank 0.

2. Areal *bit-addressable* sebanyak 16 Byte *address* dari 20H-2Fh, yang membentuk 128 *bit-addressable*
3. Areal RAM serbaguna dari *address* 30H-7FH. Areal ini adalah byte-*addressable*

2.5.6 *Special Function Register* (SFR)

Register dengan fungsi khusus (*Special Function Register*) terletak pada 128 byte bagian atas memori data internal. Wilayah SFR ini terlatak pada alamat 80H sampai FFH. Pengalamatan harus diakses secara langsung baik secara bit maupun secara byte. *Register-register* khusus dalam Mikrokontroller AT89C4051 yaitu:

1. *Accumulator*, merupakan *register* penyimpan hasil suatu operasi *Arithmetic Logic Unit* (ALU)
2. *Register* B, *register* ini digunakan untuk proses perkalian dan pembagian
3. *Program Status Word* (PSW), *register* ini berisi status program seperti ditunjukkan berikut:

PSW.7	PSW.6	PSW.5	PSW.4	PSW.3	PSW.2	PSW.1	PSW.0
CY	AC	F0	RS1	RS0	0V	-	P

Keterangan:

CY : *Carry flag*

AC : *Auxilliary Carry Flag* untuk operasi *Binary Counter Decimal* (BCD)

F0 : *Flag* 0 (untuk segala keperluan)

RS1 : Selektor bank register bit 1. Set/clear di bawah komando software untuk menentukan bank register kerja.

RS0 : Selektor bank register bit 0. Set/clear di bawah komando software untuk menentukan bank register kerja.

OV : *Over flow flag*

\- : *reserve*

P : *Prity flag*

Ada empat bank yang dapat dipilih untuk digunakan, semuanya bersifat *addressable*. Seperti ditunjukkan pada Tabel berikut:

Tabel 2.4 Empat Bank pada register RS1 dan RS0

RS1	RS0	Register
0	0	Bank 0
0	1	Bank 1
1	0	Bank 2
1	1	Bank 3

4. *Stack Pointer* (SP), merupakan register yang mempunyai lebar 8 bit. Isi register ini ditambah sebelum data disimpan, selama instruksi PUSH dan CALL. Isi register ini dikurangi ketika terdapat instruksi POP. Pada kondisi reset register SP berada pada posisi alamat 07H sehinga stack akan dimulai pada alamat 08H.

5. *Data Pointer Register* (DPTR), terdiri dari dua biah register yaitu register byte tinggi (*Data Pointer High*, DPH) dan register byte rendah (*Data Pointer Low*, DPL). Fungsinya untuk memegang alamat 16 bit. Register ini juga dapat dimanipulasi sebagai register 16 bit atau register 8 bit yang *independent*. DPTR digunakan untuk pengalamatan tidak langsung untuk memindahkan data dari atau ke memori eksternal (RAM).

6. Register Port 1 dan port 3, register-register P1 dan P3 merupakan SFR yang berfungsi sebagai *latch* dari Port 1 dan port 3.
7. *Serial Data Buffer* (SBUF), serial ini sebenarnya merupakan dua register yang terpisah, *transmit bffer register* (untuk mengirim data serial) dan *receive buffer register* (untuk menerima data serial). Ketika data dipindahkan ke SBUF, maka data akan menuju ke *transmit buffer register* dimana data ditampung untuk pengiriman serial. Memindahkan data ke SBUF berarti memulai transmisi data secara serial. Sebaliknya bila data dipindahkan dari SBUF, maka data tersebut berasal dari *receive buffer register.*
8. *Timer Register*, pasangan register TH0, TL0 dan TH1, TL1 merupakan register 16 bit yang berfungsi sebagai register *counter* untuk *timer/counter* 0 dan *timer/counter* 1.
9. *Control Register*, register ini terdiri dari IP, IE, TMOD, TCON, SCON, dan PCON yang berisi kontrol dan status bit untuk *system interupsi*, *timer/counter* dan *serial port.*

Untuk operasi AT89C51 yang tidak menggunakan alamat internal RAM (00H-7FH) dilakukan oleh SFR yang beralamat 80H-FFH, tetapi tidak semua *address* tersebut digunakan sebagai DFR, hanya alamat tertentu seperti dijelaskan pada Tabel berikut:

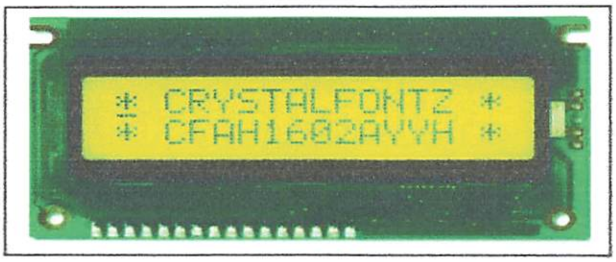
Tabel 2.5 Pembagian alamat pada SFR

SYMBOL	NAME	ADDRESS
*ACC	ACCULULAOR	0E0H
*B	REGISTER B	0F0H
*PSW	PROGRAM STACK POINTER	0D0H
SP	STACK POINTER	81H
DPL	DATA POINTER LOW BYTE	82H
DPH	DATA POINTER HIGH BYTE	83H
*P1	PORT 1	90H
*P3	PORT 3	0B0H
*IP	INTERRUPT PRIORITY CONTROL	0B8H
*IE	INTERRUPT ENABLE CONTROL	0A8H
TMOD	T/C MODE CONTROL	89H
TCON	T/C CONTROL	88H
TH0	T/C 0 HIGH CONTROL	8CH
TL0	T/C 0 LOW CONTROL	8AH
TH1	T/C 1 HIGH CONTROL	8DH
TL1	T/C 1 LOW CONTROL	8BH
*SCON	SERIAL CONTROL	98H
SBUF	SERIAL BUFFER	99H
PCON	POWER CONTROL	87H

SFR yang diberi tanda (*) adalah SFR yang dapat dialamti secara bit atau byte (*bit addressable atau byte addressable*).

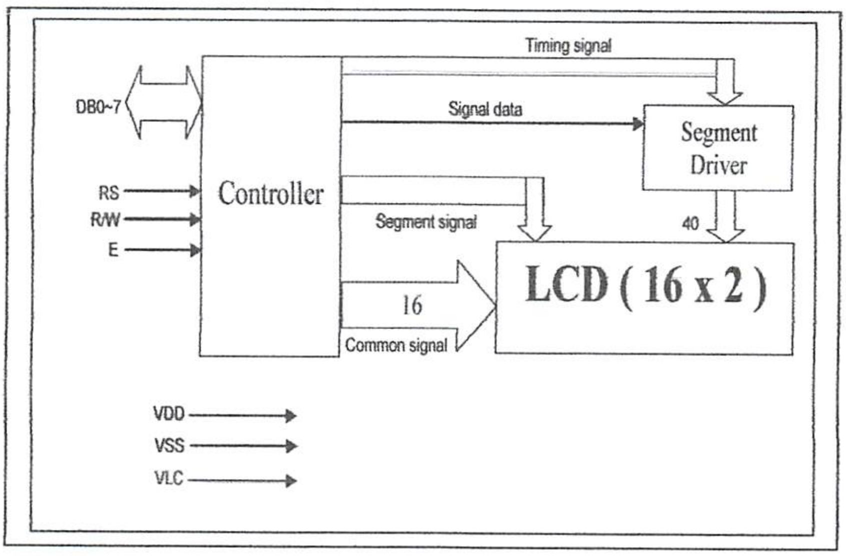
2.6 *Display* LCD (*Liquid Crystal Display*)

LCD (*Liquid Crystal Display*) adalah salah satu jenis penampil yang digunakan untuk menampilkan angka, karakter atau bahkan angaka dan karakter. LCD terdiri atas tumpukan tipis atau sel dari dua lembar kaca dengan pinggiran yang tertutup rapat. Diantara dua lembar kaca tersebut diberi bahan Kristal cair (liquid crystal) yang tembus cahaya dimana akan beremulasi apabila diberi tegangan. Tampilan berupa dot matrik 5 x 7 dengaan jenis huruf yang ditampilkan akan lebih banyak dan lebih baik resolusinya jika dibandingkan dengan seven-segment. Adapun contoh modul LCD 16x2 ditunjukkan dalam Gambar 2.12;



Gambar 2.12 LCD 16x2
Sumber: Anonymous,2009:1

Selain sebagai suatu modul tampilan yang mempunyai konsumsi daya yang relatif rendah, LCD juga memiliki keistimewaan dibandingkan tampilan yang lain seperti sevent-segment yaitu kemampuan untuk menampilkan karakter dan berbagai macam symbol. Adapun blok diagram LCD ditunjukkan dalam Gambar 2.13;



Gambar 2.13 Blok diagram Modul LCD
Sumber: Anonymous, 2009:1

Untuk dapat menggunakan LCD maka hal yang perlu diperhatikan adalah *sinyal control* dari LCD yaitu : RS, R/W dan EN. Instruksi operasi meliputi operasi dasar *register, busy flag, address counter, display data* ***RAM****, character generator* ***ROM***.

1) *Registrasi*

Kontroller LCD mempunyai dua buah register 8 bit, yaitu *register* instruksi (IR) dan *register* data (DR). kedua register ini dipilih melalui *register select* (RS). Table *register* seleksi terlihat pada Tabel 2.6;

Tabel 2.6 *register selection* pada LCD

RS	R	Operasi
0	0	*IR selection,IR write, Internal operation (Display clear, cursor)*
0	1	*Busy flag (DB7) dan Address counter*
1	0	*DR selection, DR write*
1	1	*DR selection, DR read*

2) *Busy Flag*

Busy Flag menunjukkan bahwa modul LCD siap untuk menerima instruksi selanjutnya. Sebagaimana terlihat pada tabel 2.2 *register* seleksi, sinyal akan melalui DB7 jika RS = 0 dan R/$\overline{W}$ = 1.

3) *Address counter* (AC)

Address counter menunjukkan suatu lokasi memori dalam LCD dimana suatu data diletakkan dalam modul LCD. Pemilihan lokasi alamat diberikan melalui *register* instruksi (IR). Ketika data berada pada AC, maka secara otomatis AC akan menaikan atau menurunkan alamat dari *entry mode set.*

4) *Display data RAM* (DD RAM)

Pada LCD masing-masing *line* (baris) mempunyai *range* alamat tersendiri. Alamat-alamat itu diekspresikan melalui bilangan hexadecimal. Banyaknya *line* yang tersedia ditentukan oleh tipe LCD yang digunakan. Untuk LCD tipe M1632 (16 x 2) hanya memiliki dua *line* dimana masing-masing *line* terdiri dari 16 *display digit*. Untuk *line* 1 menggunakan kisaran alamat 00H – 0fH, sedangkan pada *line* 2 menggunakan kisaran alamat 40H – 4fH. Adapun alamat diantara dua kisaran tersebut (10H – 3fH) tidak dipergunakan oleh LCD tipe M1632.

5) *Character Generator ROM* (CG ROM)

CG ROM membangkitkan 192 buah tipe 5 x 7 karakter dot matriks. Pada LCD telah tersedia ROM sebagai pembangkit karakter dalam kode ASCII. CG RAM digunakan apabila diinginkan untuk pembuatan karakter tersendiri melalui program, dengan maksimal 8 buah karakter.

LCD 16 x2 M1632 ini mempunyai 16 pin atau penyemat dengan fungsi-fungsi yang sebagaimana ditunjukkan pada Tabel 2.7

Tabel 2.7 Fungsi pin-pin pada LCD M1632

NO.	Nama Pin	Fungsi
16	V – BL	Sebagai ground dari backlight
15	V + BL	Sebagai kutub positif dari backlight
7 – 14	DB0 –	Merupakan saluran data, berisi perintah dan data yang akan
6	E	Sinyal operasi awal, sinyal ini mengaktifkan data tulis atau
5	R/W	Sinyal seleksi tulis atau baca
4	RS	Sinyal pemilih register
3	Vlc	Untuk mengendalikan kecerahan LCD dengan mengubah
2	Vcc	Tegangan Catu + 5 volt
1	Vss	Terminal ground

Sedangkan table instruksi dari LCD ditunjukkan pada Tabel 2.8

Tabel 2.8 Instruksi dari LCD

N	INSTRUKSI	RS	R/W	D7	D6	D5	D4	D3	D2	D1	D
1	*Display clear*	0	0	0	0	0	0	0	0	0	1
2	*Cursor name*	0	0	0	0	0	0	0	0	1	0
3	*Entry mode set*	0	0	0	0	0	0	0	1	0	0
4	*Display on/off control*	0	0	0	0	0	0	1	0	0	0
5	*Cursor/display shift*	0	0	0	0	0	1	0	0	0	0
6	*Function set*	0	0	0	0	1	0	0	0	0	
7	*CG RAM address set*	0	0	0	1	Alamat karakter					
8	*DD RAM address set*	0	0	1	Tampilan data alamat						
9	*BF/address set*	0	1	0	Alamat arus						
10	*Data write to CG RAM*	1	0	Byte karakter							
11	*Data read from CG RAM*	1	1	Byte karakter							

Fungsi masing-masing instruksi adalah sebagai berikut :

1. *Display clear* : membersihkan tampilan yang ada pada LCD dan mengembalikan kursor kembali ke posisi semula
2. *Cursor home* : hanya membersihkan semua tampilan dan kursor kembali semula
3. *Entry mode set* : layar beraksi sebagai tampilan tulis

   S = 1/0 : menggeser layar

   I/O = 1 : kursor bergerak ke kanan dan layar bergerak ke kiri

   I/O = 0 : kursor bergerak ke kiri dan layar bergerak ke kanan
4. *Display on/off control*

   D = 1 : layar on

   D = 0 : layar off

   C = 1 : kursor on

   C = 0 : kursor off

   B = 1 : kursor berkedip-kedip

B = 0 : kursor tidak berkedip

5. *Cursor diplay shift*

S/C = 1 : LCD diidentifikasikan sebagai layar

S/C = 0 : LCD diidentifikasikan sebagai kursor

R/L = 1 : menggeser satu spasi ke kanan

R/L = 0 : menggeser satu spasi ke kiri

6. *Function set*

DL = 1 : panjang data LCD pada 8 bit (DB7 – DB0)

DL = 0 : panjang data LCD pada 4 bit (DB7 – DB0)

Bit *upper* ditransfer terlebih dahulu kemudian diikuti dengan 4 bit *lower*

N = 1/0: LCD menggunakan 2 atau 1 baris karakter

P = 1/0 : LCD menggunakan 5 x 10 atau 5 x 7 dot matrik

7. *CG RAM address set* : menulis alamat RAM ke karakter.

8. *DD RAM address set* : menulis alamat RAM ke tampilan.

9. *BF/address set* : BF = 1/0, LCD dalam keadaan sibuk atau tidak sibuk.

10. *Data write to* CG RAM or DD RAM : menulis byte ke alamat terakhir RAM yang dipilih.

11. *Data read from* CG RAM or DD RAM : membaca byte dari alamat terakhir RAM yang dipilih.

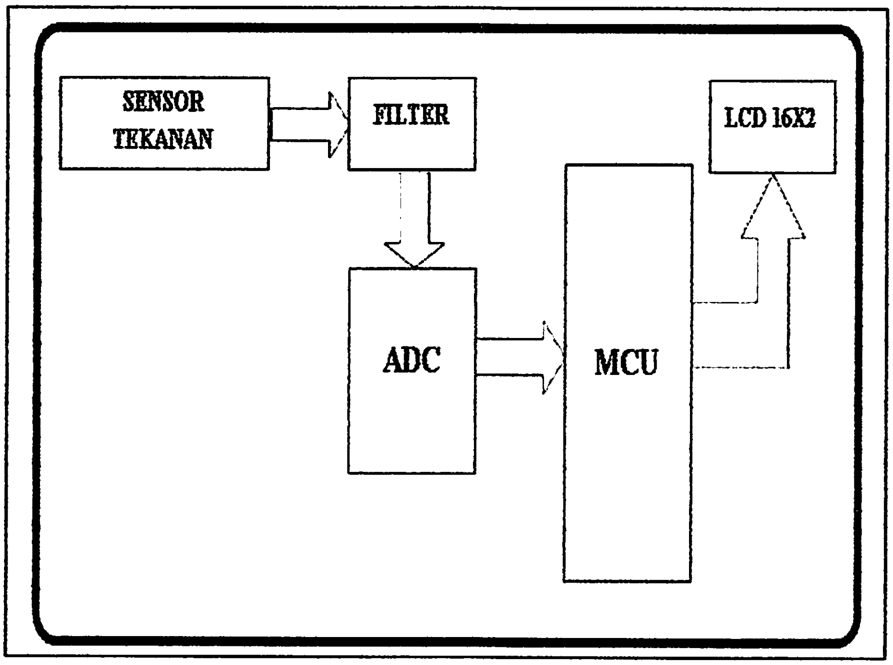
BAB III
PERANCANGAN DAN PEMBUATAN ALAT

3.1. Pendahuluan

Pada dasarnya perancangan dan pembuatan alat pengukur ketinggian dari permukaan air laut (*altimeter digital*) ini dibentuk dari dua bagian utama yaitu bagian perancangan perangkat keras (*hardware*) dan bagian perancangan perangkat lunak (*software*). Bagian perancangan *hardware* terbagi lagi menjadi lima bagian (blok) yang terpisah yaitu bagian sensor, bagian *filter*, bagian pengkonversi sinyal analog menjadi digital, bagian kontrol dan pengolah data dan yang terakhir bagian tampilan. Pada masing-masing bagian tersebut disusun dengan pemilihan beberapa jenis komponen dengan fungsi sesuai dengan perancangan, sehingga nantinya akan dihasilkan satu bentuk bagian (blok) dengan fungsi sesuai dengan perancangan yang dilakukan di awal. Pada bagian perancangan *software* dilakukan perancangan pembuatan Diaram alir program. Dengan terbentuknya bagian-bagian tersebut akan dihasilkan satu sistem altimeter digital.

3.2. Blok Diagram

Diagram blok sistem merupakan salah satu bagian terpenting dalam perancangan alat ukur ketinggian dari permukaan air laut ini, karena dari diagram blok dapat diketahui cara kerja (prinsip kerja) keseluruhan rangkaian. Adapun blok diagram sistem altimeter Digital ditunjukkan dalam Gambar 3.1.



Gambar 3.1 Blok Diagram Sistem

Keterangan dari blok diagram diatas:

1. Sensor Tekanan

Sensor yang digunakan adalah sensor tekanan udara dengan type MPX4115AP yang memiliki sensitivitas sebesar 45,9mV/kPa (*datasheet*). Sensor ini digunakan untuk mendeteksi setiap perubahan tekanan udara disekitar dimana akan menghasilkan sinyal-sinyal tegangan analog yang akan menjadi masukan bagi ADC.

2. *Filter*

Filter ini berfungsi untuk mengurangi *noise output* yang dihasilkan dari sensor tekanan.

3. ADC (*Analog to Digital Converter*)

ADC di sini berfungsi sebagai pengkonversi (*converter*) tegangan analog menjadi data-data digital agar dapat diproses oleh mikrokontroller.

4. MCU (mikrokontroller)

MCU yang digunakan disini memiliki beberapa fungsi diantaranya; memberikan instruksi pada ADC untuk mengkonversikan sinyal analog menjadi data digital, mengkonversikan dan mengolah data output dari ADC menjadi satuan ketingian yang diinginkan, memberikan instruksi pada LCD untuk menampilkan hasil pengkonversian berupa angka dalam satuan yang diinginkan.

5. LCD (*Liquid Crystal Display*)

LCD merupakan *display* yang digunakan untuk menampilkan hasil pengukuran (ketinggian) dari alat ini dengan satuan meter.

3.3. Prinsip Kerja

Metode yang digunakan dalam pengukuran ketinggian tempat dari permukaan air laut ini adalah dengan mendeteksi perubahan tekanan udara pada tempat tersebut. Perubahan tekanan tersebut dapat dideteksi dengan menggunakan sebuah sensor yang diproduksi oleh Motorola inc. MPX4115AP. Sensor tersebut dapat menghasilkan keluaran berupa tegangan yang sebanding dengan tekanan udara yang dideteksinya.

Tegangan yang dihasilkan dari sensor tersebut kemudian diumpankan ke sebuah rangkaian *low pass filter* untuk mengurangi *noise* yang dihasilkan dari sensor itu sendiri. Kemudian keluaran dari *filter* tersebut dihubungkan dengan ADC. Adapun fungsi ADC pada alat ini adalah untuk mengkonversikan perubahan sinyal-sinyal analog yang dihasilkan dari sensor tekanan udara yang sebelumnya melewati *filter* menjadi data-data digital. Data-data digital tersebut kemudian langsung diumpankan ke mikrokontroller AT89C4051 untuk diolah, dikonversikan dan mikrokontroller akan memberikan instruksi pada LCD 16x2 untuk menampilkan hasil pengkonversian berupa angka-angka desimal dalam satuan meter.

3.4. Perancangan Dan Pembuatan Alat

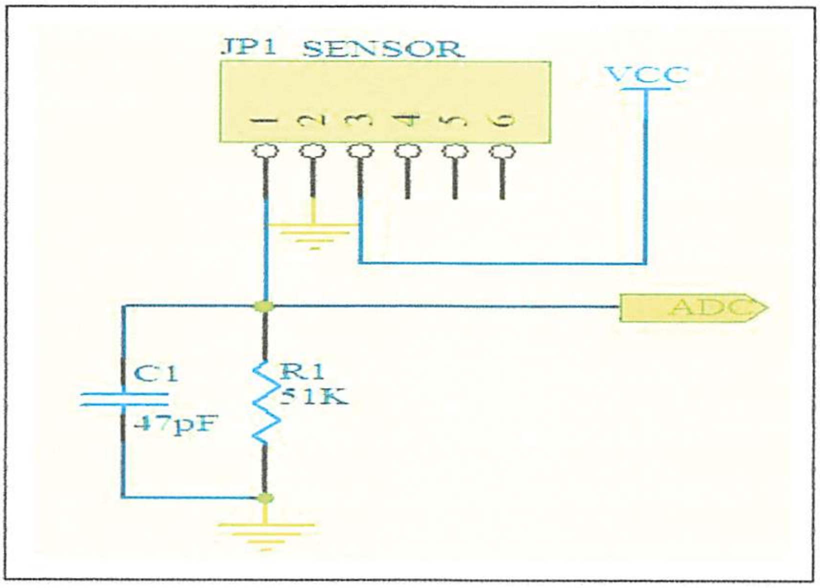
Dari Gambar 3.1 blok diagram sistem dan uraian di atas maka perancangan dari masing-masing bagian (blok) dapat diuraiakan sebagai berikut:

1. Perancangan bagian perangkat keras (*hardware*), yaitu perancangan;
   1) Bagian sensor dan filternya
   2) Bagian pengkonversi sinyal analog ke digital (ADC serial 12-bit)
   3) Bagian kontrol dan pengolah data (mikrokontroller AT89C4051) dan
   4) Bagian tampilan (LCD 16x2)
2. Perancangan bagian perangkat lunak (*software*)

3.4.1. Perancangan Bagian Sensor

Pada bagian sensor ini digunakan sensor MPX4115AP yang diproduksi oleh motorola Inc. Sensor ini akan menghasilkan sinyal keluaran analog berupa tegangan apabila dideteksi tekanan udara pada tempat tersebut. Tegangan keluaran yang dihasilkan sensor ini berada pada range 0.2 volt- 4.8 volt dengan range tekanan 15 kPa – 115 kPa dan memiliki sensitivitas sebesar 45.9 mV/kPa (*datasheet*).

Pada perencangan sensor ini dilakukan berdasarkan *datasheet* sensor dan *application note* MPX4115AP seperti terlihat dalam Gambar 3.2.



Gambar 3.2 Rangkaian sensor MPX4115AP

Dari Gambar 3.2 diatas terlihat bahwa keluaran dari *integrated pressure sensor* (IPS) pada pin 1 langsung dihubungkan dengan rangkaian *low pass filter.* Menurut datasheet sensor MPX4115AP direkomendasikan untuk menggunakan *low pass filter* dengan frekuensi *cutoff* sebesar 650Hz (*aplication note* :2005:2), yang berfungsi untuk mengurangi *Noise* yang dihasilkan oleh sensor itu sendiri. Sehingga perhitungan nilai yang digunakan adalah sebagai berikut:

Nilai C = 50pF

Fc = —— ————

R = —— = ———— = 4899,55 = 51K

dari spesifikasi altimeter digital ini dirancang dapat mengukur ketinggian 0m hingga 4095m dengan range tekanan udara 60,5kPa hingga 101,3kPa.

Untuk mendapatkan perhitungan ketinggian digunakan persamaan

$$Z = -26126 * \ln\left(\frac{P(kPa)}{101.304}\right)$$

Sumber:Kerckhoff,2001:1

Dimana Z = ketinggian (feet)

P = Tekanan (kPa)

Berikut perhitungannya:

- 60.5kPa

$$Z = -26126 \times \ln\left(\frac{60.5}{101.304}\right) = 13467 feet$$

Dengan nilai 1 feet (ft) = 0.3048*meter* maka

Z = 13467*0.3048 = 4104 meter

- 101.3kPa

$$Z = -26126 * \ln\left(\frac{101.3}{101.304}\right) = 1.03 feet$$

Z = 1.03*0.3048 = 0 *meter*

Sedangkan perhitungan untuk mendapatkan tegangan keluaran sensor adalah:

$$Vout = Vs * (0.009 * P(kPa) - 0.095) \pm error(datasheet)$$

Dimana Vout = Tegangan keluaran yang dihasilkan sensor (volt)

P = Tekanan (kPa)

Vs = Tegangan supply sensor tekanan (volt)

Berikut perhitungannya:

- 60,5kPa

$Vout = Vs * (0{,}009 * P(kPa) - 0{,}095)$

$= 5*((0,009*60,5) - 0,095) = 2,25 volt$

- 101,3kPa

$Vout = Vs*(0,009*P(kPa) - 0,095)$

$= 5*((0,009*101,3) - 0,095) = 4,08 volt$

Jadi pada range tekanan sebesar 60,5kPa hingga 101,3kPa, sensor MPX415AP akan menghasilkan jangkauan tegangan antara 2,25 volt hingga 4,08 volt. Range tegangan inilah yang akan menjadi tegangan masukan kerangkaian ADC.

3.4.2. Perancangan Bagian *Analog to Digital Converter* (ADC)

Pada bagian ini digunakan ADC MAX187 yang diproduksi oleh MAXIM semiconductor. ADC ini digunakan untuk mengubah tegangan analog menjadi data digital. ADC MAX187 merupakan ADC yang memilki keluaran serial 12-bit dengan konsumsi daya rendah dan dapat beroperasi dengan menggunakan catu daya 5 volt. Selain itu ADC ini memilki dua mode tegangan referensi yaitu tegangan referensi internal (4,096) dan tegangan referensi eksternal.

Karena keluaran dari sensor menghasilkan tegangan keluaran sebesar 2,25 volt – 4,08 volt, maka perancangan rangkaian ADC MAX187 dipilih menggunakan tegangan referensi internal sebesar 4,096 volt. Adapun perhitungan resolusi dari ADC MAX187 12-bit adalah sebagai berikut:

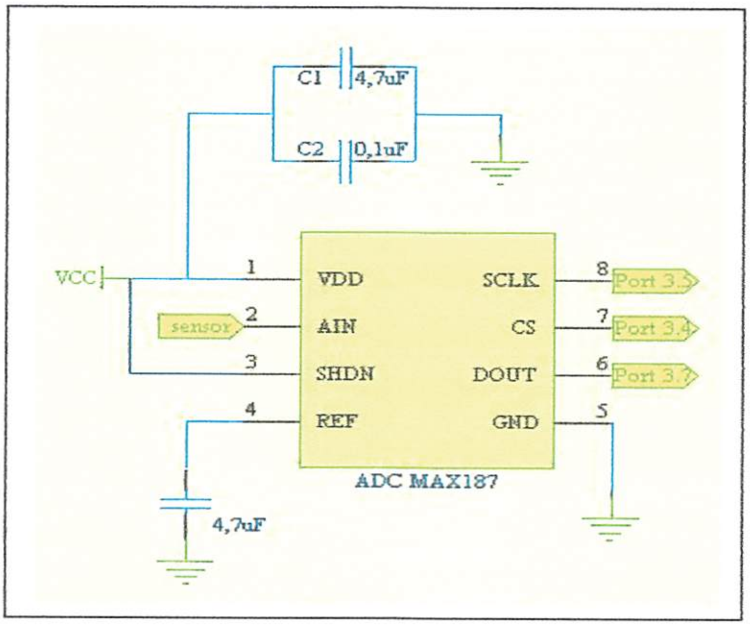
$$Resolusi = \frac{Vref}{(2^n - 1)}$$

$$= \frac{4,096}{(2^{12} - 1)} = \frac{4,096}{4095}$$

$$= 1 mV$$

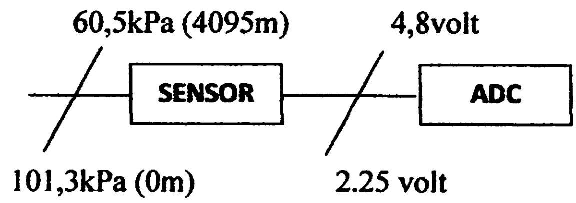
Jadi rangkaian ADC ini memiliki resolusi sebesar 1mV dengan tegangan referensi sebesar 4,096 volt. Untuk mengaktifkan tegangan referensi internal maka pin $\overline{\text{SHDN}}$ dihubungkan dengan Vcc (*high*) dan pada pin REF di*bypass* dengan kapasitor 4,7uF (Anonymous, 1993:7). Data-data analog yang dihasilkan sensor terhubung dengan pin AIN ADC.

ADC MAX187 ini menggunakan sumber clock eksternal sebesar 4Mhz, yang disupply oleh mikrokontroller melalui pin P3.5 yang terhubung dengan pin SCLK ADC. Sedangkan untuk mengaktifkan ADC MAX187 juga dikontrol melalui pin P3.4 mikrokontroller yang terhubung dengan pin $\overline{\text{CS}}$ ADC. Sedangkan data serial ADC MAX187 dikeluarkan melalui pin DOUT yang terhubung dengan pin P3.7 mikrokontroller. Perancangan rangkaian ADC ditunjukkan dalam Gambar 3.3.



Gambar 3.3 Rangkaian *Analog to Digital Converter*

Berdasarkan spesifikasi alat yang dapat mengukur ketinggian tempat 0meter hingga 4095 meter dari permukaan air laut, diharapkan dengan perubahan resolusi ADC 1mV altimeter digital ini mampu mendeteksi perubahan kenaikan ketinggian setinggi 1 meter. Perhitungan resolusi dari altimeter ini adalah sebagai berikut;



$$Resolusi \text{ alat} = \frac{\Delta Range\ ketinggian\ altimeter}{\Delta V_{IN} ADC}$$

$$= \frac{(4095-0)meter}{(4096-2.25)mV}$$

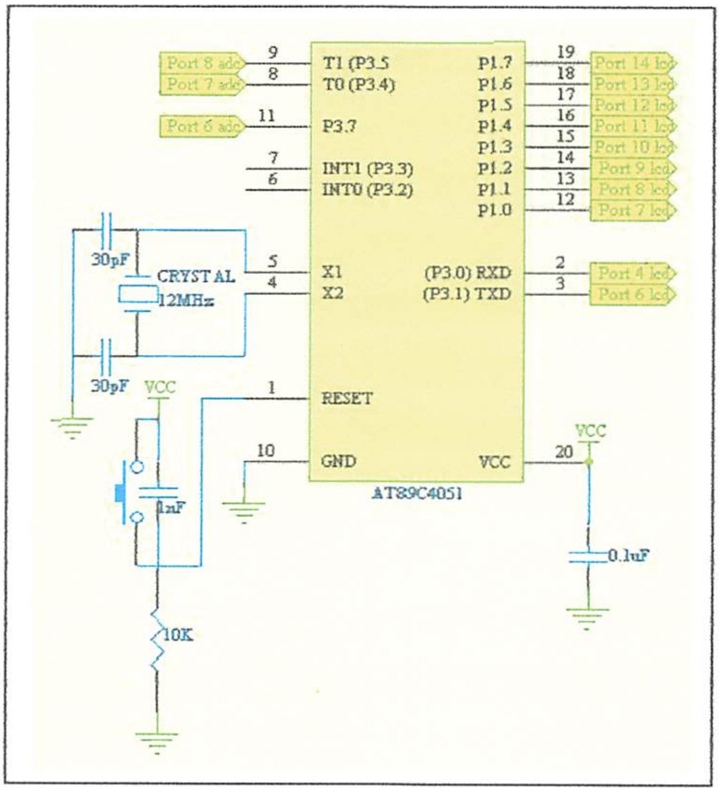
$$= 1\ {meter}/{mV}$$

Jadi dengan resolusi 1mV dari ADC, alat ini mampu mendeteksi perubahan ketinggian setinggi 1 meter.

3.4.3. Perancangan Bagian Kontrol dan Pengolah Data

Pada sistem ini komponen utamanya adalah mikrokontroler tipe AT89C4051 yang kompatible dengan keluarga MCS-51. Komponen ini merupakan sebuah chip tunggal sebagai pusat pengolahan data dan pengontrolan alat. Alasan pemilihan mikrokontroller AT89C4051 ini adalah karena mikrokontroller AT89C4051 memiliki segi efisien dalam pemrograman yang memilki program memori tipe *flash* PEROM

(*Programable and Erasable Read Only Memory*). Mikrokontroller AT8C4051 sebagai pengedali tunggal ditunjukkan dalam Gambar 3.4.



Gambar 3.4 Rangkaian Mikrokontroller AT89C4051

Pin-pin yang digunakan pada IC AT89C4051 adalah sebagai berikut:

1. Port 1 (P1.0 – P1.7)

   Digunakan sebagai keluaran data ke LCD atau sebagai masukan ke LCD data.

2. Port 3 (P3.0 – P3.5,P3.7)

   Digunakan sebagai keluaran dan masukan data. Berikut deskripsi I/O-nya;

   1) P3.0 – P3.1 : digunakan untuk mengirimkan data control LCD.

   2) P3.5 : digunakan untuk mengirimkan data *clock* ke *serial clock* (SCLK) ADC.

3) P3.4 : digunakan untuk mengirimkan data control ke *chip select* (CS) ADC.

4) P3.7 : digunakan untuk menerima data dari ADC.

3. X1 dan X2

Digunakan sebagai masukan bagi rangkaian osilator Kristal yang akan membangkitkan pulsa *clock* yang akan menggerakkan seluruh operasi internal mikrokontroller.

4. Reset

Digunakan sebagai *input reset*. Kondisi tinggi dari pin ini selama dua siklus *clock* akan menyebabkan *reset device* ini yaitu selama 2µS. berikut perhitungannya

$$t_{reset} = \frac{1}{f_{XTALL}} \times periode\ yang\ dibutuhkan$$

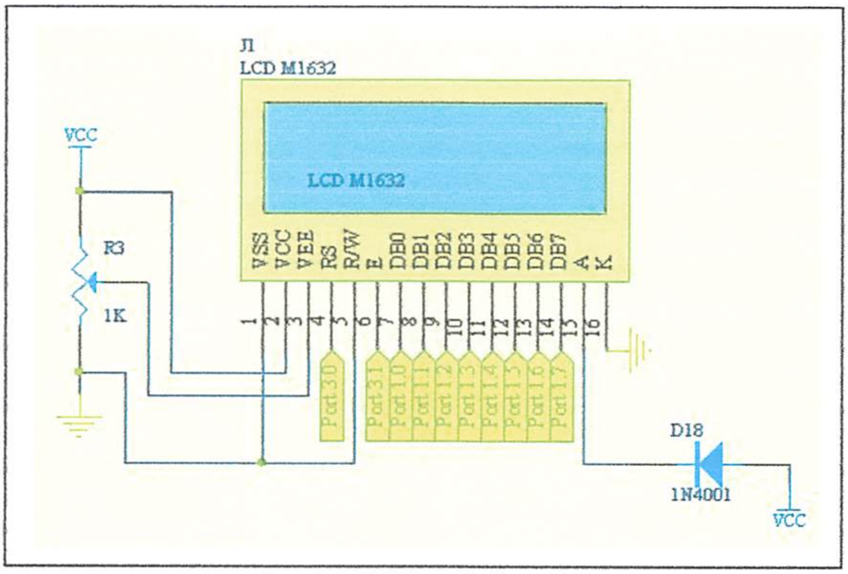
$$= \frac{1}{12MHz} \times 24$$

$$= 0{,}833.10^{-8} \times 24$$

$$= 2\mu S$$

3.4.4. Perancangan Bagian *Display*

Display pada system ini berfungsi untuk menampilkan informasi ketinggian dari suatu tempat dalam satuan meter. Pada bagian *display* ini digunakan *display* berupa *Liquid Crystal Display* (LCD) dengan tipe M1632 (16 kolom x 2 baris). LCD M1632 adalah salah satu jenis piranti output yang menggunakan daya rendah dengan pengontrol kontras dan kecerahan. LCD inilah yang akan menampilkan informasi ketinggian suatu tempat dimana data-data yang ditampilkan dikontrol oleh mikrokontroller. Perancangan LCD selengkapnya ditunjukkan dalam Gambar 3.5.



Gambar 3.5 Rangkaian LCD

Adapun keterangan pin-pin dari LCD dijelaskan dalam Tabel 3.1

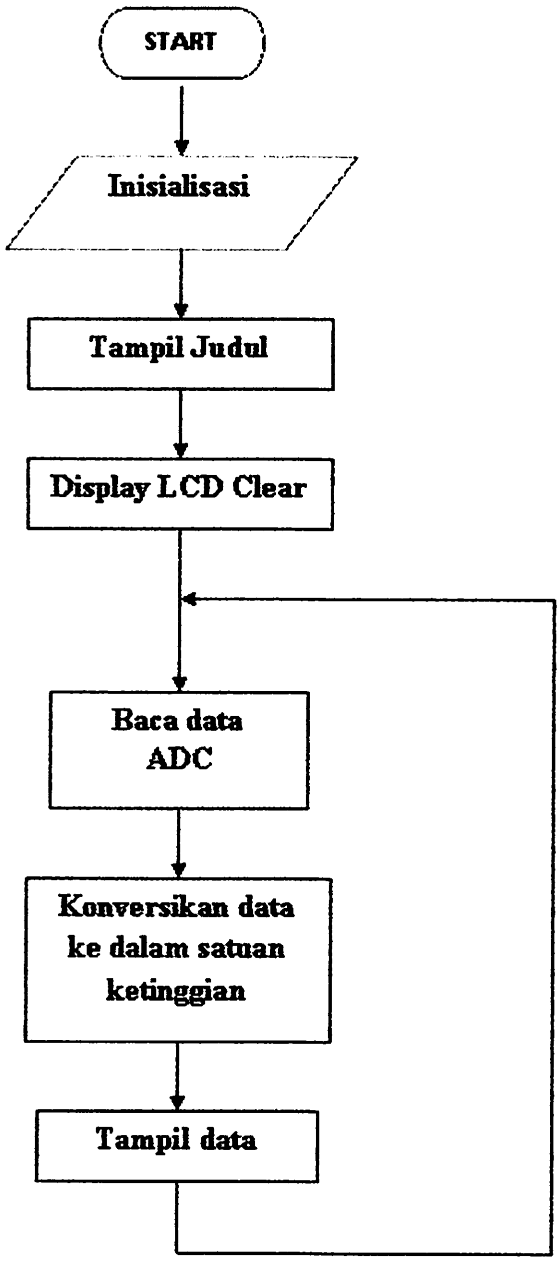
Tabel 3.1 keterangan dari pin-pin LCD

No.Pin	Nama	Keterangan
1	VSS	*Ground*
2	VCC	Tegangan power supply +5volt
3	VLC	Tegangan pengatur intensitas LCD
4	RS	Sinyal pemilih *register control*
5	R/W	Sinyal seleksi baca dan tulis
6	E	Sinyal pengaktif LCD
7	DB0	Jalur bus data
8	DB1	Jalur bus data
9	DB2	Jalur bus data
10	DB3	Jalur bus data
11	DB4	Jalur bus data
12	DB5	Jalur bus data
13	DB6	Jalur bus data
14	DB7	Jalur bus data
15	A	Anoda (+) untuk LED *backlight*
16	K	Katoda (-) untuk LED *backlight*

Berdasarkan keterangan tabel 3.1 maka pin Vss dan Vcc digunakan *variable resistor* sebesar 1kΩ sebagai pembagi tegangan yang berfungsi untuk mengatur intensitas cahaya pada tampilan LCD. Pada pin R/W dihubungkan dengan *ground* berfungsi untuk mengaktifkan instruksi tulis saja. Pin E merupakan sinyal pengaktif LCD dikontrol oleh mikrokontroller melalui pin P3.1 sama halnya dengan pin RS yang berfungsi sebagai pengaktif *register control* juga dikendalikan oleh mikrokontroller melalui pin P3.0. Sedangkan saluran datanya dihubungkan dengan port 1 mikrokontroller untuk menuliskan bit-bit data yang diperlukan LCD.

3.4.5. Perancangan Bagian Perangkat Lunak

Perangkat lunak yang dirancang dengan menggunakan bahasa BASCOM. Untuk memberikan gambaran umum jalannya program dan memudahkan pembuatan perangkat lunak, maka dibuat diagram alir yang menunjukkan jalannya program. Diagram alir utama perancangan perangkat lunak ditunjukkan dalam Gambar 3.6.



Gambar 3.6 Diagram Alir Pemrograman Perangkat Lunak

BAB IV
PENGUJIAN ALAT

Tujuan pengujian alat ini adalah untuk menentukan apakah alat yang telah dibuat berfungsi dengan baik dan sesuai dengan perancangan. Pengujian dilakukan dengan cara menguji rangkaian setiap blok secara terpisah. Pengujian setiap blok ini dilakukan untuk mempermudah analisis apabila alat ini tidak bekerja sesuai dengan perancangan.

Dalam pelaksanaan pengujian dilakukan dengan dua cara yaitu secara perangkat keras dan perangkat lunak. Secara perangkat keras dilakukan melalui pemeriksaan sambungan pengawatan dan pengukuran dengan alat ukur. Sedangkan pengujian perangkat lunak, pengujian dilakukan melalui pembuatan *software* dan hasilnya diamati dengan bantuan alat peraga atau melalui alat ukur. Pengujian ini dibagi menjadi:

1) Pengujian sensor tekanan.
2) Pengujian rangkaian ADC.
3) Pengujian *display* LCD.
4) Pengujian alat.

4.1 Pengujian Sensor Tekanan

4.1.1 Tujuan

Untuk mengetahui hubungan antara ketinggian suatu tempat atau daerah dengan tegangan keluaran yang dihasilkan sensor tekanan dan mengetahui *noise* yang dihasilkan dari sensor tekanan tersebut.

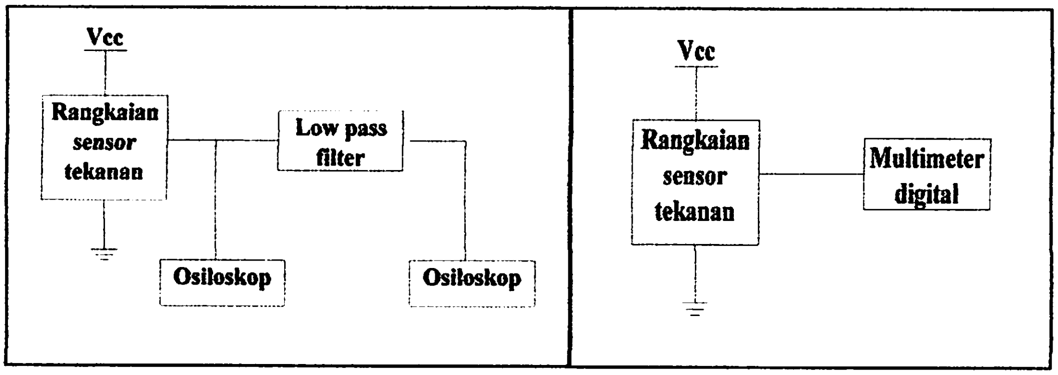
4.1.2 Peralatan yang Digunakan

1) Rangkaian sensor tekanan MPX4115AP.
2) Osiloskop.
3) Multimeter digital.
4) *Projectboard.*
5) Catu daya +5 volt.

4.1.3 Prosedur Pengujian

Langkah-langkah pengujian adalah sebagai berikut:

1) Merangakai blok rangkaian pengujian sensor tekanan seperti dalam Gambar 4.1.



Gambar 4.1a Blok pengujian sensor tekanan dengan osiloskop

Gambar 4.1b blok pengujian sensor tekanan Dengan osiloskop

2) Memberikan catu daya +5 volt pada rangkaian sensor tekanan.
3) Menghubungkan osiloskop pada bagian keluaran dari rangkaian sensor sebelum dan sesudah melalui *filter* (Gambar 4.1a), guna mengetahui *noise* yang dihasilkan dari sensor tekanan.
4) Menghubungkan multimeter digital pada bagian keluaran dari rangkaian sensor tekanan (Gambar 4.1b) untuk mengetahui tegangan keluaran yang dihasilkan sensor tersebut.

5) Hasil pengujian terdapat pada osiloskop dan multimeter digital.

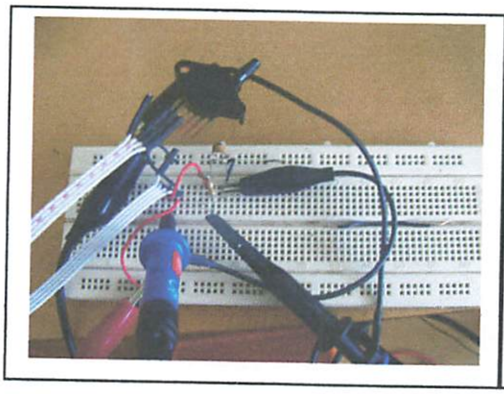
4.1.4 Hasil Pengujian

Table 4.1 menunjukkan hasil pengujian sensor tekanan.

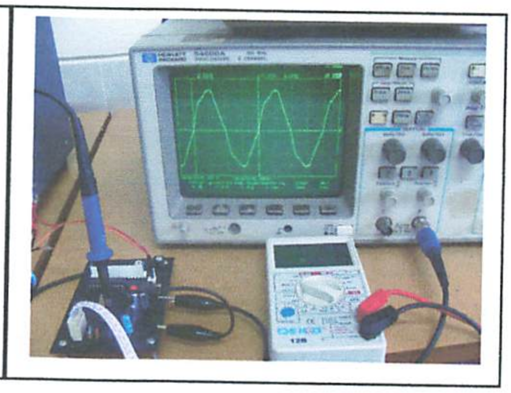
Table 4.1a Hasil Pengujian Sensor Tekanan Dengan Osiloskop

Keluaran sensor sebelum di *filter*			Keluaran sensor sesudah di *filter*		
V_{DC}	Noise		V_{DC}	Noise	
	Frekuensi	Vpp		Frekuensi	Vpp
3.83v	20Mhz	0.1 Vpp	3.83v	400Mhz	20mVpp

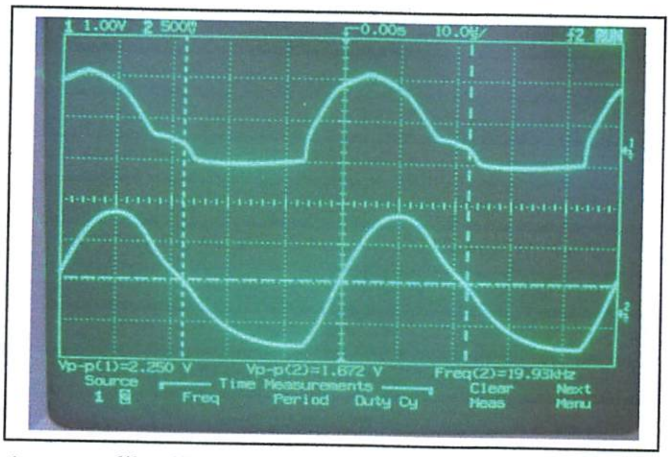
Gambar 4.2 menunjukkan hasil pengujian rangkaian sensor tekanan pada osiloskop.



Gambar 4.2a Rangkaian Sensor Tekanan



Gambar 4.2b Tegangan Keluaran Sensor Tekanan (V_{DC})



Gambar 4.2c *Noise* yang dihasilkan sensor tekanan sebelum (atas) dan sesudah (bawah) di *filter*

Tabel 4.1b Hasil pengujian sensor tekanan dengan multimeter digital

No.	Tempat (stasiun) yang diukur	Ketinggian (m)	Vout Sensor Pengkuran(Volt)	Vout Sensor Perhitungan(Volt)	Tekanan (kPa)	% *error*
1	Malang Kota Baru	530	3,79	3,78	94,77	0,26
2	Malang Kota Lama	493	3,81	3,80	95,22	0,26
3	Pakisaji	456	3,83	3,82	95,66	0,26
4	Kepanjen	400	3,86	3,85	96,33	0,26
5	Ngebruk	400	3,86	3,85	96,33	0,26
6	Sumber Pucung	364	3,88	3,87	96,77	0,26
Persentase rata-rata kesalahan Pembacaan Sensor						0,26

Berikut perhitungannya:

- Ketinggian 530 meter

  Dengan nilai 1 *feet* (ft) = 0,3048 meter maka

  $Z = \frac{530}{0,3048} = 1741\,feet$

  $Z = -26126 \times \ln\left(\frac{P(kPa)}{101.304}\right)$

  $Z = -K_1 \times \ln\left(\frac{P}{K_2}\right)$

  $\text{Ln}\left(\frac{P}{K_2}\right) = \left(\frac{Z}{-K_1}\right)$

  $\left(\frac{P}{K_2}\right) = e^{\frac{Z}{-K1}}$

  $P = K_2 \times e^{\frac{Z}{-K1}}$

  $P = 101,304 \times e^{\frac{1741}{-26126}}$

  $P = 94,77$ kPa

- V*out* Perhitungan

  V*out* = Vs x ((0,009x*P(kPa)*) – 0,095)

  V*out* = 5 x ((0,009x94,77) – 0,095)

  = 3,78 *Volt*

- Persentase error:

  $\%\text{error} = \frac{DATA_{PENGUJIAN} - DATA_{PERHITUNGAN}}{DATA_{PERHITUNGAN}} \times 100\%$

  $\%\text{error} = \frac{3,79-3,78}{3,78} \times 100\%$

  $= 0,26\%$

- Persentase rata-rata error:

  $\%\text{rata-rata\_error} = \frac{Jumlah\_\%error}{Jumlah\_pengujian}$

  $\%\text{rata-rata\_error} = \frac{1,56}{6} = 0,26\%$

4.1.5 Analisis Hasil Pengujian Sensor Tekanan Udara

Berdasarkan hasil pengujian di atas, terlihat bahwa sensor tekanan mampu mendeteksi tekanan udara. Dari tabel 4.1 menunjukkan bahwa perubahan tegangan keluaran yang dihasilkan sensor tersebut tergantung dari ketinggian tempat (daerah) yang di ukur. Berdasarkan hasil pengujian pada tabel tersebut, daerah sumber pucung yang berketinggian 364 meter (96,77kPa), sensor tekanan mampu menghasilkan tegangan keluaran sebesar 3,88 volt. Hasil ini berbeda dengan daerah dengan dataran yang lebih tinggi 530 meter (Stasiun Malang Kota Baru), dimana sensor hanya mampu menghasilkan tegangan keluaran sebesar 3,79 volt. Sehingga dapat disimpulkan bahwa makin tinggi suatu tempat atau daerah, tegangan keluaran yang dihasilkan sensor tekanan semakin kecil. Dengan kata lain makin berkurang tekanan udara suatu tempat maka tegangan keluaran yang dihasilkan sensor juga semakin berkurang.

4.1.6 Kesimpulan

1) Sensor ini mampu mendeteksi perubahan tekanan udara dengan persentase rata-rata %error 0,26%.
2) Respon keluaran sensor menunjukkan fungsi yang sesuai dengan aplikasi yaitu memberikan respon yang sesuai dengan masing-masing tempat yang diukur.
3) Keluaran sensor di sumber pucung adalah 3,88 volt dan pada dataran yang lebih tinggi adalah 3,79 volt, sesuai dengan level logika untuk masukan ke ADC.
4) Makin tinggi suatu tempat atau daerah, tegangan keluaran yang dihasilkan sensor tekanan semakin kecil.

4.2 Pengujian Rangkaian ADC

4.2.1 Tujuan

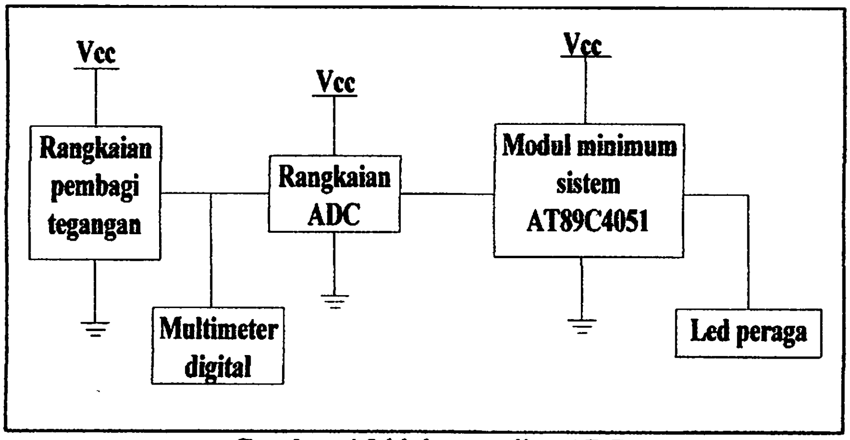
Untuk mengetahui presentase rata-rata kesalahan rangkaian ADC dalam melakukan pengkonversian tegangan analog yang berasal dari rangkaian sensor menjadi data-data digital.

4.2.2 Peralatan yang Digunakan

1) Rangkaian ADC
2) Modul minimum system mikrokontroller AT89C4051
3) Multimeter digital
4) *Light emitting diode* (LED) peraga
5) *Projectboard.*
6) Catu daya +5 volt

4.2.3 Prosedur Pengujian

1) Merangkai blok rangkaian pengujian ADC seperti dalam Gambar 4.3.



Gambar 4.3 blok pengujian ADC

2) Menghubungkan modul minimum system mikrokontroller AT89C4051 dengan blok rangkaian pengujian ADC

3) Membuat program untuk membaca data dari blok ADC pada modul minimum system mikrokontroller AT89C4051, kemudian data yang dibaca oleh mikrokontroller dari blok ADC tersebut dikonversikan menjadi kode biner dan dikirimkan melalui port0, port3 menuju modul LED peraga.
4) Memberikan catu daya +5volt pada rangkaian ADC dan modul minimum system mikrokontroller AT89C4051.
5) Memberikan masukan pada blok rangkaian pengujian ADC melalui pin 2 (AIN) berupa tegangan analog dari rangkaian pembagi tegangan.
6) Menghubungkan multimeter digital pada bagian keluaran rangkaian pembagi tegangan dan hasil pengujian terdapat pada led peraga.

4.2.4 Hasil Pengujian

Tabel 4.3 menunjukkan hasil pengujian ADC.

Tabel 4.2 hasil pengujian ADC

No.	Vin ADC (volt)	Data Keluaran Digital		Kisaran LSB	*%error*
		Perhitungan (heksadesimal)	Pengujian (heksadesimal)		
1	0,5	1F3	1F4	-1	0,20
2	1	3E7	3E8	-1	0,11
3	1,5	5DB	5DD	-2	0,13
4	2	7CF	7CD	+2	0,10
5	2,5	9CE	9C1	+2	0,08
6	3	BB7	BB6	+1	0,03
7	3,5	DAB	DAC	-1	0,02
8	4	F94	F96	-2	0,05
Rata-rata kesalahan ADC				-0,25	
Persentase rata-rata kesalahan ADC					0,09

Berikut contoh perhitungannya:

- Perhitungan = $\frac{Vin \times 2^{12}}{Vref}$

$$= \frac{0{,}5 \times 4096}{4{,}096} = 500$$

- Persentase error:

$$\%error = \frac{DATA_{PENGUJIAN} - DATA_{PERHITUNGAN}}{DATA_{PERHITUNGAN}} \times 100\%$$

$$= \frac{(1F4 - 1F3)_H}{1F3_H} = \frac{500 - 499}{499} = 0{,}2\%$$

- Persentase rata-rata error:

$$\%rata\text{-}rata\_error = \frac{Jumlah\_\%error}{Jumlah\_pengujian}$$

$$= \frac{0{,}72}{8} = 0{,}09\%$$

- Rata-rata error dalam kisaran LSB:

$$Rata\text{-}rata\_error(LSB) = \frac{jumlah\_kisaran\_LSB}{jumlah\_pengujian}$$

$$= \frac{-2}{8} = -0{,}25LSB$$

4.2.5 Analisis Hasil Pengujian Rangkaian ADC

Dari hasil pengujian diatas, ketika rangkaian ADC menerima tegangan masukan analog dari rangkaian pembagi tegangan, ADC tersebut langsung mengkonversikan data analog tersebut menjadi data 12 bit digital. Proses pengkonversian data pada ADC tersebut dikontrol oleh minimum system mikrokontroller AT89C4051. Berdasarkan tabel 4.3 pengujian di atas, ADC dapat mengkonversikan data digital sesuai dengan tegangan analog yang diberikan. Data hasil pengujian menunjukkan bahwa persentase rata-rata kesalahan pengkonversian pada ADC sebesar 0,09% dengan kisaran rata-rata kesalahan sebesar -0,25LSB.

4.2.6 Kesimpulan

1) Rangkaian ADC ini mampu mengkonversi masukan tegangan analog yang diberikan menjadi data 12 bit digital dengan persentase rata-rata %error sebesar 0,09%.

4.3 Pengujian *display* LCD

4.3.1 Tujuan

Untuk mengetahui apakah *display* LCD dapat bekerja dengan baik atau tidak.

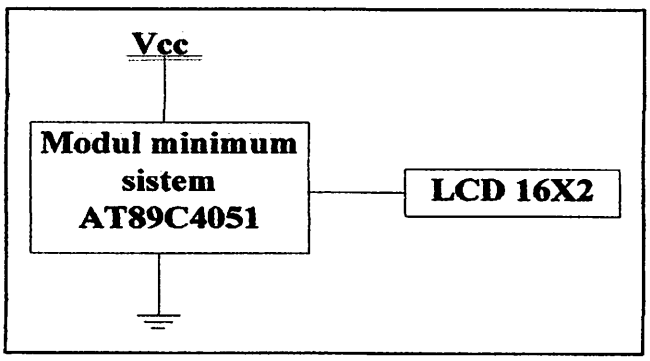
4.3.2 Peralatan yang Digunakan

1) Rangkaian *display* LCD.
2) Modul minimum system mikrokontroller AT89C4051.
3) *Projectboard.*
4) Catu daya +5volt.

4.3.3 Prosedur Pengujian

Langkah-langkah pengujian adalah sebagai berikut:

1) Merangkai blok rangkaian pengujian *display* LCD seperti dalam gambar 4.4.



Gambar 4.4 Blok pengujian *display* LCD

2) Menghubungkan modul minimum system mikrokontroller AAT89C4051 dengan blok rangkaian pengujian *display* LCD.
3) Membuat program pengujian LCD.

4) Memberikan catu daya +5 volt pada rangkaian *display* LCD dan modul minimum system mikrokontroller AT89C4051.

5) Hasil pengujian terdapat pada *display* LCD.

4.3.4 Program Pengujian LCD

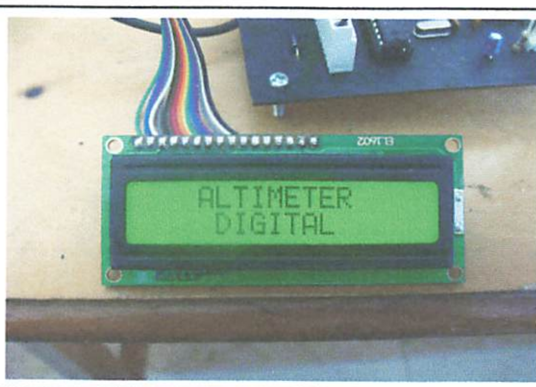
Program pengujian ini digunakan untuk menuliskan karakter huruf dan angka pada LCD dimana penulisannya di control melalui mikrokontroller.

```
--------------------------------Program pengujian LCD--------------------------------
$regfile = "89c4051.Dat"
$crystal = 12000000
'$sim
$large
Cs Alias P3.4
Sclk Alias P3.5
Dout Alias P3.7

Dim Tinggi As Integer
Dim Tinggi1 As Single
Dim Tekanan As Single
Dim Tekanan1 As Single
Dim Tekanan2 As Single
Dim Nilaibit8 As Integer
Dim Nilaibit4 As Integer

Config Lcdpin = Pin , Db4 = P1.4 , Db5 = P1.5 , Db6 = P1.6 , Db7 = P1.7 , E = P3.1 ,
Rs = P3.0
Config Lcd = 16 * 2

Dim Hasilkom1 As Byte , Hasilkom2 As Byte , Hasilkom3 As Byte
Dim Hasil1 As Byte , Hasil2 As Byte

'$sim
Hasil1 = &H00
Hasil2 = &H00
Putar:
Cls
Lcd "   M ARIFIN    "                  'display this at the top line
Lowerline                              'select the lower line
Lcd " NIM: 0412259  "
Wait 5
```

```
Cls
Lcd "  ALTIMETER   "              'display this at the top line
Lowerline                         'select the lower line
Lcd "   DIGITAL    "
Wait 5
Goto Putar
```

4.3.5 Hasil Pengujian LCD

Dari hasil pengujian diperoleh hasil bahwa modul *display* LCD mampu menampilkan karakter "Altimeter Digital" dengan baik sesuai dengan instruksi yang diberikan. Gambar 4.5 menunjukkan hasil pengujian *display* LCD.



Gambar 4.5 Hasil pengujian LCD

4.3.6 Kesimpulan

1) *Display* LCD mampu menampilkan karakter dan angka dengan baik sesuai dengan instruksi yang diberikan oleh mikrokontroller.
2) *display* LCD dapat berfungsi dan diakses oleh perangkat lunak.

4.4 Pengujian Alat

4.4.1 Tujuan

Pengujian alat bertujuan untuk mengetahui kinerja system secara keseluruhan, apakah sesuai dengan spesifikasi yang direncanakan di awal dan mengetahui persentase rata-rata kesalahan pengukuran dari alat tersebut.

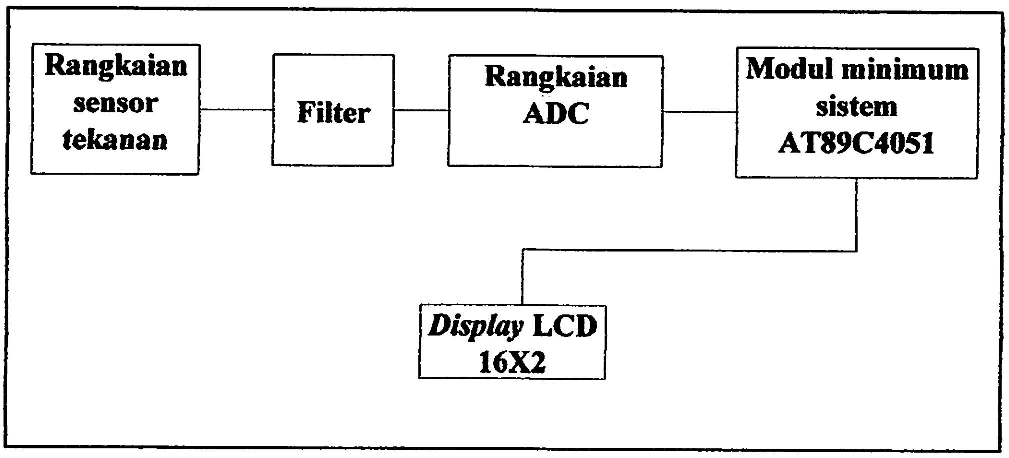
4.4.2 Peralatan yang Digunakan

1) Rangkaian sensor tekanan MPX4115AP.
2) Rangkaian *filter*.
3) Rangkaian ADC.
4) Modul mikrokontroller AT89C4051.
5) Rangkaian *display* LCD.
6) Catu daya +5 volt.

4.4.3 Prosedur Pengujian

Langkah-langkah pengujian adalah sebagai berikut:

1) Merangkai blok pengujian alat seperti dalam gambar 4.6.



Gambar 4.6 Blok pengujian alat

2) Memberikan catu daya +5 volt pada blok pengujian alat.
3) Hasil pengujian terdapat pada *display* LCD.

4) Mencatat hasil pengukuran ketinggian yang ada pada *display* LCD.

5) Membandingkan hasil pengukuran padaa alat dengan data ketinggian tempat sebenarnya.

4.4.4 Disipasi Daya Alat

Karena bentuk altimeter ini *portable* dan menggunakan baterai sebagai sumber tegangan, tentunya konsumsi daya dari alat ini perlu diperhatikan. Tabel 4.3 menunjukkan hasil pengukuran konsumsi arus pada masing-masing bagian (blok).

Tabel 4.3 Hasil pengukuran konsumsi arus pada masing-masing blok

No.	Blok Rangkaian	Konsumsi Arus (i)
1	Sensor tekanan	7mA
2	ADC	2,5mA
3	Mikrokontroller AT89C4051	10mA
4	LCD	2mA
	Konsumsi total (i total)	21,5mA

Berdasarkan tabel 4.3 jumlah arus keseluruhan rangkaian adalah mA, dengan menggunakan sumber tegangan (V) sebesar 5 volt maka diperoleh disipasi daya keseluruhan rangkaian sebesar:

$$P_{total} = i_{total} \text{ x } V$$

$$= 21{,}5mA \text{ x } 5v$$

$$= 107{,}5mW$$

Jadi disipasi daya keseluruhan pada altimeter digital ini sebesar 107,5*mW*. altimeter digital ini menggunakan baterai 9 volt dengan arus yang dihasilkan sebesar 190mAh. Sehingga baterai tersebut memiliki daya sebesar

$$\mathrm{P_{baterai}} = \mathrm{i_{baterai}} \text{ x V}$$

$$= 190\text{mAh x 9v}$$

$= 1710 mWh$

$= 1{,}710 Wh$

Berdasarkan perhitungan diatas maka dapat disimpulkan bahwa umur pemakaian baterai pada altimeter digital ini adalah selama 15 jam. berikut perhitungannya:

$$Umur\_baterai = \frac{1710mWh}{107{,}5mW} = 15.9h$$

4.4.5 Hasil Pengujian

Tabel 4.4 menunjukkan hasil pengujian alat dari beberapa tempat (stasiun)

Tabel 4.4 Hasil Pengujian Alat

No.	Nama Stasiun (pengujian)	Ketinggian sebenarnya (meter)	Ketinggian pada altimeter digital (meter)		%error
			Pengukuran1 5-08-09 (10.30-11.30)	Pengukuran2 5-08-09 (15.00-16.30)	
1	Malang kota baru	444	441	464	1,9
2	Malang kota lama	429	432	456	3,49
3	Pakisaji	386	410	433	9,19
4	Kepanjen	335	359	390	11,79
5	Ngebruk	319	343	386	14,26
6	Sumber pucung	296	334	350	15,54
Persentase rata-rata kesalahan pembacaan					9,36

Berikut contoh perhitungannya:

- Persentase error:

$$\%error = \frac{\%error(PENGUKURAN1 + PENGUKURAN2)}{2}$$

$$= \frac{100\% \times \left[\left(\frac{(441-444)}{444}\right) + \left(\frac{(464-444)}{444}\right)\right]}{2}$$

$$= 1{,}9\%$$

- Persentase rata-rata *error*:

$$\%rata\text{-}rata\_error = \frac{jumlah\_\%error}{jumlah\_pengujian}$$

%rata-rata *error* = $\frac{56,17}{6} = 9,36\%$

4.4.6 Kesimpulan Hasil Pengujian Alat Keseluruhan

Dari hasil pengujian diatas altimeter digital ini mampu mendeteksi perubahan ketinggian dari beberapa stasiun yang berbeda. Pengujian alat ini dilakukan sebanyak 2 kali pengujian pada 6 stasiun yang berbeda. Altimeter digital ini mendeteksi tekanan udara pada stasiun-stasiun tersebut. Karena tekanan udara pada beberapa stasiun berbeda maka dihasilkan pengukuran yang berbeda pula. Secara keseluruhan altimeter digital yang dibuat ini memiliki tingkat kesalahan pembacaan rata-rata sebesar 9,36% dengan keslahan pembacaan terbesar sebesar 15,54%.besarnya persentase rata-rata kesalahan pembacaan ini salah satunya disebabkan data-data ketinggian pada masing-masing stasiun yang berbeda dahulu diperoleh sejak penjajahan jaman belanda, sehingga kemungkinan didapatkan data ketinggian sebenarnya dari permukaan laut kurang akurat. Selain itu faktor cuaca dan waktu pengukuran juga mempengaruhi hasil pengujian altimeter digital ini.

4.5 Spesifikasi Alat

Alat altimeter digital ini memiliki beberapa spesifikasi berdasarkan studi literatur dari rumusan masalah yang ada. Dalam perancangan dan pembuatan alat pengukur ketinggian tempat dari permukaan air laut (*altimeter digital*) ini memiliki spesifikasi sebagai berikut:

1) *Portabel* (dapat dibawa kemana-mana) dengan ukuran yang relatif kecil panjang 13,3cm tinggi 4cm dan lebar 4,5cm.
2) Hasil pengukuran dari alat ini adalah ketinggian dalam satuan meter

3) Ketinggian yang dapat diukur pada kisaran 350 hingga 464 meter pada range tekanan udara antara 95kPa hingga 97kPa dan di desain untuk mengukur hingga 4095 meter pada range tekanan udara 60,5kPa.

4) Catu daya yang digunakan adalah baterai.

5) Hasil pengukuran ditampilkan dalam LCD 16x2.

BAB V
PENUTUP

5.1 Kesimpulan

Berdasarkan hasil pengujian dan analisis alat maka dapat ditarik kesimpulan sebagai berikut:

1) Untuk Sensor Tekanan

- Sensor mampu mendeteksi perubahan tekanan udara dengan persentase rata-rata %error 0,26%.
- Respon keluaran sensor menunjukkan fungsi yang sesuai dengan aplikasi yaitu memberikan respon yang sesuai dengan masing-masing tempat yang diukur.
- Keluaran sensor di sumber pucung adalah 3,88 volt dan pada dataran yang lebih tinggi adalah 3,79 volt, sesuai dengan level logika untuk masukan ke ADC.
- Makin tinggi suatu tempat atau daerah, tegangan keluaran yang dihasilkan sensor tekanan semakin kecil.

2) Untuk ADC

- Rangkaian ADC mampu mengkonversi masukan tegangan analog yang diberikan menjadi data 12 bit digital dengan persentase rata-rata %error sebesar 0,09%.

3) Untuk LCD

- *Display* LCD mampu menampilkan karakter dan angka dengan baik sesuai dengan instruksi yang diberikan oleh mikrokontroller.
- *display* LCD dapat berfungsi dan diakses oleh perangkat lunak.

4) Untuk Keseluruhan Alat

- Alat pengukur ketinggian dari permukaan air laut (altimeter digital) ini mampu mengukur ketinggian tempat dari permukaan air laut pada kisaran 350 hingga 464 meter dengan range tekanan udara yang diukur antara 95kPa hingga 97kPa dan di desain mampu mengukur hingga 4095 meter pada range tekanan udara 60,5kPa.
- Secara keseluruhan altimeter digital yang dibuat ini memiliki tingkat kesalahan pembacaan rata-rata sebesar 9,36%.
- Alat ini berpengaruh terhadap perubahan suhu sekitar apabila suhu udara lebih panas maka tekanan udara juga lebih rendah.

5) Umur pemakaian baterai 9 volt jenis ABC *heavyduty* sbagai sumber tegangan alat ini adalah 15jam, sehingga lewat masa pemakaian baterai tersebut harus diganti karena akan mempengaruhi keakuratan pengukuran.

5.2 Saran

Alat pengukur ketinggian dari permukaan air laut ini dapat dikembangkan lagi agar lebih sempurna dalam penggunaannya, diantaranya dapat dilakukan dengan:

1) Bentuk fisik dari alat dapat pula dibuat kecil lagi sehingga mempermudah pemakai dalam membawa dan menggunakan altimeter tersebut.
2) Tampilan dari alat ini dapat dibuat lebih bervariasi tidak hanya menampilkan ketinggian dan tekanan udara suatu tempat saja namun juga dapat mendeteksi

suhu,kelembaban udara atau parameter yang lain sesuai dengan sensor yang digunakan.

3) Perhitungan ketinggian pada perancangan perangkat lunak yang digunakan pada altimeter digital ini hendaknya menggunakan persamaan yang menyatakan hubungan antara ketinggian dengan tekanan udara.

4) Pemilihan mikrokontroller sebagai pengolah data sebaiknya memilih tipe mikrokontroller yang memiliki memori internal yang lebih besar daripada mikrokontroller tipe AT89C4051.

5) Dalam pengambilan data ketinggian tempat sebenarnya hendaknya menggunakan data yang *valid* dan memperhatikan faktor cuaca pada tempat pengukuran. Selain memperhatikan kedua hal tersebut sebelum melakukan pengukuran, alat ini dikalibrasikan dengan altimeter digital sebenarnya, sehingga persentase rata-rata kesalahan pembacaan pada alat dapat dikurangi.

DARTAR PUSTAKA

[1]. Agfianto Eka Putra, *Belajar Mikrokontroller AT 89S51/52/55*, Gava Media Yogyakarta 2002.

[2]. ATMEL, DataSheet Book

[3]. Laporan Praktikum Mikroprosessor, Laboratorium Teknik Elektronika Fakultas Teknologi Industri, Institut teknologi Nasional Malang.

[4]. Wasito S. 1985 *Vademekum Elektronika Edisi Kedua*, Penerbit Gramedia Pustaka Umum, Jakarta.

[5]. Malvino, Albert Paul, Ph. D., *Prinsip-Prinsip Elektronika*, Cetakan Ketujuh: Terjemahan Hanapi Gunawan, Erlangga, Jakarta, 1994.

[6]. http://id.wikipedia.org/wiki/Altimeter

[7]. http://www.esmartschool.com/pnu/001/PNU0010006

[8]. Data Sheet LCDm1632, Seiko Instrument Inc.

[9]. Agfianto Eko Putra, "Belajar Mikrokontroler AT89C51/52/55", Gava Media, 2002.

[10]. www.Atmel.com.data sheet IC AT89C4051

[11].Lab. Perancangan Elektronika,"Buku Panduan Pelatihan Mikrokontroler", Lab. Perancangan Elektronika, Malang, 2006.

LAMPIRAN

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

BERITA ACARA UJIAN SKRIPSI

FAKULTAS TEKNOLOGI INDUSTRI

Nama : Muhammad Arifin
NIM : 04.12.259
Jurusan : Teknik Elektro S-1
Konsentrasi : Teknik Elektronika
Judul Skripsi : PERANCANGAN DAN PEMBUATAN ALAT PENGUKUR KETINGGIAN TEMPAT DARI PERMUKAAN AIR LAUT BERBASIS MIKROKONTROLER AT89C4051 (ALTIMETER DIGITAL)

Dipertahankan di hadapan majelis penguji Skripsi jenjang Strata satu (S-1) pada :

Hari : Selasa
Tanggal : 06 oktober 2009
Dengan Nilai : 83,7 (A)

Ketua Majelis Penguji

(Ir. H. Sidik Noertjahjono, MT)
NIP.Y.1028700163

Sekretaris Majelis Penguji

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

Penguji I

(Sotyohadi, ST, MSc)
NIP.Y.1039700309

Penguji II

(Joseph Dedy Irawan, ST, MT)
NIP.132315178

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

FORMULIR PERBAIKAN SKRIPSI

Nama : Muhammad Arifin

NIM : 04.22.259

Jurusan : Teknik Elektro S-1

Konsentrasi : Teknik Elektronika

Judul : PERANCANGAN DAN PEMBUATAN ALAT PENGUKUR KETINGGIAN TEMPAT DARI PERMUKAAN AIR LAUT BERBASIS MIKROKONTROLLER AT89C4051 (ALTIMETER DIGITAL).

Hari / Tanggal Ujian Skripsi : Selasa / 06 Oktober 2009

No	Tanggal	Uraian	Paraf
1	06/10/2009	- Tabel perhitungan untuk konversi tekanan udara ke ketinggian - Pengujian sensor tekanan - lampiran	

Mengetahui,

Penguji I

(Sotyohadi, ST, MSc)
NIP.Y.1039700309

Disetujui,

Penguji II

(Joseph Dedy Irawan, ST, MT)
NIP.132315178

Mengetahui,

Dosen Pembimbing I

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

Dosen Pembimbing II

Irmalia S. Faradisa, ST. MT
NIP.P. 1030000365

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 : MUHAMAD ARIFIN
N I M : 0412259
Perbaikan meliputi :

·) BAB III → TABEL PERHITUNGAN UNTUK KONVERSI ~~KET~~ TEK UDARA KE KETINGGIAN.

·) PENGUJIAN SENSOR TEKANAN

·) LAMPIRAN

Malang, 200

( )

INSTITUT TEKNOLOGI NASIONAL
Jl. Bendungan Sigura-gura No.2
MALANG

Lampiran : 1 (satu) berkas
Pembimbing Skripsi

Kepada : Yth. Bapak **M. Ibrahim Ashari, ST. MT.**
Dosen Institut Teknologi Nasional
MALANG

Yang bertanda tangan di bawah ini :

Nama	: **Muhamad Arifin**
Nim	: **04.12.259**
Jurusan	: **Teknik Elektro S-1**
Konsentrasi	: **Teknik Elektronika/~~Energi Listrik~~**

Dengan ini mengajukan permohonan, Kiranya Bapak/Ibu bersedia menjadi dosen pembimbing Utama / Pendamping *), untuk penyusunan Skripsi dengan judul (Proposal terlampir) :

PERENCANAAN DAN PEMBUATAN ALAT PENGUKUR KETINGGIAN TEMPAT DARI PERMUKAAN AIR LAUT BERBASIS AT89S52 (*ALTIMETER DIGITAL*)

Adapun tugas tersebut sebagai salah satu syarat untuk menempuh Ujian Akhir Sarjana Teknik.

Demikian permohonan kami dan atas kesediaan Bapak/Ibu kami ucapkan terimah kasih.

Malang,

Hormat kami,

Muhamad Arifin

Ketua
Jurusan Teknik Elektro S-1

Ir. F. Yudi Limpraptono, MT
Nip.1039500274

*) Coret yang tidak perlu

Form S-3a

INSTITUT TEKNOLOGI NASIONAL
Jl. Bendungan Sigura-gura No.2
MALANG

Lampiran : 1 (satu) berkas
Pembimbing Skripsi

Kepada : Yth. Bapak **Irmalia S. Faradisa, ST. MT.**
Dosen Institut Teknologi Nasional
MALANG

Yang bertanda tangan di bawah ini :

Nama	: **Muhamad Arifin**
Nim	: **04.12.259**
Jurusan	: **Teknik Elektro S-1**
Konsentrasi	: **Teknik Elektronika/~~Energi Listrik~~**

Dengan ini mengajukan permohonan, Kiranya Bapak/Ibu bersedia menjadi dosen pembimbing Utama / Pendamping *), untuk penyusunan Skripsi dengan judul (Proposal terlampir) :

PERENCANAAN DAN PEMBUATAN ALAT PENGUKUR KETINGGIAN TEMPAT DARI PERMUKAAN AIR LAUT BERBASIS AT89S52 (*ALTIMETER DIGITAL*)

Adapun tugas tersebut sebagai salah satu syarat untuk menempuh Ujian Akhir Sarjana Teknik.

Demikian permohonan kami dan atas kesediaan Bapak/Ibu kami ucapkan terimah kasih.

Malang,
Hormat kami,

Muhamad Arifin

Ketua
Jurusan Teknik Elektro S-1

Ir. F. Yudi Limpraptono, MT
Nip.1039500274

*) Coret yang tidak perlu

Form S-3a

INSTITUT TEKNOLOGI NASIONAL
Jl. Bendungan Sigura-gura No.2
MALANG

PERNYATAAN KESEDIAAN DALAM PEMBIMBINGAN SKRIPSI

Sesuai permohonan dari mahasiswa/i :

Nama	: **Muhamad Arifin**
Nim	: **04.12.259**
Semester	: **9 (Sembilan)**
Jurusan	: **Teknik Elektro S-1**
Konsentrasi	: **Teknik Elektronika/~~Energi Listrik~~**

Dengan ini menyatakan bersedia / tidak bersedia*) Membimbing skripsi dari mahasiswa tersebut, dengan judul :

PERENCANAAN DAN PEMBUATAN ALAT PENGUKUR KETINGGIAN TEMPAT DARI PERMUKAAN AIR LAUT BERBASIS AT89S52 (ALTIMETER DIGITAL)

Demikian surat pernyataan ini kami buat agar dapat digunakan seperlunya.

Malang,
Kami yang membuat pernyataan,

Irmalia S. Faradisa, ST. MT
NIP.(P). 1030100365

Catatan :
Setelah disetujui agar formulir ini
Diserahkan mahasiswa/i yang bersangkutan
Kepada jurusan untuk diproses lebih lanjut
*) Coret yang tidak perlu

Form S-3b

INSTITUT TEKNOLOGI NASIONAL
Jl. Bendungan Sigura-gura No.2
MALANG

PERNYATAAN KESEDIAAN DALAM PEMBIMBINGAN SKRIPSI

Sesuai permohonan dari mahasiswa/i :

Nama	: **Muhamad Arifin**
Nim	: **04.12.259**
Semester	: **9 (Sembilan)**
Jurusan	: **Teknik Elektro S-1**
Konsentrasi	: **Teknik Elektronika/~~Energi Listrik~~**

Dengan ini menyatakan bersedia / tidak bersedia*) Membimbing skripsi dari mahasiswa tersebut, dengan judul :

PERENCANAAN DAN PEMBUATAN ALAT PENGUKUR KETINGGIAN TEMPAT DARI PERMUKAAN AIR LAUT BERBASIS AT89S52 (ALTIMETER DIGITAL)

Demikian surat pernyataan ini kami buat agar dapat digunakan seperlunya.

Malang, 31 [illegible] 2008
Kami yang membuat pernyataan,

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

Catatan :
Setelah disetujui agar formulir ini
Diserahkan mahasiswa/i yang bersangkutan
Kepada jurusan untuk diproses lebih lanjut
*) Coret yang tidak perlu

Form S-3b

PERKUMPULAN PENGELOLA PENDIDIKAN UMUM DAN TEKNOLOGI NASIONAL MALANG

INSTITUT TEKNOLOGI NASIONAL MALANG

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

(PERSERO) MALANG
IK NIAGA MALANG

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

Malang, 28 Juli 2009

Nomor : ITN-067/7/TA /2009
Lampiran :
Perihal : ***Bimbingan Skripsi***

Kepada :Yth. Sdr. **M. IBRAHIM ASHARI, ST, MT** *)
Dosen Pembimbing
Jurusan Teknik Elektro S-1
di
Malang

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

Nama	: **MUHAMAD ARIFIN**
Nim	: **04 12 259**
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:

16 JULI 2009 s/d 16 JANUARI 2010

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 ITN JURUSAN TEKNIK ELEKTRO STRATA-1

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

Tindasan:
1. *)Perpanjangan
2. Mahasiswa yang Bersangkutan
3. Arsip

PERKUMPULAN PENGELOLA PENDIDIKAN UMUM DAN TEKNOLOGI NASIONAL MALANG

INSTITUT TEKNOLOGI NASIONAL MALANG

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

(PERSERO) MALANG
K NIAGA MALANG

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

Malang, 28 Juli 2009

Nomor : ITN-068/7/TA /2009
Lampiran :
Perihal : *Bimbingan Skripsi*

Kepada :Yth. Sdr. **IRMALIA SURYANI FARADISA, ST, MT** *)
Dosen Pembimbing
Jurusan Teknik Elektro S-1
di
Malang

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

Nama	: MUHAMAD ARIFIN
Nim	: **04 12 259**
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:

16 JULI 2009 s/d 16 JANUARI 2010

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

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

Tindasan:
1. *)Perpanjangan
2. Mahasiswa yang Bersangkutan
3. Arsip

Institu Teknologi Nasional Malang
Fakultas Teknologi Industri

FORMULIR BIMBINGAN SKRIPSI

Nama : MUHAMAD ARIFIN
Nim : 04.12.259
Masa Bimbingan : 16-Juli-2010 s/d 16-Januari-2010
Judul Skripsi : **PERANCANGAN DAN PEMBUATAN ALAT PENGUKUR KETINGGIAN TEMPAT DARI PERMUKAAN AIR LAUT BERBASIS MIKROKONTROLLER AT89C4051 (*ALTIMETER DIGITAL*)**

NO	Tanggal	Uraian	Paraf Pembimbing
1	20 Mei '09	ACC Bab I	[signature]
2	24 Juni '09	ACC Bab II	[signature]
3	8 Juli '09	ACC Bab III	[signature]
4	15 Agustus '09	ACC Bab IV	[signature]
5	18 Agustus '09	ACC Bab V	[signature]
6			
7			
8			
9			
10			

Malang, 16 - 10 - 2009
Dosen Pembimbing I

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

Form S-4b

Institu Teknologi Nasional Malang
Fakultas Teknologi Industri

FORMULIR BIMBINGAN SKRIPSI

Nama : MUHAMAD ARIFIN
Nim : 04.12.259
Masa Bimbingan : 16-Juli-2010 s/d 16-Januari-2010
Judul Skripsi : **PERANCANGAN DAN PEMBUATAN ALAT PENGUKUR KETINGGIAN TEMPAT DARI PERMUKAAN AIR LAUT BERBASIS AT89C4051 (*ALTIMETER DIGITAL*)**

NO	Tanggal	Uraian	Paraf Pembimbing
1	29 Juli '09	Revisi Bab I : format penulisan, penataan kata".	[signature]
2	29 Juli '09	Revisi Bab II : pembahasan filter	[signature]
3	29 Juli '09	Revisi Bab III : format penulisan, rumus fc,	[signature]
4		penjelasan ketinggian yang diukur flowchart, blog diagram	[signature]
5	3 Agustus '09	Revisi Bab III : range perancangan tegangan masukan ADC	[signature]
6	13 Agustus '09	Revisi Bab IV : 1. Vout sensor pengukuran dicantumkan.	[signature]
7		2. tiap blok diberi kesimpulan 3. diberi contoh perhitungan	[signature]
8	14 Agustus '09	Revisi Bab V : diberi kesimpulan pada tiap pengujian	[signature]
9	14 September '09	ACC Kompre	[signature]
10			

Malang, 16 - OKT - 2009.
Dosen Pembimbing II

[signature]

Irmalia S. Faradisa, ST. MT
NIP.P. 1030000365

Form S-4b

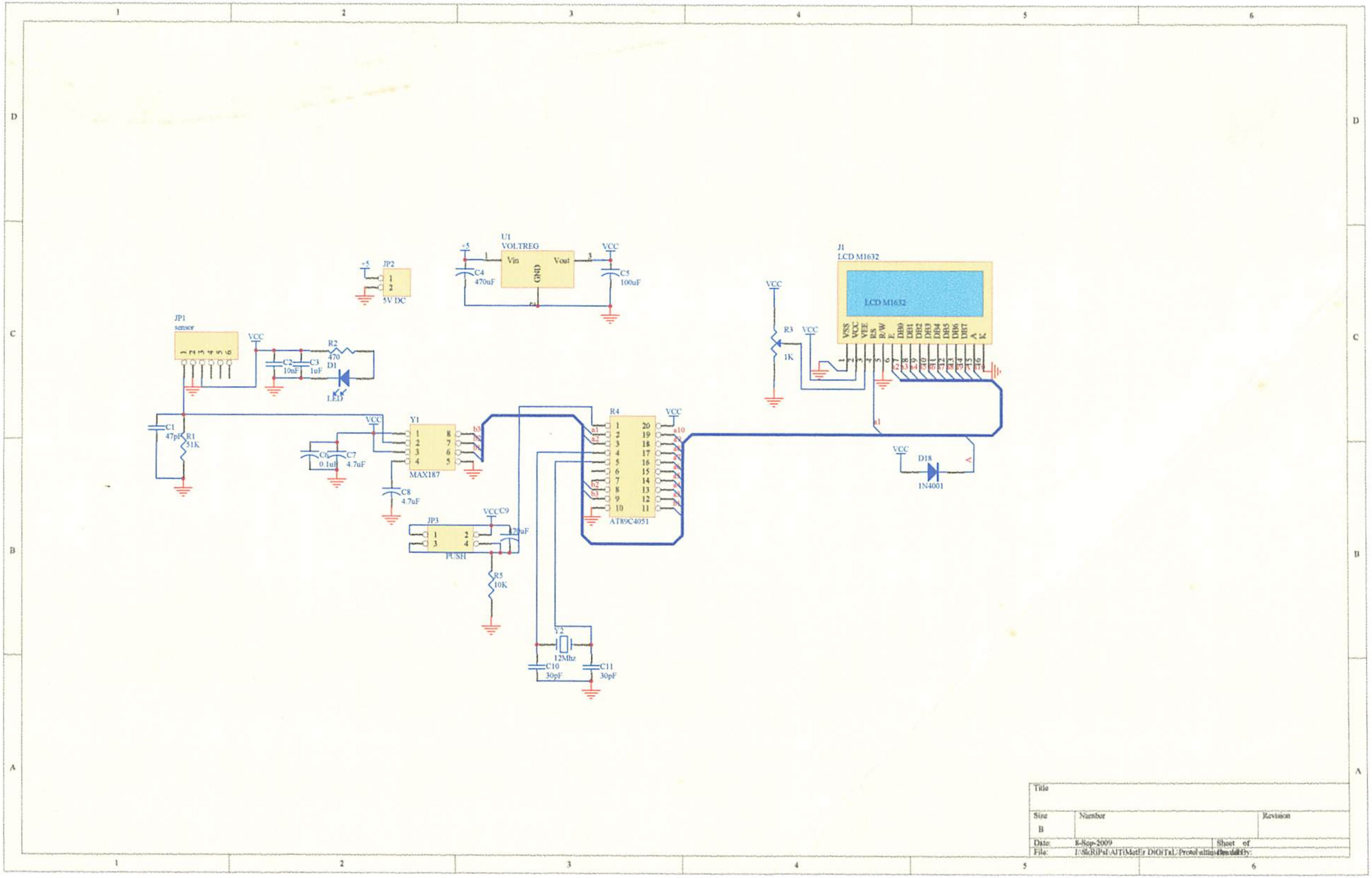
"PROGRAM ALTIMETER DIGITAL"

```
$regfile = "89c4051.Dat"

$crystal = 12000000

'$sim

$large

Cs Alias P3.4

Sclk Alias P3.5

Dout Alias P3.7


Dim Tinggi As Integer

Dim Tinggi1 As Single

Dim Tekanan As Single

Dim Tekanan1 As Single

Dim Tekanan2 As Single

Dim Nilaibit8 As Integer

Dim Nilaibit4 As Integer


Config Lcdpin = Pin , Db4 = P1.4 , Db5 = P1.5 , Db6 = P1.6 , Db7 = P1.7 , E = P3.1 ,
Rs = P3.0

Config Lcd = 16 * 2


Dim Hasilkom1 As Byte , Hasilkom2 As Byte , Hasilkom3 As Byte

Dim Hasil1 As Byte , Hasil2 As Byte


'$sim

Hasil1 = &H00
```

```
Hasil2 = &H00

Cls
Lcd "   M ARIFIN     "                    'display this at the top line
Lowerline                                 'select the lower line
Lcd " NIM: 0412259   "
Wait 1
Cls
Lcd "   ALTIMETER    "                    'display this at the top line
Lowerline                                 'select the lower line
Lcd "    DIGITAL     "
Wait 1
Putar:
'==============================
'deteksi adc
'==============================
Sclk = 0
Cs = 1
Waitms 1
Cs = 0
Waitms 8
Sclk = 1
Waitms 1
Sclk = 0
Waitms 1
'mulai
```

```
Gosub Ambildata
Gosub Ambildata
Gosub Ambildata
Gosub Ambildata
Gosub Ambildata
Gosub Ambildata
Gosub Ambildata
Gosub Ambildata
Gosub Ambildata1
Gosub Ambildata1
Gosub Ambildata1
Gosub Ambildata1

Nilaibit8 = Hasil1 * 16
Tinggi = Hasil2 + Nilaibit8
Tekanan1 = Tinggi * 0.01
Tekanan = Tekanan1 + 60.5

Hasilkom1 = Not Hasil1
Hasilkom3 = &HF0 Or Hasil2
Hasilkom2 = Not Hasilkom3

Tinggi1 = Hasilkom1 * 16
Tinggi1 = Hasilkom2 + Tinggi1
Nilaibit4 = Tinggi1 / 10
```

```
Sclk = 0
Waitms 1
Return

Ambildata1:
Sclk = 1
If P3.7 = 1 Then
Hasil2 = &H01 Or Hasil2
End If
If P3.7 = 0 Then
Hasil2 = &H00 Or Hasil2
End If
Shift Hasil2 , Left , 1
Sclk = 0
Waitms 1
Return
```



U1
VOLTREG
Vin
Vout
GND
C4
470uF
C5
100uF
+5
VCC
JP2
5V DC
JP1
sensor
R2
470
C2
10nF
C3
1uF
D1
LED
C1
47pF
R1
51K
Y1
MAX187
C6
0.1uF
C7
4.7uF
C8
4.7uF
JP3
PUSH
C9
470uF
R5
10K
R4
AT89C4051
Y2
12Mhz
C10
30pF
C11
30pF
R3
1K
J1
LCD M1632
VSS VCC VEE RS R/W E DB0 DB1 DB2 DB3 DB4 DB5 DB6 DB7 A K
D18
1N4001
Title
Size
B
Number
Revision
Date: 8-Sep-2009
Sheet of

Freescale Semiconductor
Technical Data

Document Number: MPX4115
Rev 5, 08/2006

Integrated Silicon Pressure Sensor Altimeter/Barometer Pressure Sensor On-Chip Signal Conditioned, Temperature Compensated and Calibrated

MPX4115 SERIES

OPERATING OVERVIEW INTEGRATED PRESSURE SENSOR
15 to 115kPa
(2.18 to 16.7 psi)
0.2 to 4.8 Volts Output

The MPX4115 series is designed to sense absolute air pressure in an altimeter or barometer (BAP) applications. Freescale's BAP sensor integrates on-chip, bipolar op amp circuitry and thin film resistor networks to provide a high level analog output signal and temperature compensation. The small form factor and high reliability of on-chip integration makes the Freescale BAP sensor a logical and economical choice for application designers.

Features

- 1.5% Maximum Error over 0° to 85°
- Ideally suited for Microprocessor or Microcontroller-Based Systems
- Available in Absolute, Differential and Gauge Configurations
- Durable Epoxy Unibody Element
- Easy-to-Use Chip Carrier Option

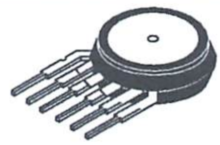
Typical Applications

- Altimeter
- Baromete

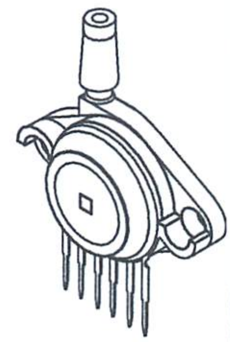
ORDERING INFORMATION[1]

Device	Options	Case No.	MPX Series Order No.	Marking
Basic Element	Absolute, Element Only	Case 867-08	MPX4115A	MPX4115A
Ported Elements	Absolute, Ported	Case 867B-04	MPX4115AP	MPX4115AP
	Absolute, Stove Pipe Port	Case 867E-03	MPX4115AS	MPX4115A
	Absolute, Axial Port	Case 867F-03	MPX4115ASX	MPX4115A

1. The MPX4115A BAP Sensor is available in the Basic Element package or with pressure port fittings that provide mounting ease and barbed hose connections.

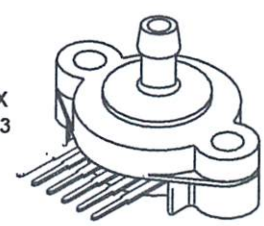


MPX4115A
CASE 867-08



MPX4115AP
CASE 867B-04

MPX4115AS
CASE 867E-03



MPX4115ASX
CASE 867F-03

PIN NUMBERS			
1	V_{OUT}[1]	4	N/C[2]
2	GND	5	N/C[2]
3	V_S	6	N/C[2]

1. Pin 1 is noted by the notch in the lead.
2. Pins 4, 5, and 6 are internal device connections. Pin 1 is noted by the notch in the Lead. Do not connect to external circuitry or ground.

© Freescale Semiconductor, Inc., 2006. All rights reserved.

freescale semiconductor

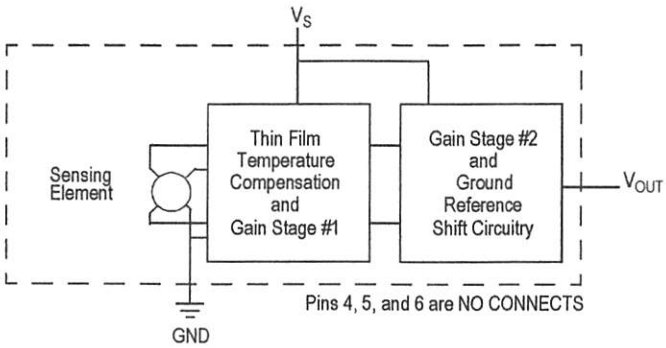


Figure 1. Integrated Pressure Sensor Schematic

Table 1. Maximum Ratings[1]

Parametrics	Symbol	Value	Unit
Overpressure[2] (P1 > P2)	P_{max}	400	kPa
Burst Pressure[2] (P1 > P2)	P_{burst}	1000	kPa
Storage Temperature	T_{stg}	-40° to +125°	°C
Operating Temperature	T_A	-40° to +125°	°C

1. T_C = 25°C unless otherwise noted.
2. Exposure beyond the specified limits may cause permanent damage or degradation to the device.

Table 2. Operating Characteristics
(V_S = 5.1 Vdc, T_A = 25°C unless otherwise noted, P1 > P2 Decoupling circuit shown in Figure 3 required to meet electrical specifications.)

Characteristic		Symbol	Min	Typ	Max	Unit
Pressure Range(1)		P_{OP}	15	-	115	kPa
Supply Voltage(2)		V_S	4.85	5.1	5.35	Vdc
Supply Current		I_o	—	7.0	10	mAdc
Minimum Pressure Offset(3) @ V_S = 5.1 Volts	(0 to 85°C)	V_{off}	0.135	0.204	0.273	Vdc
Full Scale Output(4) @ V_S = 5.1 Volts	(0 to 85°C)	V_{FSO}	4.725	4.794	4.863	Vdc
Full Scale Span(5) @ V_S = 5.1 Volts	(0 to 85°C)	V_{FSS}	—	4.59	—	Vdc
Accuracy(6)	(0 to 85°C)	—	—	—	±1.5	$\%V_{FSS}$
Sensitivity		V/P	—	46	—	mV/kPa
Response Time(7)		t_R	—	1.0	—	ms
Output Source Current at Full Scale Output		I_o+	—	0.1	—	mAdc
Warm-Up Time(8)		—	—	20	—	mSec
Offset Stability(9)		—	—	±0.5	—	$\%V_{FSS}$

1. 1.0kPa (kiloPascal) equals 0.145 psi.
2. Device is ratiometric within this specified excitation range.
3. Offset (V_{off}) is defined as the output voltage at the minimum rated pressure.
4. Full Scale Output (V_{FSO}) is defined as the output voltage at the maximum or full rated pressure.
5. Full Scale Span (V_{FSS}) is defined as the algebraic difference between the output voltage at full rated pressure and the output voltage at the minimum rated pressure.
6. Accuracy (error budget) consists of the following:
   Linearity:Output deviation from a straight line relationship with pressure, using end point method, over the specified pressure range.
   Temperature Hysteresis:Output deviation at any temperature within the operating temperature range, after the temperature is cycled to and from the minimum or maximum operating temperature points, with zero differential pressure applied.
   Pressure Hysteresis:Output deviation at any pressure within the specified range, when this pressure is cycled to and from the minimum or maximum rated pressure at 25°C.
   TcSpan:Output deviation over the temperature range of 0° to 85°C, relative to 25°C.
   TcOffset:Output deviation with minimum pressure applied, over the temperature range of 0° to 85°C, relative to 25°C.
   Variation from Nominal:The variation from nominal values, for Offset or Full Scale Span, as a percent of V_{FSS} at 25°C.
7. Response Time is defined as the time for the incremental change in the output to go from 10% to 90% of its final value when subjected to a specified step change in pressure.
8. Warm-up is defined as the time required for the product to meet the specified output voltage after the Pressure has been stabilized.
9. Offset stability is the product's output deviation when subjected to 1000 hours of Pulsed Pressure, Temperature Cycling with Bias Test.

able 3. Mechanical Characteristics

Characteristic	Symbol	Min	Typ	Max	Unit
Veight, Basic Element (Case 867)	—	—	4.0	—	Grams
Common Mode Line Pressure(1)	—	—	—	690	kPa

1. Common mode pressures beyond what is specified may result in leakage at the case-to-lead interface.

Figure 2 illustrates the absolute sensing chip in the basic chip carrier (Case 867). A fluorosilicone gel isolates the die surface and wire bonds from the environment, while allowing the pressure signal to be transmitted to the sensor diaphragm. The MPX4115A series pressure sensor operating characteristics, and internal reliability and qualification tests are based on use of dry air as the pressure media. Media, other than dry air, may have adverse effects on sensor performance and long-term reliability. Contact the factory for information regarding media compatibility in your application.

Figure 4 shows the sensor output signal relative to pressure input. Typical, minimum, and maximum output curves are shown for operation over a temperature range of 0° to 85°C. (The output will saturate outside of the specified pressure range.)

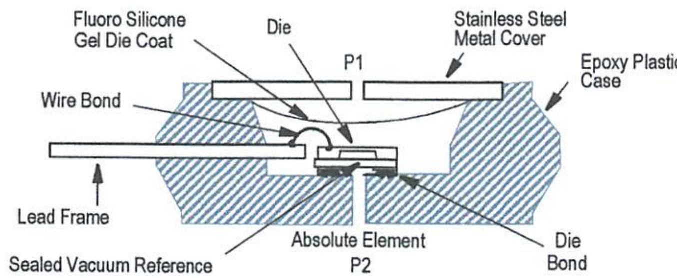


Figure 2. Cross-Sectional Diagram (Not to Scale)

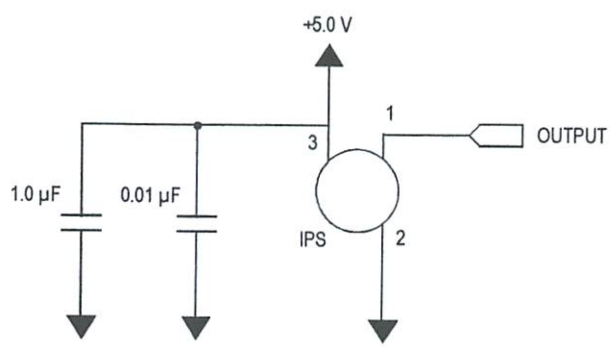


Figure 3. Recommended Power Supply Decoupling.
(For output filtering recommendations, please refer to Application Note AN1646.)

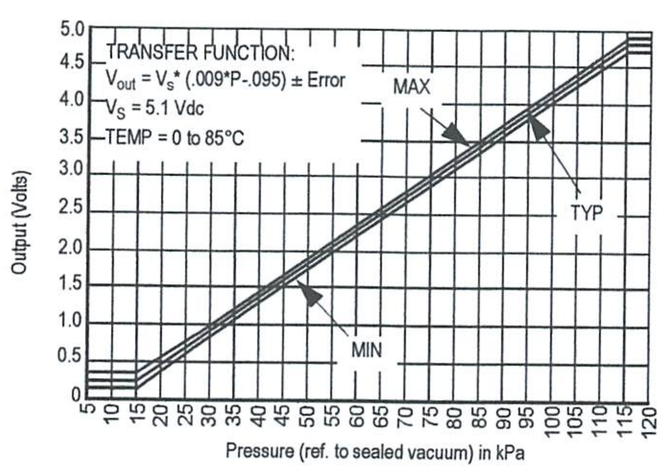


Figure 4. Output versus Absolute Pressure

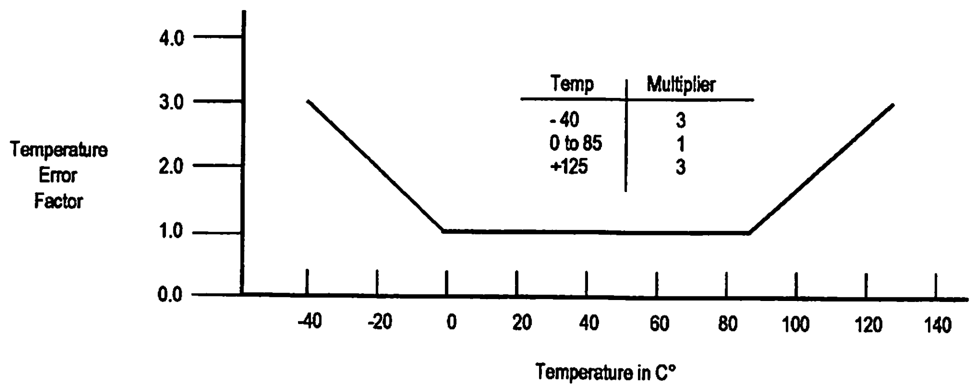
Transfer Function (MPX4115)

Nominal Transfer Value:

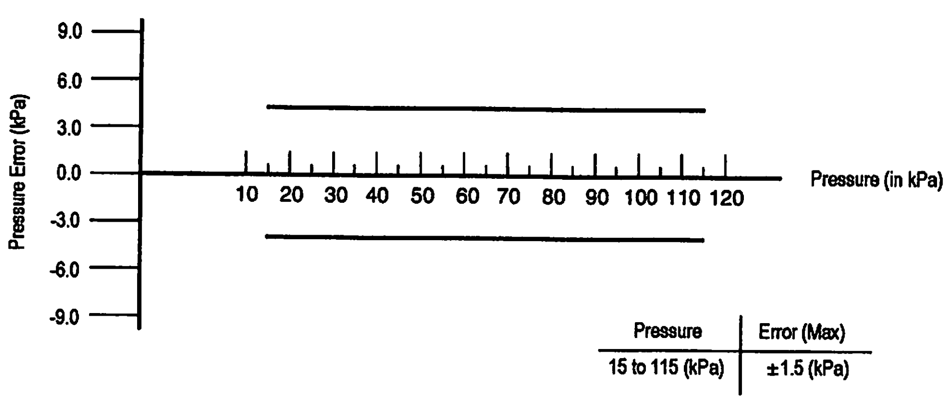
$V_{out} = V_S (P \times 0.009 - 0.095)$
$\pm$ (Pressure Error x Temp. Factor x $0.009 \times V_S$)
$V_S = 5.1\ V \pm 0.25\ Vdc$

Temperature Error Band

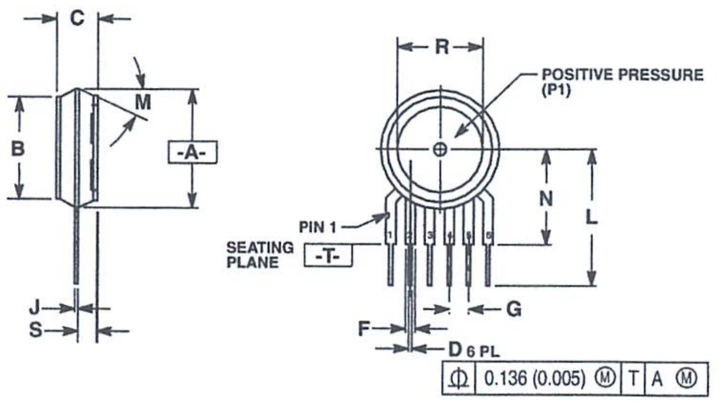
MPX4115A Series



Pressure Error Band



PACKAGE DIMENSIONS



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION -A- IS INCLUSIVE OF THE MOLD STOP RING. MOLD STOP RING NOT TO EXCEED 16.00 (0.630).

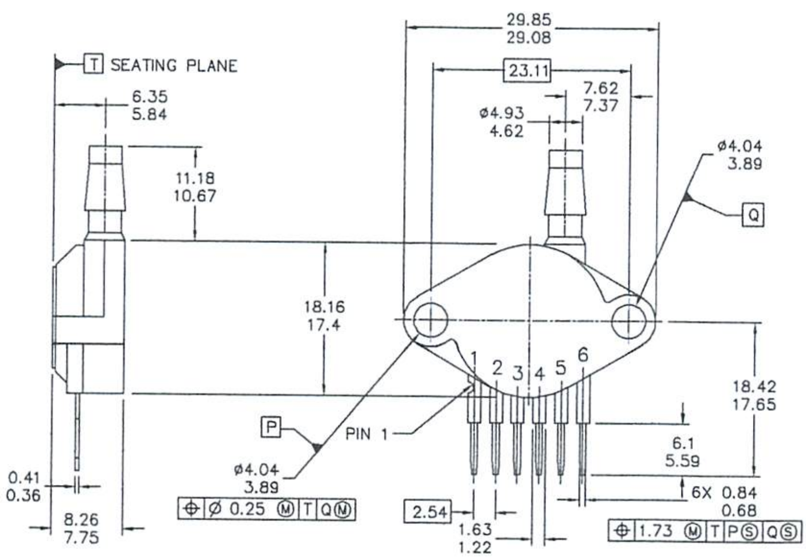
DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.595	0.630	15.11	16.00
B	0.514	0.534	13.06	13.56
C	0.200	0.220	5.08	5.59
D	0.027	0.033	0.68	0.84
F	0.048	0.064	1.22	1.63
G	0.100 BSC		2.54 BSC	
J	0.014	0.016	0.36	0.40
L	0.695	0.725	17.65	18.42
M	30˚ NOM		30˚ NOM	
N	0.475	0.495	12.07	12.57
R	0.430	0.450	10.92	11.43
S	0.090	0.105	2.29	2.66

STYLE 1:
PIN 1. VOUT
2. GROUND
3. VCC
4. V1
5. V2
6. VEX

STYLE 2:
PIN 1. OPEN
2. GROUND
3. -VOUT
4. VSUPPLY
5. +VOUT
6. OPEN

STYLE 3:
PIN 1. OPEN
2. GROUND
3. +VOUT
4. +VSUPPLY
5. -VOUT
6. OPEN

CASE 867-08
ISSUE N
BASIC ELEMENT (A, D)



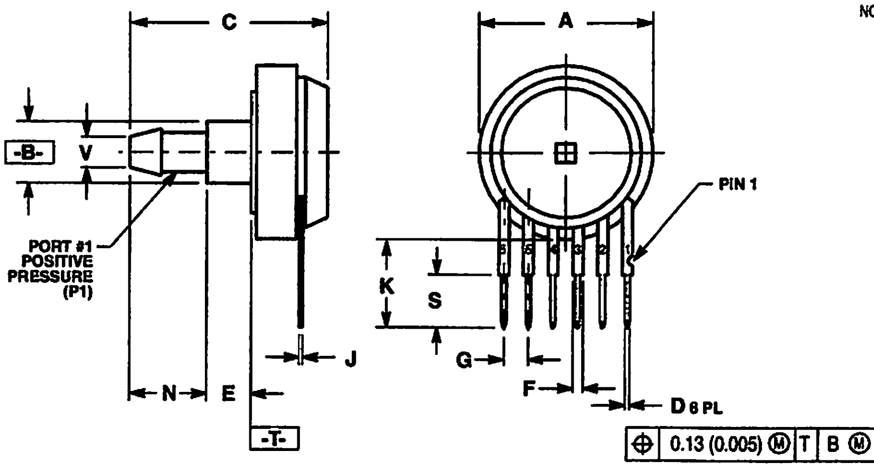
NOTES:

1. DIMENSIONS ARE IN MILLIMETERS.
2. DIMENSIONS AND TOLERANCES PER ASME Y14.5M–1994.
3. 867B–01 THRU –3 OBSOLETE, NEW STANDARD 867B–04.

STYLE 1:

PIN 1: V OUT
2: GROUND
3: VCC
4: V1
5: V2
6: V EX

CASE 867B-04
ISSUE G
PRESSURE SIDE PORTED (AP, GP)

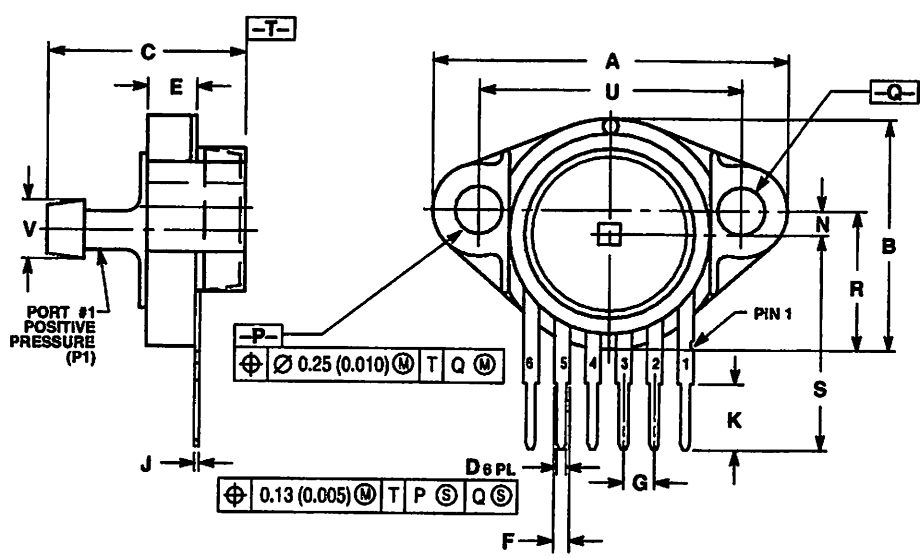


NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.

DIM	INCHES MIN	INCHES MAX	MILLIMETERS MIN	MILLIMETERS MAX
A	0.690	0.720	17.53	18.28
B	0.245	0.255	6.22	6.48
C	0.780	0.820	19.81	20.82
D	0.027	0.033	0.69	0.84
E	0.178	0.186	4.52	4.72
F	0.048	0.064	1.22	1.63
G	0.100 BSC		2.54 BSC	
J	0.014	0.016	0.36	0.41
K	0.345	0.375	8.76	9.53
N	0.300	0.310	7.62	7.87
S	0.220	0.240	5.59	6.10
V	0.182	0.194	4.62	4.93

STYLE 1:
PIN 1. V_{out}
2. GROUND
3. V_{cc}
4. V1
5. V2
6. V_{ex}

CASE 867E-03
ISSUE D
PRESSURE SIDE PORTED (AS, GS)



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.

DIM	INCHES MIN	INCHES MAX	MILLIMETERS MIN	MILLIMETERS MAX
A	1.080	1.120	27.43	28.45
B	0.740	0.760	18.80	19.30
C	0.630	0.650	16.00	16.51
D	0.027	0.033	0.68	0.84
E	0.160	0.180	4.06	4.57
F	0.048	0.064	1.22	1.63
G	0.100 BSC		2.54 BSC	
J	0.014	0.016	0.36	0.41
K	0.220	0.240	5.59	6.10
N	0.070	0.080	1.78	2.03
P	0.150	0.160	3.81	4.06
Q	0.150	0.160	3.81	4.06
R	0.440	0.460	11.18	11.68
S	0.695	0.725	17.65	18.42
U	0.840	0.860	21.34	21.84
V	0.182	0.194	4.62	4.93

STYLE 1:
PIN 1. V_{OUT}
2. GROUND
3. V_{CC}
4. V1
5. V2
6. V_{EX}

CASE 867F-03
ISSUE D
PRESSURE SIDE PORTED (ASX, GSX)

low to Reach Us:

ome Page:
ww.freescale.com

/eb Support:
ttp://www.freescale.com/support

SA/Europe or Locations Not Listed:
reescale Semiconductor, Inc.
echnical Information Center, EL516
100 East Elliot Road
empe, Arizona 85284
1-800-521-6274 or +1-480-768-2130
ww.freescale.com/support

urope, Middle East, and Africa:
reescale Halbleiter Deutschland GmbH
echnical Information Center
chatzbogen 7
1829 Muenchen, Germany
44 1296 380 456 (English)
46 8 52200080 (English)
49 89 92103 559 (German)
33 1 69 35 48 48 (French)
ww.freescale.com/support

apan:
reescale Semiconductor Japan Ltd.
eadquarters
RCO Tower 15F
-8-1, Shimo-Meguro, Meguro-ku,
okyo 153-0064
apan
120 191014 or +81 3 5437 9125
upport.japan@freescale.com

sia/Pacific:
reescale Semiconductor Hong Kong Ltd.
echnical Information Center
Dai King Street
ai Po Industrial Estate
ai Po, N.T., Hong Kong
300 2666 8080
upport.asia@freescale.com

or Literature Requests Only:
reescale Semiconductor Literature Distribution Center
.O. Box 5405
enver, Colorado 80217
800-441-2447 or 303-675-2140
ax: 303-675-2150
DCForFreescaleSemiconductor@hibbertgroup.com

PX4115
v. 5
/2006

Information in this document is provided solely to enable system and software implementers to use Freescale Semiconductor products. There are no express or implied copyright licenses granted hereunder to design or fabricate any integrated circuits or integrated circuits based on the information in this document.

Freescale Semiconductor reserves the right to make changes without further notice to any products herein. Freescale Semiconductor makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does Freescale Semiconductor assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation consequential or incidental damages. "Typical" parameters that may be provided in Freescale Semiconductor data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals", must be validated for each customer application by customer's technical experts. Freescale Semiconductor does not convey any license under its patent rights nor the rights of others. Freescale Semiconductor products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or other applications intended to support or sustain life, or for any other application in which the failure of the Freescale Semiconductor product could create a situation where personal injury or death may occur. Should Buyer purchase or use Freescale Semiconductor products for any such unintended or unauthorized application, Buyer shall indemnify and hold Freescale Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that Freescale Semiconductor was negligent regarding the design or manufacture of the part.

Freescale™ and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners.

© Freescale Semiconductor, Inc. 2006. All rights reserved.

freescale™
semiconductor

19-0196; Rev 0; 10/93

EVALUATION KIT MANUAL FOLLOWS DATA SHEET

MAXIM

+5V, Low-Power, 12-Bit Serial ADCs

MAX187/MAX189

General Description

The MAX187/MAX189 serial 12-bit analog-to-digital converters (ADCs) operate from a single +5V supply and accept a 0V to 5V analog input. Both parts feature an 8.5µs successive-approximation ADC, a fast track/hold (1.5µs), an on-chip clock, and a high-speed 3-wire serial interface.

The MAX187/MAX189 digitize signals at a 75ksps throughput rate. An external clock accesses data from the interface, which communicates without external hardware to most digital signal processors and micro-controllers. The interface is compatible with SPI™, QSPI™, and Microwire™.

The MAX187 has an on-chip buffered reference, and the MAX189 requires an external reference. Both the MAX187 and MAX189 save space with 8-pin DIP and 16-pin SO packages. Power consumption is 7.5mW and reduces to only 10µW in shutdown.

Excellent AC characteristics and very low power consumption combined with ease of use and small package size make these converters ideal for remote DSP and sensor applications, or for circuits where power consumption and space are crucial.

Applications

Portable Data Logging

Remote Digital Signal Processing

Isolated Data Acquisition

High-Accuracy Process Control

Features

- **12-Bit Resolution**
- **±½ LSB Integral Nonlinearity (MAX187A/MAX189A)**
- **Internal Track/Hold, 75kHz Sampling Rate**
- **Single +5V Operation**
- **Low Power: 2µA Shutdown Current**
  1.5mA Operating Current
- **Internal 4.096V Buffered Reference (MAX187)**
- **3-Wire Serial Interface, Compatible with SPI, QSPI, and Microwire**
- **Small-Footprint 8-Pin DIP and 16-Pin SO**

Ordering Information

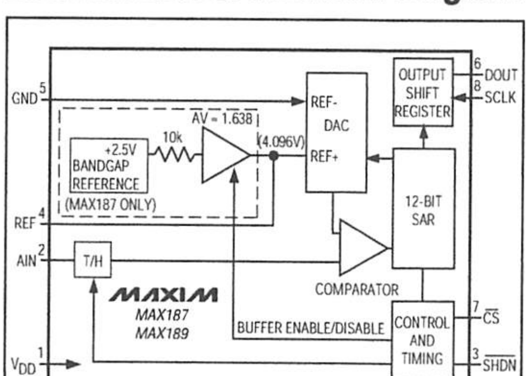
PART	TEMP. RANGE	PIN-PACKAGE	ERROR (LSB)
MAX187ACPA	0°C to +70°C	8 Plastic DIP	±½
MAX187BCPA	0°C to +70°C	8 Plastic DIP	±1
MAX187CCPA	0°C to +70°C	8 Plastic DIP	±2
MAX187ACWE	0°C to +70°C	16 Wide SO	±½
MAX187BCWE	0°C to +70°C	16 Wide SO	±1
MAX187CCWE	0°C to +70°C	16 Wide SO	±2
MAX187BC/D	0°C to +70°C	Dice*	±1

Ordering Information continued on last page.

* *Dice are specified at T_A = +25°C, DC parameters only.*

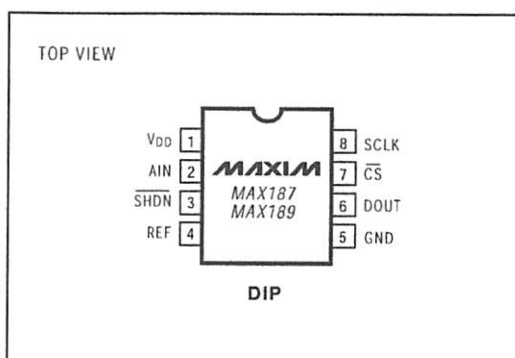
** *Contact factory for availability and processing to MIL-STD-883.*

Functional Diagram



NOTE: PIN NUMBERS SHOWN ARE FOR 8-PIN DIPs ONLY.

Pin Configurations



Pin Configurations continued on last page.

™ SPI and QSPI are trademarks of Motorola. Microwire is a trademark of National Semiconductor.

Call toll free 1-800-998-8800 for free samples or literature.

+5V, Low-Power, 12-Bit Serial ADCs

ABSOLUTE MAXIMUM RATINGS

V_{DD} to GND ....-0.3V to +6V
AIN to GND ....-0.3V to (V_{DD} + 0.3V)
REF to GND ....-0.3V to (V_{DD} + 0.3V)
Digital Inputs to GND ....-0.3V to (V_{DD} + 0.3V)
Digital Outputs to GND ....-0.3V to (V_{DD} + 0.3V)
$\overline{SHDN}$ to GND ....-0.3V to (V_{DD} + 0.3V)
REF Load Current (MAX187) ....4.0mA Continuous
REF Short-Circuit Duration (MAX187) 20sec
DOUT Current ....±20mA

Continuous Power Dissipation (T_A = +70°C)
8-Pin Plastic DIP (derate 9.09mW/°C above +70°C)..500mW
16-Pin Wide SO (derate 8.70mW/°C above +70°C)...478mW
8-Pin CERDIP (derate 8.00mW/°C above +70°C)......440mW
Operating Temperature Ranges:
MAX187_C_ _/MAX189_C_ _..............................0°C to +70°C
MAX187_E_ _/MAX189_E_ _..........................-40°C to +85°C
MAX187_MJA/MAX189_MJA ....-55°C to +125°C
Storage Temperature Range............................-60°C to +150°C
Lead Temperature (soldering, 10sec)............................+300°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

(V_{DD} = +5V ±5%; GND = 0V; unipolar input mode; 75ksps, f_{CLK} = 4.0MHz, external clock (50% duty cycle); MAX187—internal reference: V_{REF} = 4.096V, 4.7μF capacitor at REF pin, or MAX189—external reference: V_{REF} = 4.096V applied to REF pin, 4.7μF capacitor at REF pin; T_A = T_{MIN} to T_{MAX}; unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
DC ACCURACY (Note 1)						
Resolution					12	Bits
Relative Accuracy (Note 2)		MAX18_A			±½	LSB
		MAX18_B			±1	
		MAX18_C			±2	
Differential Nonlinearity	DNL	No missing codes over temperature			±1	LSB
Offset Error		MAX18_A			±1½	LSB
		MAX18_B/C			±3	
Gain Error (Note 3)		MAX187			±3	LSB
		MAX189A			±1	
		MAX189B/C			±3	
Gain Temperature Coefficient		External reference, 4.096V		±0.8		ppm/°C
DYNAMIC SPECIFICATIONS (10kHz sine wave input, 0V to 4.096V_{P-P}, 75ksps)						
Signal-to-Noise plus Distortion Ratio	SINAD		70			dB
Total Harmonic Distortion (up to the 5th harmonic)	THD				-80	dB
Spurious-Free Dynamic Range	SFDR		80			dB
Small-Signal Bandwidth		Rolloff -3dB		4.5		MHz
Full-Power Bandwidth				0.8		MHz

ELECTRICAL CHARACTERISTICS (continued)

(V_{DD} = +5V ±5%; GND = 0V; unipolar input mode; 75ksps, f_{CLK} = 4.0MHz, external clock (50% duty cycle); MAX187—internal reference: V_{REF} = 4.096V, 4.7µF capacitor at REF pin, or MAX189—external reference: V_{REF} = 4.096V applied to REF pin, 4.7µF capacitor at REF pin; T_A = T_{MIN} to T_{MAX}; unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
CONVERSION RATE							
Conversion Time	t_{CONV}			5.5		8.5	µs
Track/Hold Acquisition Time	t_{ACQ}			1.5			µs
Throughput Rate		External clock, 4MHz, 13 clocks				75	ksps
Aperture Delay	t_{APR}				10		ns
Aperture Jitter					<50		ps
ANALOG INPUT							
Input Voltage Range						0 to V_{REF}	V
Input Capacitance (Note 4)					16		pF
INTERNAL REFERENCE (MAX187 only, reference buffer enabled)							
REF Output Voltage	V_{REF}	T_A = +25°C		4.076	4.096	4.116	V
		T_A = T_{MIN} to T_{MAX}	MAX187_C	4.060		4.132	
			MAX187_E	4.050		4.140	
			MAX187_M	4.040		4.150	
REF Short-Circuit Current						30	mA
REF Tempco		MAX187AC/BC			±30	±50	ppm/°C
		MAX187AE/BE			±30	±60	
		MAX187AM/BM			±30	±80	
		MAX187C			±30		
Load Regulation (Note 5)		0mA to 0.6mA output load			1		mV
EXTERNAL REFERENCE AT REF (Buffer disabled, V_{REF} = 4.096V)							
Input Voltage Range				2.50		V_{DD} + 50mV	V
Input Current					200	350	µA
Input Resistance				12	20		kΩ
Shutdown REF Input Current					1.5	10	µA

ELECTRICAL CHARACTERISTICS (continued)

(V_{DD} = +5V ±5%; GND = 0V; unipolar input mode; 75ksps, f_{CLK} = 4.0MHz, external clock (50% duty cycle); MAX187—internal reference: V_{REF} = 4.096V, 4.7µF capacitor at REF pin, or MAX189—external reference: V_{REF} = 4.096V applied to REF pin, 4.7µF capacitor at REF pin; T_A = T_{MIN} to T_{MAX}; unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
DIGITAL INPUTS (SCLK, $\overline{CS}$, $\overline{SHDN}$)						
SCLK, $\overline{CS}$ Input High Voltage	V_{INH}		2.4			V
SCLK, CS Input Low Voltage	V_{INL}				0.8	V
SCLK, $\overline{CS}$ Input Hysteresis	V_{HYST}			0.15		V
SCLK, $\overline{CS}$ Input Leakage	I_{IN}	V_{IN} = 0V or V_{DD}			±1	µA
SCLK, $\overline{CS}$ Input Capacitance	C_{IN}	(Note 4)			15	pF
$\overline{SHDN}$ Input High Voltage	V_{INSH}		V_{DD} - 0.5			V
$\overline{SHDN}$ Input Low Voltage	V_{INSL}				0.5	V
$\overline{SHDN}$ Input Current	I_{INS}	$\overline{SHDN}$ = V_{DD} or 0V			±4.0	µA
$\overline{SHDN}$ Input Mid Voltage	V_{IM}		1.5		V_{DD} -1.5	V
$\overline{SHDN}$ Voltage, Floating	V_{FLT}	$\overline{SHDN}$ = open		2.75		V
SHDN Maximum Allowed Leakage, Mid Input		$\overline{SHDN}$ = open	-100		100	nA
DIGITAL OUTPUT (DOUT)						
Output Voltage Low	V_{OL}	I_{SINK} = 5mA			0.4	V
		I_{SINK} = 16mA		0.3		
Output Voltage High	V_{OH}	I_{SOURCE} = 1mA	4			V
Three-State Leakage Current	I_L	CS = 5V			±10	µA
Three-State Output Capacitance	C_{OUT}	$\overline{CS}$ = 5V (Note 4)			15	pF
POWER REQUIREMENTS						
Supply Voltage	V_{DD}		4.75		5.25	V
Supply Current	I_{DD}	Operating mode, MAX187		1.5	2.5	mA
		Operating mode, MAX189		1.0	2.0	
		Power-down mode		2	10	µA
Power-Supply Rejection	PSR	V_{DD} = +5V, ±5%; external reference, 4.096V; full-scale input (Note 6)		±0.06	±0.5	mV

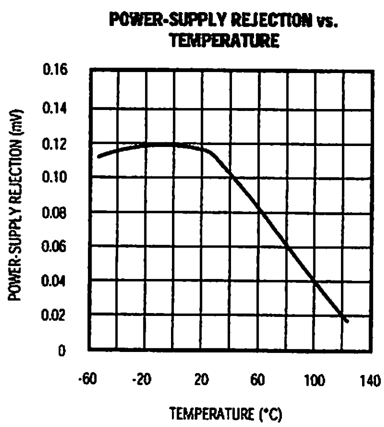
TIMING CHARACTERISTICS

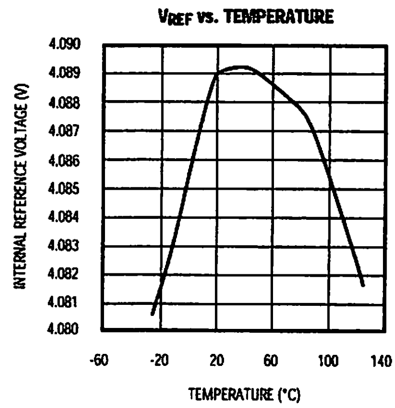
(V_{DD} = +5.0V ±5%, T_A = T_{MIN} to T_{MAX}, unless otherwise noted.)

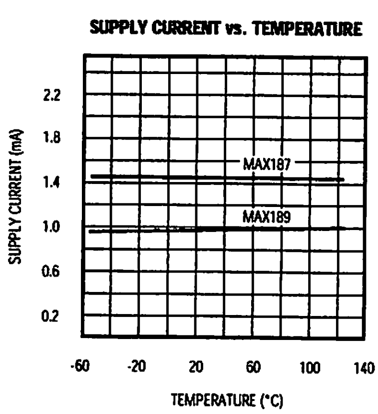
PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Track/Hold Acquisition Time	t_{ACQ}	$\overline{CS}$ = high (Note 7)		1.5			µs
SCLK Fall to Output Data Valid	t_{DO}	C_{LOAD} = 100pF	MAX18_ _C/E	20		150	ns
			MAX18_ _M	20		200	
$\overline{CS}$ Fall to Output Enable	t_{DV}	C_{LOAD} = 100pF				100	ns
$\overline{CS}$ Rise to Output Disable	t_{TR}	C_{LOAD} = 100pF				100	ns
SCLK Clock Frequency	f_{SCLK}					5	MHz
SCLK Pulse Width High	t_{CH}			100			ns
SCLK Pulse Width Low	t_{CL}			100			ns
SCLK Low to $\overline{CS}$ Fall Setup Time	t_{CSO}			50			ns
$\overline{CS}$ Pulse Width	t_{CS}			500			ns

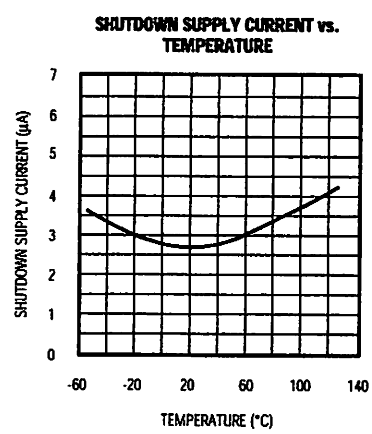
Note 1: Tested at V_{DD} = +5V.
Note 2: Relative accuracy is the deviation of the analog value at any code from its theoretical value after the full-scale range has been calibrated.
Note 3: MAX187—internal reference, offset nulled; MAX189-external +4.096V reference, offset nulled. Excludes reference errors.
Note 4: Guaranteed by design. Not subject to production testing.
Note 5: External load should not change during conversion for specified ADC accuracy.
Note 6: DC test, measured at 4.75V and 5.25V only.
Note 7: To guarantee acquisition time, t_{ACQ} is the maximum time the device takes to acquire the signal, and is also the minimum time needed for the signal to be acquired.

Typical Operating Characteristics









Pin Description

PIN		NAME	FUNCTION
DIP	WIDE SO		
1	1	V_{DD}	Supply voltage, +5V ±5%
2	3	AIN	Sampling analog input, 0V to V_{REF} range
3	6	$\overline{SHDN}$	Three-level shutdown input. Pulling $\overline{SHDN}$ low shuts the MAX187/MAX189 down to 10µA (max) supply current. Both MAX187 and MAX189 are fully operational with either $\overline{SHDN}$ high or floating. For the MAX187, pulling $\overline{SHDN}$ high enables the internal reference, and letting $\overline{SHDN}$ float disables the internal reference and allows for the use of an external reference.
4	8	REF	Reference voltage—sets analog voltage range and functions as a 4.096V output for the MAX187 with enabled internal reference. REF also serves as a +2.5V to V_{DD} input for a precision reference for both MAX187 (disabled internal reference) and MAX189. Bypass with 4.7µF if internal reference is used, and with 0.1µF if an external reference is applied.
5	—	GND	Analog and digital ground
—	10	AGND	Analog ground
—	11	DGND	Digital ground
6	12	DOUT	Serial data output. Data changes state at SCLK's falling edge.
7	15	CS	Active-low chip select initiates conversions on the falling edge. When $\overline{CS}$ is high, DOUT is high impedance.
8	16	SCLK	Serial clock input. Clocks data out with rates up to 5MHz.
—	2,4,5,7,9,13,14	N.C.	Not internally connected. Connect to AGND for best noise performance.

Detailed Description

Converter Operation

The MAX187/MAX189 use input track/hold (T/H) and successive approximation register (SAR) circuitry to convert an analog input signal to a digital 12-bit output. No external hold capacitor is needed for the T/H. Figures 3a and 3b show the MAX187/MAX189 in their simplest configuration. The MAX187/MAX189 convert input signals in the 0V to V_{REF} range in 10µs, including T/H acquisition time. The MAX187's internal reference is trimmed to 4.096V, while the MAX189 requires an external reference. Both devices accept external reference voltages from +2.5V to V_{DD}. The serial interface requires only three digital lines, SCLK, $\overline{CS}$, and DOUT, and provides easy interface to microprocessors (µPs).

Both converters have two modes: normal and shutdown. Pulling $\overline{SHDN}$ low shuts the device down and reduces supply current to below 10µA, while pulling $\overline{SHDN}$ high or leaving it floating puts the device into the operational mode. A conversion is initiated by CS falling. The conversion result is available at DOUT in unipolar serial format. A high bit, signaling the end of conversion (EOC), followed by the data bits (MSB first), make up the serial data stream.

The MAX187 operates in one of two states: (1) internal reference and (2) external reference. Select internal reference operation by forcing $\overline{SHDN}$ high, and external reference operation by floating $\overline{SHDN}$.

Analog Input

Figure 4 illustrates the sampling architecture of the ADC's analog comparator. The full-scale input voltage depends on the voltage at REF.

REFERENCE	ZERO SCALE	FULL SCALE
Internal Reference (MAX187 only)	0V	+4.096V
External Reference	0V	V_{REF}

For specified accuracy, the external reference voltage range spans from +2.5V to V_{DD}.

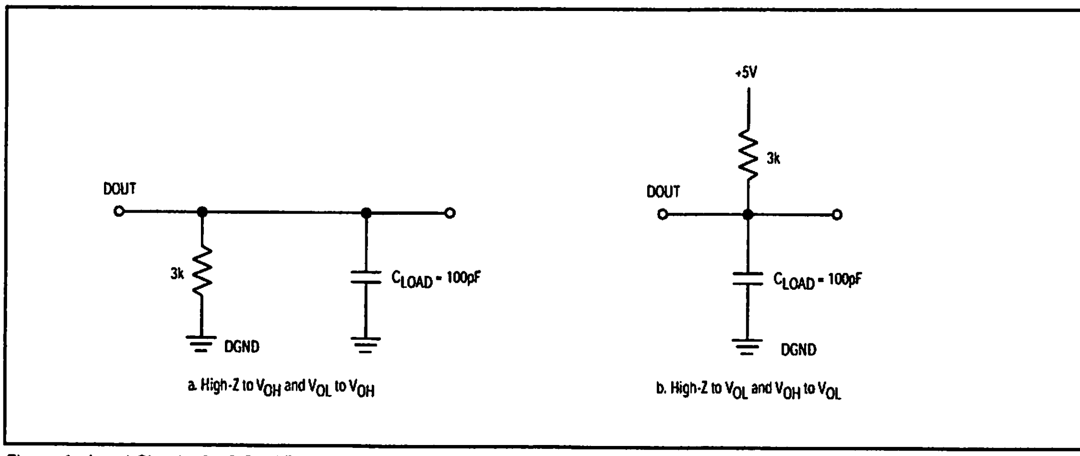


Figure 1. Load Circuits for DOUT Enable Time

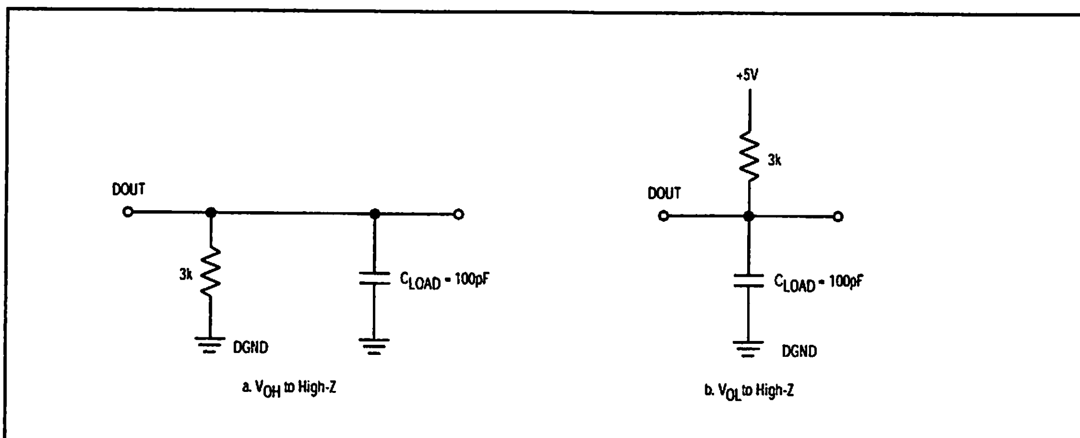


Figure 2. Load Circuits for DOUT Disable Time

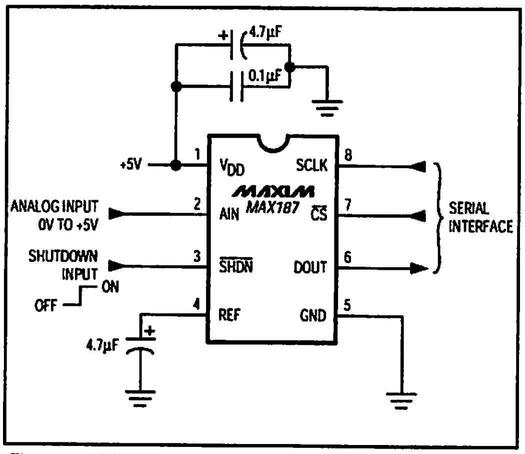


Figure 3a. MAX187 Operational Diagram

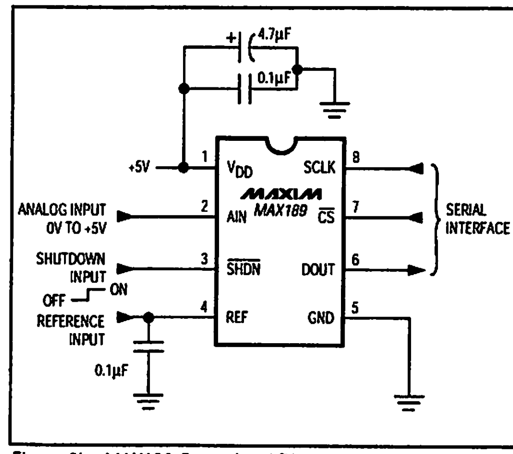


Figure 3b. MAX189 Operational Diagram

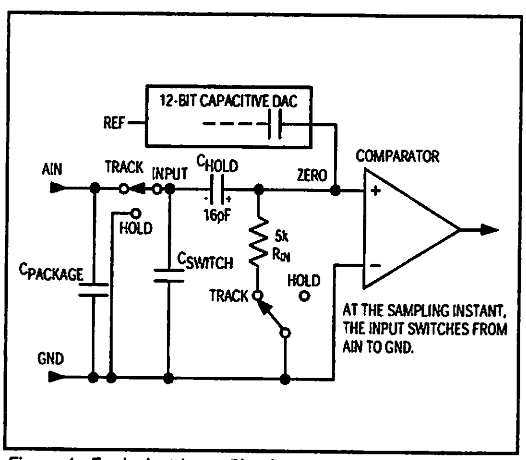


Figure 4. Equivalent Input Circuit

Track/Hold

In track mode, the analog signal is acquired and stored in the internal hold capacitor. In hold mode, the T/H switch opens and maintains a constant input to the ADC's SAR section.

During acquisition, the analog input AIN charges capacitor C_{HOLD}. Bringing $\overline{CS}$ low ends the acquisition interval. At this instant, the T/H switches the input side of C_{HOLD} to GND. The retained charge on C_{HOLD} represents a sample of the input, unbalancing the node ZERO at the comparator's input.

In hold mode, the capacitive DAC adjusts during the remainder of the conversion cycle to restore node ZERO to 0V within the limits of a 12-bit resolution. This action is equivalent to transferring a charge from C_{HOLD} to the binary-weighted capacitive DAC, which in turn forms a digital representation of the analog input signal. At the conversion's end, the input side of C_{HOLD} switches back to AIN, and C_{HOLD} charges to the input signal again.

The time required for the T/H to acquire an input signal is a function of how quickly its input capacitance is charged. If the input signal's source impedance is high, the acquisition time lengthens and more time must be allowed between conversions. Acquisition time is calculated by:

$$t_{ACQ} = 9\ (R_S + R_{IN})\ 16pF,$$

where R_{IN} = 5kΩ, R_S = the source impedance of the input signal, and t_{ACQ} is never less than 1.5µs. Source impedances below 5kΩ do not significantly affect the AC performance of the ADC.

Input Bandwidth

The ADCs' input tracking circuitry has a 4.5MHz small-signal bandwidth, and an 8V/µs slew rate. It is possible to digitize high-speed transient events and measure periodic signals with bandwidths exceeding the ADC's sampling rate by using undersampling techniques. To avoid aliasing of unwanted high-frequency signals into the frequency band of interest, an anti-alias filter is recommended. See the MAX274/MAX275 continuous-time filters data sheet.

Input Protection

Internal protection diodes that clamp the analog input allow the input to swing from GND - 0.3V to V_{DD} + 0.3V without damage. However, for accurate conversions near full scale, the input must not exceed V_{DD} by more than 50mV, or be lower than GND by 50mV.

If the analog input exceeds the supplies by more than 50mV beyond the supplies, limit the input current to 2mA, since larger currents degrade conversion accuracy.

Driving the Analog Input

The input lines to AIN and GND should be kept as short as possible to minimize noise pickup. Shield longer leads. Also see the *Input Protection* section.

Because the MAX187/MAX189 incorporate a T/H, the drive requirements of the op amp driving AIN are less stringent than those for a successive-approximation ADC without a T/H. The typical input capacitance is 16pF. The amplifier bandwidth should be sufficient to handle the frequency of the input signal. The MAX400 and OP07 work well at lower frequencies. For higher-frequency operation, the MAX427 and OP27 are practical choices. The allowed input frequency range is limited by the 75ksps sample rate of the MAX187/MAX189. Therefore, the maximum sinusoidal input frequency allowed is 37.5kHz. Higher-frequency signals cause aliasing problems unless undersampling techniques are used.

Reference

The MAX187 can be used with an internal or external reference, while the MAX189 requires an external reference.

Internal Reference

The MAX187 has an on-chip reference with a buffered temperature-compensated bandgap diode, laser-trimmed to +4.096V ±0.5%. Its output is connected to REF and also drives the internal DAC. The output can be used as a reference voltage source for other components and can source up to 0.6mA. Decouple REF with a 4.7µF capacitor. The internal reference is enabled by pulling the $\overline{SHDN}$ pin high. Letting $\overline{SHDN}$ float disables the internal reference, which allows the use of an external reference, as described in the *External Reference* section.

External Reference

The MAX189 operates with an external reference at the REF pin. To use the MAX187 with an external reference, disable the internal reference by letting $\overline{SHDN}$ float. Stay within the voltage range +2.5V to V_{DD} to achieve specified accuracy. The minimum input impedance is 12kΩ for DC currents. During conversion, the external reference must be able to deliver up to 350µA DC load current and have an output impedance of 10Ω or less. The recommended minimum value for the bypass capacitor is 0.1µF. If the reference has higher output impedance or is noisy, bypass it close to the REF pin with a 4.7µF capacitor.

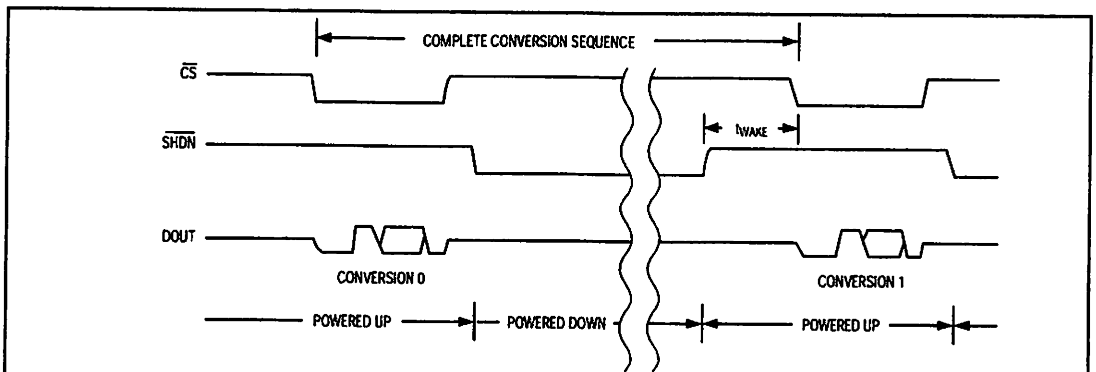


Figure 5. MAX187/MAX189 Shutdown Sequence

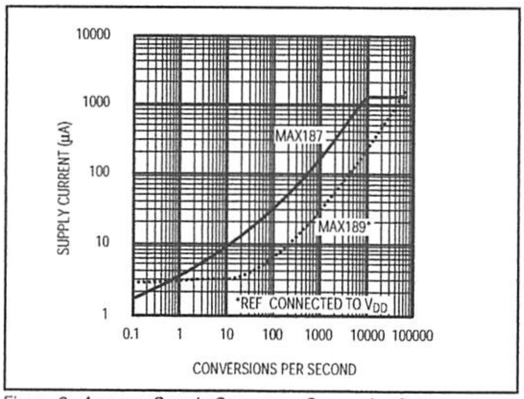


Figure 6. Average Supply Current vs. Conversion Rate

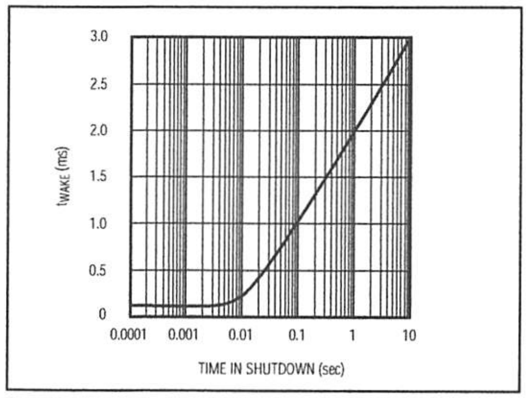


Figure 7. t_{WAKE} vs. Time in Shutdown (MAX187 only)

Serial Interface

Initialization After Power-Up and Starting a Conversion

When power is first applied, it takes the fully discharged 4.7μF reference bypass capacitor up to 20ms to provide adequate charge for specified accuracy. With $\overline{SHDN}$ not pulled low, the MAX187/MAX189 are now ready to convert.

To start a conversion, pull $\overline{CS}$ low. At $\overline{CS}$'s falling edge, the T/H enters its hold mode and a conversion is initiated. After an internally timed 8.5μs conversion period, the end of conversion is signaled by DOUT pulling high. Data can then be shifted out serially with the external clock.

Using $\overline{SHDN}$ to Reduce Supply Current

Power consumption can be reduced significantly by shutting down the MAX187/MAX189 between conversions. This is shown in Figure 6, a plot of average supply current vs. conversion rate. Because the MAX189 uses an external reference voltage (assumed to be present continuously), it "wakes up" from shutdown more quickly, and therefore provides lower average supply currents. The wakeup-time, t_{WAKE}, is the time from $\overline{SHDN}$ deasserted to the time when a conversion may be initiated. For the MAX187, this time is 2μs. For the MAX189, this time depends on the time in shutdown (see Figure 7) because the external 4.7μF reference bypass capacitor loses charge slowly during shutdown (see the specifications for shutdown, REF Input Current = 10μA max).

External Clock

The actual conversion does not require the external clock. This frees the μP from the burden of running the SAR conversion clock, and allows the conversion result to be read back at the μP's convenience at any clock rate from 0MHz to 5MHz. The clock duty cycle is unrestricted if each clock phase is at least 100ns. Do not run the clock while a conversion is in progress.

Timing and Control

Conversion-start and data-read operations are controlled by the $\overline{CS}$ and SCLK digital inputs. The timing diagrams of Figures 8 and 9 outline the operation of the serial interface.

A $\overline{CS}$ falling edge initiates a conversion sequence: The T/H stage holds input voltage, the ADC begins to convert, and DOUT changes from high impedance to logic low. SCLK must be kept inactive during the conversion. An internal register stores the data when the conversion is in progress.

End of conversion (EOC) is signaled by DOUT going high. DOUT's rising edge can be used as a framing signal. SCLK shifts the data out of this register any time after the conversion is complete. DOUT transitions on SCLK's falling edge. The next falling clock edge produces the MSB of the conversion at DOUT, followed by the remaining bits. Since there are 12 data bits and one leading high bit, at least 13 falling clock edges are needed to shift out these bits. Extra clock pulses occurring after the conversion result has been clocked out, and prior to a rising edge of $\overline{CS}$, produce trailing 0s at DOUT and have no effect on converter operation.

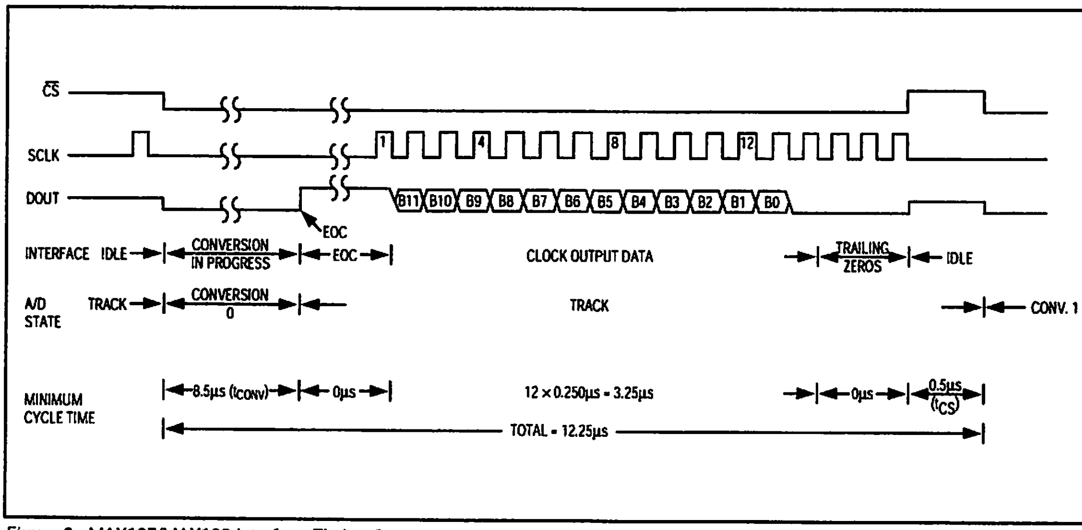


Figure 8. MAX187/MAX189 Interface Timing Sequence

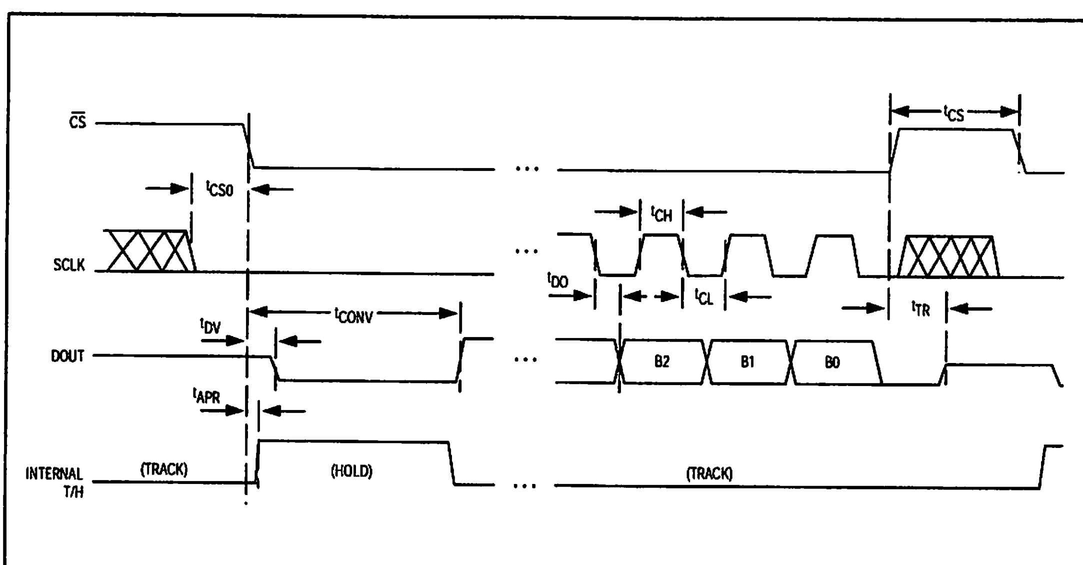


Figure 9. MAX187/MAX189 Detailed Serial-Interface Timing

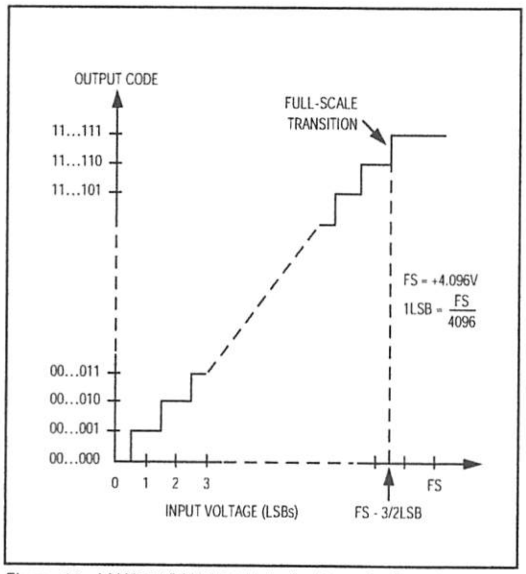


Figure 10. MAX187/MAX189 Unipolar Transfer Function, 4.096V = Full Scale

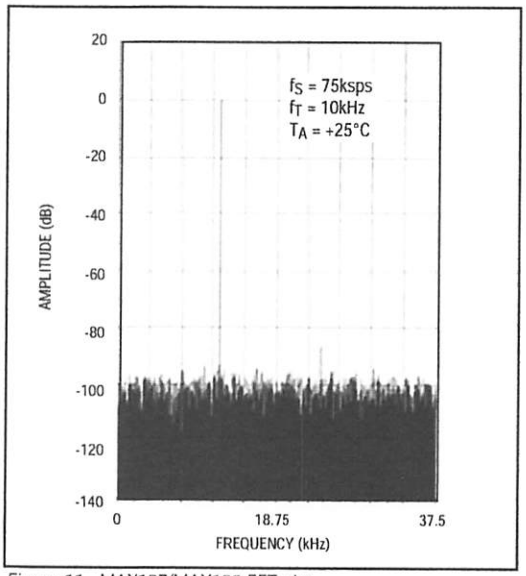


Figure 11. MAX187/MAX189 FFT plot

Minimum cycle time is accomplished by using DOUT's rising edge as the EOC signal. Clock out the data with 13 clock cycles at full speed. Raise $\overline{CS}$ after the conversion's LSB has been read. After the specified minimum time, t_{ACQ}, $\overline{CS}$ can be pulled low again to initiate the next conversion.

Output Coding and Transfer Function

The data output from the MAX187/MAX189 is binary, and Figure 10 depicts the nominal transfer function. Code transitions occur halfway between successive integer LSB values. If V_{REF} = +4.096V, then 1 LSB = 1.00mV or 4.096V/4096.

Dynamic Performance

High-speed sampling capability and a 75ksps throughput make the MAX187/MAX189 ideal for wideband signal processing. To support these and other related applications, Fast Fourier Transform (FFT) test techniques are used to guarantee the ADC's dynamic frequency response, distortion, and noise at the rated throughput. Specifically, this involves applying a low-distortion sine wave to the ADC input and recording the digital conversion results for a specified time. The data is then analyzed using an FFT algorithm that determines its spectral content. Conversion errors are then seen as spectral elements outside of the fundamental input frequency. ADCs have traditionally been evaluated by specifications such as Zero and Full-Scale Error, Integral Nonlinearity (INL), and Differential Nonlinearity (DNL). Such parameters are widely accepted for specifying performance with DC and slowly varying signals, but are less useful in signal-processing applications, where the ADC's impact on the system transfer function is the main concern. The significance of various DC errors does not translate well to the dynamic case, so different tests are required.

Signal-to-Noise Ratio and Effective Number of Bits

Signal-to-noise plus distortion (SINAD) is the ratio of the fundamental input frequency's RMS amplitude to the RMS amplitude of all other ADC output signals. The input bandwidth is limited to frequencies above DC and below one-half the ADC sample (conversion) rate.

The theoretical minimum ADC noise is caused by quantization error and is a direct result of the ADC's resolution: SINAD = (6.02N + 1.76)dB, where N is the number of bits of resolution. An ideal 12-bit ADC can, therefore, do no better than 74dB. An FFT plot of the output shows the output level in various spectral bands. Figure 11 shows the result of sampling a pure 10kHz sine wave at a 75ksps rate with the MAX187/MAX189.

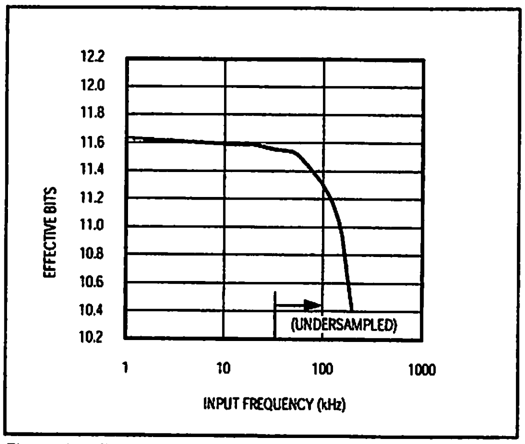


Figure 12. Effective Bits vs. Input Frequency

The effective resolution (effective number of bits) the ADC provides can be determined by transposing the above equation and substituting in the measured SINAD: N = (SINAD - 1.76)/6.02. Figure 12 shows the effective number of bits as a function of the input frequency for the MAX187/MAX189.

Total Harmonic Distortion

If a pure sine wave is sampled by an ADC at greater than the Nyquist frequency, the nonlinearities in the ADC's transfer function create harmonics of the input frequency present in the sampled output data.

Total Harmonic Distortion (THD) is the ratio of the RMS sum of all the harmonics (in the frequency band above DC and below one-half the sample rate, but not including the DC component) to the RMS amplitude of the fundamental frequency. This is expressed as follows:

$$THD = 20\log \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \ldots V_N^2}}{V_1}$$

where V_1 is the fundamental RMS amplitude, and V_2 through V_N are the amplitudes of the 2nd through Nth harmonics. The THD specification in the *Electrical Characteristics* includes the 2nd through 5th harmonics.

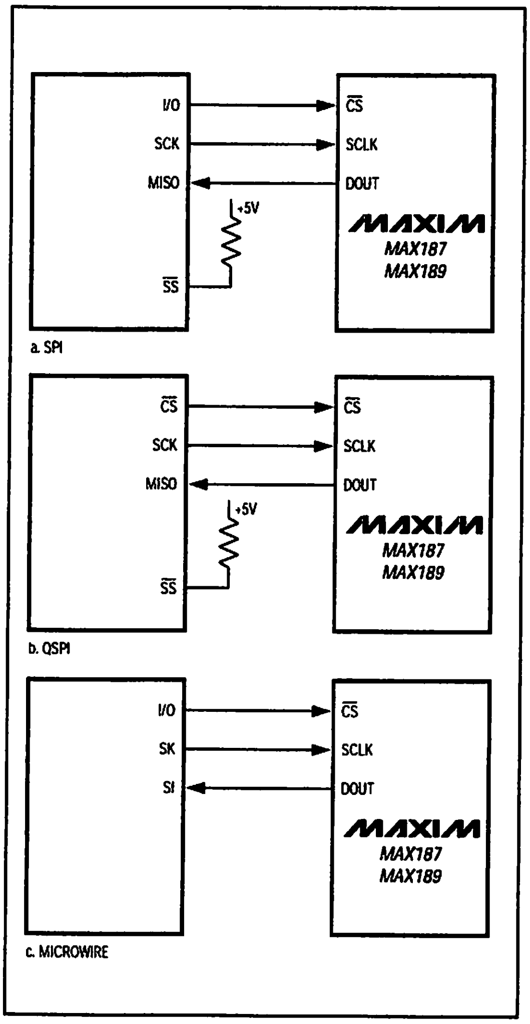


Figure 13. Common Serial-Interface Connections to the MAX187/MAX189

Applications Information

Connection to Standard Interfaces

The MAX187/MAX189 serial interface is fully compatible with SPI, QSPI, and Microwire standard serial interfaces.

If a serial interface is available, set the CPU's serial interface in master mode so the CPU generates the serial clock. Choose a clock frequency up to 2.5MHz.

1. Use a general-purpose I/O line on the CPU to pull $\overline{CS}$ low. Keep SCLK low.
2. Wait the for the maximum conversion time specified before activating SCLK. Alternatively, look for a DOUT rising edge to determine the end of conversion.
3. Activate SCLK for a minimum of 13 clock cycles. The first falling clock edge will produce the MSB of the DOUT conversion. DOUT output data transitions on SCLK's falling edge and is available in MSB-first format. Observe the SCLK to DOUT valid timing characteristic. Data can be clocked into the µP on SCLK's rising edge.
4. Pull $\overline{CS}$ high at or after the 13th falling clock edge. If $\overline{CS}$ remains low, trailing zeros are clocked out after the LSB.
5. With $\overline{CS}$ = high, wait the minimum specified time, t_{CS}, before launching a new conversion by pulling $\overline{CS}$ low. If a conversion is aborted by pulling $\overline{CS}$ high before the conversions end, wait for the minimum acquisition time, t_{ACQ}, before starting a new conversion.

Data can be output in 1-byte chunks or continuously, as shown in Figure 8. The bytes will contain the result of the conversion padded with one leading 1, and trailing 0s if SCLK is still active with CS kept low.

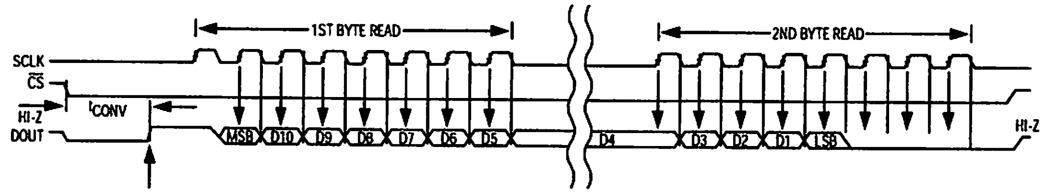


Figure 14. SPI/Microwire Serial Interface Timing (CPOL = CPHA = 0)

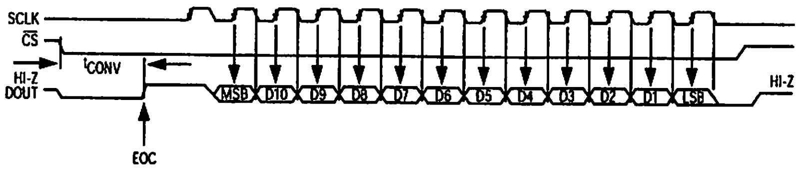


Figure 15. QSPI Serial Interface Timing (CPOL = CPHA = 0)

SPI and Microwire

When using SPI or QSPI, set CPOL = 0 and CPHA = 0. Conversion begins with a $\overline{CS}$ falling edge. DOUT goes low, indicating a conversion in progress. Wait until DOUT goes high or the maximum specified 8.5µs conversion time. Two consecutive 1-byte reads are required to get the full 12 bits from the ADC. DOUT output data transitions on SCLK's falling edge and is clocked into the µP on SCLK's rising edge.

The first byte contains a leading 1 and 7 bits of conversion result. The second byte contains the remaining 5 bits and 3 trailing 0s. See Figure 13 for connections and Figure 14 for timing.

QSPI

Set CPOL = CPHA = 0. Unlike SPI, which requires two 1-byte reads to acquire the 12 bits of data from the ADC, QSPI allows the minimum number of clock cycles necessary to clock in the data. The MAX187/MAX189 require 13 clock cycles from the µP to clock out the 12 bits of data with no trailing 0s (Figure 15). The maximum clock frequency to ensure compatibility with QSPI is 2.77MHz.

Opto-Isolated Interface, Serial-to-Parallel Conversion

Many industrial applications require electrical isolation to separate the control electronics from hazardous electrical conditions, provide noise immunity, or prevent excessive current flow where ground disparities exist between the ADC and the rest of the system. Isolation amplifiers typically used to accomplish these tasks are expensive. In cases where the signal is eventually converted to a digital form, it is cost effective to isolate the input using opto-couplers in a serial link.

The MAX187 is ideal in this application because it includes both T/H amplifier and voltage reference, operates from a single supply, and consumes very little power (Figure 16).

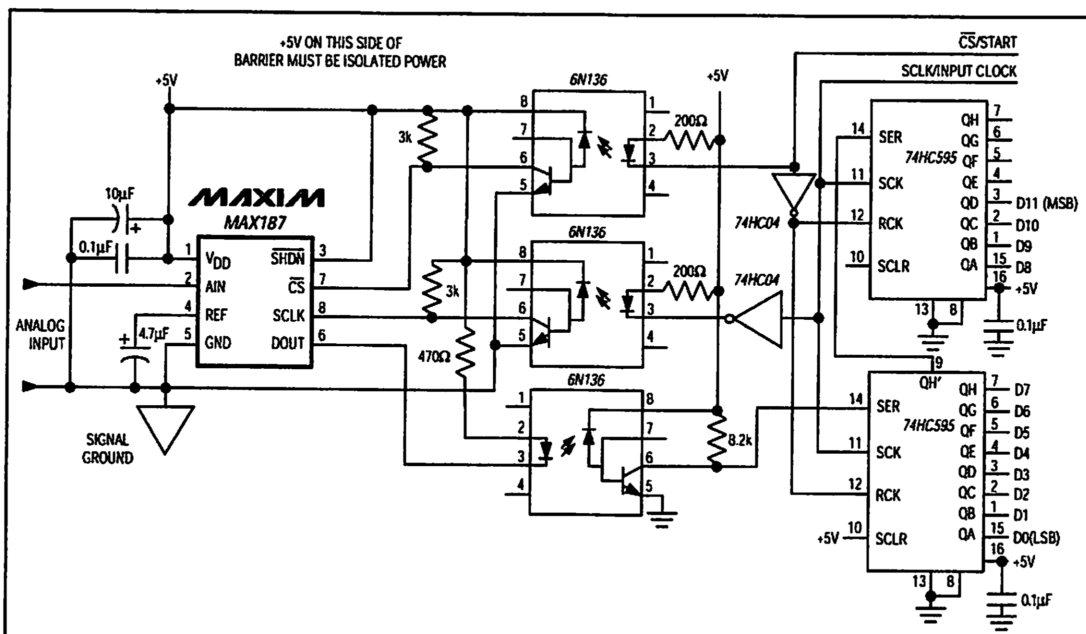


Figure 16. 12-Bit Isolated ADC

The ADC results are transmitted across a 1500V isolation barrier provided by three 6N136 opto-isolators. Isolated power must be supplied to the converter and the isolated side of the opto-couplers. 74HC595 three-state shift registers are used to construct a 12-bit parallel data output. The timing sequence is identical to the timing shown in Figure 8. Conversion speed is limited by the delay through the opto-isolators. With a 140kHz clock, conversion time is 100µs.

The universal 12-bit parallel data output can also be used without the isolation stage when a parallel interface is required. Clock frequencies up to 2.9MHz are possible without violating the 20ns shift-register setup time. Delay or invert the clock signal to the shift registers beyond 2.9MHz.

Layout, Grounding, Bypassing

For best performance, use printed circuit boards. Wire-wrap boards are not recommended. Board layout should ensure that digital and analog signal lines are separated from each other. Do not run analog and digital (especially clock) lines parallel to one another, or digital lines underneath the ADC package.

Figure 17 shows the recommended system ground connections. A single-point analog ground ("star" ground point) should be established at GND, separate from the logic ground. All other analog grounds should be connected to this ground. The 16-pin versions also have a dedicated DGND pin available. Connect DGND to this star ground point for further noise reduction. No other digital system ground should be connected to this single-point analog ground. The ground return to the power supply for this ground should be low impedance and as short as possible for noise-free operation.

High-frequency noise in the V_{DD} power supply may affect the ADC's high-speed comparator. Bypass this supply to the single-point analog ground with 0.01µF and 4.7µF bypass capacitors. Minimize capacitor lead lengths for best supply-noise rejection. If the +5V power supply is very noisy, a 10Ω resistor can be connected as a lowpass filter to attenuate supply noise (Figure 17).

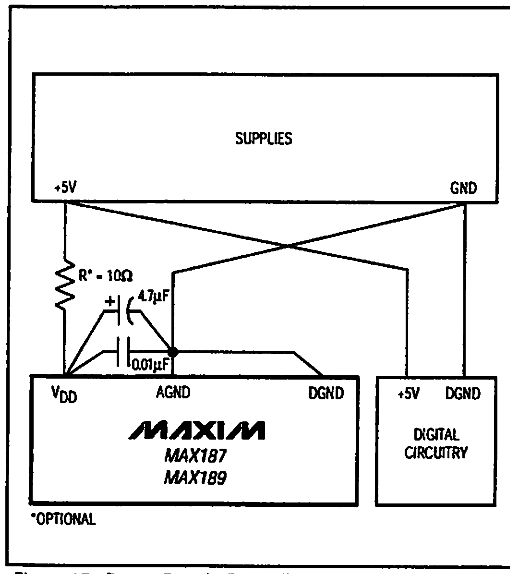


Figure 17. Power-Supply Grounding Condition

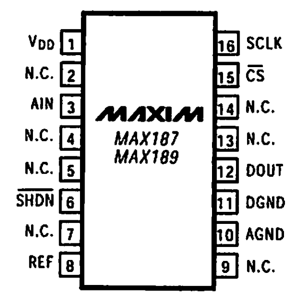
+5V, Low-Power, 12-Bit Serial ADCs

Ordering Information (continued)

PART	TEMP. RANGE	PIN-PACKAGE	ERROR (LSB)
MAX187AEPA	-40°C to +85°C	8 Plastic DIP	±½
MAX187BEPA	-40°C to +85°C	8 Plastic DIP	±1
MAX187CEPA	-40°C to +85°C	8 Plastic DIP	±2
MAX187AEWE	-40°C to +85°C	16 Wide SO	±½
MAX187BEWE	-40°C to +85°C	16 Wide SO	±1
MAX187CEWE	-40°C to +85°C	16 Wide SO	±2
MAX187AMJA	-55°C to +125°C	8 CERDIP**	±½
MAX187BMJA	-55°C to +125°C	8 CERDIP**	±1
MAX189ACPA	0°C to +70°C	8 Plastic DIP	±½
MAX189BCPA	0°C to +70°C	8 Plastic DIP	±1
MAX189CCPA	0°C to +70°C	8 Plastic DIP	±2
MAX189ACWE	0°C to +70°C	16 Wide SO	±½
MAX189BCWE	0°C to +70°C	16 Wide SO	±1
MAX189CCWE	0°C to +70°C	16 Wide SO	±2
MAX189BC/D	0°C to +70°C	Dice*	±1
MAX189AEPA	-40°C to +85°C	8 Plastic DIP	±½
MAX189BEPA	-40°C to +85°C	8 Plastic DIP	±1
MAX189CEPA	-40°C to +85°C	8 Plastic DIP	±2
MAX189AEWE	-40°C to +85°C	16 Wide SO	±½
MAX189BEWE	-40°C to +85°C	16 Wide SO	±1
MAX189CEWE	-40°C to +85°C	16 Wide SO	±2
MAX189AMJA	-55°C to +125°C	8 CERDIP**	±½
MAX189BMJA	-55°C to +125°C	8 CERDIP**	±1

** Dice are specified at T_A = +25°C, DC parameters only.*
***Contact factory for availability and processing to MIL-STD-883.*

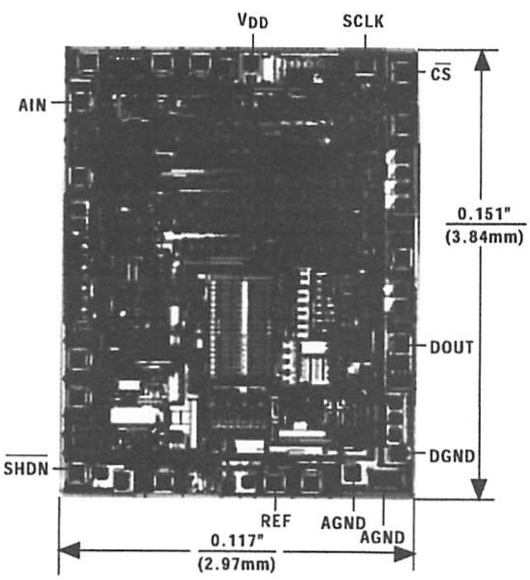
Pin Configurations (continued)



Wide SO

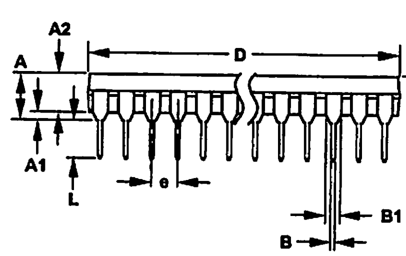
Chip Topography

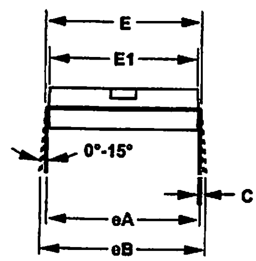
MAX187/MAX189

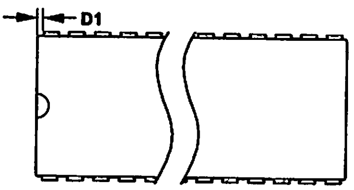


TRANSISTOR COUNT: 2278;
SUBSTRATE CONNECTED TO V_{DD}.

Package Information



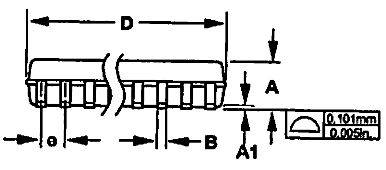


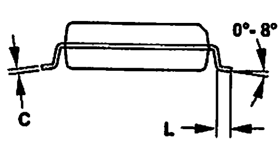


P PACKAGE
PLASTIC
DUAL-IN-LINE

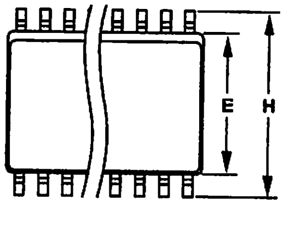
DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	–	0.200	–	5.08
A1	0.015	–	0.38	–
A2	0.125	0.175	3.18	4.45
A3	0.055	0.080	1.40	2.03
B	0.016	0.020	0.41	0.51
B1	0.045	0.065	1.14	1.65
C	0.008	0.012	0.20	0.30
D1	0.050	0.090	1.27	2.29
E	0.600	0.625	15.24	15.88
E1	0.525	0.575	13.34	14.61
e	0.100	–	2.54	–
eA	0.600	–	15.24	–
eB	–	0.700	–	17.78
L	0.120	0.150	3.05	3.81

DIM	PINS	INCHES		MILLIMETERS	
		MIN	MAX	MIN	MAX
D	24	1.230	1.270	31.24	32.26
D	28	1.430	1.470	36.32	37.34
D	40	2.025	2.075	51.44	52.71





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



W PACKAGE
SMALL
OUTLINE

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

21-0042A

Maxim cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim product. No circuit patent licenses are implied. Maxim reserves the right to change the circuitry and specifications without notice at any time.

© 1993 Maxim Integrated Products Printed USA MAXIM is a registered trademark of Maxim Integrated Products.

tures

- npatible with MCS-51™ Products
- Bytes of Reprogrammable Flash Memory
- Endurance: 1,000 Write/Erase Cycles
- V to 6V Operating Range
- ly Static Operation: 0 Hz to 24 MHz
-)-Level Program Memory Lock
- x 8-Bit Internal RAM
- Programmable I/O Lines
-) 16-Bit Timer/Counters
- Interrupt Sources
- grammable Serial UART Channel
- ect LED Drive Outputs
- Chip Analog Comparator
- / Power Idle and Power Down Modes
- wn-Out Detection

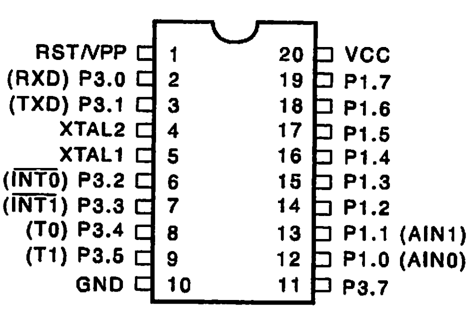
cription

\T89C4051 is a low-voltage, high-performance CMOS 8-bit microcomputer with ytes 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 satile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C4051 is a pow- microcomputer which provides a highly flexible and cost effective solution to embedded control applications.

\T89C4051 provides the following standard features: 4K 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 AT89C4051 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.

Configuration

PDIP/SOIC

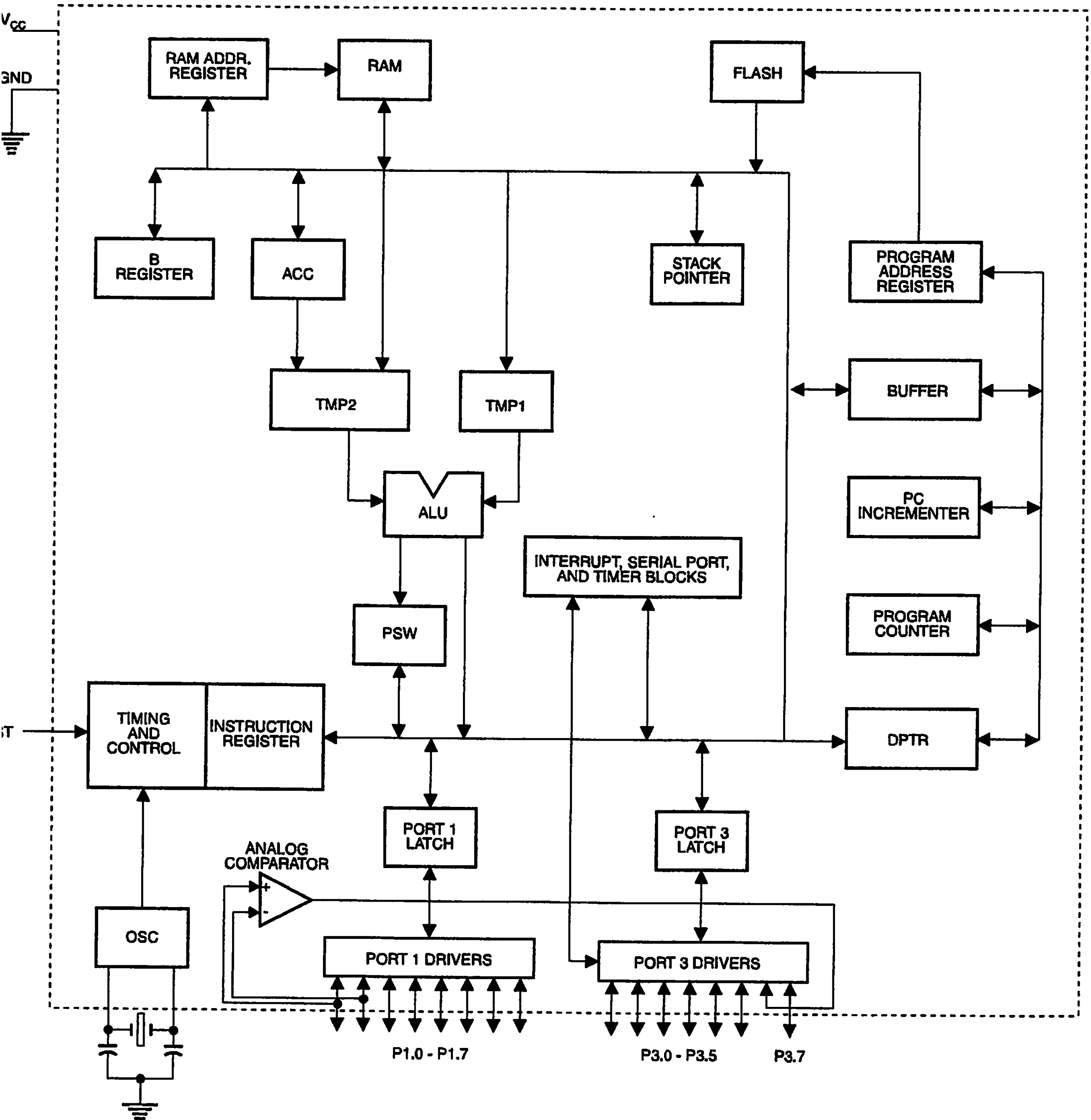


8-Bit Microcontroller with 4K Bytes Flash

AT89C4051 Preliminary

Rev. 1001A–02/98

ck Diagram


VCC
GND
RAM ADDR. REGISTER
RAM
FLASH
B REGISTER
ACC
STACK POINTER
PROGRAM ADDRESS REGISTER
TMP2
TMP1
BUFFER
ALU
PC INCREMENTER
INTERRUPT, SERIAL PORT, AND TIMER BLOCKS
PSW
PROGRAM COUNTER
T
TIMING AND CONTROL
INSTRUCTION REGISTER
DPTR
PORT 1 LATCH
PORT 3 LATCH
ANALOG COMPARATOR
OSC
PORT 1 DRIVERS
PORT 3 DRIVERS
P1.0 - P1.7
P3.0 - P3.5
P3.7

Description

y voltage.

ıd.

I

I is an 8-bit bidirectional I/O port. Port pins P1.2 to ɔrovide internal pullups. P1.0 and P1.1 require exter- ıllups. P1.0 and P1.1 also serve as the positive input) and the negative input (AIN1), respectively, of the ip precision analog comparator. The Port 1 output s can sink 20 mA and can drive LED displays directly. 1s are written to Port 1 pins, they can be used as . When pins P1.2 to P1.7 are used as inputs and are ıally pulled low, they will source current (I_{IL}) because internal pullups.

also receives code data during Flash programming ərification.

pins P3.0 to P3.5, P3.7 are seven bidirectional I/O /ith internal pullups. P3.6 is hard-wired as an input to ıtput of the on-chip comparator and is not accessible eneral purpose I/O pin. The Port 3 output buffers can 0 mA. When 1s are written to Port 3 pins they are I high by the internal pullups and can be used as . As inputs, Port 3 pins that are externally being low will source current (I_{IL}) because of the pullups.

also serves the functions of various special features AT89C4051 as listed below:

Pin	Alternate Functions
	RXD (serial input port)
	TXD (serial output port)
	$\overline{\text{INT0}}$ (external interrupt 0)
	$\overline{\text{INT1}}$ (external interrupt 1)
	T0 (timer 0 external input)
	T1 (timer 1 external input)

also receives some control signals for Flash pro- ıing and verification.

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

nachine cycle takes 12 oscillator or clock cycles.

o the inverting oscillator amplifier and input to the ıl clock operating circuit.

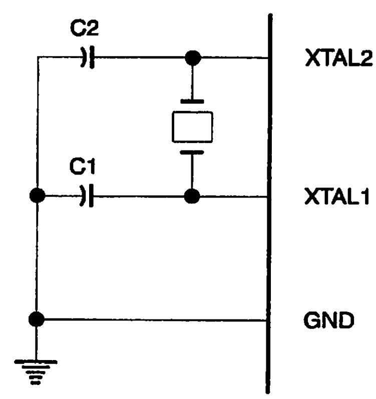
XTAL2

Output from the inverting oscillator amplifier.

Oscillator Characteristics

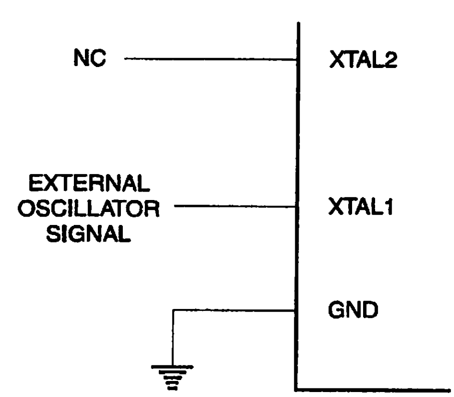
XTAL1 and XTAL2 are the input and output, respectively, of an inverting amplifier which can be configured for use as an on-chip oscillator, as shown in Figure 1. Either a quartz crystal or ceramic resonator may be used. To drive the device from an external clock source, XTAL2 should be left unconnected while XTAL1 is driven as shown in Figure 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 1. Oscillator Connections



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

Figure 2. External Clock Drive Configuration



cial Function Registers

ɔ of the on-chip memory area called the Special Func- legister (SFR) space is shown in the table below.

that not all of the addresses are occupied, and unoc- d addresses may not be implemented on the chip. accesses to these addresses will in general return m data, and write accesses will have an indetermi- 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.

1. AT89C4051 SFR Map and Reset Values

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

ıtrictions on Certain Instructions

\T89C4051 is an economical and cost-effective mem- ' Atmel's growing family of microcontrollers. It contains /tes of flash program memory. It is fully compatible :he MCS-51 architecture, and can be programmed the MCS-51 instruction set. However, there are a few derations one must keep in mind when utilizing certain ctions to program this device.

ə instructions related to jumping or branching should əstricted such that the destination address falls within ıysical program memory space of the device, which is ' the AT89C4051. This should be the responsibility of oftware programmer. For example, LJMP 0FE0H be a valid instruction for the AT89C4051 (with 4K of ɔry), whereas LJMP 1000H would not.

ınching Instructions:

L, LJMP, ACALL, AJMP, SJMP, JMP @A+DPTR

ə unconditional branching instructions will execute :tly as long as the programmer keeps in mind that the ıation branching address must fall within the physical laries of the program memory size (locations 00H to for the 89C4051). Violating the physical space limits ause unknown program behavior.

[...], DJNZ [...], JB, JNB, JC, JNC, JBC, JZ, JNZ With conditional branching instructions the same rule ı applies. Again, violating the memory boundaries ause erratic execution.

ɔplications involving interrupts the normal interrupt e routine address locations of the 80C51 family archi- ə have been preserved.

VX-related Instructions, Data Memory:

T89C4051 contains 128 bytes of internal data mem- hus, in the AT89C4051 the stack depth is limited to ytes, the amount of available RAM. External DATA ry access is not supported in this device, nor is exter- ҁOGRAM memory execution. Therefore, no MOVX ɪtructions should be included in the program.

:al 80C51 assembler will still assemble instructions, f they are written in violation of the restrictions men- above. It is the responsibility of the controller user to the physical features and limitations of the device used and adjust the instructions used correspond-

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 below:

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.

P1.0 and P1.1 should be set to '0' if no external pullups are used, or set to '1' if external pullups 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.

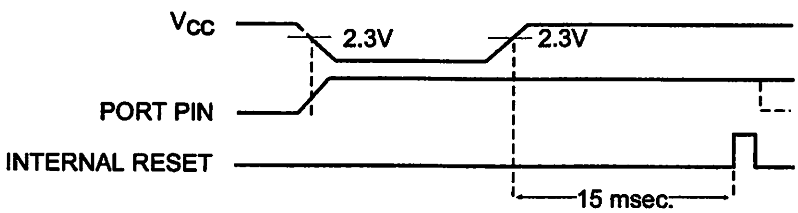
Power Down Mode

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.

P1.0 and P1.1 should be set to '0' if no external pullups are used, or set to '1' if external pullups are used.

wn-Out Detection

ι V_{CC} drops below the detection threshold, all port except P1.0 and P1.1) are weakly pulled high. When V_{CC} goes back up again, an internal Reset is automatically generated after a delay of typically 15 msec. The nominal brown-out detection threshold is 2.3V ± 10%.



ɟramming The Flash

ιT89C4051 is shipped with the 4K bytes of on-chip ›M code memory array in the erased state (i.e., con- = FFH) and ready to be programmed. The code mem- ray is programmed one byte at a time. *Once the array ɟrammed, to re-program any non-blank byte, the memory array needs to be erased electrically.*

ıal Address Counter: The AT89C4051 contains an al PEROM address counter which is always reset to on the rising edge of RST and is advanced by apply- ›ositive going pulse to pin XTAL1.

ramming Algorithm: To program the AT89C4051, lowing sequence is recommended.

wer-up sequence:
ply power between V_{CC} and GND pins
t RST and XTAL1 to GND
t pin RST to 'H'
t pin P3.2 to 'H'

ply the appropriate combination of 'H' or 'L' logic els to pins P3.3, P3.4, P3.5, P3.7 to select one of the ɟramming operations shown in the PEROM Pro- ımming Modes table.

ɟram and Verify the Array:

ɔly data for Code byte at location 000H to P1.0 to .7.

ise RST to 12V to enable programming.

se P3.2 once to program a byte in the PEROM array he lock bits. The byte-write cycle is self-timed and ically takes 1.2 ms.

verify the programmed data, lower RST from 12V to ic 'H' level and set pins P3.3 to P3.7 to the appropriate ɘls. Output data can be read at the port P1 pins.

program a byte at the next address location, pulse ՎL1 pin once to advance the internal address counter. ›ly new data to the port P1 pins.

›eat steps 5 through 8, changing data and advancing address counter for the entire 4K bytes array or until end of the object file is reached.

10. Power-off sequence:
    set XTAL1 to 'L'
    set RST to 'L'
    Turn V_{CC} power off

Data Polling: The AT89C4051 features 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. Data Polling may begin any time after a write cycle has been initiated.

Ready/Busy: The Progress of byte programming can also be monitored by the RDY/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 (4K 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.

ing the Signature Bytes: The signature bytes are by the same procedure as a normal verification of ons 000H, 001H, and 002H, except that P3.5 and nust be pulled to a logic low. The values returned are lows.

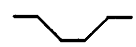
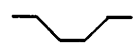
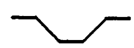
)00H) = 1EH indicates manufactured by Atmel
)01H) = 41H indicates 89C4051

Programming Interface

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

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

ᵢh Programming Modes

e		RST/VPP	P3.2/$\overline{PROG}$	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 XTAL 1 pin.
2. Chip Erase requires a 10-ms $\overline{PROG}$ pulse.
3. P3.1 is pulled Low during programming to indicate RDY/$\overline{BSY}$.

e 3. Programming the Flash Memory

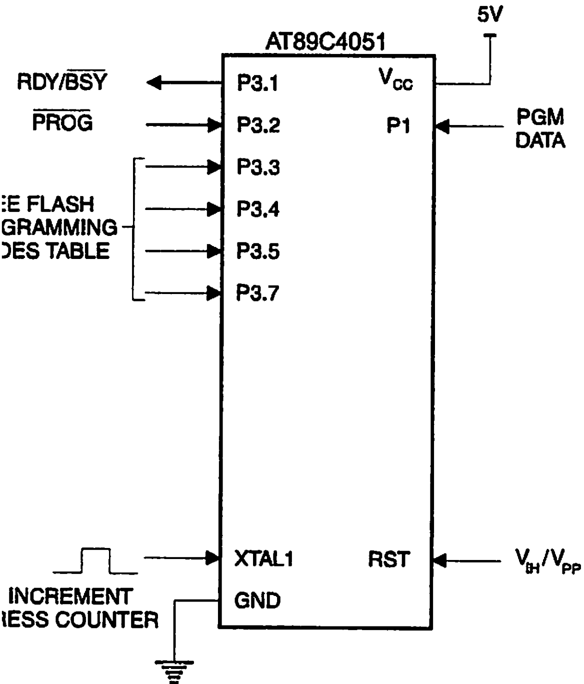
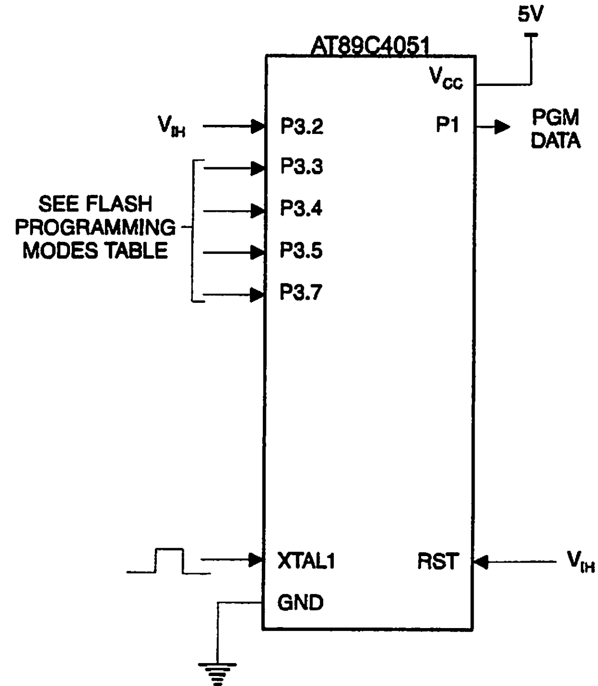


Figure 4. Verifying the Flash Memory



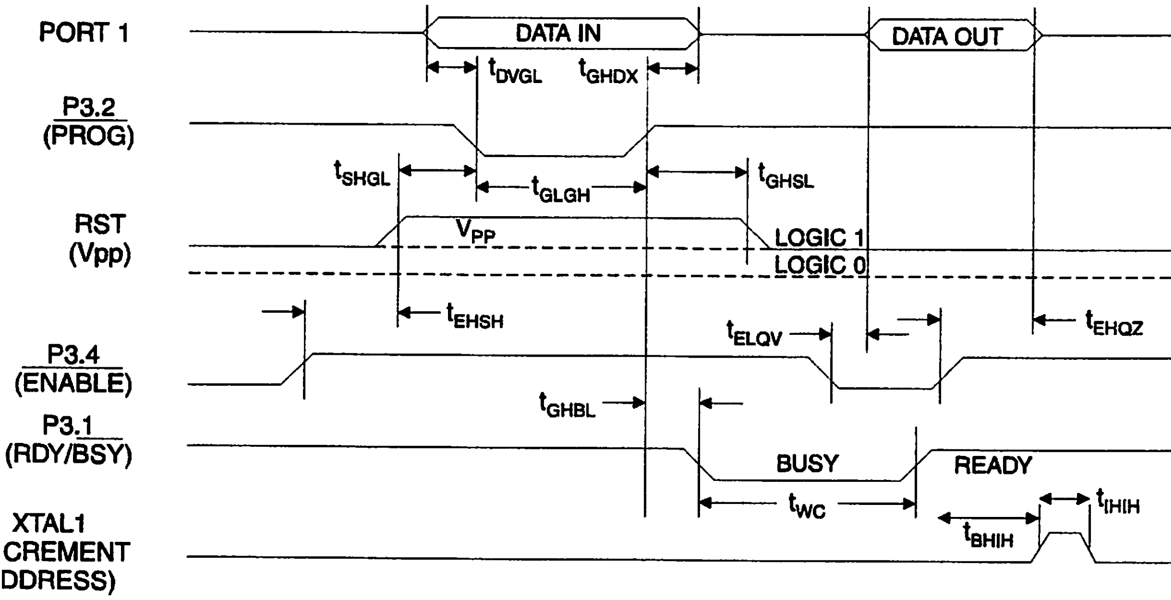
h Programming and Verification Characteristics

°C to 70°C, $V_{CC} = 5.0 \pm 10\%$

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

1. Only used in 12-volt programming mode.

ɜh Programming and Verification Waveforms



olute Maximum Ratings*

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

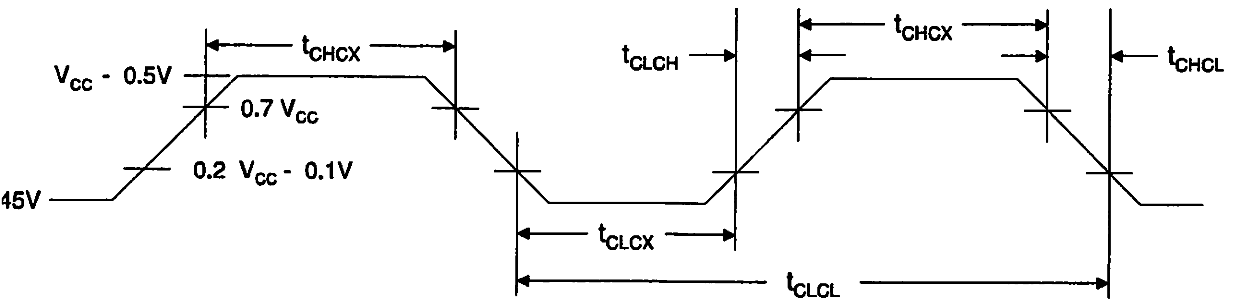
Characteristics

-40°C to 85°C, V_{CC} = 3.0V to 6.0V (unless otherwise noted)

bol	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
r	Reset Pulldown 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.

ernal Clock Drive Waveforms



ernal Clock Drive

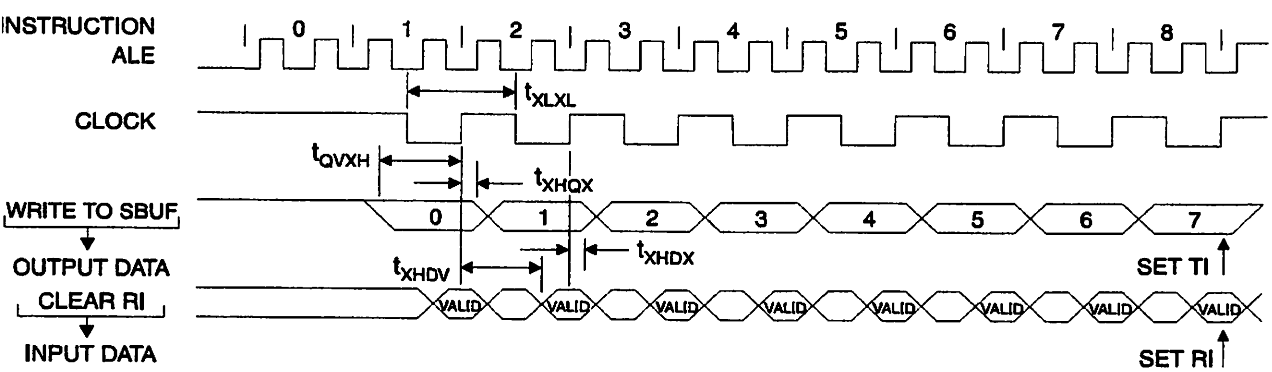
bol	Parameter	V_{CC} = 3.0V to 6.0V		V_{CC} = 4.0V to 6.0V		Units
		Min	Max	Min	Max	
CL	Oscillator Frequency	0	12	0	24	MHz
	Clock Period	83.3		41.6		ns
(	High Time	30		15		ns
:	Low Time	30		15		ns
I	Rise Time		20		20	ns
.	Fall Time		20		20	ns

al Port Timing: Shift Register Mode Test Conditions

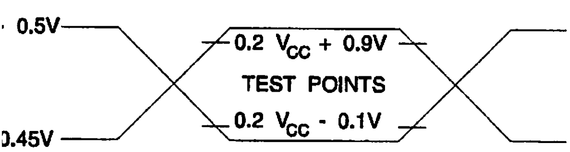
= 5.0V ± 20%; Load Capacitance = 80 pF)

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

t Register Mode Timing Waveforms

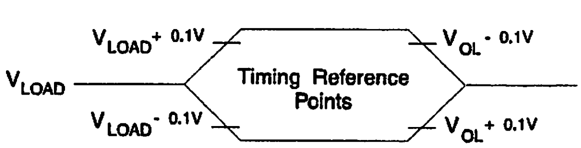


'esting Input/Output Waveforms(1)

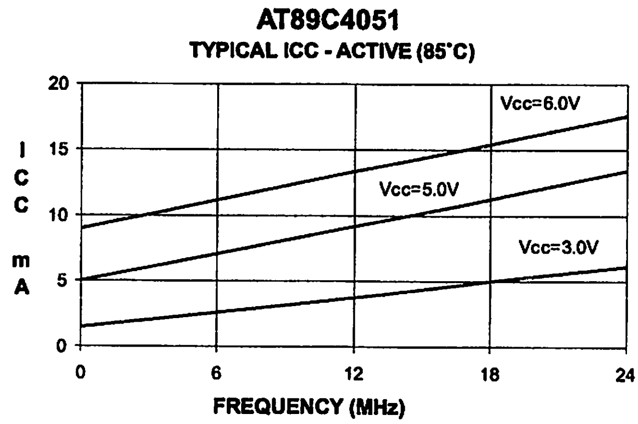


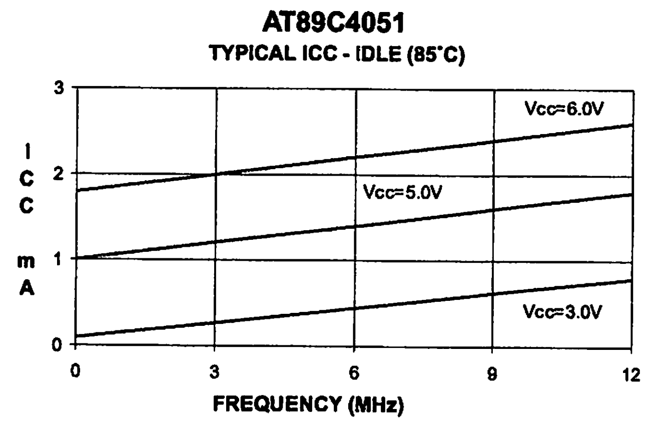
1. AC Inputs during testing are driven at V_{CC} - 0.5V for a logic 1 and 0.45V for a logic 0. Timing measurements are made at V_{IH} min. for a logic 1 and V_{IL} max. for a logic 0.

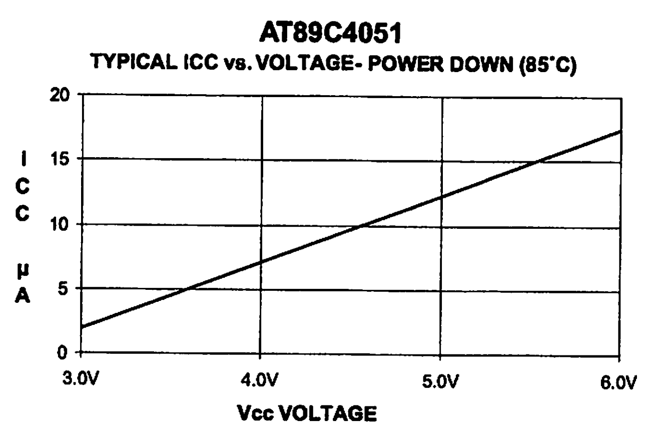
Float Waveforms(1)



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







1. XTAL1 tied to GND for I_{CC} (power down)
2. P.1.0 and P1.1 = V_{CC} or GND
3. Lock bits programmed

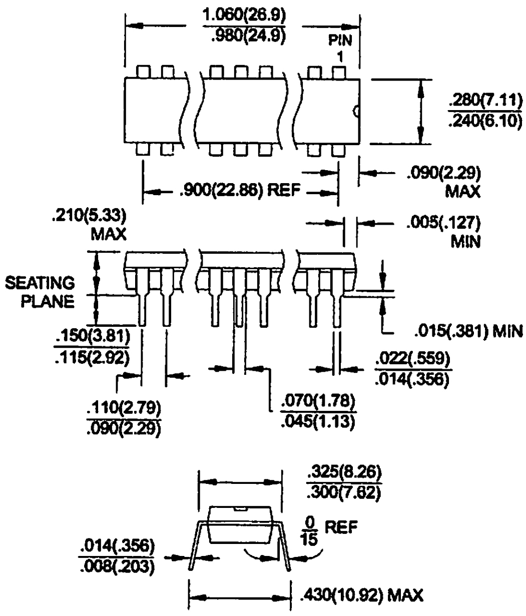
ering Information

eed Hz)	Power Supply	Ordering Code	Package	Operation Range
l2	3.0V to 6.0V	AT89C4051-12PC AT89C4051-12SC	20P3 20S	Commercial (0°C to 70°C)
		AT89C4051-12PI AT89C4051-12SI	20P3 20S	Industrial (-40°C to 85°C)
		AT89C4051-12PA AT89C4051-12SA	20P3 20S	Automotive (-40°C to 105°C)
:4	4.0V to 6.0V	AT89C4051-24PC AT89C4051-24SC	20P3 20S	Commercial (0°C to 70°C)
		AT89C4051-24PI AT89C4051-24SI	20P3 20S	Industrial (-40°C to 85°C)

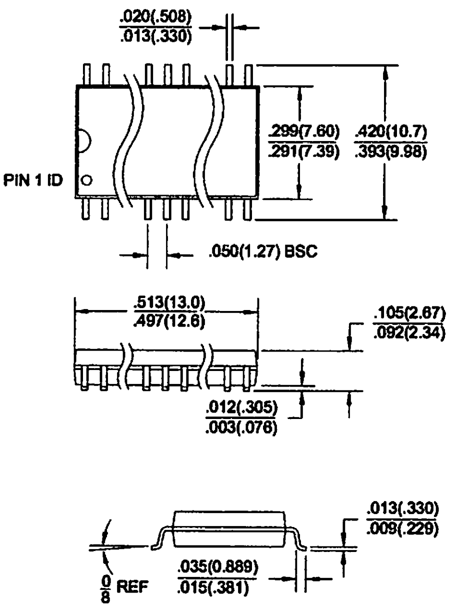
	Package Type
	20 Lead, 0.300" Wide, Plastic Dual In-line Package (PDIP)
	20 Lead, 0.300" Wide, Plastic Gull Wing Small Outline (SOIC)

kaging Information

0P3, 20-Lead, 0.300" Wide, Plastic Dual Inline ackage (PDIP)
imensions in Inches and (Millimeters)
:DEC STANDARD MS-001 AD



20S, 20-Lead, 0.300" Wide, Plastic Gull Wing Small Outline (SOIC)
Dimensions in Inches and (Millimeters)



Freescale Semiconductor, Inc.
MOTOROLA
Semiconductor Application Note
Order by AN1921/D
(Motorola Order Number)
Rev. 1.0, 04/2001
ARCHIVED BY FREESCALE SEMICONDUCTOR, INC. 2005

General DSP568xx Interface Examples using the Embedded SDK

Joseph R. Pasek

Contents

1. Introduction

The purpose of this application note is to describe the process of interfacing different devices to the Motorola DSP56824 processor using Motorola's Embedded SDK and Metrowerks' C compiler. This is in addition to the devices available on the DSP's EVM card described in the associated SDK documentation. Examples include interfacing to LCDs, Keypads, ADCs and pressure sensors.

It is assumed that the reader has some familiarity with both the Metrowerks' IDE and Motorola's Embedded Software Development Kit (SDK).

2. LCD and Keypad User Interface Description

As the DSP568xx family assumes more microcontroller roles, it must be capable of working in the embedded environment, on occasion requiring some form of user interface. This user interface is usually characterized by some combination of LCD, LEDs, buttons, and keypad. The combination used in this note is the LCD and 4x4 keypad.

The LCD used here is NetMedia's Serial LCD+, which is a 4x20 LCD serial display. It is an off-the-shelf unit (see **Figure 1**) with several interesting features. In addition to the LCD display, the Serial LCD+ provides a keypad interface, an eight channel 10-bit A/D converter, an EEPROM and RS-232 interface.

Interface Examples Using the Embedded SDK

© Motorola, Inc., 2001

MOTOROLA

For More Information On This Product,
Go to: www.freescale.com

Freescale Semiconductor, Inc.
ARCHIVED BY FREESCALE SEMICONDUCTOR, INC. 2005

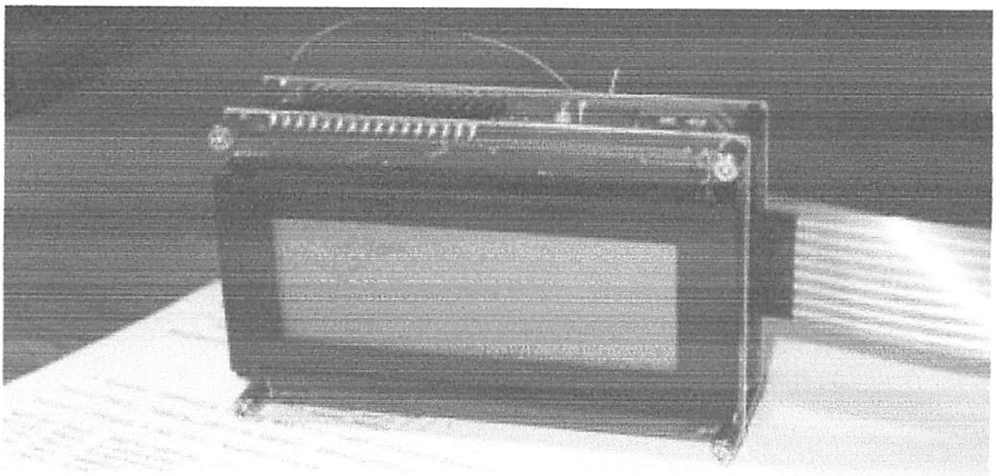


Figure 1. NetMedia's 4x20 LCD Device with RS-232 Serial and Keypad Support

The keypad is a membrane-encased, low-cost touch pad and is shown in Figure 2.

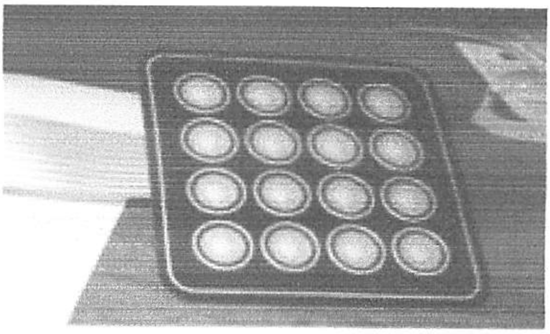


Figure 2. Low Cost Membrane Covered 4x4 Keypad that Interfaces to LCD+

All examples described here use the Motorola DSP56824 EVM board, illustrated in Figure 3. The board provides a developer with the means of both learning to know the processor featured and the capability to prototype designs. The board provides both PC parallel port and JTAG interfaces for software development.

For More Information On This Product,
Go to: www.freescale.com

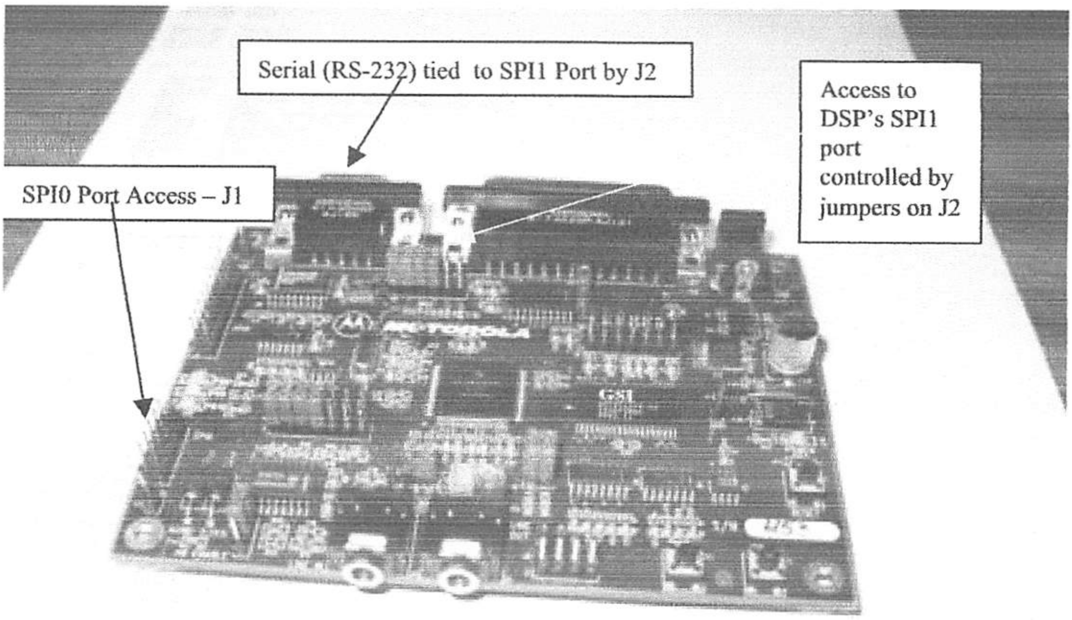


Figure 3. The DSP56824EVM board used in this note, with annotations added

The DSP56824 provides a number of interfaces: Port A provides for access to external memory located on the EVM. It also provides another interface, referred to as Port B, which has 16 general purpose I/O lines. Each of the lines are user-controlled and can be directed as either input or output. The lower eight lines can generate interrupts based on the rising or falling edge of a signal. A third interface, referred to as Port C, can be either GPIO lines or can be allocated to timers, two SPI (Serial Peripheral Interfaces) ports and an SSI (Synchronous Serial Interface) port.

The SPI port is an independent, serial communication subsystem that allows the DSP56824 to communicate synchronously with peripheral devices such as LCD drivers, A/D and D/A subsystems, and microprocessors. The SPI can be configured as either a master or a slave device with high data rates. In master mode, a transfer is initiated when data is written to the SPI data register (SPDR). In slave mode, a transfer is initiated by the reception of a clock signal.

Clock control logic allows a selection of clock polarity and a choice of two fundamentally different clocking protocols to accommodate most available synchronous serial peripheral devices. In some cases, the phase and polarity are changed between transfers to allow a master device to communicate with peripheral slaves having different requirements. When the SPI is configured as a master, software selects one of eight different bit rates for the clock.

On the DSP56824EVM board, the chip's SPI1 port is optionally interfaced by means of the jumpers placed at the board's J2 header to MAXIM's MAX3100 UART. In this case, the MAX3100 provides an interface between the SPI and RS-232 interfaces.

The EVM provides a 9-pin Sub-D connector to attach a serial cable. Direct access to the SPI1 is possible by removing the jumpers at J2. **Table 1** describes the pins found at J2.

**For More Information On This Product,
Go to: www.freescale.com**

Table 1: Signal description at J2 header between SPI1 and MAX3100 Uart

J2			
Pin #	**DSP Signal**	**Pin #**	**UART Signal**
1	MISO1/PC4	2	DOUT
3	MOSI1/PC5	4	DIN
5	SCK1/PC6	6	SCLK
7	SS1/PC7	8	CS
9	IRQA	10	IRQB
11	GND	12	GND

The Metrowerks' C compiler/IDE for the Motorola DSP568xx is used to produce the example code in C which demonstrates usage of the LCD/keypad. This code is shown in **Code Example 1** and uses Motorola's Embedded SDK serial and EVM board support libraries. The SDK's serial library accommodates the MAX3100 UART chip that is interfaced to the EVM board's DSP56824's SPI1 port. Additional support for the EVM board is provided by the SDK's bsp library; for more details, see the Embedded SDK documentation. The support to these libraries are provided by the included *serial.h* and *bsp.h* header files.

Code Example 1. *LCDsimple.c,* code used to demo DSP control and use of LCD/keypad

```
// LCDsimple.c program tests the interface to a serial port LCD and keypad

#include "port.h"
#include "io.h"
#include "bsp.h"

#include "fcntl.h"
#include "serial.h"
#include "stdio.h"
#include "string.h"


int main()
{
   UWord16     I;
   int         Uart;
   UWord16     NewUartState;
   char        astring[]={" DSP-LCD/Keypad test\n"};
   int         sum;
   char        input, inputarray[8];
   UWord16     NewScr[2]= {12,0};
   UWord16     BackLightOn[2] = {14,0};
   UWord16     LightLevel[2] = {2,70};
   UWord16     DispContrast[2] = {3,100};
   UWord16     DispKeypad[2] = {24,1};
   char        bstring[40];
   char        LF[]={10,0}, CR[]={'E'};
   UWord16     ii;
```

```
UWord16    BS[]={8,0};

/* Open Serial Device */

Uart = open(BSP_DEVICE_NAME_SERIAL_0, 0);

/* Define some of the attributes of the MAX3100 UART - note BAUD
   rate is set to 9600 */

NewUartState =  MAX3100_FIFO_DISABLE | \
                   MAX3100_INT_ENABLE_DATA | \
                   MAX3100_IR_DISABLE | \
                   MAX3100_STOPBIT_1 | \
                   MAX3100_PARITY_NONE | \
                   MAX3100_WORD_8BIT | \
                   MAX3100_BAUD_9600;

/* Modify DSP56824 EVM's MAX3100 UART characteristics */

ioctl(Uart, SERIAL_DEVICE_RESET, &NewUartState);
```

Code Example 1 continues below.

As shown in the code *LCDsimple.c,* processing starts by a call to *open(),* which allocates a handle (UART) to the application for the RS-232 serial port to which the SPI1 is interfaced. The control variable, NewUartState, is initialized to define the attributes of the interface to the MAX3100 UART chip and is directed to the MAX3100 by a call using the function *ioctl().*

Code Example 1, continued:

```
printf("State = %x \n", NewUartState );

   write( Uart, BackLightOn, 2);    /* Turn-on LCD's Backlight */
   write( Uart, LightLevel, 2 );    /* Adjust LCD's Backlight level */
   write( Uart, DispContrast, 2);   /* Adjust LCD's Display contrast */
   write( Uart, NewScr, 1 );        /* Wipe clean LCD's Display */
   write( Uart, DispKeypad, 2 );    /* Setup keypad - beep with each key
press */

   sum = write (Uart, astring, 16);
   printf(" sum = %d \n", sum );

   sum = read (Uart, &input, 1);
   printf(" input = %d  keypad = %d \n", sum, input );

   sum = 0;

   for ( I=0; I < 10; I++ )
   {
        write( Uart, NewScr, 1 );
        sprintf(astring, " %d ", I );
        write (Uart, astring, strlen(astring));

   }

   strcpy( bstring, "Keypad: hit any key.");
   strcat( bstring, LF );
   write( Uart, bstring, strlen(bstring));
   sum = read (Uart, &input, 1);
```

```
            strcpy( bstring, "Input at keypad ('0000 (CR)' to exit) ");
            strcat( bstring, LF );
            write( Uart, bstring , strlen(bstring));

            strcpy( bstring, "Hit key to start");
            strcat( bstring, LF );
            write( Uart, bstring , strlen(bstring));
            write( Uart, NewScr, 1 );

            /* The following loop polls keypad input */

            ii = 0;
            while ( true )
            {
               read( Uart, &inputarray[ii], 1);
               if ( inputarray[ii] == CR[0]  )
               {
                  sprintf(bstring,"\n");
                  write ( Uart, bstring, strlen(bstring));
                  inputarray[ii] = 0;
                  sprintf(bstring, "Input - %s ", inputarray );
                  strcat( bstring, LF );
                  printf(" %s", bstring );
                  ii = 0;
               }
                   else
               {
                  write( Uart, &inputarray[ii], 1);
                 ii++;
               }
               if ( strcmp(inputarray,"0000") == 0 ) break;
            }

            write( Uart, NewScr, 1 );
            strcpy( bstring, " Done! ");
            write(Uart, bstring, strlen(bstring) );
        }
```

Next, a series of calls using *write()* directs commands to the LCD. The commands issued are to:

- Turn on the LCD's backlight
- Adjust the light level
- Adjust the display contrast
- Clear the display area
- Set up the keypad

In this example, selected attributes cause the keypad to both beep with each keypad entry and immediately display (Echos) the entry on the LCD. More detailed information about the LCD used here is found in **Appendix A.**

A call to *write()* next directs the string that announces the test to the LCD. The number of characters passed (sum) is passed to *printf()* and displayed in the IDE's text window.

A call to *read()* yields whatever key was struck on the keypad. The ASCII code of the keypad character struck is passed to *printf()*.

The keypad's key assignments are shown in **Figure 4.**

Freescale Semiconductor, Inc.
ARCHIVED BY FREESCALE SEMICONDUCTOR, INC. 2005

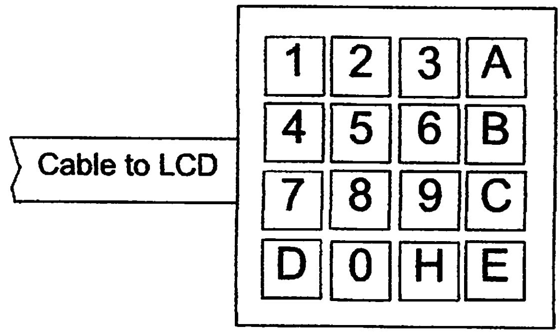


Figure 4. Keypad's Key Assignment Values

A polling loop is executed which takes input from the keypad and displays the value passed to the program in the *printf()* text window. When the user enters a string and presses the E [Enter] key, the string is displayed in the IDE's text window. After entering values, the user exits the loop by entering "0000", followed by [Enter]. The display will clear and the string "Done!" will appear.

3. Interfacing to Serial Devices Using the SPI Port

The previous section described the LCD/keypad interface and operation from the SPI1 port via the MAX3100 UART. The connection to the UART and, in turn, the EVM's RS-232 serial port was established, with the default jumpers left in place at the EVM's J2 header. The DSP's SPI0 is interfaced to a serial EEPROM via the jumpers left in place on the J1 header. Removing the jumpers and connecting wires to pins 1,3,5, and 7 permits the user to directly interface another SPI device to the DSP; see Table 2.

Table 2: Signal Description at J1 Header between SPI0 and EEPROM

J1			
Pin #	**DSP Signal**	**Pin #**	**EEPROM Signal**
1	MISO1/PC0	2	SD1
3	MOSI1/PC1	4	SD0
5	SCK1/PC2	6	SCK
7	SS1/PC3	8	CS
9	GND	10	GND

**For More Information On This Product,
Go to: www.freescale.com**

ARCHIVED BY FREESCALE SEMICONDUCTOR, INC. 2005

Table 3: Connections between SPI0 (J1) EVM Header and TLC2543 Chip

J1 Header Signal	TLC2543 lines
MISO1/PC0	DATAOUT (16)
MOSI1/PC1	DATA IN (17)
SCK1/PC2	I/O CLOCK (18)
SS1/PC3	CS (15)

The TI TLC2543 SPI device is interfaced to the DSP's SPI0 port by means of the EVM's J1 header pins. The TLC2543 is a MUXed 11-channel, 12-bit analog-to-digital converter. Control of the TLC2543 chip is performed when the application code sends a command word to it. A description of the TLC2543 command word appears in Appendix 2.

The C code is written using Motorola's Embedded SDK's SPI library and the BSP library. Using a prototype board (see **Figure 5**) to support the TLC2543, all required connections are made to provide power, reference voltages and ground to the ADC. See **Figure 6** for a schematic. Jumper wires are placed between J1's 1,3,5, and 7 pins and the CLKIN, DATAIN, DATAOUT, and CS on the TLC2543 (see **Figure 6** and **Table 3**).

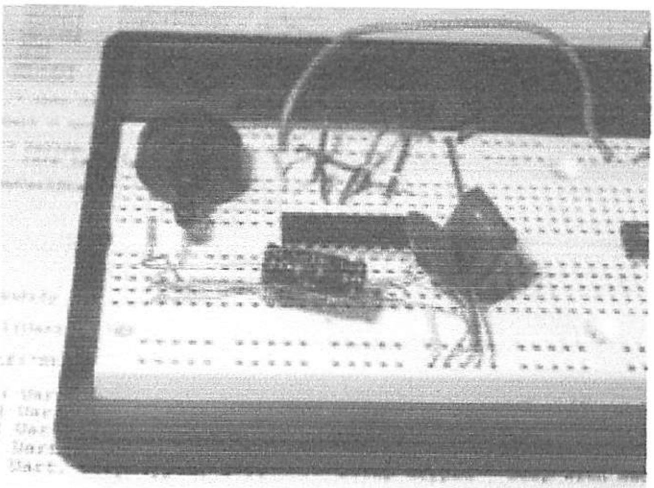


Figure 5. View of Prototype Board Showing the Motorola Absolute Barometric Sensor and TLC5423 ADC

The C code procedure (*InitTLC2453.c*) is used to establish and test the interface between the SPI0 and the ADC. **Code Example 2**, *InitTLC2543.c,* shows operation of TLC2543 from SPI0.

For More Information On This Product,
Go to: www.freescale.com

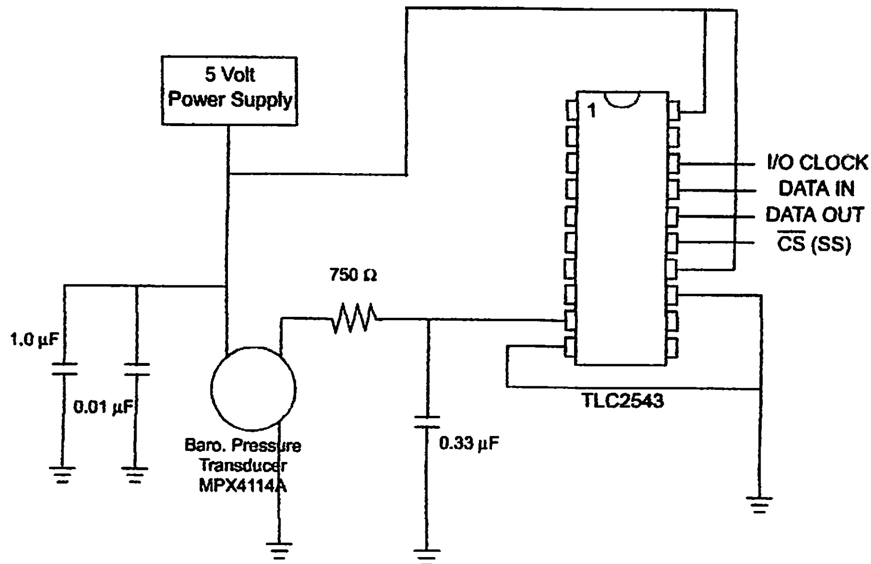


Figure 6. Integrated Pressure and TLC2543 Connections on Prototype Board

Code Example 2. InitTLC2543.c

```
/*  InitTLC2543.c - Procedure used to test interface to TLC2543 -
    12-bit analog-to-digital converter with serial control and 11 analog
    inputs. The DSP56824's SPI0 port is employed. The software is
    developed for the DSP56824 EVM environment. Jan 26, 2001*/

#include "io.h"
#include "fcntl.h"
#include "bsp.h"
#include "spi.h"
#include "stdio.h"
#include "string.h"
#include "port.h"
#include "timer.h"
#include "types.h"
#include "math.h"


void main(void)
{

    spi_sParams     SpiParams;

    int             SPIMaster;

    struct timespec OneMillisecond = {0,1000000};

    UWord16     ADcmd = 0x8c00;
    static UWord16     Datain, DataStore[70];
    Word16     i, ii;
    static Word32    sum, mean;
    static Word16     Vcount;
```


For More Information On This Product,
Go to: www.freescale.com

```
static Word16     BaroPress;

SpiParams.bSetAsMaster = 1;    /* SPI0 is set as master */

SPIMaster = open( BSP_DEVICE_NAME_SPI_0, 0, &SpiParams );

/* Set bit clock rate so sampling rate */
ioctl( SPIMaster, SPI_PHI_DIVIDER_32, NULL );

/* Set Data format for 16 bit */
ioctl( SPIMaster, SPI_DATAFORMAT_RAW, NULL );

/* SS can be left low between successive SPI bytes */
ioctl( SPIMaster, SPI_CLK_PHASE_SS_CLEAR, NULL);

/* TLC2543 is commanded to use analog input 0,
   Output data length = 16 bits,
   Output data format = MSB first, unsigned integer */

for( ; ; )
{
  sum = 0;
   for ( i = 0; i < 64; i++ )
   {
    /* send command word to TLC2543  */
    write(SPIMaster, &ADcmd, sizeof(UWord16));

    /* read input from TLC2543  */
    read(SPIMaster, (UWord16 *)&Datain, sizeof(UWord16));

    Datain = Datain >> 4;

    /* process sleeps for Tenth of sec */
    nanosleep( &OneMillisecond, NULL );

    DataStore[i] = Datain;
    sum += Datain;

}
  mean = (sum >> 6);
  Vcount = mean;

/*  The coded equation is an adaption of an
    equation taken from the Integrated Pressure sensor
    Tech Note. The equation relates the voltage out
    (Vout) with the pressure (P) and (Voltage supplied) Vs.

      Vout = Vs * (0.009*P - 0.095)

        where P is pressure in kPa

    Rewriting the equation for P yields,

      P = (Vout/Vs + 0.095)/0.009

 In this set-up for the TLC2543 Vcc = REF+ = Vs. This
 implies that max. voltage is V - ADC no. of bit = 2^12
 = 4096. The ADC delivers a count (Vcount) between 0 and 4096.
 This allows the above expression to be written as
```

```
            P = 0.0271*Vcount + 10.555 (kPa)

          Since the sensors measures absolute pressure the units can
          be converted to more recognizable units of millibars. The
          conversion factors is 1 millibar = 100 Pa applied to the
          last equation yields

            P = 0.271*Vcount + 105.55

          which is source of coded equation. The four shifts
          in the coded form of equation produce an approximation
          of 0.2715 */

        BaroPress = (Vcount >> 2) + (Vcount >> 6) + (Vcount >> 8)
                        + (Vcount >> 9 ) + 105;
        }


        close(SPIMaster);
}
```

When compiled and executed on the target EVM, the code in **Code Example 2** shows that data flows bi-directionally between the application code and the ADC chip, using the DSP's SPI0 port.

The Embedded SDK header files *spi.h* and *bsp.h* appear in procedure *InitTLC2543.c* and provide the data structures and other defines required for this code to interface to the processor in general and to the SPI port in particular. The data structure `SpiParams` is defined from the data type `spi_sParams`. The variable SPIMaster is used to store the SPI ports handle. In this example, the variable ADcmd is both defined and set to a value 0x8c00. ADcmd is the command word sent to the TLC2543 ADC chips data input. In the upper 8-bit portion of the word, it specifies use of the eighth analog input port on the ADC; a 16-bit word format, MSB first; and unsigned integer format for output.

To indicate that the DSP's SPI0 port will be the master device, a field (.bSetAsMaster) in the data structure `SpiParams` is set. A call is made to *open()* to allocate the SPI0 port, a handle to the port is returned in the variable SPIMaster. Several calls to the procedure *ioctl()* are used to further refine the SPI0 port's attributes. The first call sets the bit block rate from the PHI clock by providing a divisor term, SPI_PHI_DIVIDER_32. This controls the clock rate of the timing pulses by dividing the clock rate by 32. Next, the command word SPI_DATAFORMAT_RAW specifies that data transfers between the SPI and the slave device will be 16 bits long. The next call to *ioctl()* specifies that the generated SS signal directed to the chip's $\overline{CS}$ port be left low between the word's byte components.

All the SPI port's attributes have been set. An infinite loop now follows to exercise the link between the SPI0 and the TLC2543 ADC. To average out the possible errors in the reading of the integrated pressure sensor, MPX4115A, 64 measurements of the ADC are done, one millisecond apart. For a description of the MPX4115A integrated pressure sensor, see **Appendix E.**

The loop that performs the actual measurement consists of a call to *write()* to send the variable ADcmd to the TLC2543. A call to *read()* follows to read the previous sampling period's count from the sensor. The result is placed in Datain. The data (Datain) read must be shifted to the right by 4 bits, since it is a 12-bit result placed in a 16-bit word. A call to *nanosleep()* puts the process to sleep for one millisecond.

For More Information On This Product,
Go to: www.freescale.com

Using the IDE's debug capability, the last 64 readings are stored in the array DataStore[] for user review. The current sample is also accumulated in the variable sum to perform a batch averaging when 64 recent samples have been read.

Outside the 64 sample loop, the mean is determined and placed in the variable Vcount. Next, the current atmospheric or barometric pressure (BaroPress) is computed.

The coded equation is an adaptation of an equation taken from the MPX4115A Integrated Pressure Sensor Tech Note. The equation relates the voltage out (Vout) with the pressure (P) in kiloPascals and (Voltage supplied) Vs.

Vout = Vs * (0.009*P - 0.095)

where P is pressure in kPa

Rewriting the equation for P yields,

P = (Vout/Vs + 0.095)/0.009

In this set-up for the TLC2543, Vcc = REF+ = Vs. This implies that maximum voltage is V ~ ADC number of bits = 2^12 = 4096. The ADC delivers a count (Vcount) between 0 and 4096. This allows the above expression to be written as:

P = 0.0271*Vcount + 10.555   (kPa)

Since the sensor measures absolute pressure, the units can be converted to the more recognizable units of millibars. The conversion factor is 1 millibar = 100 kPa. When applied to the last equation, it yields:

P = 0.271*Vcount + 105.55

which is the source of the expression implemented in the code. The coded expression employs 4 shifts and 4 adds to yield the pressure in millibars.

There are several ways to visualize what is happening. The first is to halt (not kill) the process from the Metrowerks' IDE debug window. Once the process is halted, the contents of the DataStore[] array can be viewed by selecting the View menu and selecting the Global Variables Window.

After the Global Variables Window appears, select *Inttlc2543* from the list on the left. In the right half of the window, select the plus sign to the left of the listed variable name, DataStore, and the current contents of the array will appear. The range of values to be found there will fall between 3000 and 4000, depending on the user's altitude above sea level and weather conditions. If the DataStore[] does not contain a number in this range, check the connection between the EVM's SPI0 header and the ADC with the schematic in **Figure 6** and connection references in **Table 3**. The computed atmospheric pressure (BaroPressure) is also found in the right side of the Global Variables Window. The expected range should be between 800 and 1100.

Another means of checking the proper operation of this test requires access to an oscilloscope and leaving the test procedure executing on the EVM board. Placing a probe on the I/O clock line and triggering on the rising edge of the I/O CLOCK line pulse, should yield a signal similar to that shown on the lower line in **Figure 7**, which represents the SPI-generated clock pulses sent to ADC. Leaving the first probe on the I/O clock line (triggering on the clock pulses) and placing a second probe on the SPI0 MOSI line, will yield the signals seen in **Figure 8**, where the command byte is seen on the upper line and ADcmd =0x8C00.

For More Information On This Product,
Go to: www.freescale.com

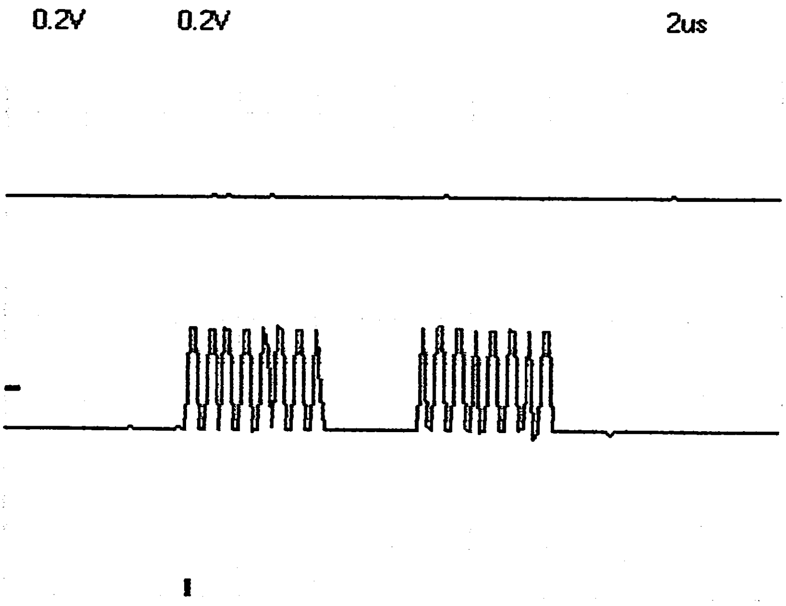


Figure 7. SPI-generated Clock Pulses

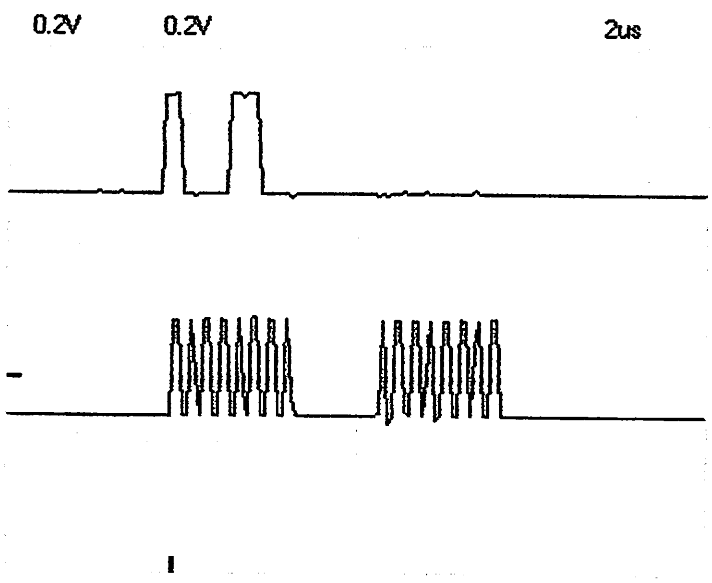


Figure 8. Command Byte (ADcmd = 0x8C00)

For More Information On This Product,
Go to: www.freescale.com

Again triggering on the clock lines' pulses and moving the second probe to the SPI0 header's, Slave Select (SS) line yields the signal seen in Figure 9. The SS is applied to the TLC2543 $\overline{CS}$ pin. When the signal goes low, processing is enabled on the ADC chip.

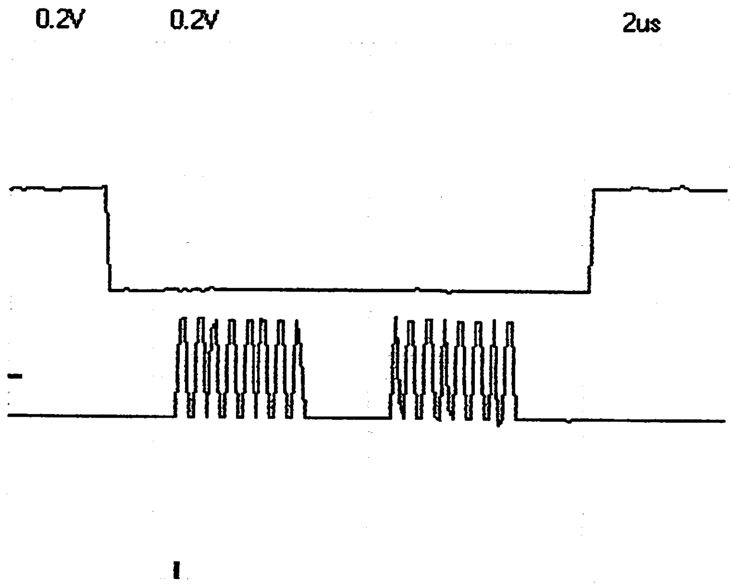


Figure 9. Probe Placed on the SPI0 Header SS Signal Line

If the interface between the SPI0 and the TLC2543 is correct, the ADC output data should be seen as shown in the upper signal in **Figure 10**. This figure shows the ADC output data signal obtained by applying the second oscilloscope probe to the SPI0's MISO port. The exact appearance of this signal is highly dependent on the nature of the data being digitized by the ADC on the prototype board; in contrast, the signals' appearances in Figure 10, Figure 11, and Figure 12 are fairly static in appearance over the period of the run.

If output data does not appear as expected, check all connections. Make sure that the ground systems are securely connected on all subsystems if noise occurs. This advice applies to all circuits discussed in this paper.

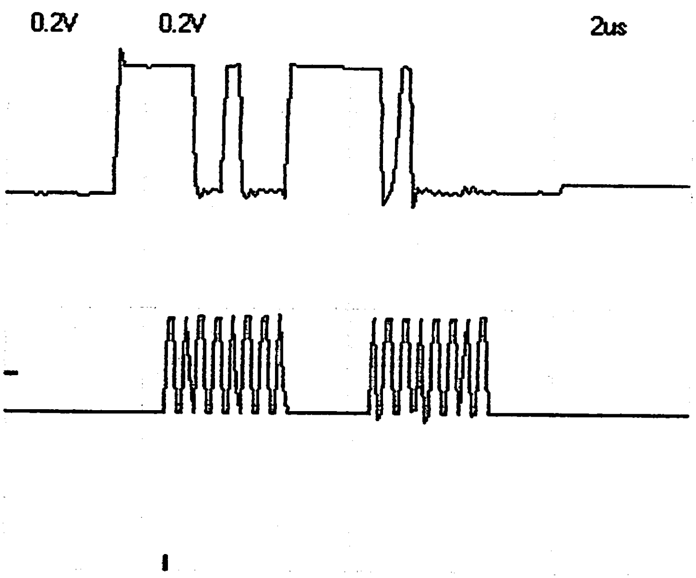


Figure 10. ADC Data

4. Integrating Devices With the EVM Board

Earlier sections of this note established the ease of interfacing to various devices, such as an LCD/keypad display and an 11-channel, 12-bit analog-to-digital converter. Remember that in the descriptions of interfacing the MPX4115A with the TLC2543 and the DSP, the barometric measurements were collected, but the debugger was required to see the results. By combining the LCD/keypad and the ADC located on the DSP's SPI0 port, it is now possible to show, in nearly real-time, the measurements collected and processed on the LCD display, using the code shown in **Code Example 3**. This code, *IntFaceBaro.c*, shows use of both LCD/keypad and TLC2543 ADC chip, interfaced to an atmospheric transducer.

Code Example 3. *IntFaceBaro.c*

```
/* IntFaceBaro.c - Procedure used to interface to TLC2543 - 12-bit analog-
   to-digital converter with serial control and 11 analog inputs. The
   DSP56824 SPI0 port is employed. The software is developed for the
   DSP56824 EVM environment. Jan 26, 2001 */
```


For More Information On This Product,
Go to: www.freescale.com

```
#include "io.h"
#include "fcntl.h"
#include "bsp.h"
#include "spi.h"
#include "stdio.h"
#include "serial.h"
#include "string.h"
#include "port.h"
#include "timer.h"
#include "types.h"
#include "math.h"
#include "lcd.h"
#include "TLC2543.h"

void BaroAdj( int , Word32 * );


void main(void)
{

   spi_sParams       SpiParams;

   int               Uart;
   UWord16           NewUartState;
   char              TitleString1[] = {"DSP Interface Demo"};
   char              TitleString2[] = {"  Barometric Meas.\n"};
   char              astring[20];
   static char       inputarrry[8];

   struct timespec TenthSecond = {0, 100000000};
   struct timespec OneMillisecond = {0,1000000};

   int               SerialMaster;
   static UWord16           ADcmd;
   static UWord16    Datain, DataStore[70];
   Word16            i, ii;
   static Word32     sum;
   static Word32     Vcount;


  static Word32    BaroPress, BAdj;


   SpiParams.bSetAsMaster = 1;    /* SPI0 is set as master */

   SerialMaster = open( BSP_DEVICE_NAME_SPI_0, 0, &SpiParams );

   /* Open Serial Port via SPI1 and Uart */

   Uart = open( BSP_DEVICE_NAME_SERIAL_0, 0 );

   NewUartState = MAX3100_FIFO_DISABLE | \
                  MAX3100_INT_ENABLE_DATA | \
                  MAX3100_IR_DISABLE | \
                  MAX3100_STOPBIT_1 | \
                  MAX3100_PARITY_NONE | \
                  MAX3100_WORD_8BIT | \
                  MAX3100_BAUD_9600;
```


For More Information On This Product,
Go to: www.freescale.com

```
ioctl( Uart, SERIAL_DEVICE_RESET, &NewUartState );

/* Set bit clock rate so sampling rate */
ioctl( SerialMaster, SPI_PHI_DIVIDER_32, NULL );

/* Set Data format for 16 bit */
ioctl( SerialMaster, SPI_DATAFORMAT_RAW, NULL );

/* SS can be left low between successive SPI bytes */
ioctl( SerialMaster, SPI_CLK_PHASE_SS_CLEAR, NULL);

/* TLC2543 is commanded to use analog input 8,
   Output data length = 16 bits,
   Output data format = MSB first, unsigned   */


ADcmd = TLC2543_port_8 | \
        TLC2543_data_16 | \
        TLC2543_MSB_first | \
        TLC2543_Unipolar;


write( Uart, NewScr, 1 );
write( Uart, TitleString1, strlen(TitleString1));
write( Uart, TitleString2, strlen(TitleString2));
 /* determine if there are any user keypad entries */

PosCursor[1] = 42;  /* Set Cursor position in LCD */


write( Uart, PosCursor, 2);

write ( Uart, "Adj. for site alt\n", 18);
ii=0;
read ( Uart, &inputarray[ii], 1);

if ( strcmp(inputarray, "A") == 0 )
{
    BaroAdj( Uart, &BAdj );
    write( Uart, NewScr, 1 );
    write( Uart, TitleString1, strlen(TitleString1));
    write( Uart, TitleString2, strlen(TitleString2));
}



ii = 0;
for(  ;  ;  )
{
   sum = 0;
   for ( i = 0; i < 64; i++ )
   {
      /* send command word to TLC2543  */
      write(SerialMaster, &ADcmd, sizeof(UWord16));

      /* read input from TLC2543  */
      read(SerialMaster, (UWord16 *)&Datain, sizeof(UWord16));

      Datain = Datain >> 4;
```

```
            /* process sleeps for 1 msec. */
            nanosleep( &OneMillisecond, NULL );

            DataStore[i] = Datain;
            sum += Datain;

        }
        Vcount = (sum >> 6);

//      BaroPress = (Vcount >> 2) + (Vcount >> 6) + (Vcount >> 8)
//                     + 105;

        /* Compute Barometric pressure in millibars, the following
           expression uses 32-bit arithmetic and 10 bits left shift on
           all coefficients, equation scaled for millibars and a
           12 bit ADC is
                    P = 0.271267*Vcount + 105.56
           Original equation taken from MPX4115A Tech Data sheet.  */

        BaroPress = (278 * Vcount + 108093) >> 10;

        BaroPress += BAdj;


        PosCursor[1] = 42;  /* Set Cursor position in LCD */
        write( Uart, PosCursor, 2);

        /* Send result to LCD  */
        sprintf( astring, "P = %ld mbars", BaroPress );
        write( Uart, astring, strlen(astring) );
    }

    close(SerialMaster);

}

/* This procedure is called when it is determined that the user desires
   to enter a correction to the barometric pressure measurement to
   compensate for the altitude above sea-level of the sensor.
   It is expected that the user will provide the pressure adjustment in
   Millibars.  */

void BaroAdj( int Uart, Word32 *padj )
{
     char astring[]={"Baro Height Adj\n"};
     char bstring[]={"Enter (mb) = "};
     char iarray[8];
     int  icount, temp, i, tenpow;

     write( Uart, NewScr, 1 );
     PosCursor[1] = 22;
     write( Uart, PosCursor, 2);
     write( Uart, astring, strlen(astring));
     PosCursor[1] = 42;
     write( Uart, PosCursor, 2);
     write( Uart, bstring, strlen(bstring));
```


For More Information On This Product,
Go to: www.freescale.com

```
        icount = 0;
        while (true)
        {
           read( Uart, &iarray[icount], 1 );
           if ( iarray[icount] == CR[0] ) break;
           if ( (iarray[icount] >= '0') && (iarray[icount] < '9'))
           {
               write( Uart, &iarray[icount], 1 );
               icount++;
           }

        }

        iarray[icount] = 0;
        sscanf(iarray, "%d", &temp );

        *padj = (Word32)temp;
    }
```

The *IntFaceBaro.c* code's header files includes two new header files: *lcd.h* and *TLC2543.h*, which provide the defines necessary to ease the use of the LCD/keypad and the TLC2543 ADC chip. The new header files are shown in **Appendix C.**

Set up the serial and SPI0 ports as in earlier examples. A message is displayed on the LCD to indicate the demo, and asks the user for input. In this case, to insert a pressure adjustment, input an "A" and "E" (=CR); for keypad key assignment values, see **Figure 4.** Another screen is generated when the procedure *BaroAdj()* requests the pressure adjustment; *BaroAdj()* works only for positions at or above sea level. The adjustment value is added to the measured value. **Appendix D.** provides information on determining this barometric pressure adjustment. If the user selects any other key, the procedure displays the barometric pressure from the MAX4115A without adjustment.

The barometric pressure results appear on the display. Since the barometric pressure changes rather slowly, you can show a rapid change of pressure by using a straw to blow into the tube-like extension that projects perpendicular to the MAX4115A cylindrical body. While blowing, you should see the barometric pressure value change on the LCD. Using the straw to blow across the pressure device's tube should decrease the pressure, an example of theVenturi Effect.

For More Information On This Product,
Go to: www.freescale.com

Appendix A. Details of NewMedia's Serial LCD+

The Serial LCD+ is a 4x20 LCD display with a built-in bi-directional serial interface. The unit is controlled using standard RS-232 serial signals from a host computer or micro-controller. The LCD+ supports the following serial data rates: 1200, 2400, 4800, 9600, 19200, 38400, and 57600 baud.

A.1 Pin Definitions

Figure A-1 shows a top down of the LCD+ (the view with the LCD display module removed). The pin definitions are denoted.

A.2 Serial I/O

The serial I/O header is made up of five connections; **Table A-1** defines the pins.

Table A-1. Serial I/O pin definitions

Pin #	Description
1	TX serial output - nearest to top in Figure 1
2	RX serial input – next pin below TX
3	Not connected
4	GND – connected to host comp/µc serial ground
5	A courtesy +5V courtesy connection (max 20 mA)

A.3 Power Input

The power input section consists of four through holes (Solder pads). The two holes marked GND are grounds. The hole marked +5.5V to +15V is tied to the LCD+ module's onboard regulator. The hole marked +5V ties to the +5V buss and is used to bypass the LCD+ onboard regulator when a regulated +5V source is supplied.

A.4 ADC Inputs

The eight ADC inputs are labeled 1 – 8. By default, all ADC inputs are set to read voltage in the 0 to +5V range.

A.5 Relay Driver Outputs

There are nine Relay Driver connections, labeled on the underside of the board as R1-8 and RLY_VDC. The connections labeled R1-8 are the relay driver chip outputs; the RLY+VDC connection provides access to the ULN2803A driver chip's internal back EMF protection diodes.

A.6 Matrix KeyPad Input

The keypad input connections (visible in **Figure A-1**) are the upper-most eight of the 8x2 header connection. The lower eight of the 8x2 header connection (not visible in **Figure A-1**) are used by the factory for programming and should remain unconnected.

**For More Information On This Product,
Go to: www.freescale.com**

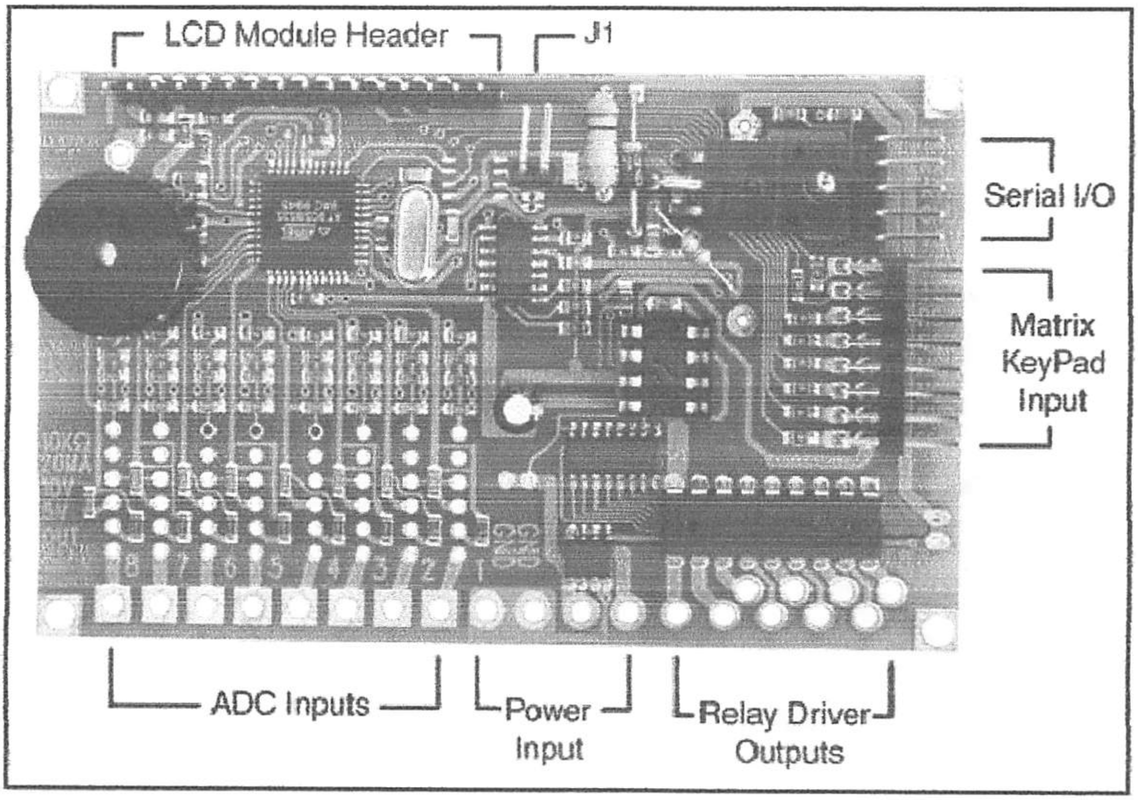


Figure A-1. LCD+ Pin-Outs

A.7 Interfacing the LCD+

The LCD+ can be controlled using any computer or microprocessor supporting 1200-57600 baud data rates with a 8,N,1 data format (8 data bits, No parity, 1 stop bit).

A.8 Keypad Interface

The keypad interface supports matrix keypads up to 4x4 in size (16 keys). Instead of predefining the keypad key serial data format as 0 through 15, each of the keypad's keys is serially represented by a user-definable byte value. This user-definable value (Tag) is stored within the LCD+ EEPROM as a 0-15 byte array. Each byte of the array corresponds to a key on the keypad (i.e. key 0 corresponds to byte 0 of the array). Whenever a key is pressed, the stored byte representation for that key number is sent serially.

A.9 Keypad Options

Various keypad options are supported by six user-definable options or modes. To set these modes, send a CTRL-X, followed by your command byte containing the desired modes. As shown in Table A-2, placing a 1 in any of the bits turns its corresponding option on, and a 0 turns it off. Control Codes for the LCD+ are shown in Table A-3.

For More Information On This Product,
Go to: www.freescale.com

Table A-2. LCD+ Keypad Options Table

Mode Byte	Name	Description
B0	"Key Beeps"	Beep buzzer during each key press
B1	"Key Press Format"	Send one byte for key down and one for key up
B2	"LCD Echo"	Echo key press data ASCII representation to LCD display
B3	"Mask Key Presses"	Display all key presses as asterisks on LCD
B4	"Auto Backlight"	Turns on backlight with any key press and off 4 seconds after last key press
B7	"Delayed Response"	Provide 3.0ms delay in response to a command. Required for interfacing with BS2

Table A-3. LCD+ Control Codes

Control Code	Function	Total bytes needed + Command_Data	Return Data
Ctrl-A	Cursor Home	1 Byte(0x01)	None
Ctrl-B	Set/Adjust Backlight Brightness	2 Bytes (0x02) + 0-255	None
Ctrl-C	Set/Adjust Contrast	2 Bytes (0x03) + 0-255	None
Ctrl-D	Hide Cursor	1 Byte (0x04)	None
Ctrl-E	Underline Cursor	1 Byte (0x05)	None
Ctrl-F	Block Cursor	1 Byte (0x06)	None
Ctrl-G	Sound Bell/Buzzer	1 Byte (0x07)	None
Ctrl-H	Backspace	1 Byte (0x08)	None
Ctrl-I	Horizontal Tab	1 Byte (0x09)	None
Ctrl-J	Line Feed	1 Byte (0x0a)	None
Ctrl-K	Reverse Line Feed	1 Byte (0x0b)	None
Ctrl-L	Form Feed/Clear Screen	1 Byte (0x0c)	None
Ctrl-M	Carriage Return	1 Byte (0x0d)	None
Ctrl-N	Backlight On	1 Byte (0x0e)	None
Ctrl-O	Backlight Off	1 Byte (0x0f)	None
Ctrl-P	Set Cursor Position	2 Bytes (0x10) + 0-79	None
Ctrl-Q	Clear Column	1 Bytes (0x11)	None
Ctrl-R	Set Relays	2 Bytes (0x12) + 0-255	None
Ctrl-S	Define Custom Character	10 Bytes (0x13) + 0-7 + 8 Bytes	None
Ctrl-T	Download Keypad Tags	17 Bytes (0x14) + 16 New keys	None

For More Information On This Product,
Go to: www.freescale.com

Ctrl-U	Set Baud Rate	2 Bytes (0x15) + 0-6	None
Ctrl-V	Read ADC Inputs	2 Bytes (0x16) + 1-8	2 Bytes
Ctrl-W	Change Bell/Buzzer Frequency	2 Bytes (0x17) + 0-255	None
Ctrl-X	Set Keypad Modes	2 Bytes (0x18) + 0-255	None
Ctrl-Y	Read Keypad Input as Port	1 Byte (0x19)	1 Byte
Ctrl-Z	Get LCD+ EEPROM Settings	1 Byte (0x20)	20 Bytes
None	Display Custom Character	1 Byte (0x80)	None

For More Information On This Product,
Go to: www.freescale.com

Appendix B. TI's TLC2543

The following data is taken from TI's TLC2543 data sheet. It is included only to provide information that the reader may need to understand the code described in this note.

The TLC2543 is a 12-bit switched-capacitor, successive approximation, ADC converter. Each device has three control inputs (chip select (CS), the I/O clock and the address input (DATA INPUT)) and is designed for communication with the serial port of a host processor or peripheral through a serial 3-state output.

The device has an on-chip 14-channel multiplexer that can select any of 11 inputs or any of three internal self-test voltages. The sample-and-hold function is automatic. At the end-of-conversion (EOC), output goes high to indicate that conversion is complete. A switched-capacitor design allows low-error conversion over the full operating temperature range.**Figure B-1** shows the pin-outs of the 20- pin DIP version of the chip used in this note.

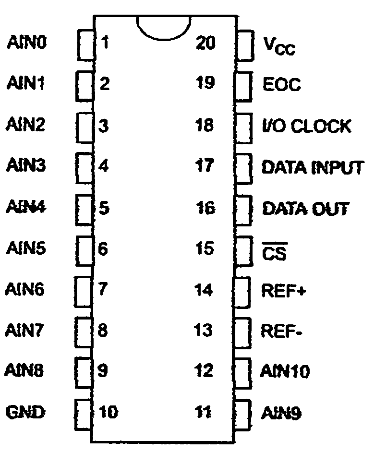


Figure B-1. TLC2543 DIP Version Pin-Outs

B.1 Operating Principles

If the $\overline{CS}$ is high, the I/O CLOCK and DATA INPUT are disabled and DATA OUT is in a high-impedance state. When the $\overline{CS}$ goes low, the conversion sequence begins by enabling the I/O CLOCK and DATA INPUT and removes the DATA OUT from the high-impedance state.

The data input is 8 bits long and is primarily a command item exercising control over the features of the chip. The following table describes the fields of the data input.

For More Information On This Product,
Go to: www.freescale.com

Freescale Semiconductor, Inc.

Table B-1. Fields of Data Input

Field	Description
D7-D4	Analog Channel Address
D3-D2	Data Length
D1	Output MSB or LSB First
D0	Unipolar or Bipolar Output

The I/O CLOCK sequence applied to the I/O CLOCK terminal transfers this data to the input data register.

The I/O CLOCK during this transfer shifts the previous conversion result from the output data register to DATA OUT. I/O CLOCK receives the input sequence of 8, 12, or 16 clock cycles long depending on the data-length selection in the input data register. Sampling of the analog input begins on the fourth falling edge of the input I/O CLOCK sequence and is held after the last falling edge of the I/O CLOCK sequence. The last falling edge of the I/O CLOCK sequence also takes EOC low and begins the conversion.

B.2 Data Input

The data input is internally connected to an 8-bit serial-input address and control register. The register defines the operation of the converter and the output data length. The host provides the data word with MSB first. Each data bit is clocked in on the rising edge of the I/O CLOCK sequence. **Table B-2** provides the details for the data input-register format.

Table B-2. Input-Register Format

FUNCTION SELECT	INPUT DATA BYTE							
	ADDRESS BITS				L1	L0	LSBF	BIP
	D7 (MSB)	D6	D5	D4	D3	D2	D1	D0 (LSB)
Select Input Channel								
AIN0	0	0	0	0				
AIN1	0	0	0	1				
AIN2	0	0	1	0				
AIN3	0	0	1	1				
AIN4	0	1	0	0				
AIN5	0	1	0	1				
AIN6	0	1	1	0				

For More Information On This Product,
Go to: www.freescale.com

Freescale Semiconductor, Inc.
ARCHIVED BY FREESCALE SEMICONDUCTOR, INC. 2005

Table B-2. Input-Register Format

AIN7	0 1	1 1			
AIN8	1 0	0 0			
AIN9	1 0	0 1			
AIN10	1 0	1 0			
Select Test Voltage					
$(V_{ref+} - V_{ref-})/2$	1 0	1 1			
V_{ref-}	1 1	0 0			
V_{ref+}	1 1	0 1			
Software Power Down	1 1	1 0			
Output Data Length					
8 bits			0 1		
12 bits			X 0		
16 bits			1 1		
Output Data Format					
MSB first				0	
LSB first (LSBF)				1	
Unipolar (binary)					0
Bipolar (BIP) Two's Complement					1

X = don't care

For More Information On This Product,
Go to: www.freescale.com

Appendix C. Header Files *TLC2543.h* and *lcd.h*

```
/*  lcd.h    some common material used with NewMedia LCD device */

   UWord16    NewScr[2]= {12,0};
   UWord16    BackLightOn[2] = {14,0};
   UWord16    LightLevel[2] = {2,70};
   UWord16    DispContrast[2] = {3,100};
   UWord16    DispKeypad[2] = {24,1};
   char       LF[]={10,0}, CR[]={'E'};
   UWord16    BS[]={8,0};
   UWord16    PosCursor[]={16,0};


/*  TLC2543.h    include file to be used with the 11 port 12-bit ADC
                  chip - TI's TLC2543   */

#define TLC2543_port_0  0x0000
#define TLC2543_port_1  0x1000
#define TLC2543_port_2  0x2000
#define TLC2543_port_3  0x3000
#define TLC2543_port_4  0x4000
#define TLC2543_port_5  0x5000
#define TLC2543_port_6  0x6000
#define TLC2543_port_7  0x7000
#define TLC2543_port_8  0x8000
#define TLC2543_port_9  0x9000
#define TLC2543_port_10 0xA000

#define TLC2543_data_8  0x0400
#define TLC2543_data_12 0x0000
#define TLC2543_data_16 0x0C00

#define TLC2543_MSB_first 0x0000
#define TLC2543_LSB_first 0x0200

#define TLC2543_Unipolar  0x0000
#define TLC2543_Bipolar   0x0001
```


For More Information On This Product,
Go to: www.freescale.com

Appendix D. Determining the Pressure Transducer's Altitude Pressure Adjustment

This section discusses the apparent error seen when using the MPX4115A Integrated Pressure Sensor. The units of barometric pressure used here are in metric units (SI) millibars. If the demo is performed at or near sea level, the displayed result should be identical to a reading provided by the local weather service via either the internet or radio weather services. As a standard, all barometric pressure values recorded and provided by the weather service are always referenced to sea level, regardless of the altitude of the weather measuring station.

When the demo is performed at a location above sea level, a divergence takes place between the demo-measured value and the current weather service value. The demo value will always be less and will decrease as the height above sea level increases. Under these circumstances, the MPX4115A is performing nothing more than an altimeter function. A mathematical relationship exists that relates the height above sea level to the pressure measurement.

For any given location, there is a means of obtaining the correction for the altitude. One way is to contact the local office of the weather service via its internet web site and observe the barometric pressure readings provided. A second means requires listening to the local radio outlet of the weather service (usually found around 162.0 MHz VHF using a NBFM radio) for the current barometric value. With the current values, a correction term (Δ) can be determined by the following expression:

$$\Delta = P_{weather\_service} - P_{measured}$$

The value (D) is a constant for a given location and it is added to the measured barometric value as follows:

$$P_{sea\text{-}level} = P_{measure} + \Delta$$

The station pressure varies with altitude above sea level in accordance with the following expression:

$$P_{station} = P_{sea\text{-}level} * \exp(-z/H)$$

where

H = 7000

z = height above sea-level (meters)

For example, a local radio station announces the barometric or sea level pressure as 1013 millibars (or hectoPascals) and you live in the mountains at 1760 meters. Using the above equation, your station pressure is 788 millibars. The Δ correction in this case is 225 millibars.

Appendix E. Motorola's MPX4115A Integrated Pressure Sensor

The following is taken from the MPX4115A Integrated Pressure Sensor Data sheet.

The Motorola MPX4115A series Manifold Absolute Pressure (MAP) sensor for engine control is designed to sense absolute air pressure. Its operating pressure range is 15 to 115 kPa (2.2 to 16.7 psi) which produces a voltage output of 0.2 to 4.8V.

Motorola's MAP sensor, integrated on-chip, bipolar op-amp circuitry and thin film resistor network to provide a high-output signal and temperature compensation. The small form factor and high reliability of on-chip integration make the Motorola MAP sensor a logical and economical choice for the automotive system designers.

Among its features:

- 1.5% maximum error over 0° to 85°C
- Ideally suited for microprocessor and microcontroller-based systems
- Temperature compensated from –40° to +125°C

Application examples:

- Aviation altimeters
- Industrial controls
- Engine control
- Weather stations and weather reporting devices

Figure E-1 shows the sensor output signal relative to pressure input. Typical minimum and maximum output curves are shown for operation over 0 to 85°C temperature range. Output will saturate outside of the rated pressure range. **Figure E-2** depicts the version of the sensor employed with this demo and also shows the pins to aid in proper use and installation.

For More Information On This Product,
Go to: www.freescale.com

Freescale Semiconductor, Inc.
ARCHIVED BY FREESCALE SEMICONDUCTOR, INC. 2005

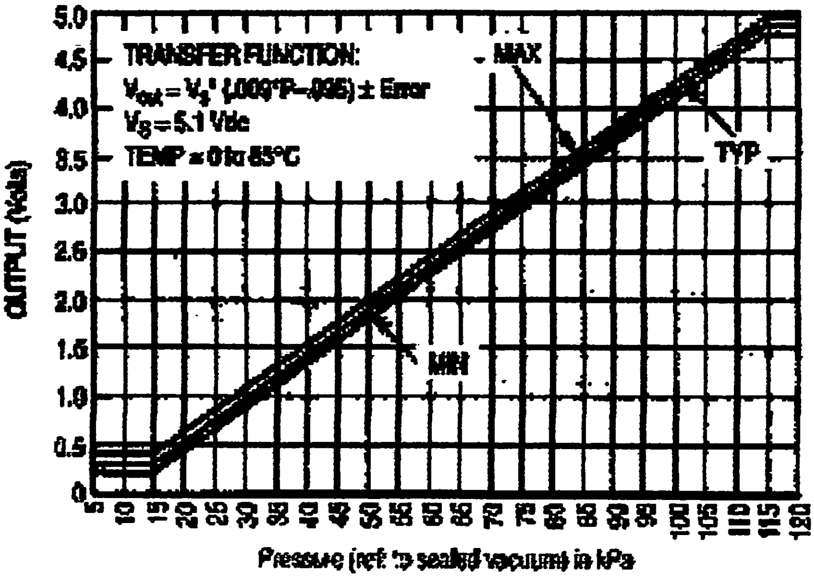


Figure E-1. Output vs. Absolute Pressure

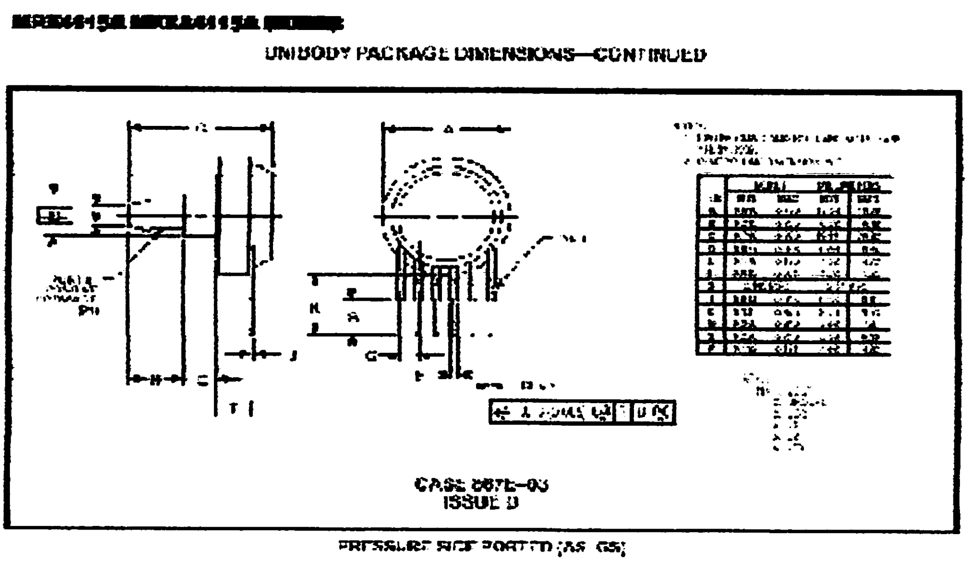


Figure E-2. MPX4115A and Pin-Outs

For More Information On This Product,
Go to: www.freescale.com

Freescale Semiconductor, Inc.
ARCHIVED BY FREESCALE SEMICONDUCTOR, INC. 2005

NOTES:

For More Information On This Product,
Go to: www.freescale.com

ARCHIVED BY FREESCALE SEMICONDUCTOR, INC. 2005

OnCE™ is a registered trademark of Motorola, Inc.

lotorola reserves the right to make changes without further notice to any products herein. Motorola makes no warranty, representation or guarantee regarding the uitability of its products for any particular purpose, nor does Motorola assume any liability arising out of the application or use of any product or circuit, and pecifically disclaims any and all liability, including without limitation consequential or incidental damages. "Typical" parameters which may be provided in Motorola ata sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including Typicals" must be validated for each customer application by customer's technical experts. Motorola does not convey any license under its patent rights nor the ghts of others. Motorola products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or other pplications intended to support or sustain life, or for any other application in which the failure of the Motorola product could create a situation where personal injury r death may occur. Should Buyer purchase or use Motorola products for any such unintended or unauthorized application, Buyer shall indemnify and hold Motorola nd its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees rising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that lotorola was negligent regarding the design or manufacture of the part. Motorola and Ⓜ are registered trademarks of Motorola, Inc. Motorola, Inc. is an Equal pportunity/Affirmative Action Employer.

w to reach us:

iA/EUROPE/Locations Not Listed: Motorola Literature Distribution: P.O. Box 5405, Denver, Colorado 80217.
303-675-2140 or 1-800-441-2447

PAN: Motorola Japan Ltd.; SPS, Technical Information Center, 3-20-1 Minami-Azabu. Minato-ku, Tokyo 106-8573 Japan.
-3-3440-3569

IA/PACIFIC: Motorola Semiconductors H.K. Ltd.; Silicon Harbour Centre, 2 Dai King Street, Tai Po Industrial Estate, Tao Po, N.T.,
ng Kong. 852-26668334

chnical Information Center: 1-800-521-6274

ME PAGE: http://motorola.com/semiconductors/dsp   MOTOROLA HOME PAGE: http://motorola.com/semiconductors/

MOTOROLA

AN1921/D

LCM

Liquid Crystal Display Modules

Seiko Instruments GmbH

ot Matrix Liquid Crystal Display Modules

ARACTER 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 :

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

r Format (character x line)		16 x 1	16 x 2	16 x 2	16 x 2	16 x 4	20 x 2
		M1641	M1632	L1642	L1652	L1614	L2012
		M16410AS	M16320AS	L164200J000S	L165200J200S	L161400J000S	L201200J000S
ght		M16419DWS	M16329DWS	L164221J000S	L165221J200S	L161421J000S	L201221J000S
light		M16417DYS	M16327DYS	L1642B1J000S	L1652B1J200S	L1614B1J000S	L2012B1J000S
(wide temp)		M16410CS	M16320CS	L164200L000S	L165200L200S	L161400L000S	L201200L000S
light (wide temp)		M16417JYS	M16327JYS	L1642B1L000S	L1652B1L200S	L1614B1L000S	L2012B1L000S
font		5x7 dots + cursor	5x7 dots + cursor	5x7 dots + cursor	5x7 dots + cursor	5x7 dots + cursor	5x7 dots + cursor
	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
mm	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
rea (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
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
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
pply voltage (VDD-VSS) V		+ 5 V	+ 5 V	+ 5 V	+ 5 V	+ 5 V	+ 5 V
onsumption	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
ethod (duty)		1/16	1/16	1/16	1/16	1/16	1/16
SI		KS0066 or equivalent	KS0066 MSM5839 or equivalent	KS0066 MSM5839 or equivalent	KS0066 MSM5839 or equivalent	KS0066 KS0063 or equivalent	KS0066 KS0063 or equivalent
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
mperature (°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
	Reflective	25	25	25	50	50	40
	EL backlight	30	30	30	55	55	45
	LED backlight	35	40	35	65	65	60
	Model	5S	5S	5S	5C	5A	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
	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

ing cursor

ternal temperature compensation

ig EL backlight

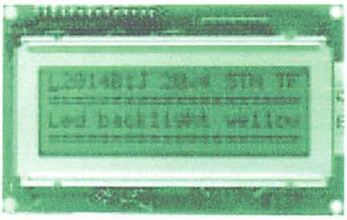
in normal temperature range

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

olicy 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

haracter Format (character x line)		20 x 2	20 x 4	24 x 2	40 x 2	40 x 4
odel		L2022	L2014	L2432	L4042	M4024
eflective		-	L201400J000S	L243200J000S	L404200J000S	M40240AS
. backlight		-	L201421J000S	L243221J000S	L404221J000S	M40249DWS
D backlight		-	L2014B1J000S	L2432B1J000S	L4042B1J000S	M40247DYS
eflective (wide temp)		L202200P000S	L201400L000S	L243200L000S	L404200L000S	M40240CS
D backlight (wide temp)		L2022B1P000S	L2014B1L000S	L2432B1L000S	L4042B1L000S	M40247JYS
haracter font		5x7 dots + cursor	5x7 dots + cursor	5x7 dots + cursor	5x7 dots + cursor	5x7 dots + cursor
odule	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
ze	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
xVxT) mm	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
ewing 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
aracter 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
ot 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
ower supply voltage (VDD-VSS) V		+ 5 V	+ 5 V	+ 5 V	+ 5 V	+ 5 V
rrent consumption	IDD	4,2	2,9	2,5	3,0	8,0
A,typ)	ILC *4	2,6	1,2	0,5	1,0	3,0
iving method (duty)		1/16	1/16	1/16	1/16	1/16
ilt-in LSI		KS0066 KS0063 or equivalent	KS0066 MSM5839 or equivalent	KS0066 KS0063 or equivalent	KS0066 KS0063 or equivalent	KS0066 MSM5839 or equivalent
erating 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
orage 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
eight	Reflective	80	55	40	70	90
typ.)	EL backlight	-	60	45	75	105
	LED backlight	110	70	60	95	140
	Model	-	5A	5A	5C	5D
erters	Power supply (V)	+ 5.0	+ 5.0	+ 5.0	+ 5.0	+ 5.0
EL	current consumption (mA) *3	-	45	45	25	80
D	Forward current consumption (mA)	320	240	150	260	480
cklight	Forward input voltage (V,typ.)	+ 4,1	+ 4,1	+ 4,1	+ 4,1	+ 4,1

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

With external temperature compensation

Including EL backlight

Based on normal temperature range

ot Matrix Liquid Crystal Display Modules

RAPHIC TYPE

• FEATURES :

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

• SPECIFICATIONS :

t (HxV,dot)			97 x 32	128 x 32	128 x 64	128 x 64
			Y97031	G1213	G1216	G1226
	Reflective	built-in RAM	-	-	-	-
de)	Reflective wide temp.	built-in RAM	-	G121300N000S	G121600N000S	-
	LED backlight	built-in RAM	-	-	-	G1226B1J000S
	LED backlight wide temp	built-in RAM	-	G1213B1N000S	G1216B1N000S	-
e	Transmissive	-	-	-	-	-
de)	with CFL backlight	built-in controller	-	-	-	-
	Transflective	built-in RAM	Y97031LF60W	-	-	-
ze	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	-
T)	LED backlight		-	75,0 x 41,5 x 8,9	75,0 x 52,7 x 8,9	93,0 x 70,0 x 11,4
	CFL backlight		-	-	-	-
rea (HxV) mm			43,5 x 23,9	60,0 x 21,3	60,0 x 32,5	70,7 x 38,8
H x V) mm			0,35 x 0,48	0,40 x 0,48	0,40 x 0,40	0,44 x 0,44
H x V) mm			0,39 x 0,52	0,43 x 0,51	0,43 x 0,43	0,48 x 0,48
pply voltage (V)		(VDD - VSS)	+ 5,0	+ 5,0	+ 5,0	+ 5,0
		(VLC - VSS)	-	- 8,0	- 8,1	-8,2
nsumption		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
l		Driver	SED1530 or equivalent	HD61202 HD61203 or equivalent	HD61202 HD61203 or equivalent	KS0107 KS0108 or equivalent
		Controller	-	-	-	-
temperature range (°C)			- 20 to + 70	- 20 to + 70	- 20 to + 70	0 to + 50
mperature range (°C)			- 30 to + 80	- 30 to + 80	- 30 to + 80	- 20 to + 60
	Reflective (Transflective no backlight)		10	23	35	-
	LED backlight		-	35	45	72
	CFL backlight		-	-	-	-
ght	Forward current consumption (mA)		-	40	90	125
	Forward input voltage (V, typ.)		-	3,8	4,1	4,1
	Mode		-	-	-	-
r CFL	Power supply voltage (V)		-	-	-	-
	Current consumption (mA, typ.)		-	-	-	-

DC/DC converter (single power source)

th external temperature compensation circuit

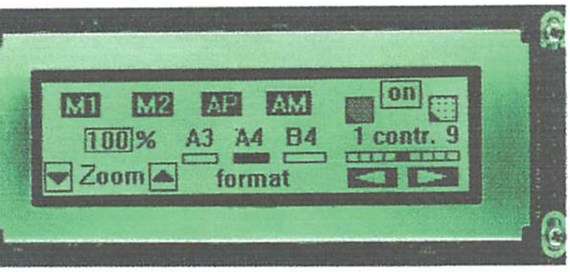
policy is one of continues improvements we reserve the right to change the specifications of the products in the catalogue without notice.

rmat (HxV,dot)			240 x 64	240 x 128	320 x 200	320 x 240	640 x 200
l			G2446	G242C	G321D	G324E	G649D
type / mode)	Reflective	built-in RAM	-	-	-	-	-
	Reflective wide temp.	built-in RAM	-	-	-	-	-
	LED backlight	built-in RAM	-	-	-	-	-
	LED backlight wide temp	built-in RAM	-	-	-	-	-
l type / mode)	Transmissive with CFL backlight	-	G2446X5R1A0S	G242CX5R1ACS	G321DX5R1A0S	G324EX5R1A0S	G649DX5R010S
		built-in controller	G2446X5R1ACS	G242CX5R1A0S	G321DX5R1ACS	G324EX5R1ACS	-
	Transflective	built-in RAM	-	-	-	-	-
le size / x T)	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
ng 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
ze (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
tch (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
r 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
nt consumption		IDD	12	30	8	7,5	11
		IDD (built-in controller)	15	40	23	23	-
yp.)		ILC	-	-	6	6,5	9
	Driving method (duty)		1/64	1/128	1/200	1/240	1/200
n 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	-
ting temperature range (°C)			0 to + 50	0 to + 50	0 to + 50	0 to + 50	0 to + 50
ge temperature range (°C)			- 20 to + 60	- 20 to + 60	- 20 to + 60	- 20 to + 60	- 20 to + 60
t .)	Reflective (Transflective no backlight)		-	-	-	-	-
	LED backlight		-	-	-	-	-
	CFL backlight		200	280	350	350	420
acklight	Forward current consumption (mA)		-	-	-	-	-
	Forward input voltage (V, typ.)		-	-	-	-	-
er 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

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

se with external temperature compensation

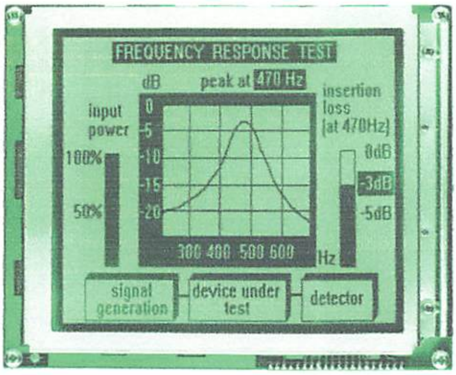
our policy is one of continous improvemets, we reserve the right to change the specifications of the products in the catalogue without notice.



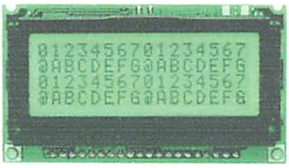
G2446

G1226

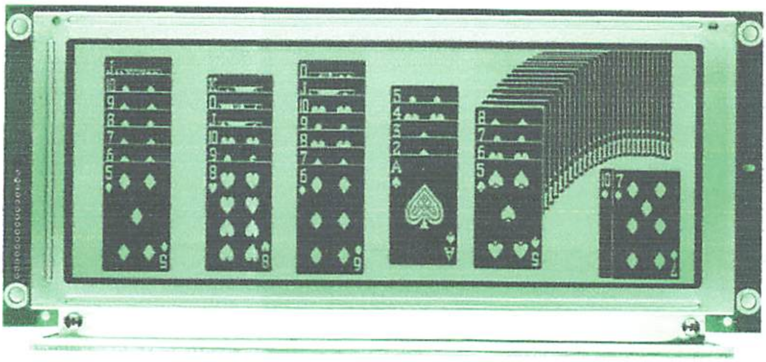
G1216



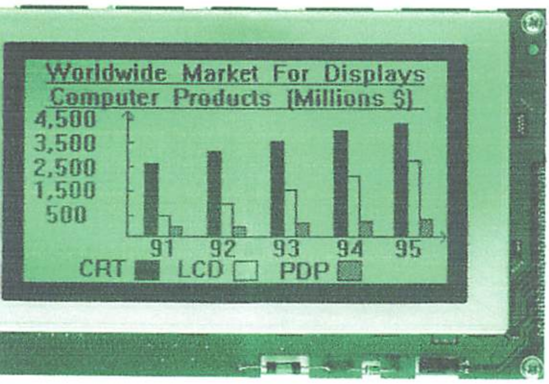
G321D



G1213



G649D



G242C

G324E

:CK LIST FOR CUSTOM DESIGNED LCD MODULE

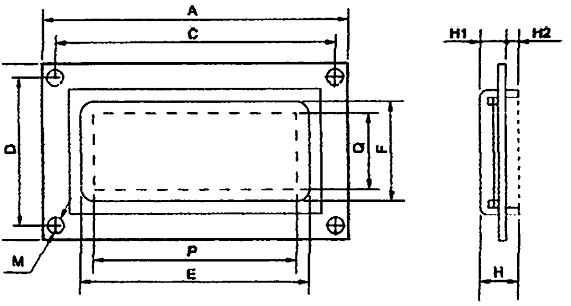
mpany________________ 2. Application______________ 3. Customer Specified Part No.________________

sign

lew ☐Modified : Manufacturer______________, Part No.______________, Remarks ______________

:quivalent: Manufacturer______________, Part No.______________, Remarks ______________

M 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

splay Contents

:haracter type:__________characters______lines

:haracter font____________x____________dots + cursor

:haracter pitch____________x____________mm

lot pitch____________x____________mm

lot size____________x____________mm

iraphics (Full dot) type:____________x____________dots

lot pitch____________x____________mm

lot size____________x____________mm

egment type:__________digits__________lines

Ithers______________________________

D Panel

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

e: ☐TN ☐FSTN (Black and white)

]STN (☐Yellow green ☐Gray ☐Blue)

Chromaticity coordinates

(______ ≦ x ≦ ______ , ______ ≦ y ≦ ______)

]Positive type ☐Negative type

]Reflective ☐Transflective ☐Transmissive

]Others______________________________

/ scale: ☐Yes______ gray scale ☐No

erential specifications:

|Response time t_{on} ____ ms (____ °C) t_{off} ____ ms (____ °C)

|Viewing angle ____ deg. (____ °C) ☐ Contrast ____ (____ °C)

|Others______________________________

surface finishing:

|Normal ☐Anti-glare☐______________

rizer color: ☐Normal (neutral gray) ☐Red

|Green ☐Blue ☐______________

ving Method

plexing:1/__________duty, 1/__________bias

ie frequency: ______________Hz

driver: ☐Specified ☐Unspecified

egment driver ______________(Manufacturer ______________)

ommon driver ______________(Manufacturer ______________)

roller: ☐Internal ☐External

pe No.______________(Manufacturer ______________)

l: ☐Internal ☐External

pe No.______________(Manufacturer ______________)

l: ☐Internal ☐External

pe No. /Memory size_____(Kbit) (Manufacturer ______________)

wer Supply

ngle power supply: ☐5V ☐__________V

power supplies

or logic: (V_{DD}-V_{SS}) : ☐5V ☐__________V

or 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

›id Crystal Displays

CK LIST FOR CUSTOM DESIGNED LCD

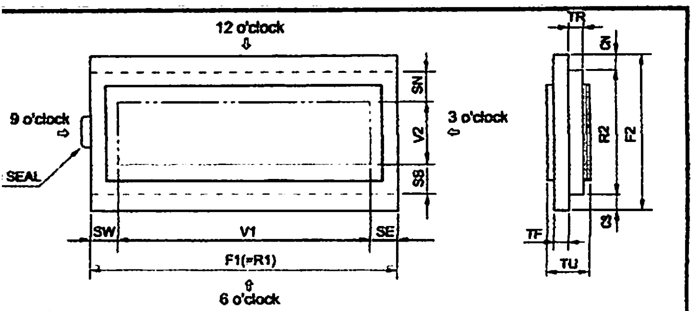
ıpany_______________ 2. Application_______________3. Customer Specified Part No._______________

ign

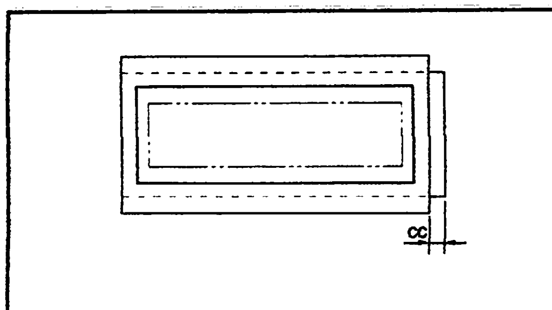
w ☐Modified: Manufacturer __________ , Part No.________ , Remarks ________________

uivalent: Manufacturer_______________ , Part No.________ , Remarks________________

el Dimensions



- Type A (connection through conductive material) -



- Type B (direct common) -

izontal length of upper glass ________________mm

ical length of upper glass ________________mm

izontal length of lower glass ________ the same as F1

rtical length of lower glass ________________mm

generally longer than F2 when terminals are with pin.

**: Thickness of glass ________________mm

ndard type: 1.1 mm or 0.7 mm

ckness of LCD ________________mm

ıl:☐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

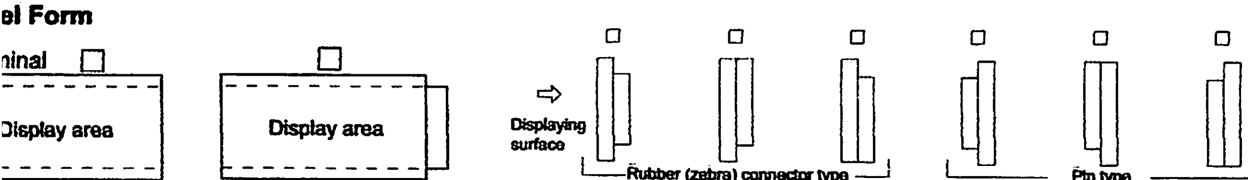
SE,SW,SN,SS : Seal width

(According to design or manufacturing condition:

about 2.0 mm to 4.0 mm)

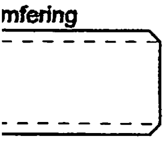
el Form

ninal ☐ ☐



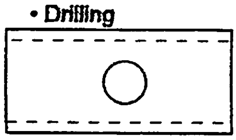
- Type A - - Type B -

mfering



☐ Yes
☐ No

• Drilling



☐ Yes
☐ No

lay Mode

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

☐TN ☐FSTN (Black and white)

ʲTN: (☐ Yellow green ☐ Gray ☐ Blue)

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

'ositive type ☐Negative type

łeflective ☐Transflective ☐Transmissive

ential specifications:

łesponse time t_{on} ____ms (°C) t_{off} ____ms (°C)

'iewing angle ____deg. (°C) ☐Contrast____(°C)

)thers ________________

rizer

e finishing: ☐Normal ☐Anti-glare ☐__________

☐Normal (neutral gray) ☐Red ☐Green

☐Blue ☐__________

oolarizer : ☐ Attached type ☐ Separate type

olarizer : ☐ Attached type ☐ Separate type

ng Method

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

ting voltage (V_{opr}) :____________V

e frequency:____________Hz

g IC:________(Manufacturer ____________)

nt 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

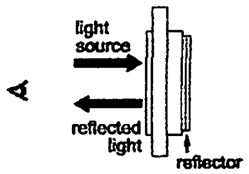
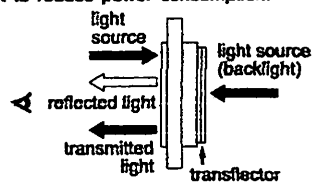
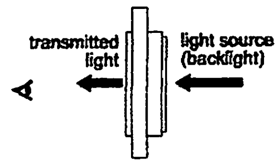
Mass production : Target price : ________________

Delivery ________ , Total quantity:____________pcs

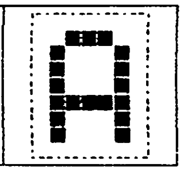
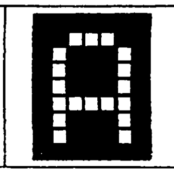
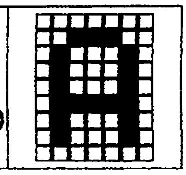
Quantity per month:________________pcs

id Crystal Display Modules

LECTIVE/TRANSFLECTIVE/TRANSMISSIVE LCD

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

ITIVE/NEGATIVE MODE

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

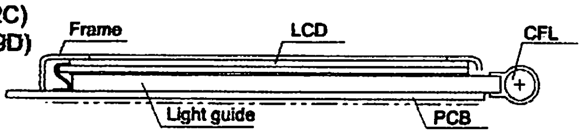
YPE/STN TYPE/FSTN TYPE

	(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.)
	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.
	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.

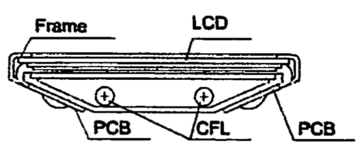
JCTURE AND FEATURE OF LCD MODULE WITH BACKLIGHT

(Cold Cathode Fluorescent Lamp) backlight
ures: high brightness, long service life, inverter required

ge backlight type
32446,G242C)
3321D,G649D)

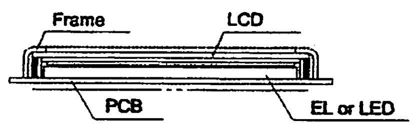


klight type



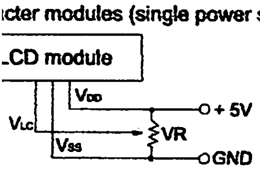
EL (Electroluminescent Lamp) backlight
LED (Light Emitting Diode) backlight

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

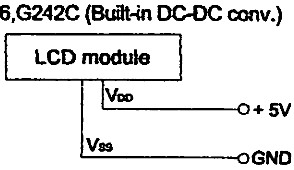


ER SUPPLY

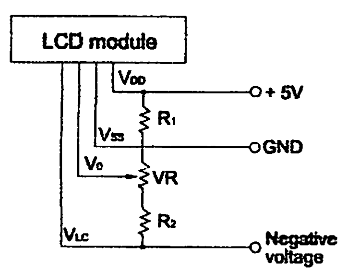
cter modules (single power supply)



• G2446,G242C (Built-in DC-DC conv.)

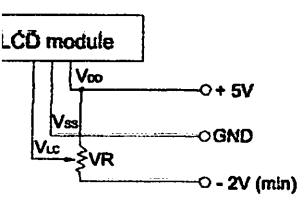


• G321D, G324E and G649D

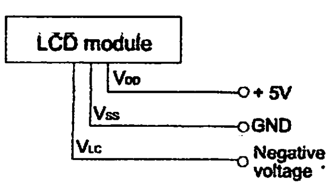


Note 1:Contrast can be adjusted by VR.
Note 2:For module with backlight, power supply for backlight is necessary.

acter Modules(Dual power supply)



• Y1206 and G1226



*Negative voltage should be variable for contrast adjustment.

›cautions

/ Instructions

ɘ LCD panel is damaged, be careful not to get the d crystal in your mouth and not to be injured by ıhed glasses.

ıu should swallow the liquid crystal, first, wash your ıth thoroughly with water, then, drink a lot of water induce vomiting, and then, consult a physician.

e liquid crystal should get in your eye, flush your with running water for at least fifteen minutes.

e liquid crystal touches your skin or clothes, re- 're it and wash the affected part of your skin or hes with soap and running water.

ɔr CFL backlight is driven by a high voltage with an ırter. Do not touch the connection part or the wir- pattern of the inverter.

ıot use inverters without a load or in the short-cir- mode.

the LCD module within the rated voltage to pre- t overheating and/or damage. Also, take steps to ure that the connector does not come off.

ling Precautions

ɔe the LCD panel has glass substrate, avoid apply- mechanical shock or pressure on the module. Do drop, bend, twist or press the module.

ıot soil or damage LCD panel terminals.

ɔe the polarizer is made of easily-scratched mate- be careful not to touch or place objects on the dis- surface.

p the display surface clean. Do not touch it with skin.

ƆS LSI is used in the LCD module. Be careful of c electricity.

ıot disassemble the module or remove the liquid tal panel or the panel frame.

ıot damage the film surface of the EL lamp; other- ı the lamp will be damaged by humidity.

ıet an EL lamp in an LCD module, push the EL ɔ with its emitting side up, without pushing the rub- ɔonnectors too hard. If you damage them, the LCD ule may not work properly.

ting and Designing

rotect the polarizer and the LCD panel, cover the lay surface with a transparent plate (e.g., acrylic ass) with a small gap between the transparent plate the display surface.

p the module dry. Avoid condensation to prevent ransparent electrodes from being damaged.

ɘ LCD panel with AC waveform in which DC ele- t is not included to prevent deterioration in the LCD ɘl.

trast of LCD varies depending on the ambient tem- ture. To offer the optimum contrast, LC drive volt- should be adjusted. LCD driven in a high duty must be provided with drive voltage adjustment ıod.

nt a LCD module with the specified mounting part/ s.

- 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

- Seiko Instruments GmbH reserves the right to make changes without notice to the specifications and materials contained herein.
- The colors of the products reproduced herein may be different from the actual colors. Check color on actual products before using the product.
- The information contained herein shall not be reproduced in whole or in part without the express written consent of Seiko Instruments GmbH
- The products described herein are designed for consumer equipment and cannot be used as part of any device or equipment which influences the human body or requires a significantly high reliability, such as physical exercise equipment, medical equipment, disaster prevention equipment, gas related equipment, vehicles, aircraft and equipment mounted on vehicles.

otes :

FAIRCHILD
SEMICONDUCTOR®

www.fairchildsemi.com

MC78XX/LM78XX/MC78XXA

3-Terminal 1A Positive Voltage Regulator

Features

- Output Current up to 1A
- Output Voltages of 5, 6, 8, 9, 10, 12, 15, 18, 24V
- Thermal Overload Protection
- Short Circuit Protection
- Output Transistor Safe Operating Area Protection

Description

The MC78XX/LM78XX/MC78XXA series of three terminal positive regulators are available in the TO-220/D-PAK package and with several fixed output voltages, making them useful in a wide range of applications. Each type employs internal current limiting, thermal shut down and safe operating area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.

TO-220

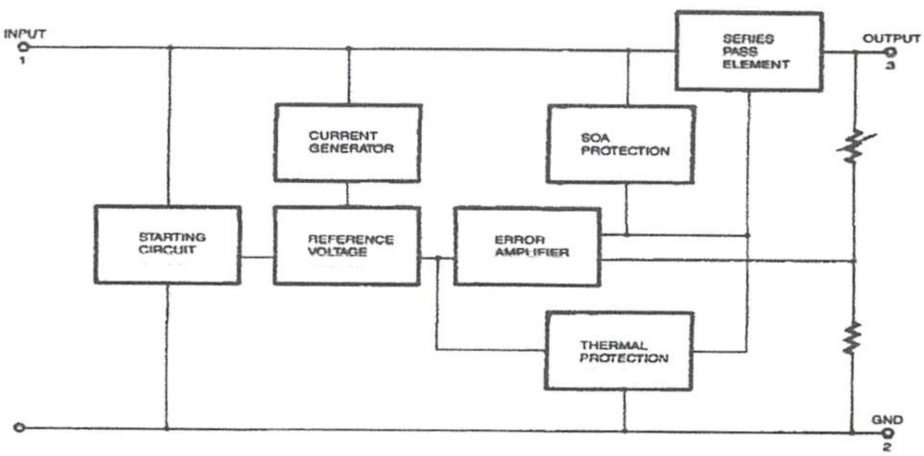
1

D-PAK

1

1. Input 2. GND 3. Output

Internal Block Digram



Rev. 1.0.1

001 Fairchild Semiconductor Corporation

Absolute Maximum Ratings

Parameter	Symbol	Value	Unit
Input Voltage (for V_O = 5V to 18V) (for V_O = 24V)	V_I V_I	35 40	V V
Thermal Resistance Junction-Cases (TO-220)	$R_{\theta JC}$	5	°C/W
Thermal Resistance Junction-Air (TO-220)	$R_{\theta JA}$	65	°C/W
Operating Temperature Range	T_{OPR}	0 ~ +125	°C
Storage Temperature Range	T_{STG}	-65 ~ +150	°C

Electrical Characteristics (MC7805/LM7805)

Refer to test circuit ,0°C < T_J < 125°C, I_O = 500mA, V_I = 10V, C_I= 0.33μF, C_O= 0.1μF, unless otherwise specified)

Parameter	Symbol	Conditions		MC7805/LM7805			Unit
				Min.	Typ.	Max.	
Output Voltage	V_O	T_J =+25 °C		4.8	5.0	5.2	V
		5.0mA ≤ Io ≤ 1.0A, P_O ≤ 15W V_I = 7V to 20V		4.75	5.0	5.25	
Line Regulation (Note1)	Regline	T_J=+25 °C	V_O = 7V to 25V	-	4.0	100	mV
			V_I = 8V to 12V	-	1.6	50	
Load Regulation (Note1)	Regload	T_J=+25 °C	I_O = 5.0mA to1.5A	-	9	100	mV
			I_O =250mA to 750mA	-	4	50	
Quiescent Current	I_Q	T_J =+25 °C		-	5.0	8.0	mA
Quiescent Current Change	ΔI_Q	I_O = 5mA to 1.0A		-	0.03	0.5	mA
		V_I= 7V to 25V		-	0.3	1.3	
Output Voltage Drift	$\Delta V_O/\Delta T$	I_O= 5mA		-	-0.8	-	mV/ °C
Output Noise Voltage	V_N	f = 10Hz to 100KHz, T_A=+25 °C		-	42	-	μV/Vo
Ripple Rejection	RR	f = 120Hz V_O = 8V to 18V		62	73	-	dB
Dropout Voltage	V_{Drop}	I_O = 1A, T_J =+25 °C		-	2	-	V
Output Resistance	r_O	f = 1KHz		-	15	-	mΩ
Short Circuit Current	I_{SC}	V_I = 35V, T_A =+25 °C		-	230	-	mA
Peak Current	I_{PK}	T_J =+25 °C		-	2.2	-	A

ote:

. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

Electrical Characteristics (MC7806)

(Refer to test circuit ,0°C < T_J < 125°C, I_O = 500mA, V_I =11V, C_I= 0.33µF, C_O= 0.1µF, unless otherwise specified)

Parameter	Symbol	Conditions		MC7806 Min.	Typ.	Max.	Unit
Output Voltage	V_O	T_J =+25 °C		5.75	6.0	6.25	V
		5.0mA ≤ I_O ≤ 1.0A, P_O ≤ 15W V_I = 8.0V to 21V		5.7	6.0	6.3	
Line Regulation (Note1)	Regline	T_J =+25 °C	V_I = 8V to 25V	-	5	120	mV
			V_I = 9V to 13V	-	1.5	60	
Load Regulation (Note1)	Regload	T_J =+25 °C	I_O =5mA to 1.5A	-	9	120	mV
			I_O =250mA to750A	-	3	60	
Quiescent Current	I_Q	T_J =+25 °C		-	5.0	8.0	mA
Quiescent Current Change	ΔI_Q	I_O = 5mA to 1A		-	-	0.5	mA
		V_I = 8V to 25V		-	-	1.3	
Output Voltage Drift	$\Delta V_O/\Delta T$	I_O = 5mA		-	-0.8	-	mV/ °C
Output Noise Voltage	V_N	f = 10Hz to 100KHz, T_A =+25 °C		-	45	-	µV/Vo
Ripple Rejection	RR	f = 120Hz V_I = 9V to 19V		59	75	-	dB
Dropout Voltage	V_{Drop}	I_O = 1A, T_J =+25 °C		-	2	-	V
Output Resistance	r_O	f = 1KHz		-	19	-	mΩ
Short Circuit Current	I_{SC}	V_I= 35V, T_A=+25 °C		-	250	-	mA
Peak Current	I_{PK}	T_J =+25 °C		-	2.2	-	A

Note:

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

Electrical Characteristics (MC7808)

(Refer to test circuit ,0°C < T_J < 125°C, I_O = 500mA, V_I =14V, C_I= 0.33μF, C_O= 0.1μF, unless otherwise specified)

Parameter	Symbol	Conditions		MC7808 Min.	Typ.	Max.	Unit
Output Voltage	V_O	T_J =+25 °C		7.7	8.0	8.3	V
		5.0mA ≤ I_O ≤ 1.0A, P_O ≤ 15W V_I = 10.5V to 23V		7.6	8.0	8.4	
Line Regulation (Note1)	Regline	T_J =+25 °C	V_I = 10.5V to 25V	-	5.0	160	mV
			V_I = 11.5V to 17V	-	2.0	80	
Load Regulation (Note1)	Regload	T_J =+25 °C	I_O = 5.0mA to 1.5A	-	10	160	mV
			I_O= 250mA to 750mA	-	5.0	80	
Quiescent Current	I_Q	T_J =+25 °C		-	5.0	8.0	mA
Quiescent Current Change	ΔI_Q	I_O = 5mA to 1.0A		-	0.05	0.5	mA
		V_I = 10.5A to 25V		-	0.5	1.0	
Output Voltage Drift	$\Delta V_O/\Delta T$	I_O = 5mA		-	-0.8	-	mV/ °C
Output Noise Voltage	V_N	f = 10Hz to 100KHz, T_A =+25 °C		-	52	-	μV/Vo
Ripple Rejection	RR	f = 120Hz, V_I= 11.5V to 21.5V		56	73	-	dB
Dropout Voltage	V_{Drop}	I_O = 1A, T_J=+25 °C		-	2	-	V
Output Resistance	r_O	f = 1KHz		-	17	-	mΩ
Short Circuit Current	I_{SC}	V_I= 35V, T_A =+25 °C		-	230	-	mA
Peak Current	I_{PK}	T_J =+25 °C		-	2.2	-	A

Note:

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

:lectrical Characteristics (MC7809)

Refer to test circuit ,0°C < T_J < 125°C, I_O = 500mA, V_I =15V, C_I= 0.33µF, C_O= 0.1µF, unless otherwise specified)

Parameter	Symbol	Conditions		MC7809 Min.	Typ.	Max.	Unit
Output Voltage	V_O	T_J =+25°C		8.65	9	9.35	V
		5.0mA≤ I_O ≤1.0A, P_O ≤15W V_I= 11.5V to 24V		8.6	9	9.4	
Line Regulation (Note1)	Regline	T_J=+25°C	V_I = 11.5V to 25V	-	6	180	mV
			V_I = 12V to 17V	-	2	90	
Load Regulation (Note1)	Regload	T_J=+25°C	I_O = 5mA to 1.5A	-	12	180	mV
			I_O = 250mA to 750mA	-	4	90	
Quiescent Current	I_Q	T_J=+25°C		-	5.0	8.0	mA
Quiescent Current Change	ΔI_Q	I_O = 5mA to 1.0A		-	-	0.5	mA
		V_I = 11.5V to 26V		-	-	1.3	
Output Voltage Drift	$\Delta V_O/\Delta T$	I_O = 5mA		-	-1	-	mV/ °C
Output Noise Voltage	V_N	f = 10Hz to 100KHz, T_A =+25 °C		-	58	-	µV/Vo
Ripple Rejection	RR	f = 120Hz V_I = 13V to 23V		56	71	-	dB
Dropout Voltage	V_{Drop}	I_O = 1A, T_J=+25°C		-	2	-	V
Output Resistance	r_O	f = 1KHz		-	17	-	mΩ
Short Circuit Current	I_{SC}	V_I= 35V, T_A =+25°C		-	250	-	mA
Peak Current	I_{PK}	T_J= +25°C		-	2.2	-	A

ote:

Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

Electrical Characteristics (MC7810)

(Refer to test circuit ,0°C< T_J < 125°C, I_O = 500mA, V_I =16V, C_I= 0.33μF, C_O=0.1μF, unless otherwise specified)

Parameter	Symbol	Conditions		MC7810 Min.	Typ.	Max.	Unit
Output Voltage	V_O	T_J =+25 °C		9.6	10	10.4	V
		5.0mA ≤ I_O≤1.0A, P_O ≤15W V_I = 12.5V to 25V		9.5	10	10.5	
Line Regulation (Note1)	Regline	T_J =+25°C	V_I = 12.5V to 25V	-	10	200	mV
			V_I = 13V to 25V	-	3	100	
Load Regulation (Note1)	Regload	T_J =+25°C	I_O = 5mA to 1.5A	-	12	200	mV
			I_O = 250mA to 750mA	-	4	400	
Quiescent Current	I_Q	T_J =+25°C		-	5.1	8.0	mA
Quiescent Current Change	ΔI_Q	I_O = 5mA to 1.0A		-	-	0.5	mA
		V_I = 12.5V to 29V		-	-	1.0	
Output Voltage Drift	$\Delta V_O/\Delta T$	I_O = 5mA		-	-1	-	mV/°C
Output Noise Voltage	V_N	f = 10Hz to 100KHz, T_A =+25 °C		-	58	-	μV/Vo
Ripple Rejection	RR	f = 120Hz V_I = 13V to 23V		56	71	-	dB
Dropout Voltage	V_{Drop}	I_O = 1A, T_J=+25 °C		-	2	-	V
Output Resistance	r_O	f = 1KHz		-	17	-	mΩ
Short Circuit Current	I_{SC}	V_I = 35V, T_A=+25 °C		-	250	-	mA
Peak Current	I_{PK}	T_J =+25 °C		-	2.2	-	A

Note:

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

:lectrical Characteristics (MC7812)

Refer to test circuit ,0°C < T_J < 125°C, I_O = 500mA, V_I =19V, C_I= 0.33μF, C_O=0.1μF, unless otherwise specified)

Parameter	Symbol	Conditions		MC7812			Unit
				Min.	Typ.	Max.	
Output Voltage	V_O	T_J =+25 °C		11.5	12	12.5	V
		5.0mA ≤ I_O≤1.0A, P_O≤15W V_I = 14.5V to 27V		11.4	12	12.6	
Line Regulation (Note1)	Regline	T_J =+25 °C	V_I = 14.5V to 30V	-	10	240	mV
			V_I = 16V to 22V	-	3.0	120	
Load Regulation (Note1)	Regload	T_J =+25 °C	I_O = 5mA to 1.5A	-	11	240	mV
			I_O = 250mA to 750mA	-	5.0	120	
Quiescent Current	I_Q	T_J =+25 °C		-	5.1	8.0	mA
Quiescent Current Change	ΔI_Q	I_O = 5mA to 1.0A		-	0.1	0.5	mA
		V_I = 14.5V to 30V		-	0.5	1.0	
Output Voltage Drift	$\Delta V_O/\Delta T$	I_O = 5mA		-	-1	-	mV/ °C
Output Noise Voltage	V_N	f = 10Hz to 100KHz, T_A =+25 °C		-	76	-	μV/Vo
Ripple Rejection	RR	f = 120Hz V_I = 15V to 25V		55	71	-	dB
Dropout Voltage	V_{Drop}	I_O = 1A, T_J=+25 °C		-	2	-	V
Output Resistance	r_O	f = 1KHz		-	18	-	mΩ
Short Circuit Current	I_{SC}	V_I = 35V, T_A=+25 °C		-	230	-	mA
Peak Current	I_{PK}	T_J = +25 °C		-	2.2	-	A

'ote:

. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

:lectrical Characteristics (MC7815)

Refer to test circuit ,0°C < T_J < 125°C, I_O = 500mA, V_I =23V, C_I= 0.33µF, C_O=0.1µF, unless otherwise specified)

Parameter	Symbol	Conditions		MC7815 Min.	MC7815 Typ.	MC7815 Max.	Unit
Output Voltage	V_O	T_J =+25 °C		14.4	15	15.6	V
		5.0mA ≤ I_O ≤ 1.0A, P_O ≤ 15W V_I = 17.5V to 30V		14.25	15	15.75	
Line Regulation (Note1)	Regline	T_J =+25 °C	V_I = 17.5V to 30V	-	11	300	mV
			V_I = 20V to 26V	-	3	150	
Load Regulation (Note1)	Regload	T_J =+25 °C	I_O = 5mA to 1.5A	-	12	300	mV
			I_O = 250mA to 750mA	-	4	150	
Quiescent Current	I_Q	T_J =+25 °C		-	5.2	8.0	mA
Quiescent Current Change	ΔI_Q	I_O = 5mA to 1.0A		-	-	0.5	mA
		V_I = 17.5V to 30V		-	-	1.0	
Output Voltage Drift	$\Delta V_O/\Delta T$	I_O = 5mA		-	-1	-	mV/ °C
Output Noise Voltage	V_N	f = 10Hz to 100KHz, T_A =+25 °C		-	90	-	µV/Vo
Ripple Rejection	RR	f = 120Hz V_I = 18.5V to 28.5V		54	70	-	dB
Dropout Voltage	V_{Drop}	I_O = 1A, T_J=+25 °C		-	2	-	V
Output Resistance	r_O	f = 1KHz		-	19	-	mΩ
Short Circuit Current	I_{SC}	V_I = 35V, T_A=+25 °C		-	250	-	mA
Peak Current	I_{PK}	T_J =+25 °C		-	2.2	-	A

lote:

. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

:lectrical Characteristics (MC7818)

Refer to test circuit ,0°C < T_J < 125°C, I_O = 500mA, V_I =27V, C_I= 0.33µF, C_O=0.1µF, unless otherwise specified)

Parameter	Symbol	Conditions		MC7818 Min.	MC7818 Typ.	MC7818 Max.	Unit
Output Voltage	V_O	T_J =+25 °C		17.3	18	18.7	V
		5.0mA ≤ I_O ≤1.0A, P_O ≤15W V_I = 21V to 33V		17.1	18	18.9	
Line Regulation (Note1)	Regline	T_J =+25 °C	V_I = 21V to 33V	-	15	360	mV
			V_I = 24V to 30V	-	5	180	
Load Regulation (Note1)	Regload	T_J =+25 °C	I_O = 5mA to 1.5A	-	15	360	mV
			I_O = 250mA to 750mA	-	5.0	180	
Quiescent Current	I_Q	T_J =+25 °C		-	5.2	8.0	mA
Quiescent Current Change	ΔI_Q	I_O = 5mA to 1.0A		-	-	0.5	mA
		V_I = 21V to 33V		-	-	1	
Output Voltage Drift	$\Delta V_O/\Delta T$	I_O = 5mA		-	-1	-	mV/ °C
Output Noise Voltage	V_N	f = 10Hz to 100KHz, T_A =+25 °C		-	110	-	µV/Vo
Ripple Rejection	RR	f = 120Hz V_I = 22V to 32V		53	69	-	dB
Dropout Voltage	V_{Drop}	I_O = 1A, T_J=+25 °C		-	2	-	V
Output Resistance	r_O	f = 1KHz		-	22	-	mΩ
Short Circuit Current	I_{SC}	V_I = 35V, T_A=+25 °C		-	250	-	mA
Peak Current	I_{PK}	T_J =+25 °C		-	2.2	-	A

lote:

. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

Electrical Characteristics (MC7824)

(Refer to test circuit ,0°C < T_J < 125°C, I_O = 500mA, V_I =33V, C_I= 0.33µF, C_O=0.1µF, unless otherwise specified)

Parameter	Symbol	Conditions		MC7824			Unit
				Min.	Typ.	Max.	
Output Voltage	V_O	T_J =+25 °C		23	24	25	V
		5.0mA ≤ I_O ≤ 1.0A, P_O ≤ 15W V_I = 27V to 38V		22.8	24	25.25	
Line Regulation (Note1)	Regline	T_J =+25 °C	V_I = 27V to 38V	-	17	480	mV
			V_I = 30V to 36V	-	6	240	
Load Regulation (Note1)	Regload	T_J =+25 °C	I_O = 5mA to 1.5A	-	15	480	mV
			I_O = 250mA to 750mA	-	5.0	240	
Quiescent Current	I_Q	T_J =+25 °C		-	5.2	8.0	mA
Quiescent Current Change	ΔI_Q	I_O = 5mA to 1.0A		-	0.1	0.5	mA
		V_I = 27V to 38V		-	0.5	1	
Output Voltage Drift	$\Delta V_O/\Delta T$	I_O = 5mA		-	-1.5	-	mV/ °C
Output Noise Voltage	V_N	f = 10Hz to 100KHz, T_A =+25 °C		-	60	-	µV/Vo
Ripple Rejection	RR	f = 120Hz V_I = 28V to 38V		50	67	-	dB
Dropout Voltage	V_{Drop}	I_O = 1A, T_J=+25 °C		-	2	-	V
Output Resistance	r_O	f = 1KHz		-	28	-	mΩ
Short Circuit Current	I_{SC}	V_I = 35V, T_A=+25 °C		-	230	-	mA
Peak Current	I_{PK}	T_J =+25 °C		-	2.2	-	A

Note:

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

lectrical Characteristics (MC7805A)

efer to the test circuits. 0°C < T_J < 125°C, I_O =1A, V_I = 10V, C_I=0.33µF, C_O=0.1µF, unless otherwise specified)

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit
Output Voltage	V_O	T_J =+25 °C		4.9	5	5.1	V
		I_O = 5mA to 1A, P_O ≤ 15W V_I = 7.5V to 20V		4.8	5	5.2	
Line Regulation (Note1)	Regline	V_I = 7.5V to 25V I_O = 500mA		-	5	50	mV
		V_I = 8V to 12V		-	3	50	
		T_J =+25 °C	V_I= 7.3V to 20V	-	5	50	
			V_I= 8V to 12V	-	1.5	25	
Load Regulation (Note1)	Regload	T_J =+25 °C I_O = 5mA to 1.5A		-	9	100	mV
		I_O = 5mA to 1A		-	9	100	
		I_O = 250mA to 750mA		-	4	50	
Quiescent Current	I_Q	T_J =+25 °C		-	5.0	6	mA
Quiescent Current Change	ΔI_Q	I_O = 5mA to 1A		-	-	0.5	mA
		V_I = 8 V to 25V, I_O = 500mA		-	-	0.8	
		V_I = 7.5V to 20V, T_J =+25 °C		-	-	0.8	
Output Voltage Drift	ΔV/ΔT	I_O = 5mA		-	-0.8	-	mV/ °C
Output Noise Voltage	V_N	f = 10Hz to 100KHz T_A =+25 °C		-	10	-	µV/Vo
Ripple Rejection	RR	f = 120Hz, I_O = 500mA V_I = 8V to 18V		-	68	-	dB
Dropout Voltage	V_{Drop}	I_O = 1A, T_J =+25 °C		-	2	-	V
Output Resistance	r_O	f = 1KHz		-	17	-	mΩ
Short Circuit Current	I_{SC}	V_I= 35V, T_A =+25 °C		-	250	-	mA
Peak Current	I_{PK}	T_J= +25 °C		-	2.2	-	A

ote:

Load and line regulation are specified at constant junction temperature. Change in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

:lectrical Characteristics (MC7806A)

Refer to the test circuits. 0°C < T_J < 125°C, I_o =1A, V_I =11V, C_I=0.33μF, C_O=0.1μF, unless otherwise specified)

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit
Output Voltage	VO	TJ =+25 °C		5.58	6	6.12	V
		IO = 5mA to 1A, PO ≤ 15W VI = 8.6V to 21V		5.76	6	6.24	
Line Regulation (Note1)	Regline	VI= 8.6V to 25V IO = 500mA		-	5	60	mV
		VI= 9V to 13V		-	3	60	
		TJ =+25 °C	VI= 8.3V to 21V	-	5	60	
			VI= 9V to 13V	-	1.5	30	
Load Regulation (Note1)	Regload	TJ =+25 °C IO = 5mA to 1.5A		-	9	100	mV
		IO = 5mA to 1A		-	4	100	
		IO = 250mA to 750mA		-	5.0	50	
Quiescent Current	IQ	TJ =+25 °C		-	4.3	6	mA
Quiescent Current Change	ΔIQ	IO = 5mA to 1A		-	-	0.5	mA
		VI = 9V to 25V, IO = 500mA		-	-	0.8	
		VI= 8.5V to 21V, TJ =+25 °C		-	-	0.8	
Output Voltage Drift	ΔV/ΔT	IO = 5mA		-	-0.8	-	mV/ °C
Output Noise Voltage	VN	f = 10Hz to 100KHz TA =+25 °C		-	10	-	μV/Vo
Ripple Rejection	RR	f = 120Hz, IO = 500mA VI = 9V to 19V		-	65	-	dB
Dropout Voltage	VDrop	IO = 1A, TJ =+25 °C		-	2	-	V
Output Resistance	rO	f = 1KHz		-	17	-	mΩ
Short Circuit Current	ISC	VI= 35V, TA =+25 °C		-	250	-	mA
Peak Current	IPK	TJ=+25 °C		-	2.2	-	A

ote:

Load and line regulation are specified at constant junction temperature. Change in VO due to heating effects must be taken into account separately. Pulse testing with low duty is used.

:lectrical Characteristics (MC7808A)

Refer to the test circuits. 0°C < T_J < 125°C, I_o =1A, V_I = 14V, C_I=0.33μF, C_O=0.1μF, unless otherwise specified)

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit
Output Voltage	V_O	T_J =+25 °C		7.84	8	8.16	V
		I_O = 5mA to 1A, P_O ≤15W V_I = 10.6V to 23V		7.7	8	8.3	
Line Regulation (Note1)	Regline	V_I= 10.6V to 25V I_O = 500mA		-	6	80	mV
		V_I= 11V to 17V		-	3	80	
		T_J =+25 °C	V_I= 10.4V to 23V	-	6	80	
			V_I= 11V to 17V	-	2	40	
Load Regulation (Note1)	Regload	T_J =+25 °C I_O = 5mA to 1.5A		-	12	100	mV
		I_O = 5mA to 1A		-	12	100	
		I_O = 250mA to 750mA		-	5	50	
Quiescent Current	I_Q	T_J =+25 °C		-	5.0	6	mA
Quiescent Current Change	ΔIQ	I_O = 5mA to 1A		-	-	0.5	mA
		V_I = 11V to 25V, I_O = 500mA		-	-	0.8	
		V_I= 10.6V to 23V, T_J =+25 °C		-	-	0.8	
Output Voltage Drift	ΔV/ΔT	I_O = 5mA		-	-0.8	-	mV/ °C
Output Noise Voltage	V_N	f = 10Hz to 100KHz T_A =+25 °C		-	10	-	μV/Vo
Ripple Rejection	RR	f = 120Hz, I_O = 500mA V_I = 11.5V to 21.5V		-	62	-	dB
Dropout Voltage	V_{Drop}	I_O = 1A, T_J =+25 °C		-	2	-	V
Output Resistance	r_O	f = 1KHz		-	18	-	mΩ
Short Circuit Current	I_{SC}	V_I= 35V, T_A =+25 °C		-	250	-	mA
Peak Current	I_{PK}	T_J=+25 °C		-	2.2	-	A

ote:

Load and line regulation are specified at constant junction temperature. Change in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

:lectrical Characteristics (MC7809A)

ʔefer to the test circuits. 0°C < T_J < 125°C, I_o =1A, V_I = 15V, C_I=0.33µF, C_O=0.1µF, unless otherwise specified)

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit
Output Voltage	VO	TJ =+25°C		8.82	9.0	9.18	V
		IO = 5mA to 1A, PO≤15W VI = 11.2V to 24V		8.65	9.0	9.35	
Line Regulation (Note1)	Regline	VI= 11.7V to 25V IO = 500mA		-	6	90	mV
		VI= 12.5V to 19V		-	4	45	
		TJ =+25°C	VI= 11.5V to 24V	-	6	90	
			VI= 12.5V to 19V	-	2	45	
Load Regulation (Note1)	Regload	TJ =+25°C IO = 5mA to 1.0A		-	12	100	mV
		IO = 5mA to 1.0A		-	12	100	
		IO = 250mA to 750mA		-	5	50	
Quiescent Current	IQ	TJ =+25 °C		-	5.0	6.0	mA
Quiescent Current Change	ΔIQ	VI = 11.7V to 25V, TJ=+25 °C		-	-	0.8	mA
		VI = 12V to 25V, IO = 500mA		-	-	0.8	
		IO = 5mA to 1.0A		-	-	0.5	
Output Voltage Drift	ΔV/ΔT	IO = 5mA		-	-1.0	-	mV/ °C
Output Noise Voltage	VN	f = 10Hz to 100KHz TA =+25 °C		-	10	-	µV/Vo
Ripple Rejection	RR	f = 120Hz, IO = 500mA VI = 12V to 22V		-	62	-	dB
Dropout Voltage	VDrop	IO = 1A, TJ =+25 °C		-	2.0	-	V
Output Resistance	rO	f = 1KHz		-	17	-	mΩ
Short Circuit Current	ISC	VI= 35V, TA =+25 °C		-	250	-	mA
Peak Current	IPK	TJ=+25°C		-	2.2	-	A

ote:

Load and line regulation are specified at constant, junction temperature. Change in VO due to heating effects must be taken into account separately. Pulse testing with low duty is used.

lectrical Characteristics (MC7810A)

Refer to the test circuits. 0°C < T_J < 125°C, I_O =1A, V_I = 16V, C_I=0.33µF, C_O=0.1µF, unless otherwise specified)

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit
Output Voltage	V_O	T_J =+25°C		9.8	10	10.2	V
		I_O = 5mA to 1A, P_O ≤ 15W V_I =12.8V to 25V		9.6	10	10.4	
Line Regulation (Note1)	Regline	V_I= 12.8V to 26V I_O = 500mA		-	8	100	mV
		V_I= 13V to 20V		-	4	50	
		T_J =+25°C	V_I= 12.5V to 25V	-	8	100	
			V_I= 13V to 20V	-	3	50	
Load Regulation (Note1)	Regload	T_J =+25°C I_O = 5mA to 1.5A		-	12	100	mV
		I_O = 5mA to 1.0A		-	12	100	
		I_O = 250mA to 750mA		-	5	50	
Quiescent Current	I_Q	T_J =+25°C		-	5.0	6.0	mA
Quiescent Current Change	ΔI_Q	V_I = 13V to 26V, T_J=+25°C		-	-	0.5	mA
		V_I = 12.8V to 25V, I_O = 500mA		-	-	0.8	
		I_O = 5mA to 1.0A		-	-	0.5	
Output Voltage Drift	ΔV/ΔT	I_O = 5mA		-	-1.0	-	mV/°C
Output Noise Voltage	V_N	f = 10Hz to 100KHz T_A =+25°C		-	10	-	µV/Vo
Ripple Rejection	RR	f = 120Hz, I_O = 500mA V_I = 14V to 24V		-	62	-	dB
Dropout Voltage	V_{Drop}	I_O = 1A, T_J =+25°C		-	2.0	-	V
Output Resistance	r_O	f = 1KHz		-	17	-	mΩ
Short Circuit Current	I_{SC}	V_I= 35V, T_A =+25°C		-	250	-	mA
Peak Current	I_{PK}	T_J=+25°C		-	2.2	-	A

ote:

Load and line regulation are specified at constant junction temperature. Change in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

:lectrical Characteristics (MC7812A)

₹efer to the test circuits. 0°C < T_J < 125°C, I_O =1A, V_I = 19V, C_I=0.33µF, C_O=0.1µF, unless otherwise specified)

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit
Output Voltage	V_O	T_J =+25°C		11.75	12	12.25	V
		I_O = 5mA to 1A, P_O ≤15W V_I = 14.8V to 27V		11.5	12	12.5	
Line Regulation (Note1)	Regline	V_I= 14.8V to 30V I_O = 500mA		-	10	120	mV
		V_I= 16V to 22V		-	4	120	
		T_J =+25°C	V_I= 14.5V to 27V	-	10	120	
			V_I= 16V to 22V	-	3	60	
Load Regulation (Note1)	Regload	T_J =+25°C I_O = 5mA to 1.5A		-	12	100	mV
		I_O = 5mA to 1.0A		-	12	100	
		I_O = 250mA to 750mA		-	5	50	
Quiescent Current	I_Q	T_J =+25°C		-	5.1	6.0	mA
Quiescent Current Change	ΔI_Q	V_I = 15V to 30V, T_J=+25°C		-		0.8	mA
		V_I = 14V to 27V, I_O = 500mA		-		0.8	
		I_O = 5mA to 1.0A		-		0.5	
Output Voltage Drift	$\Delta V/\Delta T$	I_O = 5mA		-	-1.0	-	mV/°C
Output Noise Voltage	V_N	f = 10Hz to 100KHz T_A =+25°C		-	10	-	µV/Vo
Ripple Rejection	RR	f = 120Hz, I_O = 500mA V_I = 14V to 24V		-	60	-	dB
Dropout Voltage	V_{Drop}	I_O = 1A, T_J =+25°C		-	2.0	-	V
Output Resistance	r_O	f = 1KHz		-	18	-	mΩ
Short Circuit Current	I_{SC}	V_I= 35V, T_A =+25°C		-	250	-	mA
Peak Current	I_{PK}	T_J=+25°C		-	2.2	-	A

ɔte:

Load and line regulation are specified at constant junction temperature. Change in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

:lectrical Characteristics (MC7815A)

ɿefer to the test circuits. 0°C < T_J < 125°C, I_o =1A, V_I =23V, C_I=0.33µF, C_O=0.1µF, unless otherwise specified)

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit
Output Voltage	V_O	T_J =+25 °C		14.7	15	15.3	V
		I_O = 5mA to 1A, P_O ≤15W V_I = 17.7V to 30V		14.4	15	15.6	
Line Regulation (Note1)	Regline	V_I= 17.9V to 30V I_O = 500mA		-	10	150	mV
		V_I= 20V to 26V		-	5	150	
		T_J =+25°C	V_I= 17.5V to 30V	-	11	150	
			V_I= 20V to 26V	-	3	75	
Load Regulation (Note1)	Regload	T_J =+25 °C I_O = 5mA to 1.5A		-	12	100	mV
		I_O = 5mA to 1.0A		-	12	100	
		I_O = 250mA to 750mA		-	5	50	
Quiescent Current	I_Q	T_J =+25 °C		-	5.2	6.0	mA
Quiescent Current Change	ΔI_Q	V_I = 17.5V to 30V, T_J =+25 °C		-	-	0.8	mA
		V_I = 17.5V to 30V, I_O = 500mA		-	-	0.8	
		I_O = 5mA to 1.0A		-	-	0.5	
Output Voltage Drift	ΔV/ΔT	I_O = 5mA		-	-1.0	-	mV/°C
Output Noise Voltage	V_N	f = 10Hz to 100KHz T_A =+25 °C		-	10	-	µV/Vo
Ripple Rejection	RR	f = 120Hz, I_O = 500mA V_I = 18.5V to 28.5V		-	58	-	dB
Dropout Voltage	V_{Drop}	I_O = 1A, T_J =+25 °C		-	2.0	-	V
Output Resistance	r_O	f = 1KHz		-	19	-	mΩ
Short Circuit Current	I_{SC}	V_I= 35V, T_A =+25 °C		-	250	-	mA
Peak Current	I_{PK}	T_J=+25°C		-	2.2	-	A

ote:

Load and line regulation are specified at constant junction temperature. Change in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

lectrical Characteristics (MC7818A)

Refer to the test circuits. 0°C < T_J < 125°C, I_o =1A, V_I = 27V, C_I=0.33µF, C_O=0.1µF, unless otherwise specified)

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit
Output Voltage	V_O	T_J =+25°C		17.64	18	18.36	V
		I_O = 5mA to 1A, P_O ≤15W V_I = 21V to 33V		17.3	18	18.7	
Line Regulation (Note1)	Regline	V_I= 21V to 33V I_O = 500mA		-	15	180	mV
		V_I= 21V to 33V		-	5	180	
		T_J =+25°C	V_I= 20.6V to 33V	-	15	180	
			V_I= 24V to 30V	-	5	90	
Load Regulation (Note1)	Regload	T_J =+25°C I_O = 5mA to 1.5A		-	15	100	mV
		I_O = 5mA to 1.0A		-	15	100	
		I_O = 250mA to 750mA		-	7	50	
Quiescent Current	I_Q	T_J =+25°C		-	5.2	6.0	mA
Quiescent Current Change	ΔI_Q	V_I = 21V to 33V, T_J=+25°C		-	-	0.8	mA
		V_I = 21V to 33V, I_O = 500mA		-	-	0.8	
		I_O = 5mA to 1.0A		-	-	0.5	
Output Voltage Drift	ΔV/ΔT	I_O = 5mA		-	-1.0	-	mV/°C
Output Noise Voltage	V_N	f = 10Hz to 100KHz T_A =+25°C		-	10	-	µV/Vo
Ripple Rejection	RR	f = 120Hz, I_O = 500mA V_I = 22V to 32V		-	57	-	dB
Dropout Voltage	V_{Drop}	I_O = 1A, T_J =+25°C		-	2.0	-	V
Output Resistance	r_O	f = 1KHz		-	19	-	mΩ
Short Circuit Current	I_{SC}	V_I= 35V, T_A =+25°C		-	250	-	mA
Peak Current	I_{PK}	T_J=+25°C		-	2.2	-	A

ote:

Load and line regulation are specified at constant junction temperature. Change in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

:lectrical Characteristics (MC7824A)

≀efer to the test circuits. 0°C < T_J < 125°C, I_o =1A, V_I = 33V, C_I=0.33μF, C_O=0.1μF, unless otherwise specified)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Output Voltage	VO	TJ =+25°C	23.5	24	24.5	V
		IO = 5mA to 1A, PO ≤15W VI = 27.3V to 38V	23	24	25	
Line Regulation (Note1)	Regline	VI= 27V to 38V IO = 500mA	-	18	240	mV
		VI= 21V to 33V	-	6	240	
		TJ =+25°C, VI= 26.7V to 38V	-	18	240	
		TJ =+25°C, VI= 30V to 36V	-	6	120	
Load Regulation (Note1)	Regload	TJ =+25°C IO = 5mA to 1.5A	-	15	100	mV
		IO = 5mA to 1.0A	-	15	100	
		IO = 250mA to 750mA	-	7	50	
Quiescent Current	IQ	TJ =+25°C	-	5.2	6.0	mA
Quiescent Current Change	ΔIQ	VI = 27.3V to 38V, TJ =+25°C	-	-	0.8	mA
		VI = 27.3V to 38V, IO = 500mA	-	-	0.8	
		IO = 5mA to 1.0A	-	-	0.5	
Output Voltage Drift	ΔV/ΔT	IO = 5mA	-	-1.5	-	mV/°C
Output Noise Voltage	VN	f = 10Hz to 100KHz TA = 25°C	-	10	-	μV/Vo
Ripple Rejection	RR	f = 120Hz, IO = 500mA VI = 28V to 38V	-	54	-	dB
Dropout Voltage	VDrop	IO = 1A, TJ =+25°C	-	2.0	-	V
Output Resistance	rO	f = 1KHz	-	20	-	mΩ
Short Circuit Current	ISC	VI= 35V, TA =+25°C	-	250	-	mA
Peak Current	IPK	TJ=+25°C	-	2.2	-	A

ɔte:

Load and line regulation are specified at constant junction temperature. Change in VO due to heating effects must be taken into account separately. Pulse testing with low duty is used.

ypical Perfomance Characteristics

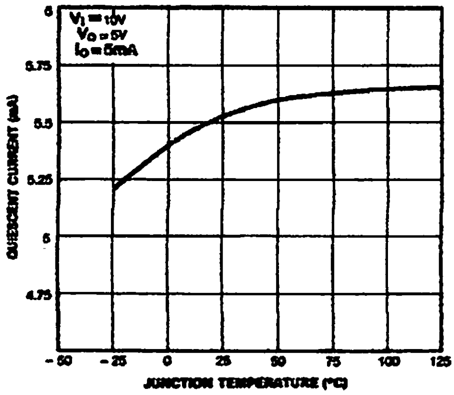


Figure 1. Quiescent Current

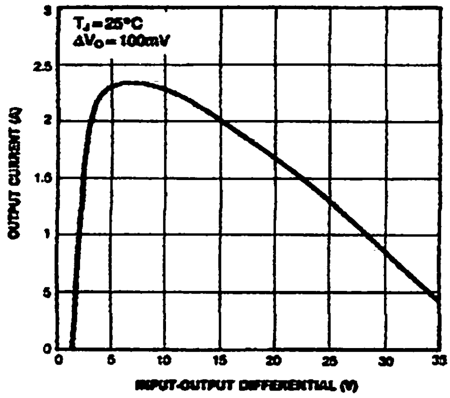


Figure 2. Peak Output Current

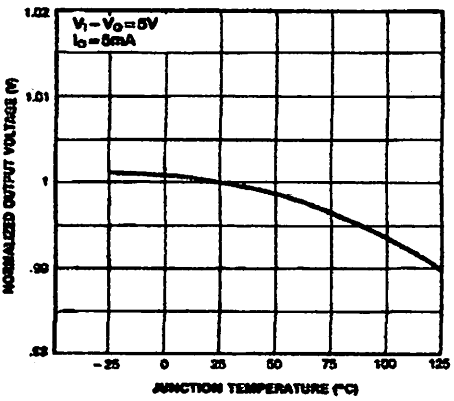


Figure 3. Output Voltage

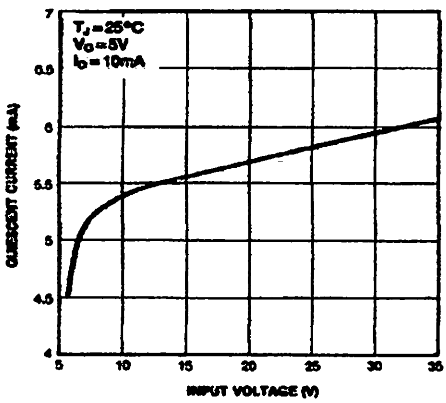


Figure 4. Quiescent Current

ypical Applications

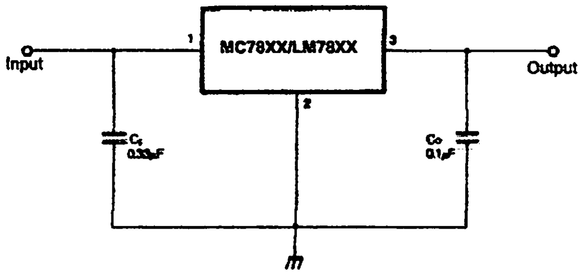


Figure 5. DC Parameters

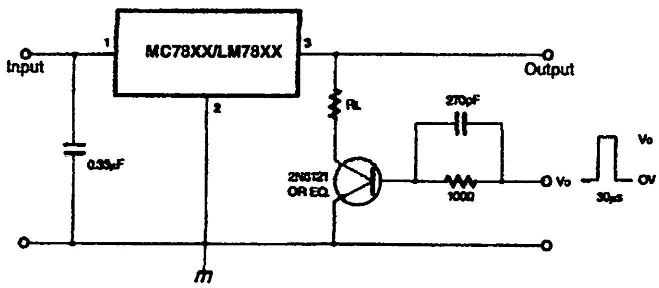


Figure 6. Load Regulation

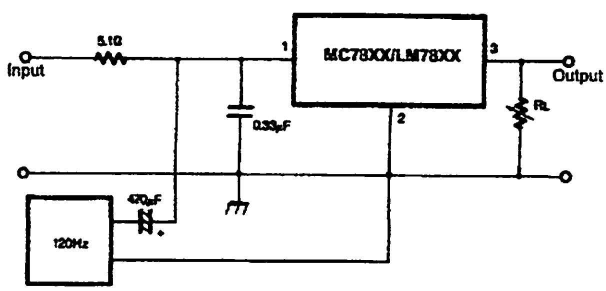


Figure 7. Ripple Rejection

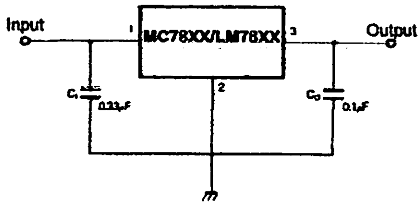
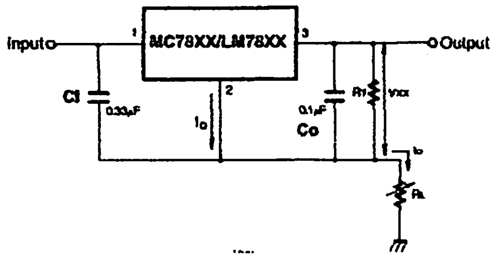


Figure 8. Fixed Output Regulator



$$I_O = \frac{V_{XX}}{R_1} + I_Q$$

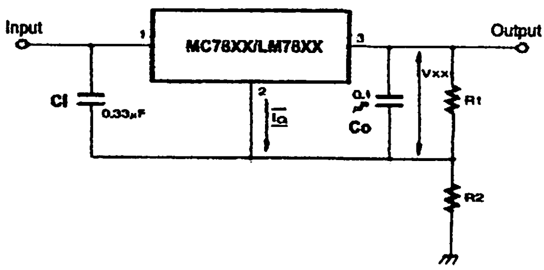
Figure 9. Constant Current Regulator

otes:

) To specify an output voltage. substitute voltage value for "XX." A common ground is required between the input and the Output voltage. The input voltage must remain typically 2.0V above the output voltage even during the low point on the input ripple voltage.

) C_I is required if regulator is located an appreciable distance from power Supply filter.

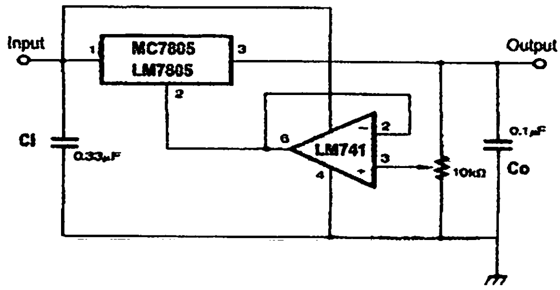
) C_O improves stability and transient response.



$$I_{R1} \geq 5I_Q$$

$$V_O = V_{XX}(1+R_2/R_1)+I_QR_2$$

Figure 10. Circuit for Increasing Output Voltage



$$I_{RI} \geq 5\ I_Q$$

$$V_O = V_{XX}(1+R_2/R_1)+I_QR_2$$

Figure 11. Adjustable Output Regulator (7 to 30V)

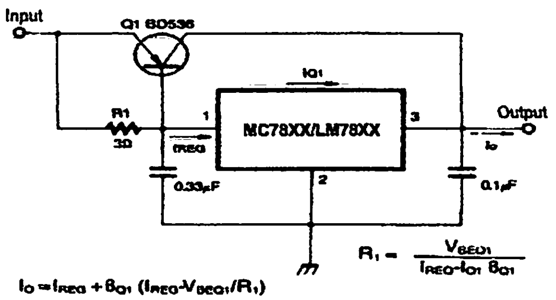


Figure 12. High Current Voltage Regulator

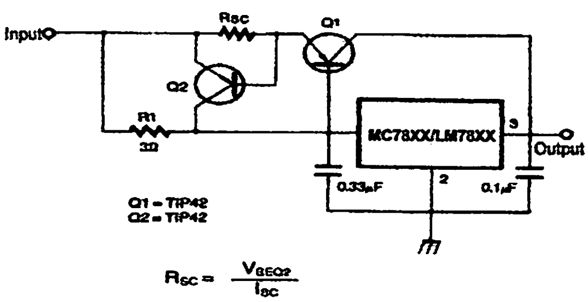


Figure 13. High Output Current with Short Circuit Protection

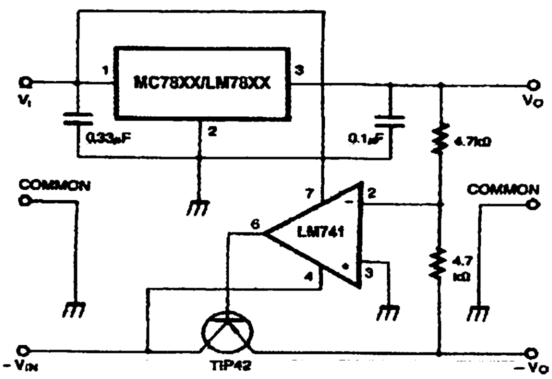


Figure 14. Tracking Voltage Regulator

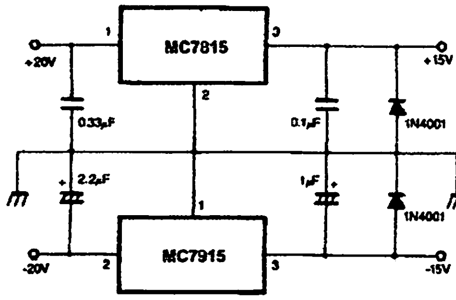


Figure 15. Split Power Supply (±15V-1A)

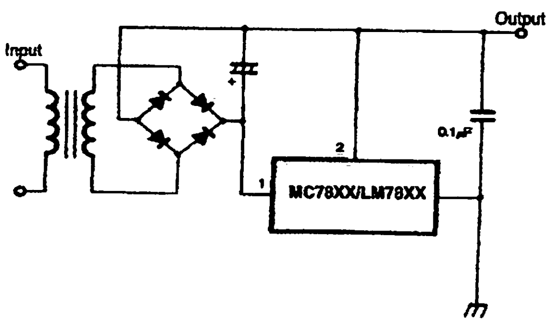


Figure 16. Negative Output Voltage Circuit

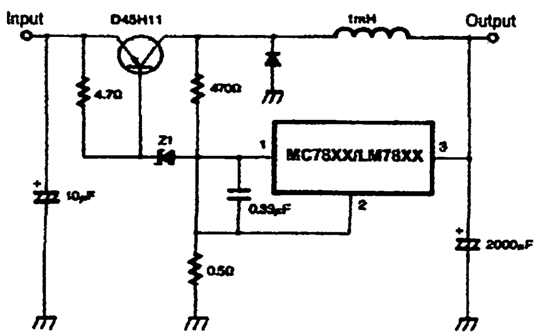
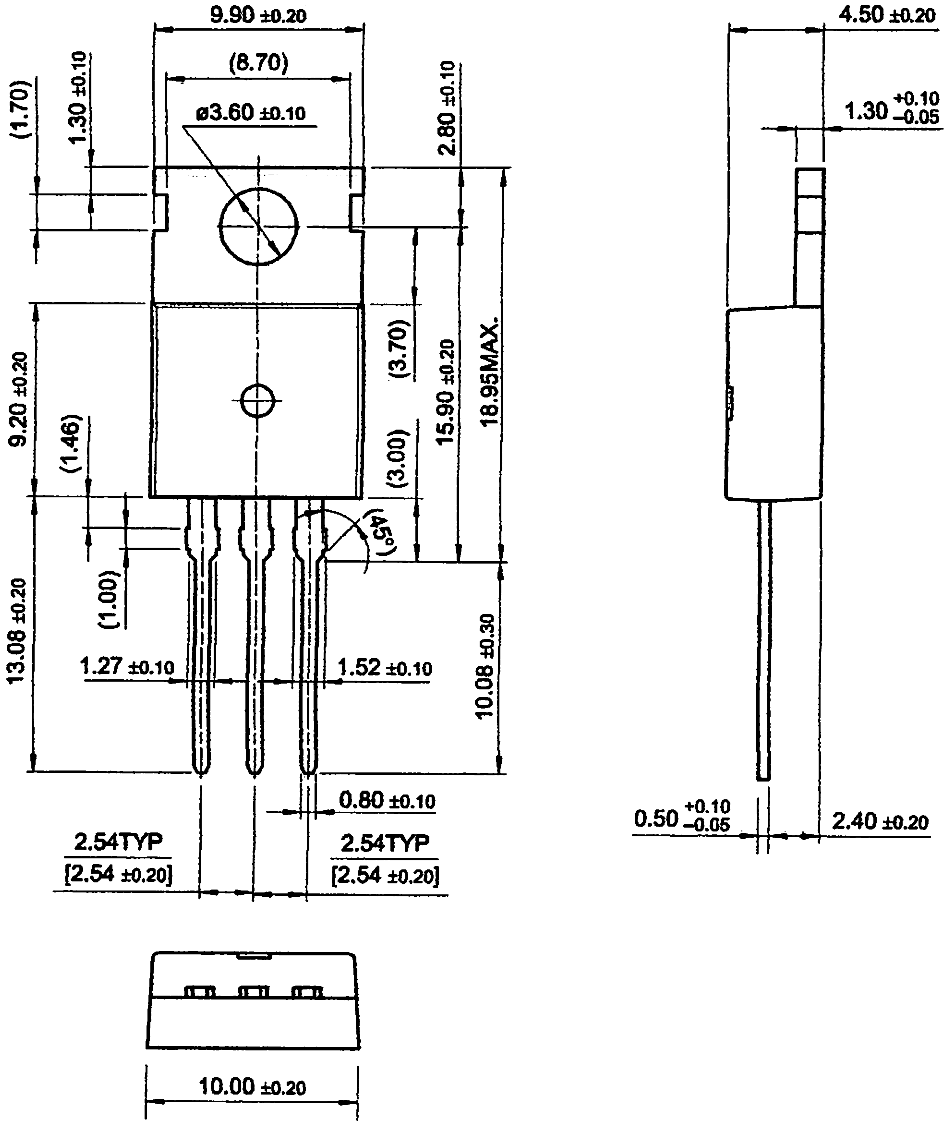


Figure 17. Switching Regulator

lechanical Dimensions

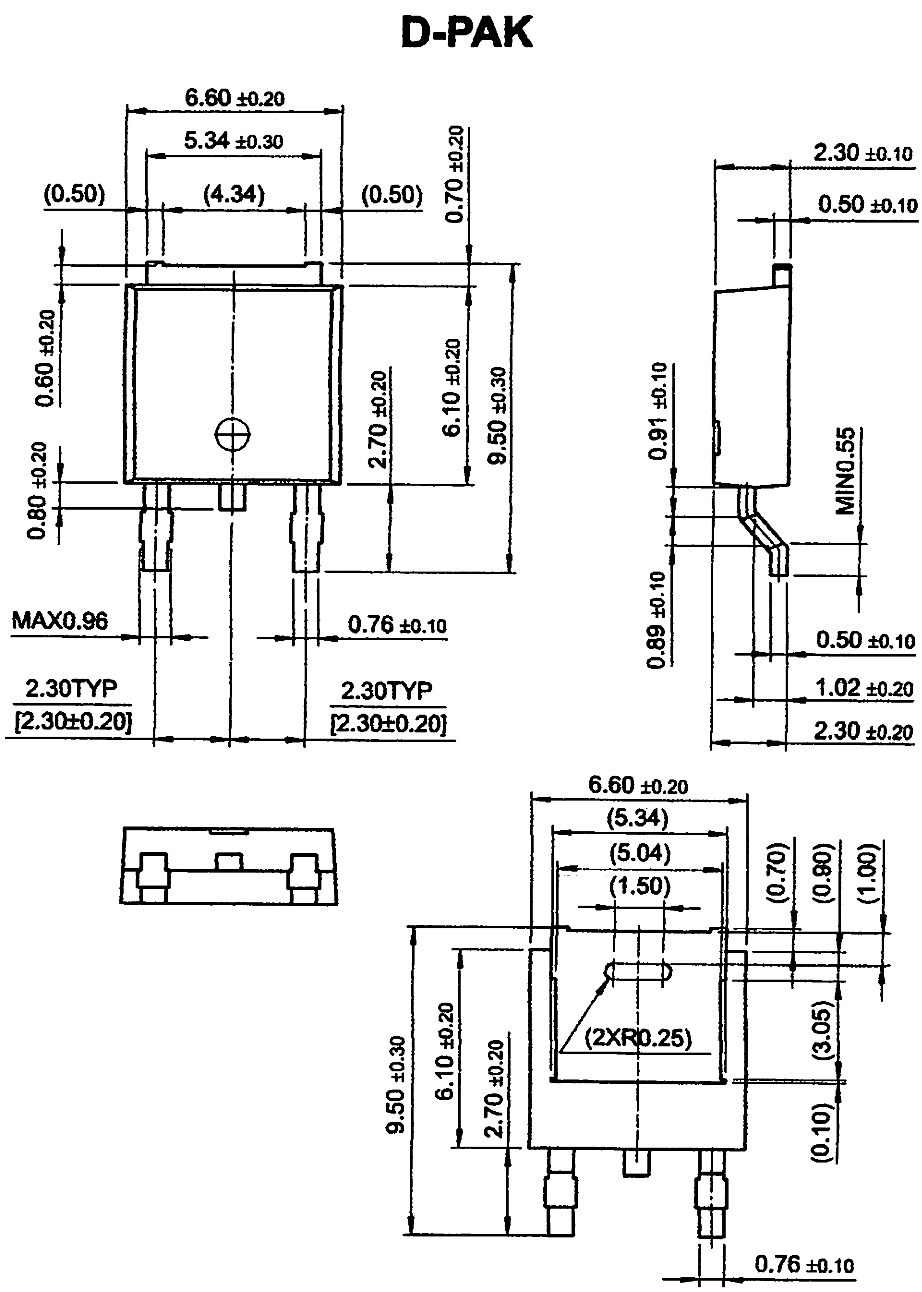
ackage

TO-220



lechancal Dimensions (Continued)

ackage



rdering Information

Product Number	Output Voltage Tolerance	Package	Operating Temperature
LM7805CT	±4%	TO-220	0 ~ + 125°C

Product Number	Output Voltage Tolerance	Package	Operating Temperature
MC7805CT	±4%	TO-220	0 ~ + 125°C
MC7806CT			
MC7808CT			
MC7809CT			
MC7810CT			
MC7812CT			
MC7815CT			
MC7818CT			
MC7824CT			
MC7805CDT		D-PAK	
MC7806CDT			
MC7808CDT			
MC7809CDT			
MC7810CDT			
MC7812CDT			
MC7805ACT	±2%	TO-220	
MC7806ACT			
MC7808ACT			
MC7809ACT			
MC7810ACT			
MC7812ACT			
MC7815ACT			
MC7818ACT			
MC7824ACT			

:CLAIMER

IRCHILD SEMICONDUCTOR RESERVES THE RIGHT TO MAKE CHANGES WITHOUT FURTHER NOTICE TO ANY ODUCTS HEREIN TO IMPROVE RELIABILITY, FUNCTION OR DESIGN. FAIRCHILD DOES NOT ASSUME ANY BILITY ARISING OUT OF THE APPLICATION OR USE OF ANY PRODUCT OR CIRCUIT DESCRIBED HEREIN; NEITHER IES IT CONVEY ANY LICENSE UNDER ITS PATENT RIGHTS, NOR THE RIGHTS OF OTHERS.

E SUPPORT POLICY

RCHILD'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR ;TEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT OF FAIRCHILD SEMICONDUCTOR RPORATION. As used herein:

Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and (c) whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury of the user.

2. A critical component in any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

© 2001 Fairchild Semiconductor Corporation

escale Semiconductor
plication Note

AN1646
Rev 2, 05/2005

oise Considerations for Integrated Pressure Sensors

Ador Reodique, Sensor and Systems Applications Engineering
and Warren Schultz, Field Engineering

INTRODUCTION

he Integrated Pressure Sensors (IPS) have trimmed uts, built-in temperature compensation and an amplified le-ended output which make them compatible with Analog igital converters (A/D's) on low cost micro-controllers. ough 8-bit A/D's are most common, higher resolution s are becoming increasingly available. With these higher lution A/D's, the noise that is inherent to piezo-resistive ges becomes a design consideration.

he two dominant types of noise in a piezo-resistive grated pressure sensor are shot (white) noise and 1/f ker noise). Shot noise is the result of non-uniform flow of ers across a junction and is independent of temperature. second, 1/f, results from crystal defects and also due to r processing. This noise is proportional to the inverse of uency and is more dominant at lower frequencies.

Noise can also come from external circuits. In a sensor system, power supply, grounding and PCB layout is important and needs special consideration.

The following discussion presents simple techniques for mitigating these noise signals, and achieving excellent results with high resolution A/D converters.

EFFECTS OF NOISE IN SENSOR SYSTEM

The transducer bridge produces a very small differential voltage in the millivolt range. The on-chip differential amplifier amplifies, level shifts and translates this voltage to a single-ended output of typically 0.2 volts to 4.7 volts. Although the transducer has a mechanical response of about 500 Hz, its noise output extends from 500 Hz to 1 MHz. This noise is amplified and shows up at the output as depicted in Figure 1.

There is enough noise here to affect 1 count on an 8-bit A/D, and 4 or 5 counts on a 10-bit A/D. It is therefore important to consider filtering. Filtering options are discussed as follows.

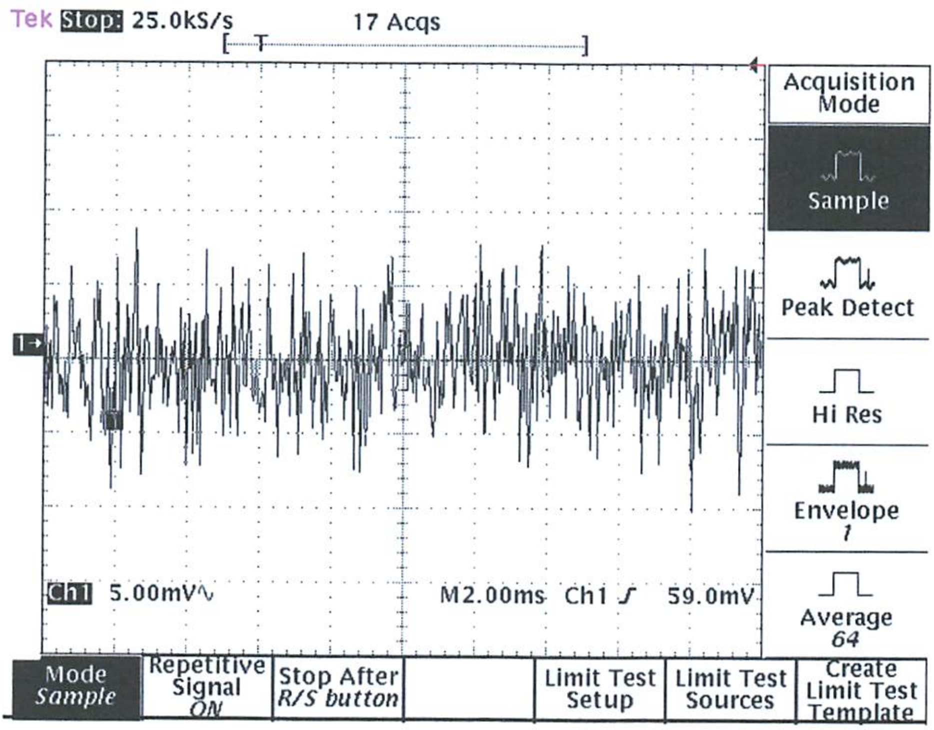


Figure 1. MPX5006 Raw Output

eescale Semiconductor, Inc., 2005. All rights reserved.

NOISE FILTERING TECHNIQUES AND CONSIDERATIONS

or mitigating the effects of this sensor noise, two general oaches are effective, low pass filtering with hardware, and pass filtering with software. When filtering with hardware, a low-pass RC filter with a cutoff frequency of 650 Hz is recommended. A 750 ohm resistor and a 0.33 μF capacitor have been determined to give the best results (see Figure 2) since the 750 ohm series impedance is low enough for most A/D converters

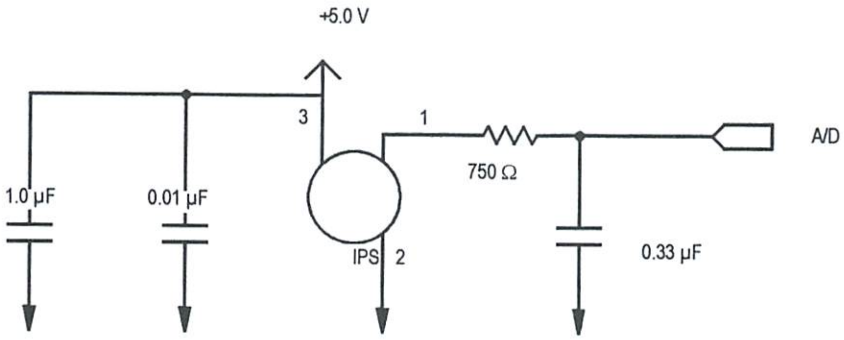


Figure 2. Integrated Pressure Sensor with RC LP Filter to Filter Out Noise

his filter has been tested with an MC68HC705P9 ocontroller which has a successive approximation A/D erter. Successive approximation A/D's are generally patible with the DC source impedance of the filter in re 2. Results are shown in Figure 4.

ome A/D's will not work well with the source impedance of gle pole RC filter. Please consult your A/D converter technical data sheet if input impedance is a concern. In applications where the A/D converter is sensitive to high source impedance, a buffer should be used. The integrated pressure sensor has a rail-to-rail output swing, which dictates that a rail-to-rail operational amplifier (op amp) should be used to avoid saturating the buffer. A MC33502 rail-to-rail input and output op amp works well for this purpose (see Figure 3).

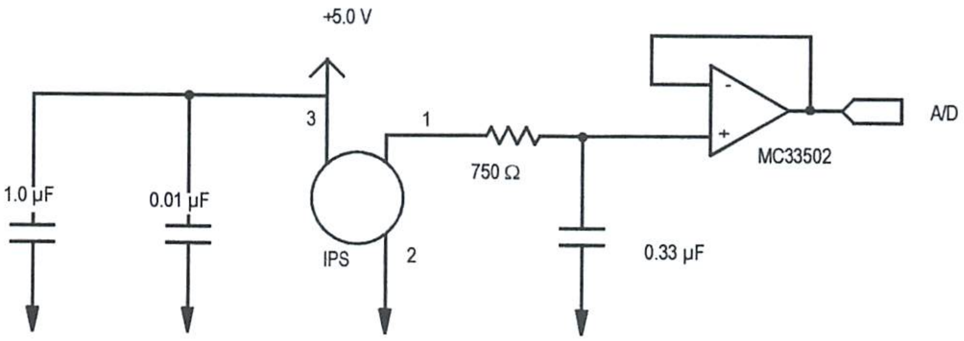


Figure 3. Use a Rail-to-Rail Buffer to Reduce Output Impedance of RC Filter

eraging is also effective for filtering sensor noise. aging is a form of low pass filtering in software. A rolling ge of eight to 64 samples will clean up most of the noise. sample average reduces the noise to about 2.5 mV peak ak and a 64 sample average reduces the noise to about peak to peak (see Figure 5 and Figure 6).

is method is simple and requires no external onents. However, it does require RAM for data storage, computation cycles and code. In applications where the controller is resource limited or pressure is changing vely rapidly, averaging alone may not be the best on. In these situations, a combination of RC filtering and ted number of samples gives the best results. For ple, a rolling average of four samples combined with the ter in Figure 2 results in a noise output on the order of peak-to-peak.

Another important consideration is that the incremental effectiveness of averaging tends to fall off as the number of samples is increased. In other words, the signal-to-noise (S/N) ratio goes up more slowly than the number of samples. To be more precise, the S/N ratio improves as the square root of the number of samples is increased. For example, increasing the number of samples from 10 to 64, in Figure 5, and in Figure 6, reduced noise by a factor of 2.5.

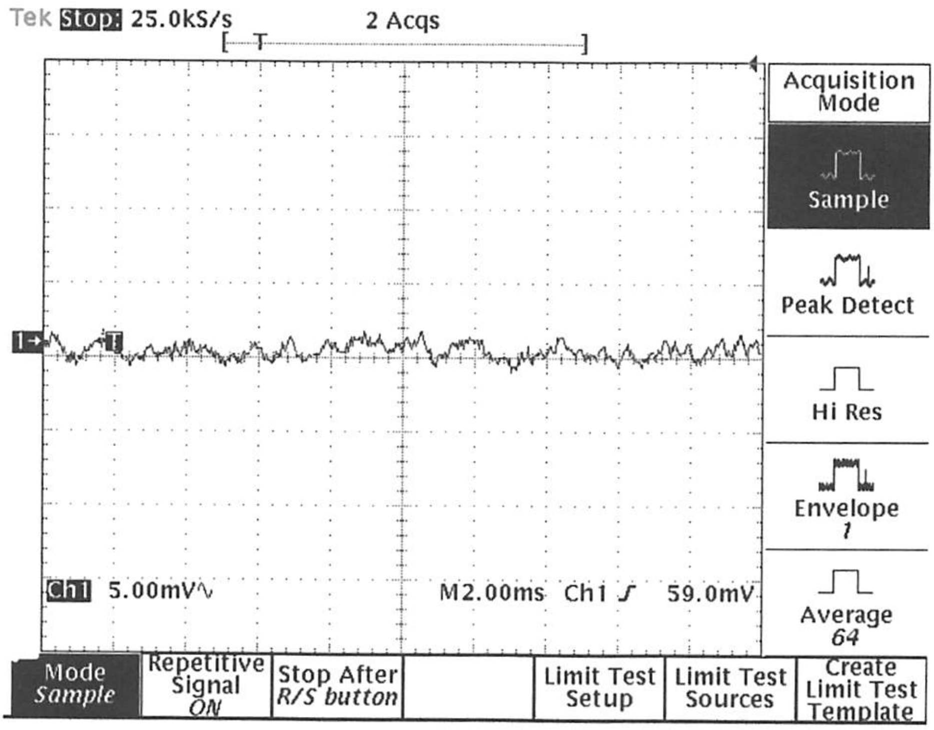


Figure 4. Output After Low Pass Filtering

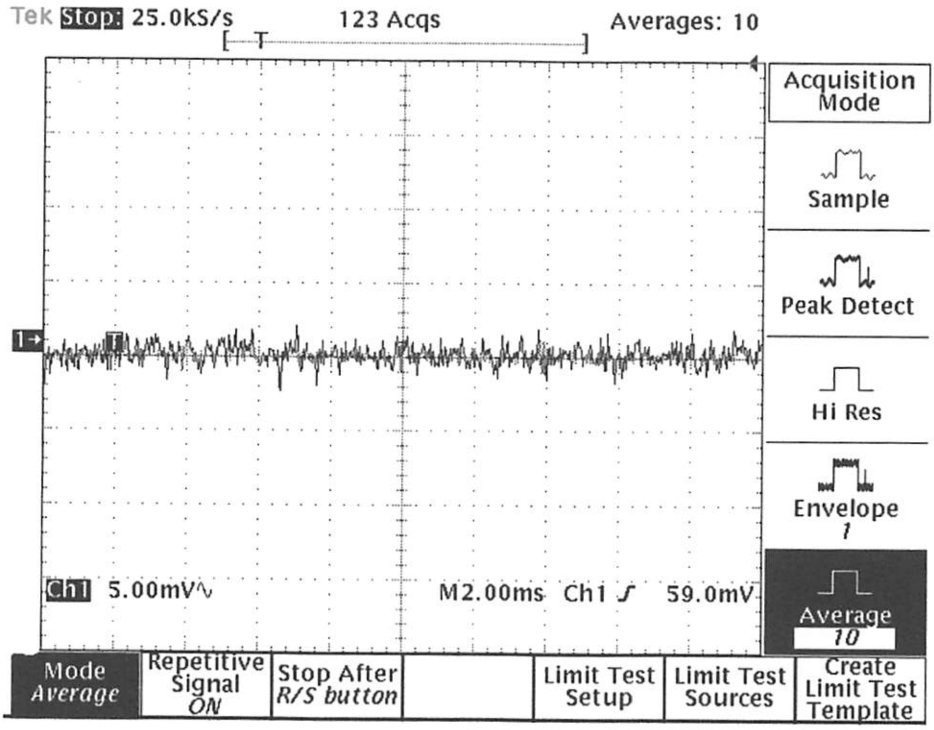


Figure 5. Output with 10 Averaged Samples

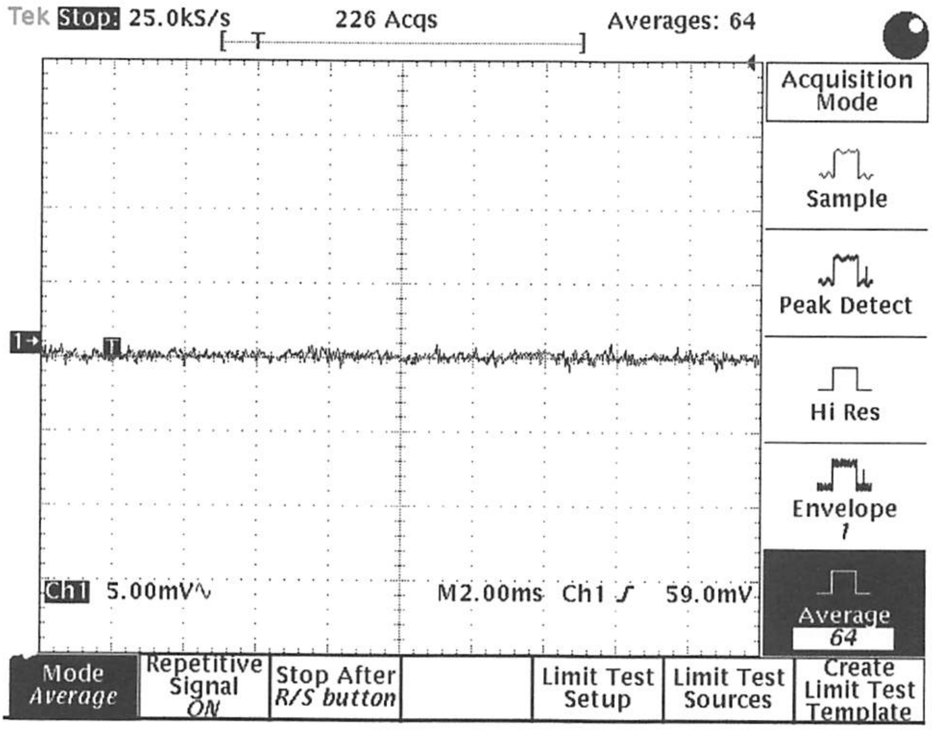


Figure 6. Output with 64 Averaged Samples

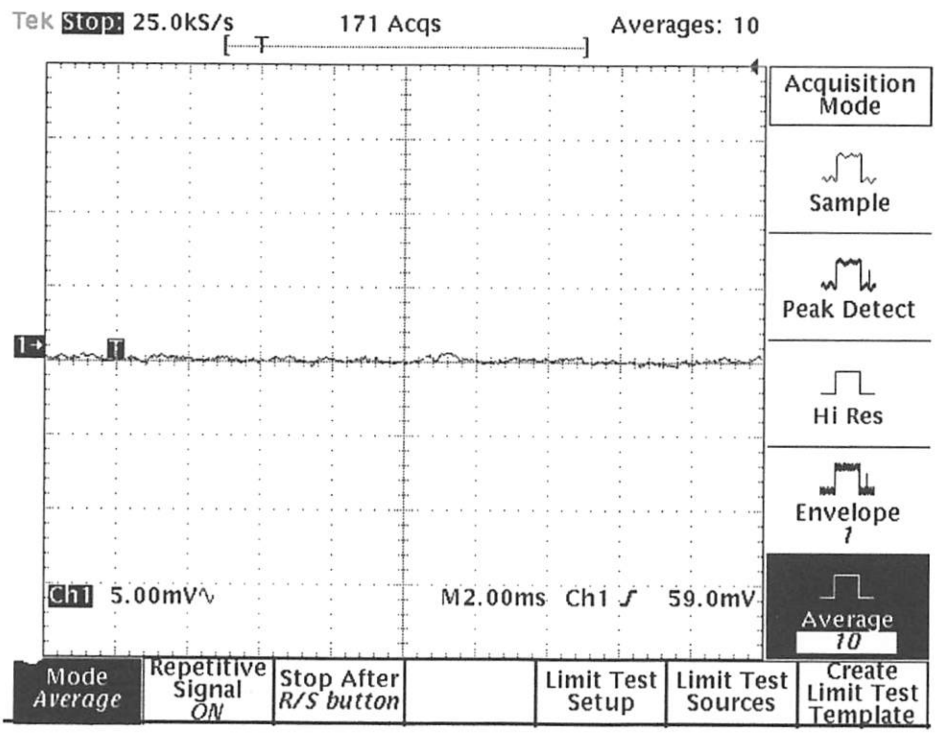


Figure 7. Filtered Sensor Output and Averaged Over 10 Samples

POWER SUPPLY

ince the sensor output is ratiometric with the supply ıge, any variation in supply voltage will also proportionally ear at the output of the sensor. The integrated pressure sor is designed, characterized and trimmed to be powered a 5.0 V ±5% power supply which can supply the imum 10 mA current requirement of the sensor. Powering ntegrated sensor at another voltage than specified is not mmended because the offset, temperature coefficient of et (TCO) and temperature coefficient of span (TCS) trim be invalidated and will affect the sensor accuracy.
rom a noise point of view, adequate de-coupling is ortant. A 0.33 µF to 1.0 µF ceramic capacitor in parallel a 0.01 µF ceramic capacitor works well for this purpose. , with respect to noise, it is preferable to use a linear lator such as an MC78L05 rather than a relatively more y switching power supply 5.0 volt output. An additional ideration is that the power to the sensor and the A/D ge reference should be tied to the same supply. Doing akes advantage of the sensor output ratiometricity. Since /D resolution is also ratiometric to its reference voltage, tions in supply voltage will be canceled by the system.

LAYOUT OPTIMIZATION

mixed analog and digital systems, layout is a critical part e total design. Often, getting a system to work properly nds as much on layout as on the circuit design. The wing discussion covers some general layout principles, al section layout and analog section layout.

eral Principles

here are several general layout principles that are rtant in mixed systems. They can be described as five .

1: Minimize loop areas.

is is a general principle that applies to both analog and l circuits. Loops are antennas. At noise sensitive inputs, rea enclosed by an incoming signal path and its return is ortional to the amount of noise picked up by the input. At l output ports, the amount of noise that is radiated is also ortional to loop area.

2: Cancel fields by running equal currents that flow posite directions as close as possible to each other.

wo equal currents flow in opposite directions, the ting electromagnetic fields will cancel as the two currents rought infinitely close together. In printed circuit board t, this situation can be approximated by running signals heir returns along the same path but on different layers. cancellation is not perfect due to the finite physical ration, but is sufficient to warrant serious attention in al paths. Looked at from a different perspective, this is her way of looking at Rule # 1, i.e., minimize loop areas.

Rule 3: On traces that carry high speed signals avoid 90 degree angles, including "T" connections.

If you think of high speed signals in terms of wavefronts moving down a trace, the reason for avoiding 90 degree angles is simple. To a high speed wavefront, a 90 degree angle is a discontinuity that produces unwanted reflections. From a practical point of view, 90 degree turns on a single trace are easy to avoid by using two 45 degree angles or a curve. Where two traces come together to form a "T" connection, adding some material to cut across the right angles accomplishes the same thing.

Rule 4: Connect signal circuit grounds to power grounds at only one point.

The reason for this constraint is that transient voltage drops along the power grounds can be substantial, due to high values of di/dt flowing through finite inductance. If signal processing circuit returns are connected to power ground at multiple points, then these transients will show up as return voltage differences at different points in the signal processing circuitry. Since signal processing circuitry seldom has the noise immunity to handle power ground transients, it is generally necessary to tie signal ground to power ground at only one point.

Rule 5: Use ground planes selectively.

Although ground planes are highly beneficial when used with digital circuitry, in the analog world they are better used selectively. A single ground plane on an analog board puts parasitic capacitance in places where it is not desired, such as at the inverting inputs of op amps. Ground planes also limit efforts to take advantage of field cancellation, since the return is distributed.

ANALOG LAYOUT

In analog systems, both minimizing loop areas and field cancellation are useful design techniques. Field cancellation is applicable to power and ground traces, where currents are equal and opposite. Running these two traces directly over each other provides field cancellation for unwanted noise, and minimum loop area.

Figure 8 illustrates the difference between a power supply de-coupling loop that has been routed correctly and one that has not. In this figure, the circles represent pads, the schematic symbols show the components that are connected to the pads, and the routing layers are shown as dark lines (top trace) or grey lines (bottom trace). Note, by routing the two traces one over the other, the critical loop area is minimized. In addition, it is important to keep de-coupling capacitors close to active devices such as MPX5000-series sensors and operational amplifiers. As a rule of thumb, when 50 mil ground and Vcc traces are used, it is not advisable to have more than 1 inch between a de-coupling capacitor and the active device that it is intended to be de-coupled.

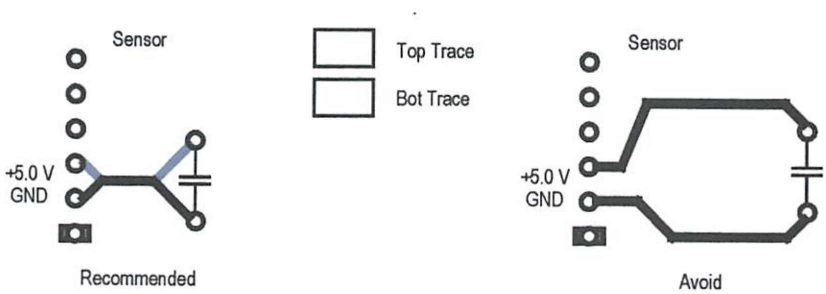


Figure 8. Minimizing Loop Areas

or similar reasons it is desirable to run sensor output als and their return traces as close to each other as sible. Minimizing this loop area will minimize the amount of rnal noise that is picked up by making electrical ections to the sensor.

DIGITAL LAYOUT

he primary layout issue with digital circuits is ground tioning. A good place to start is with the architecture that own in Figure 9. This architecture has several key utes. Analog ground and digital ground are both separate distinct from each other, and come together at only one . For analog ground it is preferable to make the one point ose as possible to the analog to digital converter's ground ence (V_{REFL}). The power source ground connection ld be as close as possible to the microcontroller's power ly return (V_{SS}). Note also that the path from V_{REFL} to V_{SS} lated from the rest of digital ground until it approaches

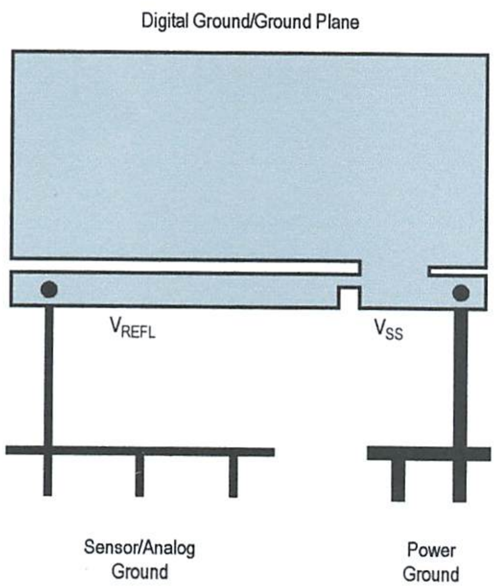


Figure 9. Ground Partitioning

addition to grounding, the digital portion of a system fits from attention to avoiding 90 degree angles, since are generally a lot of high speed signals on the digital n of the board. Routing with 45 degree angles or curves nizes unwanted reflections, which increases noise immunity. Single traces are easy, two forty five degree angles or a curve easily accomplish a 90 degree turn. It is just as important to avoid 90 degree angles in T connections. Figure 10 illustrates correct versus incorrect routing for both cases.

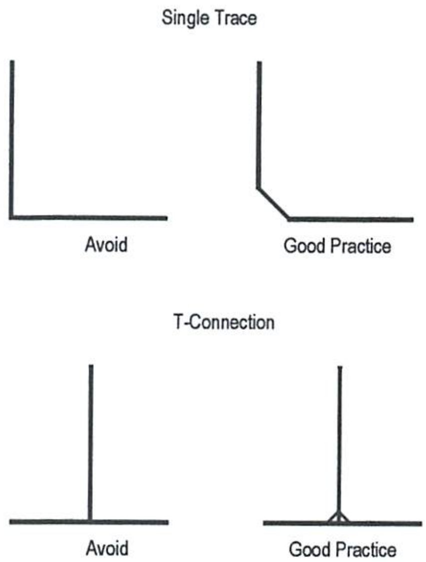


Figure 10. Degree Angles

CONCLUSION

Piezo-resistive pressure sensors produce small amounts of noise that can easily be filtered out with several methods. These methods are low pass filtering with an RC filter, averaging or a combination of both which can be implemented with minimal hardware cost.

In a mixed sensor system, noise can be further reduced by following recommended power supply, grounding and layout techniques.

REFERENCES

1. AN1626 Noise Management in Motor Drives, Warren Schultz, Freescale Semiconductor, Inc.
2. Noise Reduction Techniques In Electronic Systems 2nd Edition, Henry W. Ott, John Wiley & Sons.
3. Noise: Comparing Integrated Pressure Sensors and Op Amps, Ira Basket, Freescale Semiconductor, Inc. Sensor Products Division internal paper.

r to Reach Us:

e Page:
freescale.com

il:
ɔrt@freescale.com

Europe or Locations Not Listed:
ɪcale Semiconductor
ɪical Information Center, CH370
N. Alma School Road
dler, Arizona 85224
)0-521-6274 or +1-480-768-2130
ɔrt@freescale.com

pe, Middle East, and Africa:
ɪcale Halbleiter Deutschland GmbH
ɪical Information Center
zbogen 7
) Muenchen, Germany
296 380 456 (English)
52200080 (English)
9 92103 559 (German)
69 35 48 48 (French)
ɪrt@freescale.com

ɪ:
cale Semiconductor Japan Ltd.
ɪuarters
) Tower 15F
Shimo-Meguro, Meguro-ku,
153-0064

191014 or +81 3 5437 9125
ɪrt.japan@freescale.com

Pacific:
cale Semiconductor Hong Kong Ltd.
ical Information Center
King Street
Industrial Estate
, N.T., Hong Kong
2666 8080
rt.asia@freescale.com

terature Requests Only:
cale Semiconductor Literature Distribution Center
ox 5405
r, Colorado 80217
441-2447 or 303-675-2140
03-675-2150
ɔrFreescaleSemiconductor@hibbertgroup.com

Information in this document is provided solely to enable system and software implementers to use Freescale Semiconductor products. There are no express or implied copyright licenses granted hereunder to design or fabricate any integrated circuits or integrated circuits based on the information in this document.

Freescale Semiconductor reserves the right to make changes without further notice to any products herein. Freescale Semiconductor makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does Freescale Semiconductor assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation consequential or incidental damages. "Typical" parameters that may be provided in Freescale Semiconductor data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals", must be validated for each customer application by customer's technical experts. Freescale Semiconductor does not convey any license under its patent rights nor the rights of others. Freescale Semiconductor products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or other applications intended to support or sustain life, or for any other application in which the failure of the Freescale Semiconductor product could create a situation where personal injury or death may occur. Should Buyer purchase or use Freescale Semiconductor products for any such unintended or unauthorized application, Buyer shall indemnify and hold Freescale Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that Freescale Semiconductor was negligent regarding the design or manufacture of the part.

Freescale™ and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners.
© Freescale Semiconductor, Inc. 2005. All rights reserved.

freescale™
semiconductor