

**DESAIN PENGGERAK KAMERA BERBASIS GYROSCOPIC
DENGAN MENGGUNAKAN MIKROKONTROLER ATMEGA
8535**

SKRIPSI



**Disusun oleh :
Bayu Perwira Negara
NIM. 05.12.214**

**JURUSAN TEKNIK ELEKTRO S-1
KONSENTRASI TEKNIK ELEKTRONIKA
FAKULTAS TEKNOLOGI INDUSTRI
INSTITUT TEKNOLOGI NASIONAL MALANG
2011**

LEMBAR PERSETUJUAN

DESAIN PENGGERAK KAMERA BERBASIS GYROSCOPIC DENGAN MENGGUNAKAN MIKROKONTROLER ATMEGA 8535

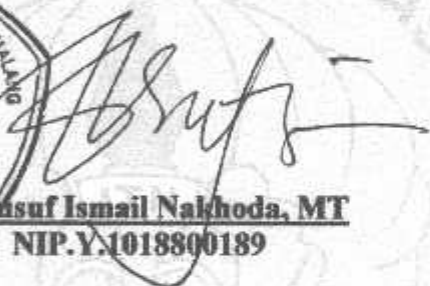
SKRIPSI

Disusun dan diajukan untuk melengkapi dan memenuhi persyaratan guna mencapai gelar Sarjana Teknik Elektro Strata satu (S-1)

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**JURUSAN TEKNIK ELEKTRO S-1
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INSTITUT TEKNOLOGI NASIONAL MALANG**

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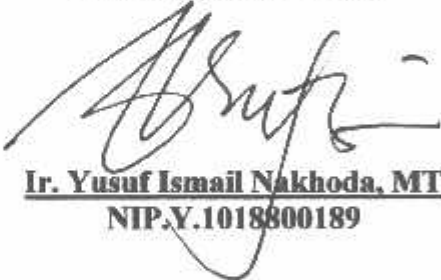
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GYROSCOPIC DENGAN MENGGUNAKAN
MIKROKONTROLER ATMEGA 8535**

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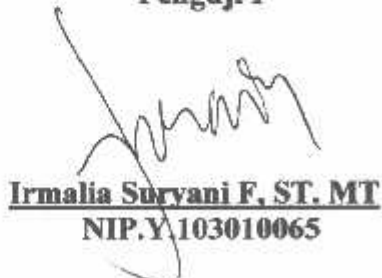

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DESAIN PENGGERAK KAMERA BERBASIS GYROSCOPIC DENGAN MENGGUNAKAN MIKROKONTROLER ATMEGA 8535

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ABSTRAK

Sebagian besar orang ingin mencoba menghasilkan pergerakan kamera yang stabil agar dapat menghasilkan gambar yang bagus dan jelas, tentunya akan menemui banyak kesulitan terutama hasil gambar bergoyang. Untuk sebagian besar kameramen amatir, ini menjadi sebuah hal yang selalu terjadi dalam penggunaan kamera yang hanya di kontrol oleh tangan. Disaat kita bergerak sambil mengambil gambar, seakan - akan kamera mendapatkan guncangan akibat dari pergerakan tubuh, bahkan sebesar apapun usaha kita untuk mencoba membuatnya stabil. Pada akhirnya, kita membutuhkan alat yang dapat menstabilkan pergerakan kamera untuk memperkecil guncangan. Untuk itu perlu didesain Penggerak Kamera berbasis Gyroscopic atau yang sering disebut Gyroscopic Cam ini akan digerakan oleh motor servo dan Mikrokontroler. Pada penelitian kali ini akan dikembangkan dengan menggunakan mikrokontroler yang tidak sepenuhnya dikontrol melalui komputer tetapi menggunakan mikrokontroler untuk mengatur gerak kamera. Dengan memanfaatkan teknologi ini, maka didapat hasil pengukuran sudut kemiringan 90° sebesar 1.68 mv.

Kata kunci : sensor, motor servo, mikrokontroler, kamera.

KATA PENGANTAR

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“DESAIN PENGGERAK KAMERA BERBASIS GYROSCOPIC DENGAN MENGGUNAKAN MIKROKONTROLER ATMEGA 8535”

Skripsi ini disusun sebagai salah satu persyaratan dalam menyelesaikan studi program strata satu (S-1) Jurusan Teknik Elektro / Konsentrasi Teknik Elektronika, Fakultas Teknologi Industri, Institut Teknologi Nasional Malang.

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Malang, Agustus 2011

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BAB I

PENDAHULUAN

1.1 LATAR BELAKANG

Sebagian besar orang ingin mencoba menghasilkan pergerakan kamera yang stabil agar dapat menghasilkan gambar yang bagus dan jelas, tentunya akan menemui banyak kesulitan terutama hasil gambar bergoyang. Untuk sebagian besar kameramen amatir, ini menjadi sebuah hal yang selalu terjadi dalam penggunaan kamera yang hanya di kontrol oleh tangan. Disaat kita bergerak sambil mengambil gambar, seakan-akan kamera mendapatkan guncangan akibat dari pergerakan tubuh, bahkan sebesar apapun usaha kita untuk mencoba membuatnya stabil. Pada akhirnya, kita membutuhkan alat yang dapat menstabilkan pergerakan kamera, bagaimana caranya untuk memperkecil guncangan oleh sebuah alat yang memiliki konstruksi yang sederhana dan berat yang ringan untuk mengoptimalkan pengoperasian yang mudah. Umumnya kru menggunakan tripod atau sebuah landasan beroda yang dijalankan di sebuah lapangan atau jalanan rata. Tripot dan landasan beroda tersebut sangat berguna dalam pengambilan gambar, tapi memiliki keterbatasan pula.

Giroskop adalah perangkat untuk mengukur atau mempertahankan orientasi, berdasarkan prinsip-prinsip konservasi momentum sudut. Gyroscopic Cam merupakan kamera yang memiliki poros ditengah yang berguna untuk mempertahankan posisinya secara tegak lurus. Artinya bahwa gambar yang diambil kamera tersebut tetap pada posisi tegak lurus.

Desain Penggerak Kamera berbasis Gyroscopic atau yang sering disebut Gyroscopic Cam ini akan digerakan oleh motor servo dan Mikrokontroler. Pada penelitian kali ini akan dikembangkan dengan menggunakan mikrokontroler yang tidak sepenuhnya dikontrol melalui komputer tetapi menggunakan mikrokontroler untuk mengatur arah gerak Gyroscopic Cam.

Dengan memanfaatkan teknologi pada mikrokontroler Atmega 8535 yang diprogram Gyroscopic Cam dapat bergerak secara horizontal serta dapat bergerak membentuk sudut tertentu.

1.2 Rumusan Masalah

Pada alat yang dibuat, penulis ingin menyampaikan beberapa permasalahan dari alat yang dibuat sebagai berikut :

- Bagaimana Mempertahankan Kamera agar tetap Stabil dalam pengambilan Objek.

Sehubungan dengan permasalahan diatas, maka dalam skripsi ini dipilih judul **DESAIN PENGGERAK KAMERA BERBASIS GYROSCOPIC DENGAN MENGGUNAKAN MIKROKONTROLER ATMEGA 8535.**

1.3 Tujuan penulisan

Tujuan pembuatan alat ini adalah bagaimana mendesain suatu alat yang dapat membuat kamera menjadi stabil pada posisi horizontal yang dapat mempertahankan posisinya secara tegak lurus, sehingga pada kondisi Horizontal kamera akan tetap stabil dalam pengambilan objek.

1.4 Batasan Masalah

Agar pembahasan skripsi ini dapat memenuhi sasaran maka perlu batasan masalah dalam pengkajiannya, batasan masalah ini dibatasi hanya pada rangkaian yang dibuat diantaranya sebagai berikut :

- Pergerakan kamera secara horizontal.
 - Sensivitas atau tingkat kepekaan Sensor MMA7260QT
-

BAB II LANDASAN TEORI

Dalam merencanakan dan merealisasikan system ini dibutuhkan pemahaman mengenai pengetahuan yang berhubungan dengan aplikasi tersebut. Pemahaman tersebut akan sangat bermanfaat dalam perancangan perangkat keras maupun perangkat lunak. Adapun pengetahuan yang mendukung perencanaan dan realisasi alat antara lain pengetahuan mengenai mikrokontroler ATMEGA8535, Gyroscopic, Motor Servo.

2.1 Minimum system ATMEGA8535

2.1.1. Mikrokontroler ATMEGA8535

Mikrokontroler AVR (*Alf and Vegard's Risc processor*) dari Atmel ini menggunakan arsitektur RISC (*Reduced Instruction Set Computer*) yang artinya processor tersebut memiliki set instruksi program yang lebih sedikit dibandingkan dengan MCS-51 yang menerapkan Arsitektur CISC (*Complex Instruction Set Computer*).

Hampir semua instruksi prosesor RISC adalah instruksi dasar (belum tentu sederhana), sehingga instruksi – instruksi ini umumnya hanya memerlukan 1 siklus mesin untuk menjalankannya. Kecuali instruksi percabangan yang membutuhkan 2 siklus mesin. RISC biasanya dibuat dengan arsitektur *Harvard*, karena arsitektur ini yang memungkinkan untuk membuat eksekusi instruksi selesai dikerjakan dalam satu atau dua siklus mesin, sehingga akan semakin cepat dan handal. Proses downloading programnya relatif lebih mudah karena dapat dilakukan langsung pada sistemnya.

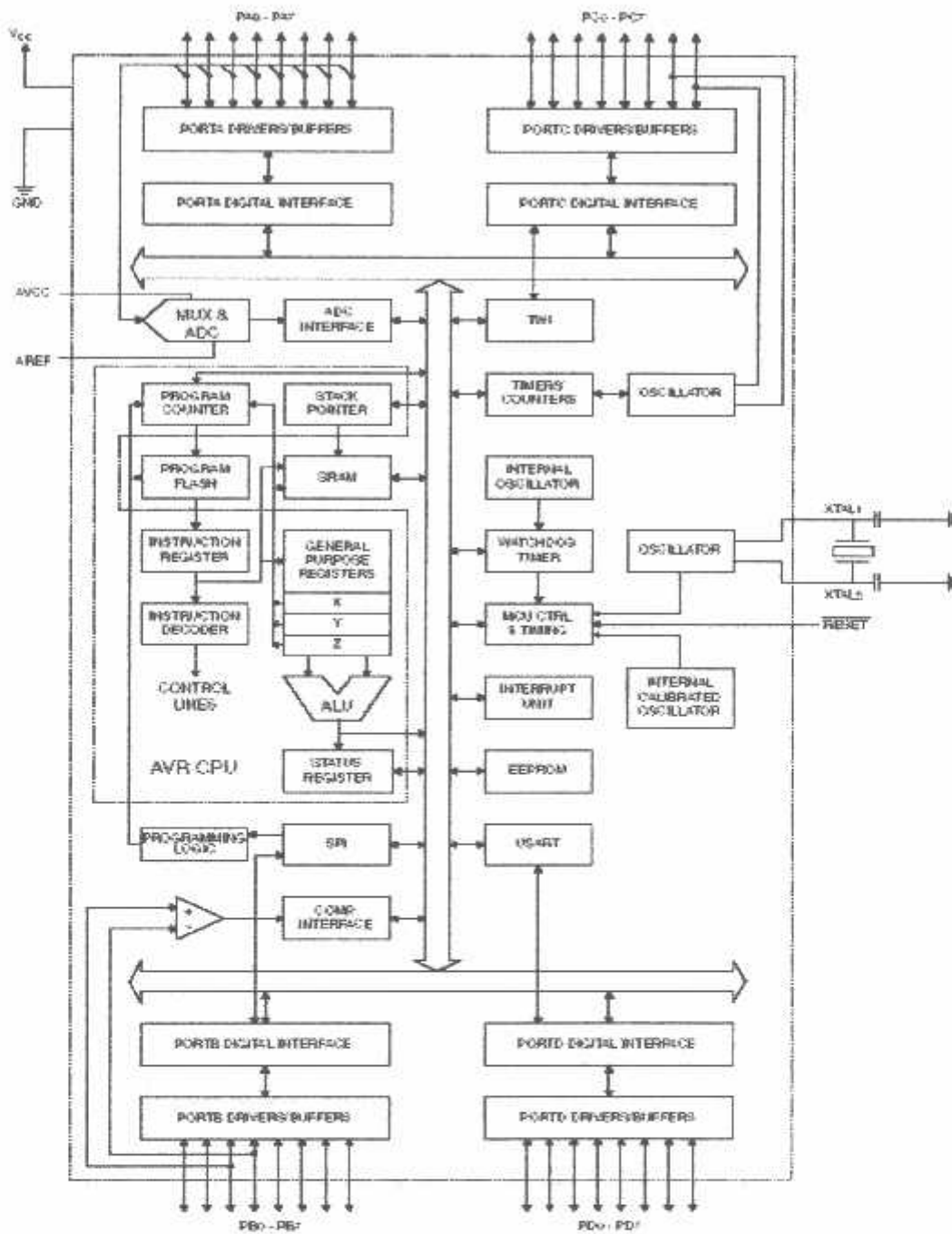
Sekarang ini, AVR dapat dikelompokkan menjadi 6 kelas, yaitu keluarga AT, keluarga AT90Sxx, keluarga ATmega, keluarga AT90CAN, keluarga AT90PWM dan AT86RFxx. Pada dasarnya yang membedakan masing – masing kelas adalah memori, peripheral, dan fungsinya, sedangkan dari segi arsitektur dan instruksi yang digunakan, mereka hampir sama. Sebagai pengendali utama dalam pembuatan robot ini, digunakan salah satu produk ATMEL dari keluarga ATmega yaitu ATmega8535.

2.1.2. Arsitektur ATmega8535

Mikrokontroler ATmega8535 memiliki fitur – fitur utama, seperti berikut:

1. Saluran I/O sebanyak 32 buah yaitu port A, port B, port C, dan port D.
2. ADC 10 bit sebanyak 8 saluran.
3. Tiga unit *Timer/Counter* dengan kemampuan perbandingan.
4. CPU yang terdiri atas 32 register.
5. Watchdog Timer dengan osilator internal.
6. SRAM sebesar 512 byte.
7. Memori flash sebesar 8 kb dengan kemampuan Read While Write.
8. Unit interupsi internal dan eksternal.
9. Port antarmuka SPI.
10. EEPROM sebesar 512 byte yang dapat di program saat operasi.
11. Antarmuka komparator analog.
12. Port USART untuk komunikasi serial.

Mikrokontroler AVR ATmega8535 merupakan mikrokontroler produksi Atmel dengan 8 kb *In-System Programmable Flash*, 512 byte EEPROM dan 512 Bytes Internal SRAM. AVR ATmega8535 memiliki seluruh fitur yang dimiliki AT90S8535. Selain itu, konfigurasi Pin AVR ATmega8535 juga kompatibel dengan AT90S8535. Diagram blok arsitektur ATmega8535 ditunjukkan dalam gambar 2.1.



Gambar 2.1. Arsitektur ATmega8535

Sumber : Design dan implementasi system embedded

Mikrokontroler ATMEGA8535 dengan bahasa basic, iswanto

Terdapat sebuah inti prosesor (*processor core*) yaitu *Central Processing Unit*, dimana terjadi proses pengumpulan instruksi (*fetching*) dan komputasi data. Seluruh register umum sebanyak 32 buah terhubung langsung dengan unit

ALU (Arithmetic and Logic Unit). Terdapat empat buah port masing – masing delapan bit dapat difungsikan sebagai masukan maupun keluaran.

Media penyimpan program berupa *Flash Memory*, sedangkan penyimpan data berupa SRAM (*Statistic Random Access Memory*) dan EEPROM (*Electrical Erasable Programmable Read Only Memory*). Untuk komunikasi data tersedia fasilitas SPI (*Serial Peripheral Interface*), USART (*Universal Synchronous and Asynchronous serial Receiver and Transmitter*), serta TWI (*Two-wire Serial Interface*).

Di samping itu terdapat fitur tambahan, antara lain AC (*Analog Comparator*), 8 kanal 10-bit ADC (*Analog to Digital Converter*), 3 buah Timer/Counter, WDT (*Watchdog Timer*), manajemen penghematan daya (*Sleep Mode*), serta osilator internal 8 MHz. Seluruh fitur terhubung ke bus 8 bit. Unit interupsi menyediakan sumber interupsi hingga 21 macam. Sebuah stack pointer selebar 16 bit dapat digunakan untuk menyimpan data sementara saat interupsi. Mikrokontroler dapat dipasang pada frekuensi kerja hingga 16 MHz (maksimal 8MHz untuk versi ATmega8535L). Sumber frekuensi bias dari luar berupa osilator Kristal, atau menggunakan osilator internal.

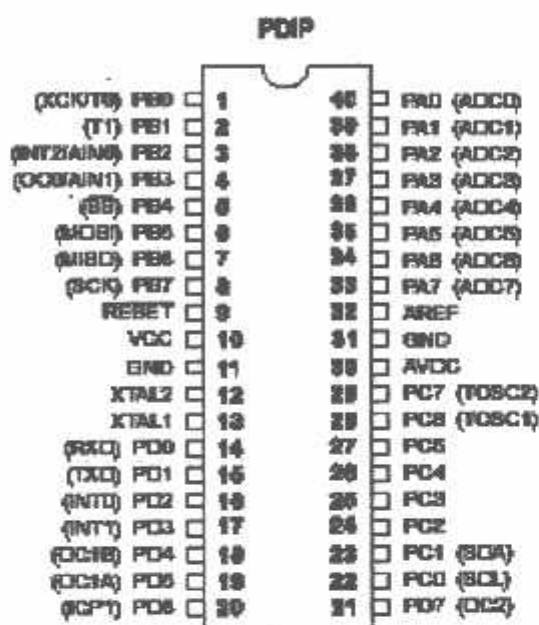
Keluarga AVR dapat mengeksekusi instruksi dengan cepat karena menggunakan teknik “memegang sambil mengerjakan”.dalam satu siklus clock,terdapat dua register independent yang dapat di akses oleh satu instruksi.

2.1.3 Konfigurasi PIN

1. VCC untuk tegangan pencatu daya positif.
 2. GND untuk tegangan pencatu daya negatif.
 3. PortA (PA0 – PA7) sebagai port Input/Output dan memiliki kemampuan lain yaitu sebagai input untuk ADC.
 4. PortB (PB0 – PB7) sebagai port Input/Output dan juga memiliki kemampuan yang lain.
 5. PortC (PC0 – PC7) sebagai port Input/Output untuk ATmega8535.
 6. PortD (PD0 – PD7) sebagai port Input/Output dan juga memiliki kemampuan yang lain.
 7. RESET untuk melakukan reset program dalam mikrokontroler.
 8. XTAL1 dan XTAL2 untuk input pembangkit sinyal clock.
-

9. AVCC untuk pin masukan tegangan pencatu daya untuk ADC.
10. AREF untuk pin tegangan referensi ADC.

Gambar konfigurasi Pin Mikrokontroler ATmega8535 ditunjukkan dalam gambar 2.2:



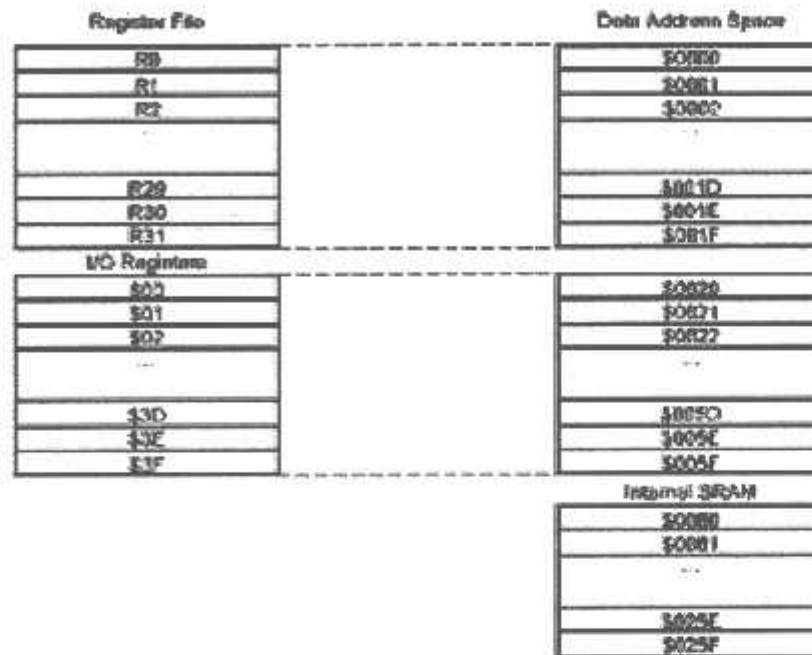
Gambar 2.2 PIN Mikrokontroler ATmega8535

Sumber : Design dan implementasi system embedded Mikrokontroler ATMEGA8535 dengan bahasa basic, iswanto

2.1.4 Peta Memori

ATmega8535 memiliki ruang pengalamatan memori data dan memori program yang terpisah. Memori data terbagi menjadi 3 bagian yaitu : 32 buah register umum, 64 buah register I/O, dan 512 byte SRAM internal. Register untuk keperluan umum menempati space data pada alamat terbawah yaitu \$00 sampai \$1F. Sementara itu register khusus untuk menangani I/O dan kontrol terhadap mikrokontroler menempati 64 alamat berikutnya, yaitu mulai dari \$20 sampai \$5F. Register tersebut merupakan register yang khusus digunakan untuk mengatur fungsi terhadap berbagai peripheral mikrokontroler, seperti kontrol register, timer/counter, fungsi fungsi I/O, dan sebagainya. Alamat memori berikutnya digunakan untuk SRAM 512 byte, yaitu pada lokasi \$60 sampai

dengan \$25F. Register khusus alamat memori secara lengkap dapat dilihat dalam gambar 2.3.



Gambar 2.3 Memori data AVR ATmega8535

Sumber : Design dan implementasi system embedded Mikrokontroler ATMEGA8535 dengan bahasa basic.iswanto

2.1.5 Stack Pointer

Stack Pointer merupakan suatu bagian dari AVR yang berguna untuk menyimpan data sementara, variable local, dan alamat kembali dari suatu interupsi ataupun subrutin. Stack Pointer diwujudkan sebagai dua unit register, yaitu SPH dan SPL.

Saat awal SPH dan SPL akan bernilai nol, sehingga perlu dianalisis terlebih dahulu. SPH merupakan bit atas (MSB), sedangkan SPL merupakan bit bawah (LSB). Hal ini berlaku hanya berlaku untuk AVR dengan kapasitas SRAM lebih dari 256 byte. Bila tidak, maka SPH tidak di definisikan dan tidak dapat digunakan.

2.1.6 Komunikasi serial dengan UART

AVR ATmega8535 memiliki 4 buah register I/O yang berkaitan dengan komunikasi UART, yaitu UART I/O Data Register (UDR), UART Baud Rate Register (UBRR), UART Status Register (USR) dan UART Control Register (UCR).

2.1.7 Register Data I/O UART (UDR)

Proses pengiriman data secara serial dapat di mulai setelah UDR diberi karakter data. Pada sisi penerima, UART memiliki *buffer* sehingga UDR dapat dibaca ketika sebuah data baru sedang digeser masuk.

2.1.8 Register BAUD RATE UART (UBRR)

UBRR digunakan untuk menentukan clock yang dibangkitkan oleh *baud rate generator*. Nilai *baud rate* di tentukan dengan mengisi register UBRR.

2.1.9 Timer Atmega 8535

AVR ATmega8535 memiliki 3 buah timer yaitu, *Timer/couner* (8 bit), *Timer/counter* (16 bit), dan *Timer/counter* 2(8 bit). *Timer/counter*0 adalah timer/counter 8 bit yang multi fungsi. Fitur – fitur dari *Timer/counter*0 pada Atmega8535 adalah :

- a. Counter 1 kanal.
- b. Timer di nol kan saat proses perbandingan tercapai (*Compare match*).
- c. Sebagai pembangkit gelombang PWM.
- d. Sebagai pembangkit Frekuensi.
- e. Clock *prescaler* 10 bit.
- f. Sumber interupsi dari *compare match* (OCF0) dan overflow (TOV0).

2.1.10 Interupsi

Atmega 8535 memiliki 21 buah sumber Intrupsi. Interupsi tersebut bekerja jika bit I pada Register status atau *Status Register* (SREG) dan bit pada masing - masing register bernilai 1. Penjelasan sumber interupsi terdapat dalam tabel 2.1 :

Tabel 2.1 sumber interupsi

Sumber :Design dan implementasi system embedded Mikrokontroler
ATMEGA8535 dengan bahasa basic, iswanto

| No | Alamat | Sumber | Keterangan |
|----|--------|-----------------|---|
| 1 | 0x000 | RESET | Hardware pin, Power-on reset and Watchdog Reset |
| 2 | 0x001 | INT0 | External Interrupt Request 0 |
| 3 | 0x002 | INT1 | External Interrupt Request 1 |
| 4 | 0x003 | TIMER2 COMP | Timer / counter 2 Compare Match |
| 5 | 0x004 | TIMER2 OVF | Timer / counter 2 Overflow |
| 6 | 0x005 | TIMER1 CAPT | Timer / counter 1 Capture Event |
| 7 | 0x006 | TIMER1 COMPA | Timer / counter1 Compare Match A |
| 8 | 0x007 | TIMER1 COMPB | Timer / Counter1 Compare Match B |
| 9 | 0x008 | TIMER1 OVF | Timer / Counter1 Overflow |
| 10 | 0x009 | TIMER0 OVF | Timer / Counter0 Overflow |
| 11 | 0x00A | SPI, STC | SPI Serial Transfer Complete |
| 12 | 0x00B | UART, RX | UART, RX Complete |
| 13 | 0x00C | UART, UDRE | UART, Data Register Empty |
| 14 | 0x00D | UART, TX | UART, TX Complete |

| | | | |
|----|-------|-------------|-------------------------------|
| 15 | 0x00E | ADC | ADC Conversion Complete |
| 16 | 0x00F | EE_RDY | EEPROM Ready |
| 17 | 0x010 | ANA_COMP | Analog Comparator |
| 18 | 0x011 | TWI | Two Wire Serial Interface |
| 19 | 0x012 | INT2 | External Interrupt Request 2 |
| 20 | 0x013 | TIMER0 COMP | Timer / Counter Compare Match |
| 21 | 0x014 | SPM_RDY | Store Program Memory Ready |

2.1.11 Analog to Digital converter (ADC)

ADC pada ATmega8535 merupakan ADC 10-bit tipe *Successive Approximation*, yang terhubung ke sebuah multiplexer analog yang akan memilih satu dari delapan kanal. Untuk menjaga validitas data, terdapat untai *Sample and Hold*. Tegangan ADC terpisah dari tegangan suplai mikrokontroler, tetapi selisihnya tidak boleh lebih dari 0,3V.

Terdapat 8 kanal ADC masing – masing selebar 10 bit. ADC dapat digunakan dengan memberikan masukan tegangan pada port ADC, yaitu port A.0 sampai dengan port A.7.

Ada dua mode ADC yang dapat digunakan, yaitu *single conversion* dan *free running*. Pada mode *Single conversion*, pengguna harus mengaktifkan setiap kali ADC akan digunakan. Sedangkan pada mode *free running*, pengguna cukup sekali mengaktifkan, sehingga ADC akan terus mengkonversi tanpa henti.

Dalam kemasan TQFP (*Thin Quad Flat Package*) terdapat fasilitas tambahan, yaitu kanal diferensial dan anal diferensial dengan penguatan, yang memungkinkan dua kanal ADC digunakan sekaligus. Kemasan PDIP tidak menyediakan fasilitas ini.

Tegangan Refrensi ADC dapat dipilih menggunakan teganga refrensi internal maupun external. Jika menggunakan tegangan refrensi internal, bisa dipilih on-chip internal reference voltage yaitu sebesar 2,56V atau sebesar

AVCC. Jika menggunakan tegangan referensi eksternal, dapat dihubungkan melalui pin AREF.

ADC mengkonversi tegangan input analog menjadi data digital 8bit atau 10bit. Data digital tersebut akan disimpan di dalam ADC data Register yaitu ADCH dan ADCL. Sekali ADCL dibaca, maka akses ke data register tidak dapat dilakukan. Dan ketika, ADCH dibaca, maka akses ke data register kembali enable.

Terdapat beberapa register I/O yang terlibat dalam proses konversi ADC antara lain : ADMUX (*ADC Multiplexer Selection Register*). Register ADMUX berisi bit bit yang mengatur pilihan kanal (MUX4:0), bit pengatur penyajian data (ADLAR), dan bit – bit pemilih tegangan refrensi (REFS1:0).

Dalam mengaskes ADC, terdapat proses pengaturan register – register I/O yang terlibat dalam ADC. Proses pengaturan tersebut meliputi :

a. Menentukan Sumber Tegangan Reverensi

Reverensi pada ADC merupakan batas rentang representasi nilai digital hasil konversi. Hasil konversi pada mode *single ended conversion* dirumuskan sebagai berikut :

$$ADC = \frac{V_{in} \cdot 1024}{V_{ref}}$$

Dengan V_{in} :Tegangan masukan analog pada kanal ADC yang aktif.

V_{ref} : Tegangan Refrensi yang dipilih.

Ada tiga sumber reverensi yang dapat digunakan, dan dipilih dengan mengatur bit REF1:0 (*Reference Selection Bit1:0*) pada register ADMUX. Tabel 2.2 menunjukkan pengaturan bit – bit tersebut dan pilihan reverensi yang tersedia.

Tabel 2.2 Pemilihan Tegangan Reverensi pada ADC

Sumber : Design dan implementasi system embedded Mikrokontroler ATMEGA8535 dengan bahasa basic, iswanto

| REF1 | REF0 | Tegangan Referensi yang Dipilih |
|------|------|--|
| 0 | 0 | Tegangan pada pin AREF |
| 0 | 1 | Tegangan pada pin AVCC, dengan kapasitor eksternal |

| | | |
|---|---|--|
| | | pada pin AREF |
| 1 | 0 | Dilarang |
| 1 | 1 | Tegangan referensi internal 2,56 V, dengan kapasitor eksternal pada pin AREF |

b. Menentukan Bentuk Penyajian Data ADC.

Bentuk penyajian data pada register ADCL dan ADCH ditentukan oleh bit ADLAR (*ADC Left Adjusted Result*) pada register ADMUX. Data hasil konversi memiliki panjang 10 bit, sedangkan setiap register data dapat menampung 8 bit. Artinya jika sebuah register diisi penuh, maka register lain tidak penuh berisi. Jika bit ADLAR dibiarkan tetap '0' (**clear**), delapan bit rendah disimpan di ADCL, dan ADCH sisanya. Dan sebaliknya.

c. Memilih kanal yang aktif (satu dari delapan).

Kanal yang aktif ditentukan oleh bit – bit MUX4:0 (*Analog Channel and Gain Selection Bits*) pada register ADMUX. Tabel 2.3 menunjukkan konfigurasi bit – bit tersebut.

Tabel 2.3 Konfigurasi Bit – bit ADMUX4:0

Sumber : Design dan implementasi system embedded Mikrokontroler ATMEGA8535 dengan bahasa basic, iswanto

| MUX4 | MUX3 | MUX2 | MUX1 | MUX0 | Kanal yang Aktif |
|------|------|------|------|------|------------------|
| 0 | 0 | 0 | 0 | 0 | ADC0 |
| 0 | 0 | 0 | 0 | 1 | ADC1 |
| 0 | 0 | 0 | 1 | 0 | ADC2 |
| 0 | 0 | 0 | 1 | 1 | ADC3 |
| 0 | 0 | 1 | 0 | 0 | ADC4 |
| 0 | 0 | 1 | 0 | 1 | ADC5 |
| 0 | 0 | 1 | 1 | 0 | ADC6 |
| 0 | 0 | 1 | 1 | 1 | ADC7 |

d. Menentukan mode ADC

Mode *single conversion* atau *free running* ditentukan dengan menulisi bit *ADATE (ADC Auto Trigger Enable)* pada register *ADCSRA*. Jika dibiarkan '0' (*clear*), maka mode *single conversion* yang dijalankan. Apabila diberi logika '1' (*set*), ADC beraksi dalam mode *free running*. Sebagai catatan, register *SFIOR* dibiarkan apa adanya (*default setting*). Apabila ADC diinginkan disulut oleh sumber lain, maka bit – bit *ADTS2:0 (ADC Auto Trigger Source2:0)* di register *SFIOR* harus diberi nilai. Tabel 2.4 menunjukkan konfigurasi bit – bit pemilih sumber penyulut ADC.

Tabel 2.4 Konfigurasi Bit – bit ADTS2:0

Sumber : Design dan implementasi system embedded Mikrokontroler ATMEGA8535 dengan bahasa basic, iswanto

| ADTS2 | ADTS1 | ADTS0 | Sumber Penyulut |
|-------|-------|-------|--|
| 0 | 0 | 0 | Mode <i>free running</i> |
| 0 | 0 | 1 | <i>Analog Comparator</i> |
| 0 | 1 | 0 | Sumber interupsi eksternal <i>INT0</i> |
| 0 | 1 | 1 | <i>Compare match</i> pada <i>Timer/Counter0</i> |
| 1 | 0 | 0 | Limpahan (<i>overflow</i>) <i>Timer/Counter0</i> |
| 1 | 0 | 1 | <i>Compare match B</i> pada <i>Timer/Counter1</i> |
| 1 | 1 | 0 | Limpahan (<i>overflow</i>) <i>Timer/Counter1</i> |
| 1 | 1 | 1 | Rekam kejadian (<i>capture event</i>) pada <i>Timer/Counter1</i> |

e. Menentukan *prescaler* (clock ADC)

Prescaler merupakan faktor pembagi yang diterapkan pada *clock* mikrokontroler agar untai *successive approximation* ADC mampu menerima *clock* yang cukup sehingga data hasil konversi cukup valid. Untuk ketelitian ADC 10 bit, rentang frekuensi *clock* yang diperbolehkan adalah 50 kHz hingga 200 kHz. Frekuensi *clock* yang lebih tinggi dapat digunakan jika resolusi lebih rendah

dari 10 bit. Nilai *prescaler* ditentukan oleh bit – bit ADPS2:0 (*ADC Prescaler Select Bits2:0*). Tabel 2.5 menunjukkan konfigurasi bit – bit tersebut.

Tabel 2.5 Konfigurasi Bit – bit ADPS

Sumber : Design dan implementasi system embedded Mikrokontroler ATMEGA8535 dengan bahasa basic, iswanto

| ADPS2 | ADPS1 | ADPS0 | Nilai <i>Prescaler</i> |
|-------|-------|-------|------------------------|
| 0 | 0 | 0 | 2 |
| 0 | 0 | 1 | 2 |
| 0 | 1 | 0 | 4 |
| 0 | 1 | 1 | 8 |
| 1 | 0 | 0 | 16 |
| 1 | 0 | 1 | 32 |
| 1 | 1 | 0 | 64 |
| 1 | 1 | 1 | 128 |

f. Inisialisasi ADC

Untuk mengaktifkan ADC, bit ADEN (*ADC Enable*) harus diberi logika '1'. Dan untuk memulai ADC, logika '1' juga harus diberikan pada bit ADSC (*ADC Start Conversion*). Kedua bit ini terletak pada register ADCSRA. Waktu yang diperlukan untuk satu konversi adalah 25 siklus *clock* ADC pada konversi pertama, dan 13 siklus *clock* ADC untuk konversi berikutnya.

Idealnya, ADC dapat melakukan konversi secara linear antara GND dan V_{REF} dan 2^n langkah. Sehingga faktor pengali hasil konversi terendah adalah 0, dan tertinggi $2^n - 1$. Indeks n menunjukkan resolusi ADC (8, 9, atau 10 bit). Tetapi terdapat beberapa hal yang menyebabkan ADC tidak mencapai kondisi ideal, yaitu galat yang terjadi saat konversi, antara lain:

- a. offset error
- b. gain error
- c. integral non-linearity

- d. differential non-linearity
- e. quantization error

Dengan adanya galat – galat tersebut, pada akhirnya fasilitas ADC memiliki akurasi absolut sebesar ± 2 LSB.

2.1.12 Pulse Width Modulation (PWM)

Mikrokontroler Atmega8535 menyediakan fitur *Timer/Counter1* yang dapat diatur sebagai *timer*, pencacah (*counter*), perekam waktu kejadian (*even occurrence time capture*), pembangkit isyarat PWM (*Pulse Width Modulation*), serta *autoreload timer (Clear Timer on Compare/CTC)*. Dengan lebar 16 bit, *Timer/Counter1* dapat digunakan secara fleksibel untuk berbagai tujuan yang berkaitan dengan waktu dan pembangkit gelombang.

2.2 Motor Servo

2.2.1 Pengertian Motor Servo

Servo adalah perangkat sejenis motor yang dapat diputar dalam besaran sudut tertentu yang diinginkan. Servo terdiri dari empat komponen dasar, yaitu: motor, gear, feedback device (berupa potensiometer) dan rangkaian pengontrol. Motor akan memutar poros servo –melalui beberapa gear– dan potensiometer secara bersamaan. Potensiometer mengirim sinyal kepada rangkaian pengontrol. Apabila rangkaian pengontrol mendeteksi posisi yang benar, maka rangkaian pengontrol akan menghentikan motor. Untuk mengoperasikannya yaitu dengan memberikan Pulsa digital tertentu pada motor ini. Dalam Gambar 2.4 ditunjukkan gambar motor servo.



Gambar 2.4 Motor Servo

Sumber : jenis jenis motor <http://v4z4.wordpress.com/2010/03/30/jenis-jenis-motor-dalam-pada-elektronika/>

2.2.2 Kegunaan servo

Servo biasa digunakan untuk steering/kemudi pada pesawat atau mobil RC, untuk lengan robot, untuk pengarah sensor dan untuk keperluan lain yang membutuhkan gerakan.

2.2.3 Cara Kerja servo

Servo dapat digerakkan dengan mengirimkan pulsa tegangan 5V DC yang diulang setiap 20 milidetik. Panjang pulsa menentukan posisi putaran. Servo dirancang untuk menerima pulsa tegangan dengan variasi 0.75 milidetik sampai dengan 2.25 milidetik.

Pada umumnya servo yang ada di pasaran sekarang ini mempunyai jangkauan gerakan 0 s.d 180 derajat. Ini berarti pulsa 0.75 milidetik untuk 0 derajat. Pulsa 2.25 milidetik untuk 180 derajat dan pulsa 1.5 milidetik untuk 90 derajat.

2.2.4 Jenis – jenis servo

1. Motor Servo 180° (servo standard)

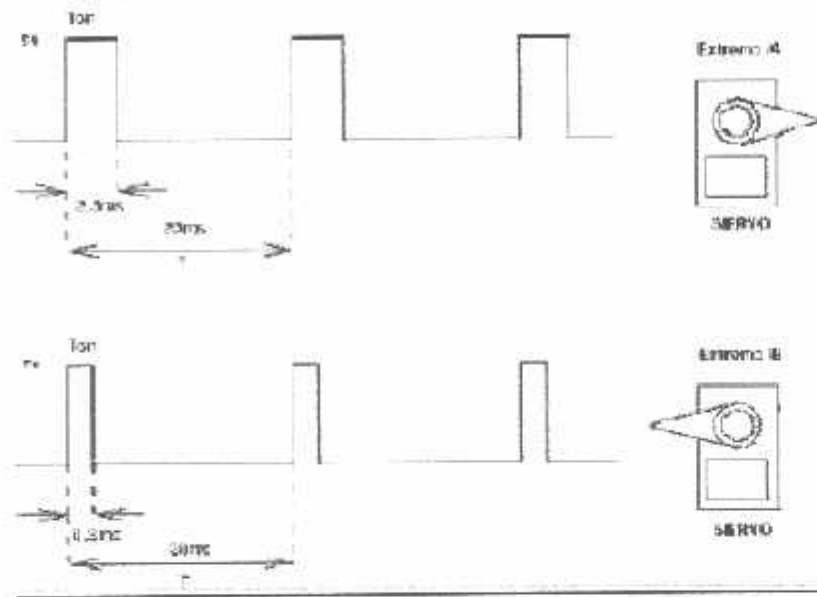
Motor servo jenis ini hanya mampu bergerak dua arah (CW dan CCW) dengan defleksi masing-masing sudut mencapai 90° sehingga total defleksi sudut dari kanan – tengah – kiri adalah 180°.

2. Motor Servo 360° (Continuous)

Motor servo jenis ini mampu bergerak dua arah (CW dan CCW) tanpa batasan defleksi sudut putar (dapat berputar secara kontinyu). Untuk mengatur arah putarannya yaitu dengan membedakan lebar pulsa saat kondisi ON (logic "1).

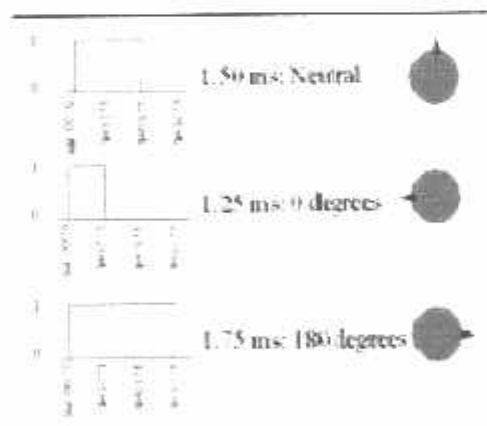
2.2.5 Pensinyalan Motor Servo

Mode pensinyalan motor servo tampak dalam gambar 2.5.



Gambar 2.5 Pensinyalan Motor Servo

Contoh dimana bila diberikan pulsa dengan besar 1.5ms mencapai gerakan 90 derajat, maka bila kita berikan data kurang dari 1.5 ms maka posisi mendekati 0 derajat dan bila kita berikan data lebih dari 1.5 ms maka posisi mendekati 180 derajat. Contoh Posisi dan Waktu Pemberian Pulsa tampak dalam gambar 2.6.



Gambar 2.6 Contoh Posisi dan Waktu Pemberian Pulsa

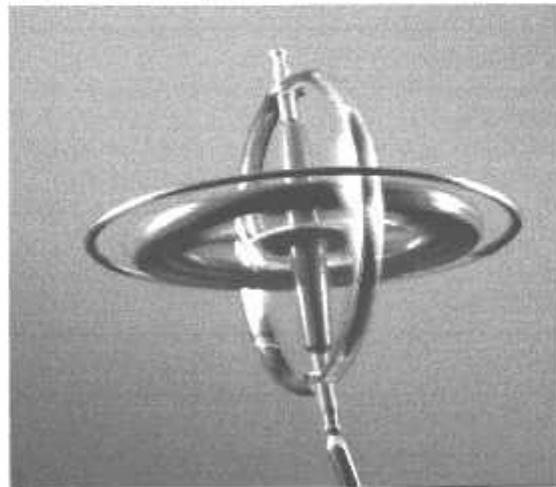
- ↓ Motor Servo akan bekerja secara baik jika pada bagian pin kontrolnya diberikan sinyal PWM dengan frekuensi 50Hz.

- ↓ Dimana pada saat sinyal dengan frekuensi 50Hz tersebut dicapai pada kondisi Ton duty cycle 1.5ms, maka rotor dari motor akan berhenti tepat di tengah-tengah (sudut 0° / netral).
- ↓ Pada saat Ton duty cycle dari sinyal yang diberikan kurang dari 1.5ms, maka rotor akan berputar ke arah kiri dengan membentuk sudut yang besarnya linier terhadap besarnya Ton duty cycle, dan akan bertahan diposisi tersebut.
- ↓ Dan sebaliknya, jika Ton duty cycle dari sinyal yang diberikan lebih dari 1.5ms, maka rotor akan berputar ke arah kanan dengan membentuk sudut yang linier pula terhadap besarnya Ton duty cycle, dan bertahan diposisi tersebut.

2.3 Gyroscopic / Gyroscope

2.3.1 Pengertian Gyroscope

Gyroscope adalah berupa sensor gyro untuk menentukan orientasi gerak dengan bertumpu pada roda atau cakram yang berotasi dengan cepat pada sumbu. Gerak cakram sangat labil dan ini dimanfaatkan simpangan gerakannya. perangkat genggam saat ini menggunakan microelectro mechanical (MEM) gyro untuk membantu dalam pemrograman yang memanfaatkan teknologi gyro. Gambar gyroscope ditunjukkan dalam gambar 2.7 dibawah ini :



Gambar 2.7 Gyroscope

Sebuah giroskop mekanis pada dasarnya adalah sebuah roda yang berputar atau disk poros bebas untuk mengambil orientasi apapun. Orientasi ini berubah jauh lebih sedikit dalam respon terhadap torsi eksternal yang diberikan

daripada akan tanpa momentum sudut besar terkait dengan putaran tingkat tinggi giroskop.

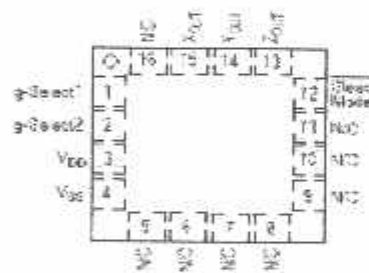
2.3.2 Prinsip kerja Giroskop

Jika suatu giroskop berputar, maka ia mempunyai vektor arah dan kecepatan. Sekali ia berputar, maka gangguan dari luar hanya akan mempengaruhi sementara, lalu giroskop menyeimbangkan dirinya kembali. Efek giroskop bisa dijelaskan seperti berikut, Jika ada suatu benda memiliki momen pada satu arah tertentu dan ada momen gangguan datang (momen kedua), maka akan muncul (efek) momen ketiga yang akan menyeimbangkan.

2.4 Sensor MMA 7260QT Accelerometer

Sensor Accelerometer MMA 7260QT dengan 3 sumbu pengukuran, yaitu terhadap sumbu x, sumbu y, dan sumbu z. Sensor accelerometer ini digunakan untuk mengukur percepatan benda dalam satuan gravitasi (g). Untuk memperoleh data jarak dari sensor accelerometer, diperlukan proses integral ganda terhadap keluaran sensor. MMA7260QT. Accelerometer ini memiliki fitur yang Mampu mendeteksi getaran dan kemiringan.

Sensor accelerometer dapat mengukur percepatan dari 1,5 g sampai 6 g. Sensor MMA7260QT dan konfigurasi pinnya dapat dilihat dalam gambar 2.8.



Gambar 2.8 Konfigurasi Pin output Sensor MMA7260QT Accelerometer

Sumber : Data sheet MMA 7260QT Accelerometer halaman 5

Pada sensor accelerometer MMA7260QT ini memiliki fasilitas g-select yang memungkinkan sensor ini bekerja pada tingkat sensitifitas yang berbeda – beda. Penguatan internal pada sensor akan berubah sesuai dengan tingkat sensitifitas yang dipilih, yaitu 1,5 g, 2 g, 4 g atau 6 g. Sensivitas accelerometer dapat diubah sewaktu – waktu selama accelerometer beroperasi. Pemilihan

tingkat sensitivitas ini dilakukan dengan memberikan input logika pada pin g-select1 dan g-select2 seperti yang terlihat dalam tabel 2.6.

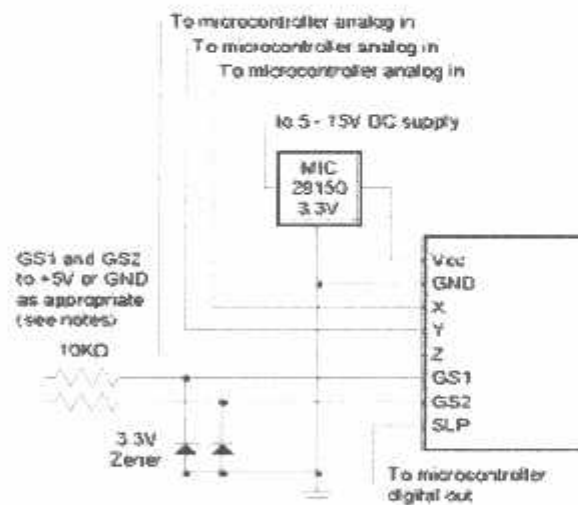
Tabel 2.6 Pemilihan tingkat sensitivitas sensor

Sumber : Data sheet MMA 7260QT Accelerometer halaman 4

| g-select1 | g-select2 | g-range | sensitivity |
|-----------|-----------|---------|-------------|
| 0 | 0 | 1,5 | 800 mV/g |
| 0 | 1 | 2 | 600 m V/g |
| 1 | 0 | 4 | 300 m V/g |
| 1 | 1 | 6 | 200 m V/g |

Ketika sensor dalam keadaan diam, keluaran sensor pada sumbu x akan menghasilkan tegangan offset yang besarnya setengah dari tegangan masukan sensor (V_{dd}). Tegangan offset accelerometer dipengaruhi oleh orientasi sensor dan percepatan statis tiap sumbu akibat gaya gravitasi bumi. Untuk percepatan positif maka sinyal keluaran akan meningkat diatas tegangan offset, sedangkan untuk percepatan negative sinyal keluaran akan semakin menurun dibawah tegangan offset.

Dalam gambar 2.9 ditunjukkan pin MMA7260QT dan spesifikasinya sebagai berikut :



Gambar 2.9 sinyal output MMA7260QT

Sumber: <http://www.famosastudio.com/accelerometer-mma7260QT>

Spesifikasi :

- Voltage:3.3-8V
- Selectable sensitivity:±1. 5g/2g/4g/6g
- Low power:500μA @ measurement mode, 3μA @standby ;
- High sensivity: 800 mV/g @ 1.5g ;
- Low pass filter
- Size:23x26mm
- Weight: 5 gram

MMA7260QT mengeluarkan output analog voltage untuk 3 outputnya. Output voltasenya menggunakan perbandingan sesuai dengan akselerasi yang diukur dan supply voltase (ratiometric). Mempunyai sensitifitas yang bisa diatur dengan dip switch. Anda membutuhkan hardware tambahan untuk mengkonversi sinyal analog ke sinyal digital yang dapat digunakan.

Dalam gambar 2.10 ditunjukkan Interface Accelerometer dengan Mikrokontroler.

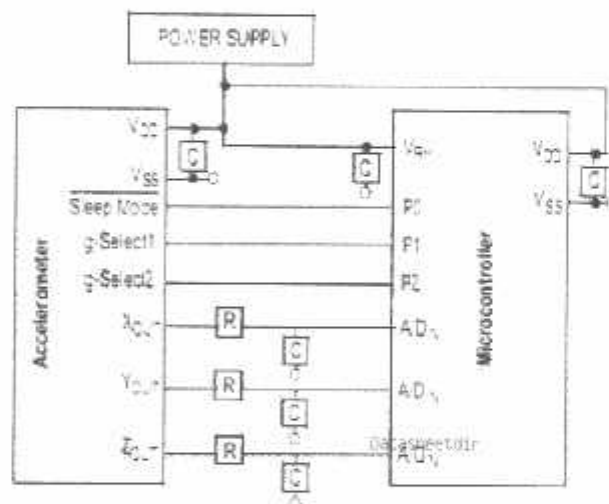


Figure 6 Recommended PCB Layout for Interfacing Accelerometer to Microcontroller

Gambar 2.10 Interface Accelerometer dengan Mikrokontroler

Sumber : Data sheet MMA 7260QT Accelerometer halaman 5

Dalam Gambar 2.11 ditunjukkan diagram koneksi MMA 7260QT.

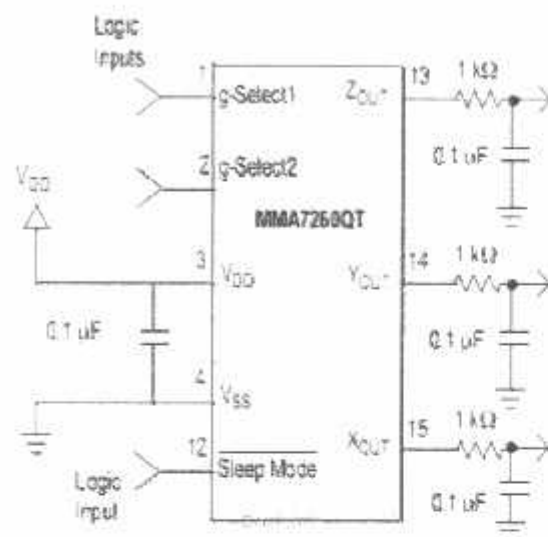


Figure 5. Accelerometer with Recommended Connection Diagram

Gambar 2.11 Diagram koneksi MMA7260QT

Sumber : Data sheet MMA 7260QT Accelerometer halaman 5

BAB III

PERANCANGAN DAN PEMBUATAN ALAT

3.1 Umum

Bab ini membahas pembuatan alat Penggerak kamera berbasis Gyroscopic dengan menggunakan mikrokontroler ATMEGA 8535. Pembuatan alat disini dibagi dalam beberapa blok perangkat yang mempunyai fungsi sendiri – sendiri. Pembuatan alat terdiri dari perangkat keras dan perangkat lunak.

3.2 Perangkat keras

Pada tahap ini akan menjelaskan mengenai perangkat keras apa saja yang akan digunakan di dalam Alat.

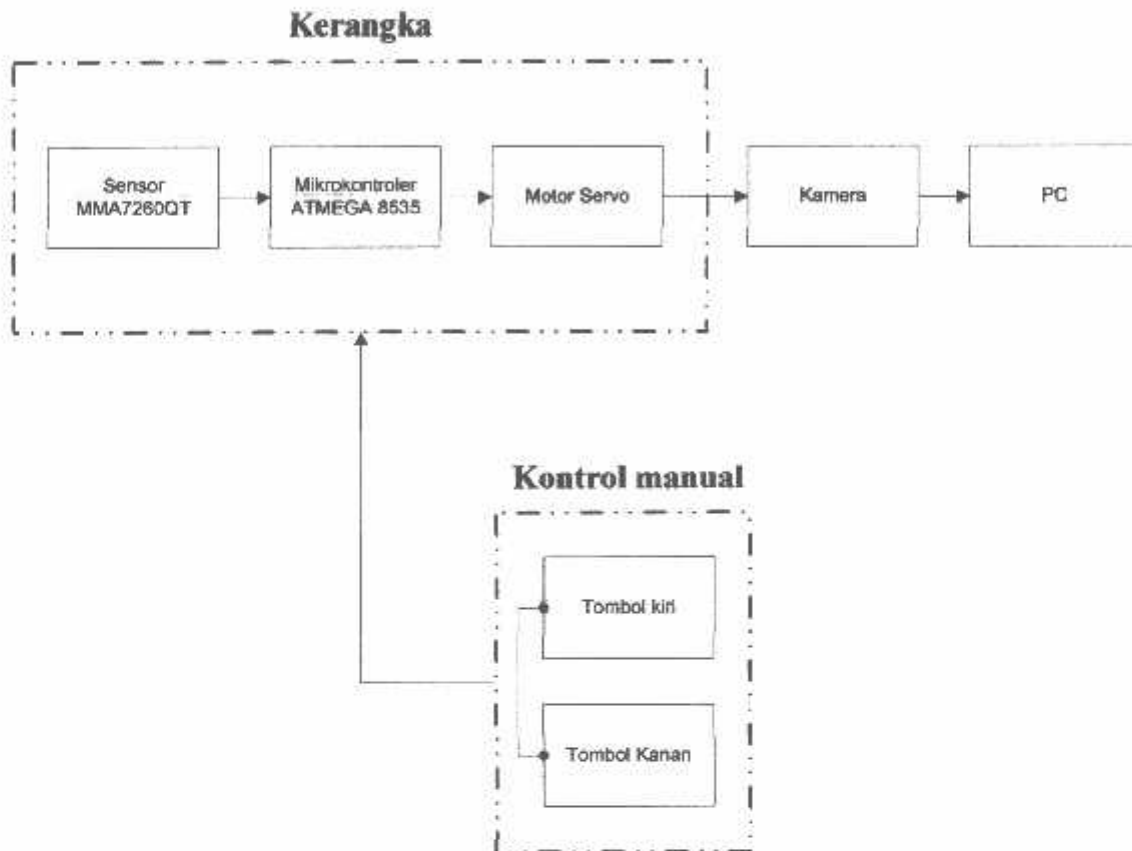
3.2.1 Komponen Mekanik Gyroscopic

Komponen mekanik gyroscopic terdiri dari :

- Mikrokontroler ATMEGA 8535
 - Sensor 3-Axis MMA 7260QT accelerometer module
 - Motor servo GWS 03T
 - Kotak
 - Tombol manual
-

3.2.2 Diagram Blok

Diagram blok pada perangkat keras (Hardware) yang di rencanakan, di perlihatkan dalam gambar 3.1 :



Gambar 3.1 Diagram Blok Alat

Penjelasan masing – masing blok sebagai berikut :

1. Tombol kiri dan kanan berupa joystick sebagai pengendali kamera secara manual.
2. Sensor MMA760QT berfungsi sebagai sinyal input penstabil kamera agar tetap stabil.
3. Mikrokontroler ATMEGA 8535 Sebagai pengolah data dari keseluruhan system.
4. Motor servo berfungsi sebagai penggerak Kamera.
5. Kamera berfungsi sebagai penangkap objek.

3.2.3 Cara kerja alat

Pada dasarnya Prinsip kerja dari Desain Penggerak Kamera Berbasis Gyroscopic Dengan Menggunakan Mikrokontroler ATMEGA 8535 ini dapat di kendalikan secara manual dan otomatis.

1) Pengendalian kamera secara manual

Mulanya untuk menggerakkan perangkat gyroscopic cam ini joystick akan memerikan masukan kepada mikrokontroler yang selanjutnya akan menggerakkan motor servo untuk mengerakan kamera secara horizontal ke kiri dan kanan.

2) Pengendalian kamera secara otomatis

Selain secara manual Gyroscopic cam ini dapat bergerak secara otomatis. Ini disebabkan karena dalam perangkat tersebut terdapat sebuah sensor Accelerometer yg mengirimkan sinyal input ke Mikrokontroler yang selanjutnya menggerakkan motor servo.

Pengendalian Gyroscopic Cam secara otomatis ini sangat mudah. Hanya dengan memiringkan perangkat ini ke kiri dan ke kanan maka secara otomatis Sensor MMA760QT akan menirimkan perubahan tegangan. Dari perubahan tegangan ini dibaca oleh mikrokontroler ATMEGA 8535, selanjutnya mikrokontroler memerintahkan motor servo tersebut untuk berputar melawan pergeseran alat agar kembali pada posisi 0° . Sehingga kamera tetap tegak lurus, stabil dalam penangkapan objek.

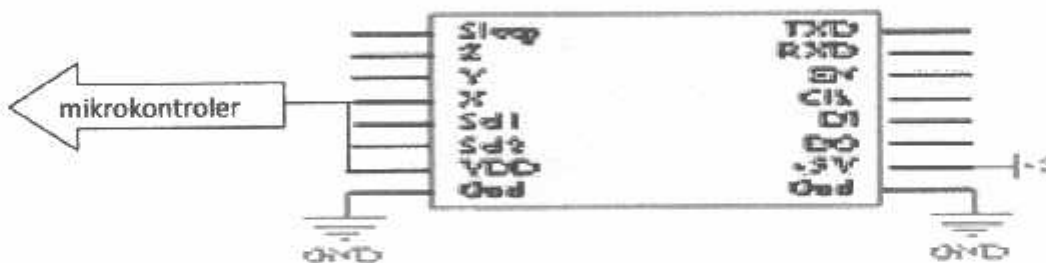
3.2.4 Perancangan Sensor MMA7260QT

MMA7260QT mengeluarkan output analog voltage untuk 3 outputnya. Output voltasenya menggunakan perbandingan sesuai dengan akselerasi yang diukur dan supply voltase (ratiometric). Mempunyai sensitifitas yang bisa diatur dengan dip switch.

Spesifikasi :

- Voltage:3.3-8V
- Selectable sensitivity:±1.5g/2g/4g/6g
- Low power:500µA @ measurement mode, 3µA @standby ;
- High sensitivity: 800 mV/g @ 1.5g ;
- Low pass filter
- Size:23x26mm
- Weight: 5 gram

Dalam gambar 3.2 ditunjukkan Perancangan rangkaian Sensor MMA7260QT :



Gambar 3.2 Perancangan Sensor MMA7260QT

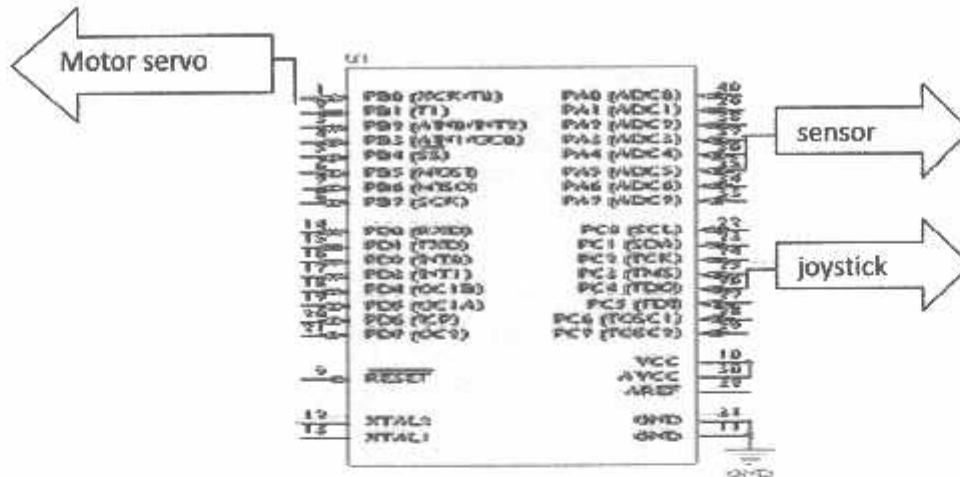
Dalam perancangan Rangkaian Sensor MMA7260QT pin yang digunakan untuk terhubung dengan mikrokontroler adalah sebagai berikut :

- sumbu x dihubungkan dengan pin PA3 (ADC3).
- Sel 1 dan sel 2 masing – masing dihubungkan pada port PA4(ADC4) pin 36 dan PA5(ADC5) pin 35, berfungsi sebagai pemilihan tingkat sensitivitas sensor.
- Gnd merupakan ground dari sensor.

Perancangan ADC mikrokontroler ATMEGA 8535 yang digunakan untuk menghubungkan antara mikrokontroler dengan sensor yaitu menghubungkan dan mengaktifkan port A ADC pada pin 37 ATMEGA8535 dengan sumbu x pada sensor Accelerometer 7260QT dengan memberikan logika 1 sehingga proses ADC pada sensor dapat berfungsi.

3.2.5 Perancangan Mikrokontroler

Perancangan rangkaian mikrokontroler ditunjukkan dalam gambar 3.4 :



Gambar 3.3 Perancangan Mikrokontroler ATMEGA8535

Untuk fungsi masing – masing port pada ATMEGA8535 yang digunakan ,penjelasannya sebagai berikut :

- **Port A**

Port I/O 8-bit dua arah dengan resistor pull-up internal. Juga berfungsi sebagai masukan analog ke ADC (ADC0 s.d. ADC7). Terdapat pada pin 33- 40. Digunakan sebagai port keluaran ke sensor 3axis MMA7260QT accelerometer.

- **Port B**

Port I/O 8-bit dua arah dengan resistor pull-up internal. Terdapat pada pin 1-8. Pin 1 T0 (timer / counter0 external counter input) digunakan sebagai port keluaran ke motor servo.

- **Port C**

Port I/O 8-bit dua arah dengan resistor pull-up internal. Terdapat pada pin 22-29. Port 3 dan 4 pada pin 26-b27 digunakan sebagai inputan swich control manual motor servo.

- **RESET**

Masukan reset. Sebuah reset terjadi jika pin ini diberi logika rendah melebihi periode minimum yang diperlukan. Masukan reset terdapat pada pin 9 berfungsi untuk reset Master ATMEGA8535.

- **Oscilator**

Oscilator yang disediakan pada chip dikemudikan dengan XTAL yang di hubungkan pada pin12 dan pin 13.

- **VCC**

ATMEGA8535 dioperasikan dengan tegangan supply 5V. Pin VCC terdapat pada pin 10 sedangkan Vss (Ground) terdapat pada pin 11.

3.2.6 Perancangan Motor Servo

Perancangan rangkaian Motor Servo ditunjukkan dalam gambar 3.5



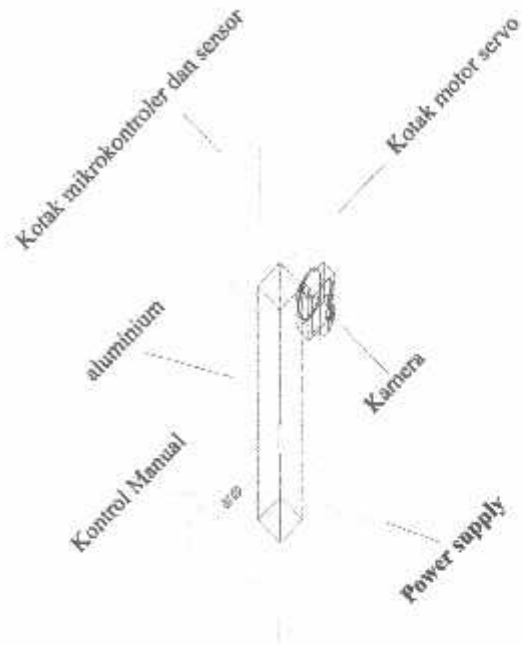
Gambar 3.4 Rangkaian Motor Servo

Dalam perancangan rangkaian motor servo, rangkaian motor servo akan dihubungkan dengan mikrokontroler dengan menghubungkan kabel positif/control (kuning) motor servo dengan port PB0 pada Mikrokontroler ATMEGA8535. Kabel vss (merah) merupakan tegangan motor servo yaitu 5V. kabel ground (hitam) merupakan kabel negative pada motor servo.

3.2.7 Desain Mekanik Perancangan Alat

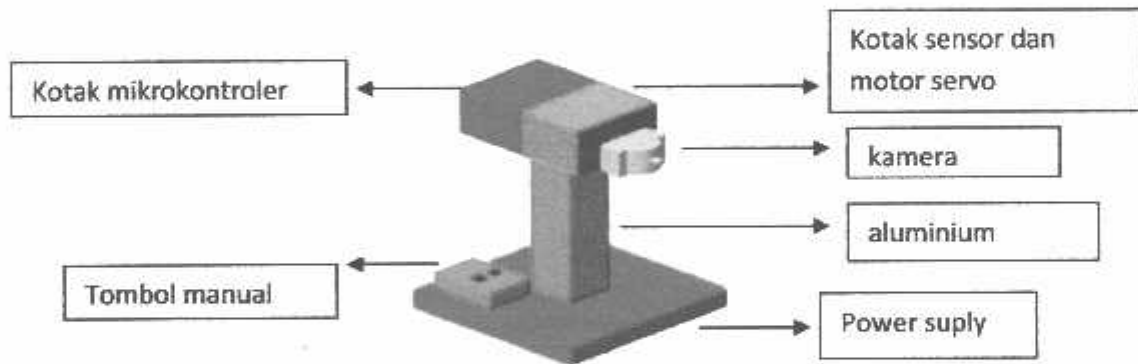
Dalam perancangan alat ini, perlu dibuat suatu sketsa desain perancangan Mekanik alat agar alat ini menjadi lebih mudah dioperasikan, diuji, dan minimalis.

Dibawah ini adalah gambar Desain Mekanik Alat tersebut beserta bagian – bagiannya ditunjukkan dalam gambar 3.5 :



Gambar 3.5 Desain dan bagian perancangan alat

Dalam gambar 3.6 ditunjukan gambar alat keseluruhan.



Gambar 3.6 Desain alat keseluruhan

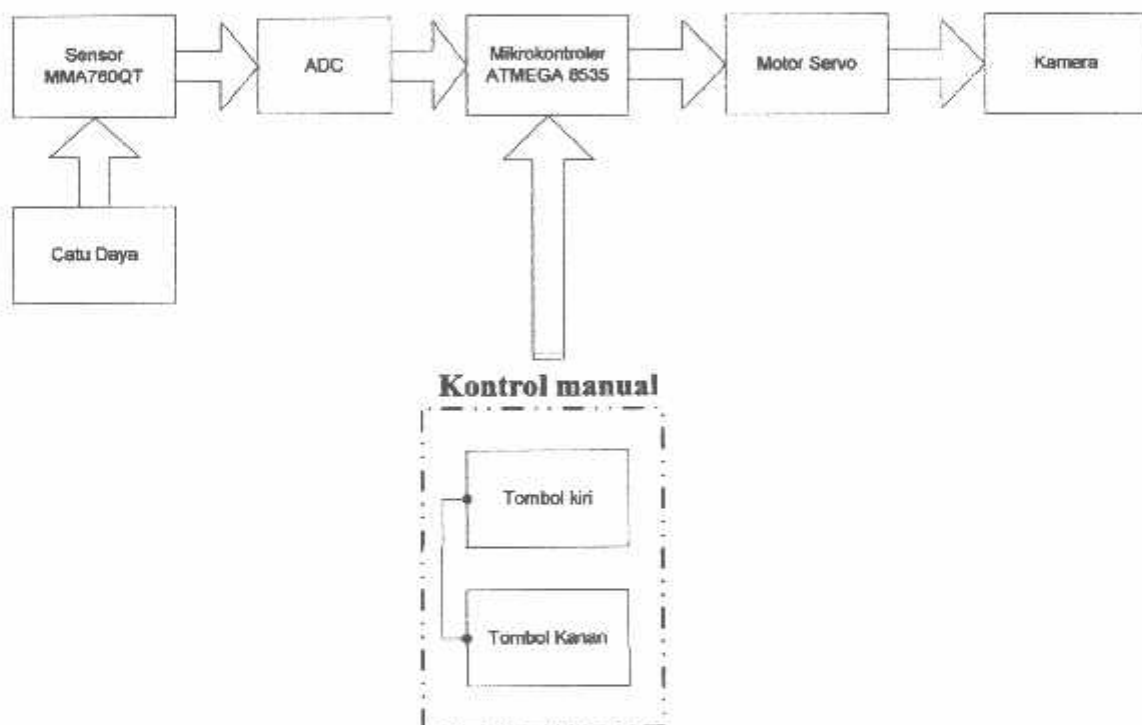
BAB IV

PENGUJIAN ALAT

Bab ini akan membahas mengenai pengujian alat yang telah dirancang. Tujuan pengujian alat ini adalah untuk mengetahui kerja dari system yang dibuat masing – masing blok, sehingga dapat diketahui kepresisian kerja dari alat yang direncanakan. Secara umum tujuan dari pengujian alat tersebut adalah sebagai berikut :

1. Mengetahui proses kerja dari masing – masing rangkaian (blok).
2. Memudahkan Pendataan spesifikasi alat.

Pengujian dilakukan secara berulang – ulang untuk mendapatkan hasil pengukuran yang tepat. Diagram Pengujian Alat ditunjukkan dalam gambar 4.1 :



Gambar 4.1 Diagram Pengujian Alat

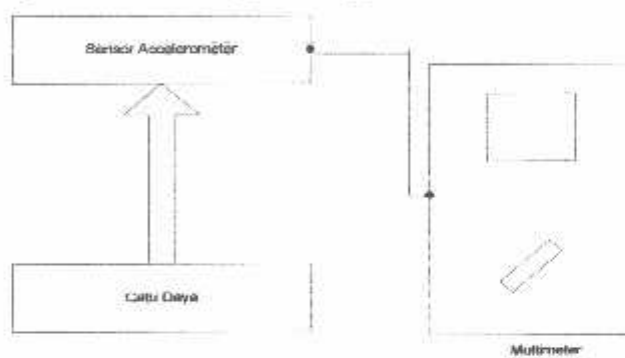
4.1 Pengujian Sensor Accelerometer MMA7260QT

4.1.1 Peralatan yang Digunakan

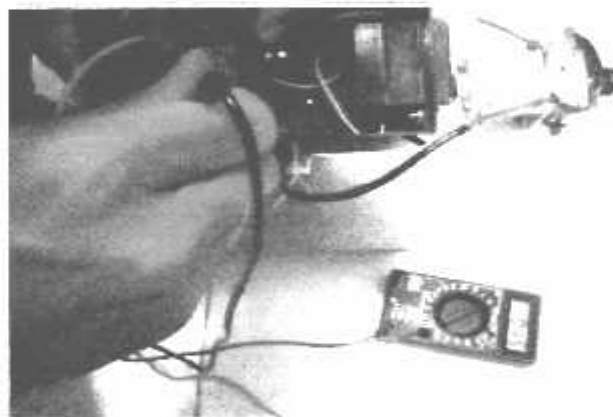
1. Voltmeter
2. Catu Daya
3. Alat Perancangan Sensor Accelerometer MMA7260QT

4.1.2 Pelaksanaan Pengujian

1. Merangkai Rangkaian sensor Accelerometer Seperti dalam gambar 4.1
2. Menghubungkan dengan Catu Daya
3. Menghubungkan Output rangkaian Accelerometer dengan voltmeter
4. Memberikan inputan sesuai dengan keinginan



Gambar 4.2 Pengujian Rangkaian Sensor Accelerometer MMA7260QT



Gambar 4.3 foto Pengujian Alat

4.1.3 Hasil dan Analisa Pengujian

Dari pengujian yang dilakukan dapat dijelaskan sebagai berikut
Tingkat sensitivitas sensor yang digunakan adalah 300mv/g dimana :
1 g = 10 mv/g jika sensitivitas yang digunakan sebesar 300mv/g maka perubahan tegangan tiap 1g yaitu $300 \div 10 = 30$ mv/g.

4.2 Pengujian Switch

Dari pengujian yang dilakukan dapat diperoleh data pengukuran seperti dalam tabel 4.2

Tabel 4.2 Tabel hasil pengujian tegangan tombol control manual

| Tombol Switch | Tidak ditekan | Ditekan |
|---------------|---------------|---------|
| Tombol 1 | 4.9 V | 0 V |
| Tombol 2 | 4.9 V | 0 V |

4.3 Pengujian ADC

4.3.1 Analisa Perhitungan nilai ADC sensor Accelerometer 7260QT

ADC ATMEGA8535 sebesar 10bit dengan tegangan suply $\pm 0.3V$.Tegangan refrensi pada chip internal sebesar 2.56V.Dari data tersebut dapat dihitung nilai tegangan ADC sebagai berikut :

$$ADC = \frac{V_{in} \cdot 1024}{V_{ref}}$$

Dengan demikian perhitungan ADC untuk tiap sudut dapat dihitung :

- Sudut $30^\circ = \frac{1.94 \times 1024}{2.5} = 794.6$ V
- Sudut $40^\circ = \frac{1.89 \times 1024}{2.5} = 774.1$ V
- Sudut $50^\circ = \frac{1.85 \times 1024}{2.5} = 757.7$ V
- Sudut $60^\circ = \frac{1.81 \times 1024}{2.5} = 741.3$ V
- Sudut $70^\circ = \frac{1.76 \times 1024}{2.5} = 720.8$ V
- Sudut $80^\circ = \frac{1.72 \times 1024}{2.5} = 704.5$ V

- Sudut $90^\circ = \frac{1.68 \times 1024}{2.5} = 688.1 \text{ V}$
- Sudut $100^\circ = \frac{1.63 \times 1024}{2.5} = 667.6 \text{ V}$
- Sudut $110^\circ = \frac{1.59 \times 1024}{2.5} = 651.2 \text{ V}$
- Sudut $120^\circ = \frac{1.55 \times 1024}{2.5} = 634.8 \text{ V}$
- Sudut $130^\circ = \frac{1.51 \times 1024}{2.5} = 618.1 \text{ V}$
- Sudut $140^\circ = \frac{1.47 \times 1024}{2.5} = 602.1 \text{ V}$
- Sudut $150^\circ = \frac{1.43 \times 1024}{2.5} = 585.7 \text{ V}$

Dari perhitungan yang dilakukan ADC sensor Accelerometer 7260QT dapat diperoleh hasil perhitungan seperti dalam tabel 4.3.

Tabel 4.3 Tabel hasil perhitungan ADC sensor Accelerometer 7260QT

| No | Sudut ($^\circ$) | Vin Sensor | Vout ADC |
|----|--------------------|------------|----------|
| 1 | 30 | 1.94 | 794.6 |
| 2 | 40 | 1.89 | 774.1 |
| 3 | 50 | 1.85 | 757.7 |
| 4 | 60 | 1.81 | 741.3 |
| 5 | 70 | 1.76 | 720.8 |
| 6 | 80 | 1.72 | 704.5 |
| 7 | 90 | 1.68 | 688.1 |
| 8 | 100 | 1.63 | 667.6 |
| 9 | 110 | 1.59 | 651.2 |
| 10 | 120 | 1.55 | 634.8 |
| 11 | 130 | 1.51 | 618.4 |
| 12 | 140 | 1.47 | 602.1 |
| 13 | 150 | 1.43 | 585.7 |

4.4 Pengujian Motor Servo

4.4.1 Analisa Pengukuran tegangan motor servo ketika terjadi respon kemiringan.

Motor servo jenis GWS03 memiliki tegangan sebesar 4.8V. Respon perubahan tegangan pada motor terhadap kemiringan berubah – ubah sesuai dengan perubahan sudut kemiringan. Dari hasil pengujian pengukuran tegangan yang dilakukan, respon perubahan tegangan motor servo terhadap sudut kemiringan ditunjukkan dalam tabel 4.4 :

Tabel 4.4 Hasil Pengukuran Respon Motor servo ketika terjadi perubahan kemiringan

| Tegangan Motor Servo (V) | Sudut (°) | Respon Perubahan tegangan motor terhadap sudut kemiringan (V) |
|--------------------------|-----------|---|
| 4.8 | 30 | 0.51 |
| 4.8 | 40 | 0.49 |
| 4.8 | 50 | 0.48 |
| 4.8 | 60 | 0.45 |
| 4.8 | 70 | 0.44 |
| 4.8 | 80 | 0.42 |
| 4.8 | 90 | 0.4 |
| 4.8 | 100 | 0.38 |
| 4.8 | 110 | 0.37 |
| 4.8 | 120 | 0.36 |
| 4.8 | 130 | 0.34 |
| 4.8 | 140 | 0.33 |
| 4.8 | 150 | 0.31 |

BAB V

KESIMPULAN DAN SARAN

5.1 Kesimpulan

Setelah dilakukan pengujian hasil perancangan alat Desain Penggerak Kamera Berbasis Gyroscopic dengan Menggunakan Mikrokontroler ATMEGA 8535, maka dapat diambil beberapa kesimpulan :

- Dari pengujian yang dilakukan dapat diperoleh data pengukuran tegangan sudut Kemiringan 90° sebesar 1,68mv.
- Dari pengujian yang dilakukan dapat diperoleh data pengukuran tegangan motor servo ketika terjadi perubahan kemiringan pada sudut 90° sebesar 0.4 V.
- Dari pengujian yang dilakukan dapat diperoleh data perhitungan nilai ADC sensor Accelerometer MMA 7260QT pada sudut 90° sebesar 688.1 V.
- Data pengukuran control manual (switch) pada saat tidak ditekan sebesar 4.9 V.
- Setiap perangkat, baik software maupun hardware dalam perancangan dan pembuatan alat ini mempunyai peran penting yang saling berkesinambungan satu sama lain agar tercipta sistemkerja yang maksimal.

5.2 Saran

- Pada alat desain penggerak kamera berbasis gyroscopic dengan menggunakan mikrokontroler ATMEGA 8535 ini dapat dikembangkan kembali dengan memanfaatkan ketiga sumbu sensor MMA7260QT sehingga alat dapat berfungsi dengan maksimal.
 - Untuk mendapatkan hasil yang lebih presisi dapat digunakan instrument ukur yang lebih presisi dan akurat.
 - Prancangan Mekanik sangat menentukan kualitas desain alat ini.
-

DAFTAR PUSTAKA

1. **Design dan implementasi system embedded Mikrokontroler ATMEGA8535 dengan bahasa basic**, iswanto, penerbit Gava Media, Yogyakarta
 2. <http://www.atmel.com>.
 3. <http://www.alldatasheet.com>
 4. **jenis jenis motor** <http://v4z4.wordpress.com/2010/03/30/jenis-jenis-motor-dalam-pada-cleckttronika/>
 5. <http://www.wikipedia.com/gyroscope>
 6. <http://jayaputrasbloq.blogspot.com/2011/04/definisi-atau-pengertian-istilah.html>
 7. <http://forum.onlineconversion.com/showthread.php?t=10523>
 8. <https://electrocontrol.wordpress.com/tag/motor-servo-rotasi/>
 9. <http://www.digitdude.com/2010/06/rangkaian-servo-motor-controller.html>
 10. www.sturdy.com
 11. <http://id.answers.yahoo.com/question/index?qid=20100905051309AAradzI>
 12. <http://archive.kaskus.us/thread/4806515>
 13. <http://www.motogp.com/en/news/2010/New%20Gyroscopic%20OnBoard%20Camera%20at%20Sachsenring>
 14. <http://archive.kaskus.us/thread/5333745>
 15. <http://www.robotshop.com/gws-mini-std-servo-motor.html>
 16. www.gws.com.tw
 17. www.gwsus.com
-

LAMPIRAN



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FORMULIR BIMBINGAN SKRIPSI

Nama : Bayu Perwira Negara
Nim : 05.12.214
Masa Bimbingan : 18 Juni 2011 s/d 18 Desember 2011
Judul Skripsi : Desain Penggerak Kamera Berbasis Gyroscopic Dengan Menggunakan Mikrokontroler ATmega 8535

| No | Tanggal | Uraian | Paraf Pembimbing |
|----|-----------|---------------------------------|------------------|
| 1 | 19-6-2011 | Konsultasi Gyro | |
| 2 | | Konsultasi bab I | |
| 3 | | Konsultasi sensor Accelerometer | |
| 4 | | Diagram blok | |
| 5 | 23/7 2011 | Bab 4 Pengujian Alat | |
| 6 | 26/7 2011 | Makalah seminar Hasil | |
| 7 | | laporan skripsi | |
| 8 | | | |
| 9 | | | |
| 10 | | | |

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NIP Y. 1930800417

Form S-4B



FORMULIR BIMBINGAN SKRIPSI

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Nim : 05.12.214
Masa Bimbingan : 18 Juni 2011 s/d 18 Desember 2011
Judul Skripsi : Desain Penggerak Kamera Berbasis Gyroscopic Dengan Menggunakan Mikrokontroler ATmega 8535

| No | Tanggal | Uraian | Paraf Pembimbing |
|----|-----------|---------------------------------|------------------|
| 1 | | Konsultasi Gyro sensor | |
| 2 | | Konsultasi Bab 1 | |
| 3 | | Konsultasi sensor Accelerometer | |
| 4 | | Diagram Alat | |
| 5 | 29/7 2011 | Bab 4 Pengujian Alat | |
| 6 | 28/7 2011 | Makalah Seminar hasil | |
| 7 | 16/8 2011 | Laporan Skripsi | |
| 8 | | | |
| 9 | | | |
| 10 | | | |

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FORMULIR PERBAIKAN SKRIPSI

Dalam pelaksanaan ujian skripsi jenjang Strata Satu (S-1) Jurusan Teknik Elektro Konsentrasi Teknik Elektronika, maka perlu adanya perbaikan skripsi untuk mahasiswa:

NAMA : BAYU PERWIRA NEGARA
NIM : 05.12.214
JURUSAN : Teknik Elektro S-1
KONSENTRASI : Teknik Elektronika
MASA BIMBINGAN: 18 juni 2011 s/d 18 Desember 2011
JUDUL : **DESAIN PENGGERAK KAMERA BERBASIS GYROSCOPIC DENGAN MENGGUNAKAN MIKROKONTROLER ATMEGA 8535**

| Tanggal | Uraian | Paraf |
|------------------------------|---|-------|
| Penguji I 20 - 08 - 2011 | Sensor MMA perancangannya Gambar 3.1 revisi Bab III Perancangan tiap Blok Pengujian sudut Kesimpulan diubah | |
| Penguji II 20 - 08 - 2011 | Pengujian on / off tombol Tambahkan error Daftar pustaka ditambah Gambar data sheet | |

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INSTITUT TEKNOLOGI NASIONAL MALANG
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 JURUSAN TEKNIK ELEKTRO

Formulir Perbaikan Ujian Skripsi

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NAMA : Brya Perdana Nugraha
 NIM : 0602211
 Perbaikan meliputi :

bab 3 dan 4 revisi

BAB 3 : perancangan tap blok

4. pengujian → skema 2

kesimpulan dan saran

Malang,

[Signature]



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FAKULTAS TEKNOLOGI INDUSTRI
JURUSAN TEKNIK ELEKTRO

Formulir Perbaikan Ujian Skripsi

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

NAMA

Bayu Purwita Negara.

NIM

051224.

Perbaikan meliputi

Penyisipan on/off → simbol

tambahan error

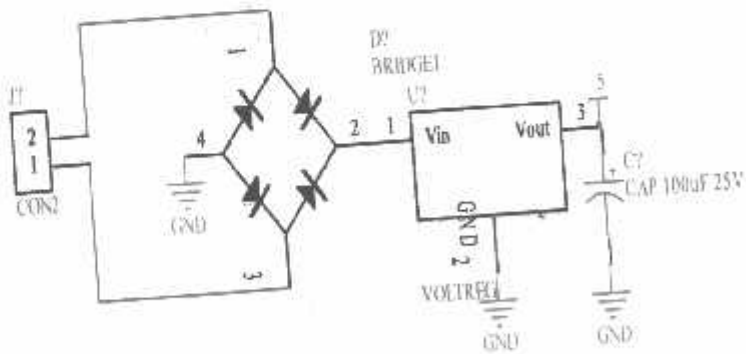
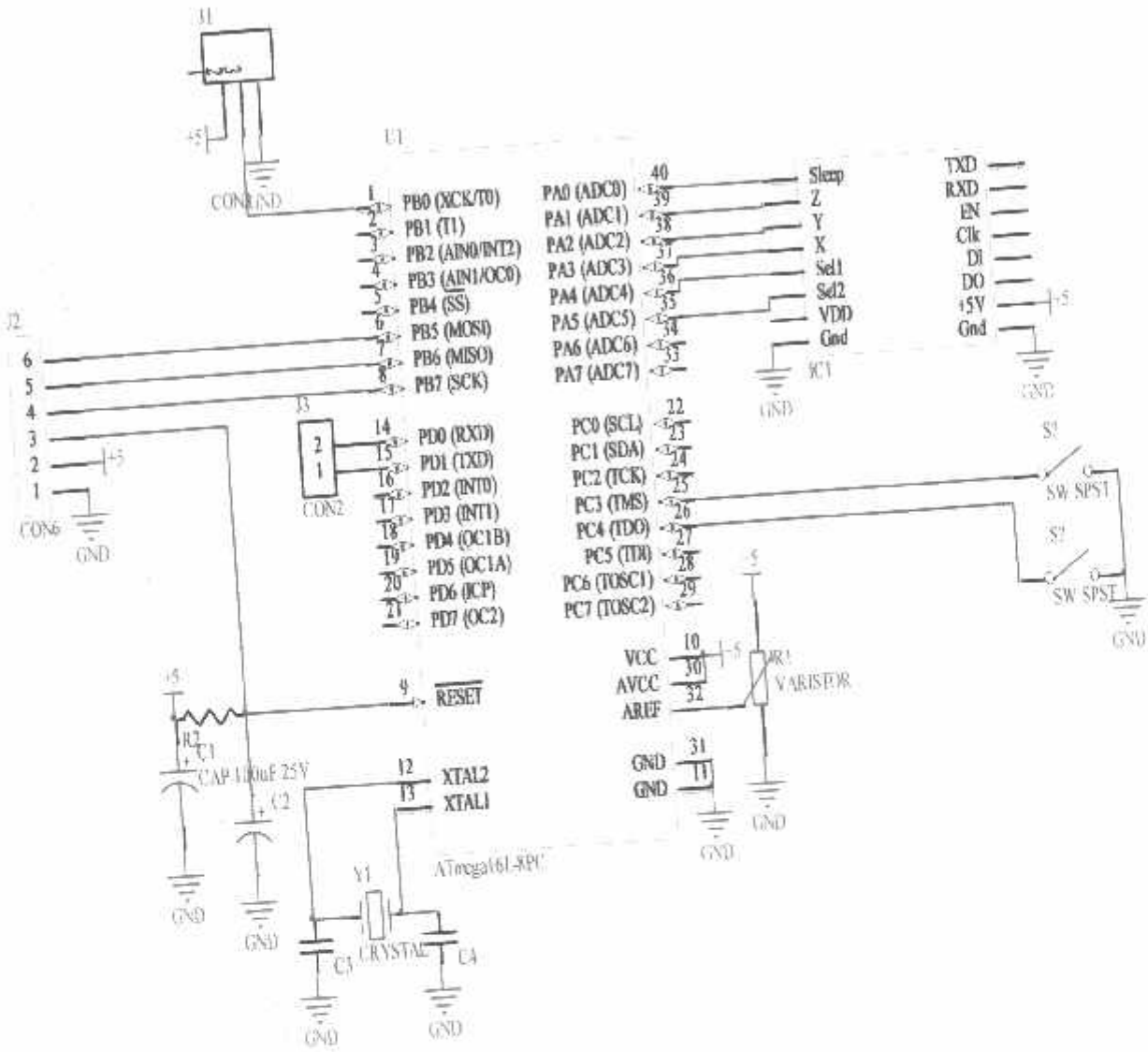
Daftar pustaka ditambahkan

misalnya kean dibawa tabel

Malang,

20 August 2016


M. Ibrahim Akhri, ST, MT



```
le = "m8535.dat"  
t al = 12000000  
= 9600
```

```
3  
g Adc = Single , Prescaler = Auto  
g Pina.0 = Output : Set Porta.0  
g Pina.4 = Output : Set Porta.4  
g Pina.5 = Output : Set Porta.5  
g Pind.4 = Input : Set Portd.4  
g Pind.6 = Input : Set Portd.6
```

```
g Servos = 1 , Servo1 = Portb.0 , Reload = 5  
g Portb = Output  
le Interrupts
```

```
t Mns = 70  
st Maxs = 255  
st Midl = 167  
A(100) As Wbrd , 1 As Byte , P1 As Byte , Setpy As Wbrd  
= 167  
o(1) = P1  
3
```

```
py = 330  
Start Adc  
A(1) = Getadc(2)  
Stop Adc  
f Setpy = A(1) Then  
P1 = Midl  
elseif Setpy > A(1) Then  
A(2) = Setpy - A(1)  
l = A(2)  
If l > 90 Then  
P1 = Mns  
Else  
P1 = Midl - l  
End If  
elseif Setpy < A(1) Then  
A(2) = A(1) - Setpy  
l = A(2)  
If l > 220 Then  
P1 = 220  
Else  
P1 = Midl + l  
End If  
nd if  
ervo(1) = P1  
@itms 1  
rint !  
Until Pind 4 = 0  
1
```

```
f Pind.4 = 0 Then  
Incr P1  
If P1 > 250 Then P1 = 250  
elseif Pind.6 = 0 Then  
Decr P1  
If P1 < Mns Then P1 = Mns  
nd if  
ervo(1) = P1  
@itms 10  
Until Pind.4 = 0 And Pind.6 = 0  
1 : Goto Awal
```

```
'end program
```

Features

- High-performance, Low-power AVR[®] 8-bit Microcontroller
- Advanced RISC Architecture
 - 130 Powerful Instructions – Most Single Clock Cycle Execution
 - 32 x 8 General Purpose Working Registers
 - Fully Static Operation
 - Up to 16 MIPS Throughput at 16 MHz
 - On-chip 2-cycle Multiplier
- Nonvolatile Program and Data Memories
 - 8K Bytes of In-System Self-Programmable Flash
 - Endurance: 10,000 Write/Erase Cycles
 - Optional Boot Code Section with Independent Lock Bits
 - In-System Programming by On-chip Boot Program
 - True Read-While-Write Operation
 - 512 Bytes EEPROM
 - Endurance: 100,000 Write/Erase Cycles
 - 512 Bytes Internal SRAM
 - Programming Lock for Software Security
- Peripheral Features
 - Two 8-bit Timer/Counters with Separate Prescalers and Compare Modes
 - One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
 - Real Time Counter with Separate Oscillator
 - Four PWM Channels
 - 8-channel, 10-bit ADC
 - 8 Single-ended Channels
 - 7 Differential Channels for TQFP Package Only
 - 2 Differential Channels with Programmable Gain at 1x, 10x, or 200x for TQFP Package Only
 - Byte-oriented Two-wire Serial Interface
 - Programmable Serial USART
 - Master/Slave SPI Serial Interface
 - Programmable Watchdog Timer with Separate On-chip Oscillator
 - On-chip Analog Comparator
- Special Microcontroller Features
 - Power-on Reset and Programmable Brown-out Detection
 - Internal Calibrated RC Oscillator
 - External and Internal Interrupt Sources
 - Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby and Extended Standby
- I/O and Packages
 - 32 Programmable I/O Lines
 - 40-pin PDIP, 44-lead TQFP, 44-lead PLCC, and 44-pad QFN/MLF
- Operating Voltages
 - 2.7 - 5.5V for ATmega8535L
 - 4.5 - 5.5V for ATmega8535
- Speed Grades
 - 0 - 8 MHz for ATmega8535L
 - 0 - 16 MHz for ATmega8535



8-bit AVR[®]
Microcontroller
with 8K Bytes
In-System
Programmable
Flash

ATmega8535
ATmega8535L

Summary

2502KS-AVR-10/06

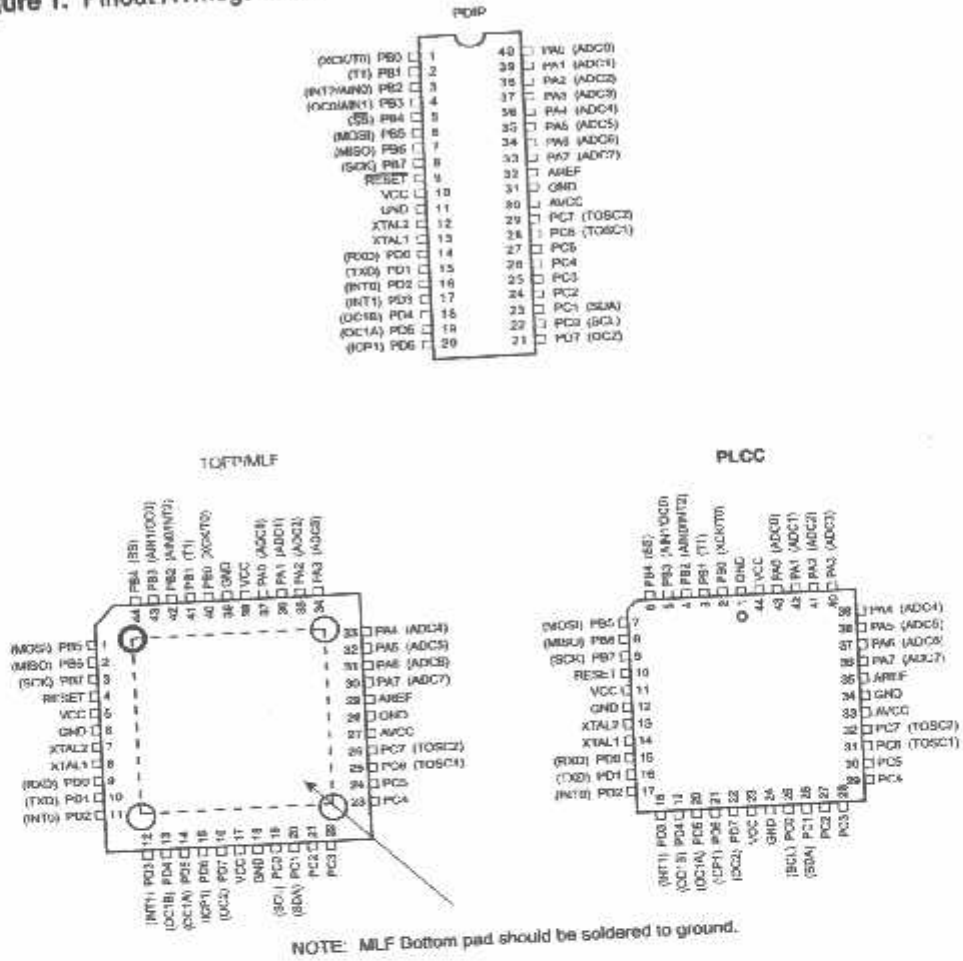


Note: This is a summary document. A complete document is available on our Web site at www.atmel.com.



Pin Configurations

Figure 1. Pinout ATmega8535



Disclaimer

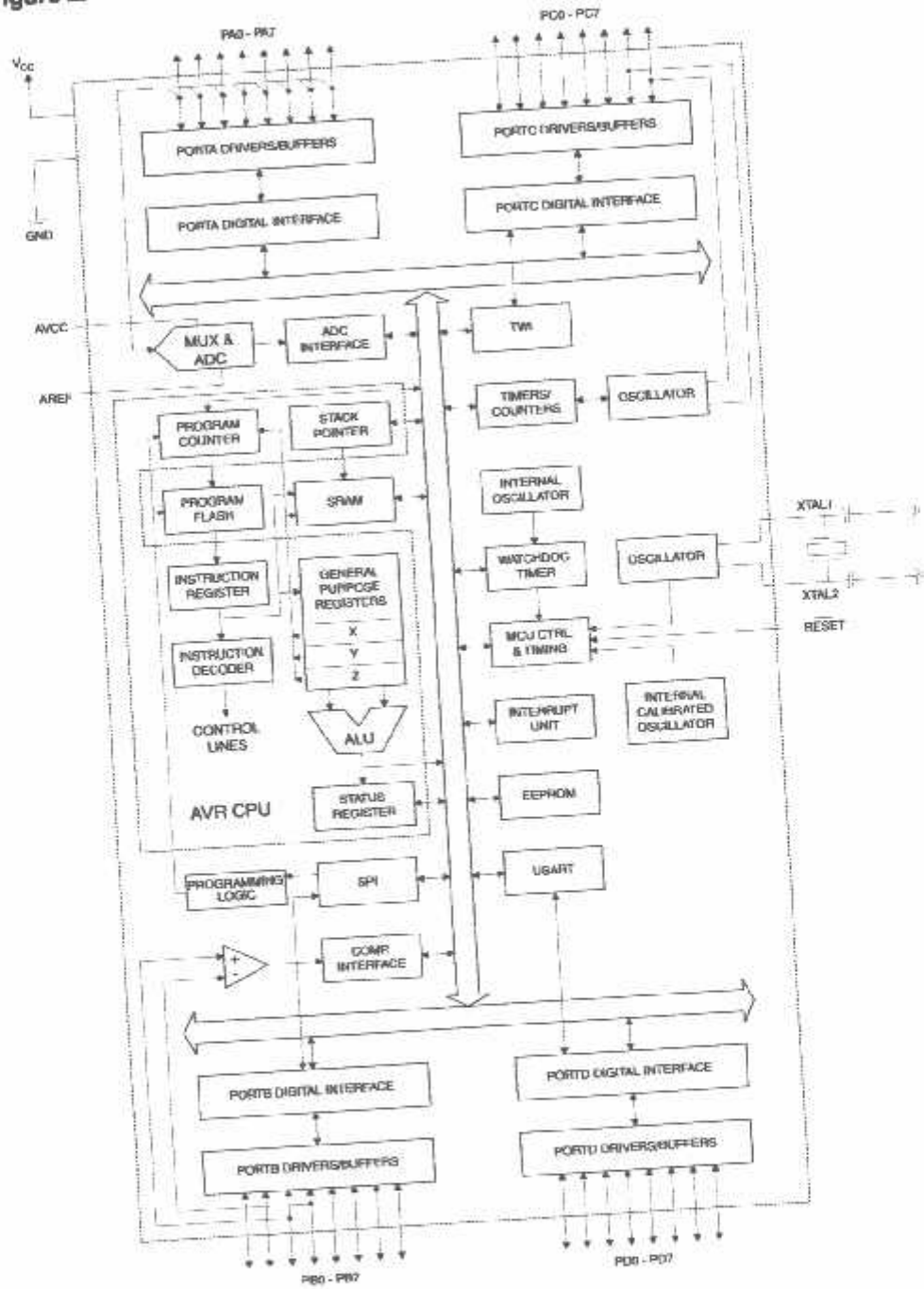
Typical values contained in this data sheet are based on simulations and characterization of other AVR microcontrollers manufactured on the same process technology. Min and Max values will be available after the device is characterized.

Overview

The ATmega8535 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing instructions in a single clock cycle, the ATmega8535 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

Block Diagram

Figure 2. Block Diagram





The AVR core combines a rich instruction set with 32 general purpose working registers. All 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers.

The ATmega8535 provides the following features: 8K bytes of In-System Programmable Flash with Read-While-Write capabilities, 512 bytes EEPROM, 512 bytes SRAM, 32 general purpose I/O lines, 32 general purpose working registers, three flexible Timer/Counters with compare modes, internal and external interrupts, a serial programmable USART, a byte oriented Two-wire Serial Interface, an 8-channel, 10-bit ADC with optional differential input stage with programmable gain in TQFP package, a programmable Watchdog Timer with Internal Oscillator, an SPI serial port, and six software selectable power saving modes. The Idle mode stops the CPU while allowing the SRAM, Timer/Counters, SPI port, and interrupt system to continue functioning. The Power-down mode saves the register contents but freezes the Oscillator, disabling all other chip functions until the next interrupt or Hardware Reset. In Power-save mode, the asynchronous timer continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping. The ADC Noise Reduction mode stops the CPU and all I/O modules except asynchronous timer and ADC, to minimize switching noise during ADC conversions. In Standby mode, the crystal/resonator Oscillator is running while the rest of the device is sleeping. This allows very fast start-up combined with low-power consumption. In Extended Standby mode, both the main Oscillator and the asynchronous timer continue to run.

The device is manufactured using Atmel's high density nonvolatile memory technology. The On-chip ISP Flash allows the program memory to be reprogrammed In-System through an SPI serial interface, by a conventional nonvolatile memory programmer, or by an On-chip Boot program running on the AVR core. The boot program can use any interface to download the application program in the Application Flash memory. Software in the Boot Flash section will continue to run while the Application Flash section is updated, providing true Read-While-Write operation. By combining an 8-bit RISC CPU with In-System Self-Programmable Flash on a monolithic chip, the Atmel ATmega8535 is a powerful microcontroller that provides a highly flexible and cost effective solution to many embedded control applications.

The ATmega8535 AVR is supported with a full suite of program and system development tools including: C compilers, macro assemblers, program debugger/simulators, In-Circuit Emulators, and evaluation kits.

AT90S8535 Compatibility

The ATmega8535 provides all the features of the AT90S8535. In addition, several new features are added. The ATmega8535 is backward compatible with AT90S8535 in most cases. However, some incompatibilities between the two microcontrollers exist. To solve this problem, an AT90S8535 compatibility mode can be selected by programming the S8535C fuse. ATmega8535 is pin compatible with AT90S8535, and can replace the AT90S8535 on current Printed Circuit Boards. However, the location of fuse bits and the electrical characteristics differs between the two devices.

AT90S8535 Compatibility Mode

Programming the S8535C fuse will change the following functionality:

- The timed sequence for changing the Watchdog Time-out period is disabled. See "Timed Sequences for Changing the Configuration of the Watchdog Timer" on page 45 for details.
- The double buffering of the USART Receive Register is disabled. See "AVR USART vs. AVR UART - Compatibility" on page 146 for details.

Pin Descriptions

| | |
|--------------------------|---|
| V_{CC} | Digital supply voltage. |
| GND | Ground. |
| Port A (PA7..PA0) | <p>Port A serves as the analog inputs to the A/D Converter.</p> <p>Port A also serves as an 8-bit bi-directional I/O port, if the A/D Converter is not used. Port pins can provide internal pull-up resistors (selected for each bit). The Port A output buffers have symmetrical drive characteristics with both high sink and source capability. When pins PA0 to PA7 are used as inputs and are externally pulled low, they will source current if the internal pull-up resistors are activated. The Port A pins are tri-stated when a reset condition becomes active, even if the clock is not running.</p> |
| Port B (PB7..PB0) | <p>Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port B output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port B pins that are externally pulled low will source current if the pull-up resistors are activated. The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not running.</p> <p>Port B also serves the functions of various special features of the ATmega8535 as listed on page 60.</p> |
| Port C (PC7..PC0) | <p>Port C is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port C output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port C pins that are externally pulled low will source current if the pull-up resistors are activated. The Port C pins are tri-stated when a reset condition becomes active, even if the clock is not running.</p> |
| Port D (PD7..PD0) | <p>Port D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port D output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port D pins that are externally pulled low will source current if the pull-up resistors are activated. The Port D pins are tri-stated when a reset condition becomes active, even if the clock is not running.</p> <p>Port D also serves the functions of various special features of the ATmega8535 as listed on page 64.</p> |
| RESET | <p>Reset input. A low level on this pin for longer than the minimum pulse length will generate a reset, even if the clock is not running. The minimum pulse length is given in Table 15 on page 37. Shorter pulses are not guaranteed to generate a reset.</p> |
| XTAL1 | Input to the inverting Oscillator amplifier and input to the internal clock operating circuit. |
| XTAL2 | Output from the inverting Oscillator amplifier. |
| AVCC | AVCC is the supply voltage pin for Port A and the A/D Converter. It should be externally connected to V _{CC} , even if the ADC is not used. If the ADC is used, it should be connected to V _{CC} through a low-pass filter. |
| AREF | AREF is the analog reference pin for the A/D Converter. |



A comprehensive set of development tools, application notes and datasheets are available for download on <http://www.atmel.com/avr>.

Resources

About Code Examples

This documentation contains simple code examples that briefly show how to use various parts of the device. These code examples assume that the part specific header file is included before compilation. Be aware that not all C compiler vendors include bit definitions in the header files and interrupt handling in C is compiler dependent. Please confirm with the C Compiler documentation for more details.



Register Summary

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Page |
|-------------|--------|--|--------|--------|--------|--------|------------|--------|--------|-----------------------|
| 0x3F (0x5F) | SREG | I | I | H | S | V | N | Z | C | 10 |
| 0x3E (0x5E) | SPH | - | - | - | - | - | - | SP0 | SP8 | 12 |
| 0x3D (0x5D) | SPL | SP7 | SP6 | SP5 | SP4 | SP3 | SP2 | SP1 | SP0 | 12 |
| 0x3C (0x5C) | OCR0 | Timer/Counter0 Output Compare Register | | | | | | | | 49, 69 |
| 0x3B (0x5B) | GICR | INT1 | INT0 | INT2 | - | - | - | IVSEL | IVCE | 70 |
| 0x3A (0x5A) | GIFR | INTF1 | INTF0 | INTF2 | OCIE1A | OCIE1B | TOIE1 | OCIE0 | TOIE0 | 85, 115, 133 |
| 0x39 (0x59) | TIMSK | OCIE2 | TOIE2 | ICF1 | OCF1A | OCF1B | TOV1 | OCF0 | TOV0 | 86, 116, 134 |
| 0x38 (0x58) | TIFR | OCF2 | TOV2 | ICF1 | OCF1A | OCF1B | PGWRT | PGERS | SPMEN | 228 |
| 0x37 (0x57) | SPMCR | SPMIE | RWWSB | - | RWWSRE | BLBSET | TWEN | - | TWIE | 181 |
| 0x36 (0x56) | TWCR | TWINT | TWEA | TWSTA | TWSTO | TWWC | ISC11 | ISC10 | ISC01 | ISC00 |
| 0x35 (0x55) | MCUCR | SM2 | SE | SM1 | - | WDRF | BORF | EXTRF | PORF | 40, 69 |
| 0x34 (0x54) | MCUCSR | - | ISC2 | - | - | WGM01 | CS02 | CS01 | CS00 | 83 |
| 0x33 (0x53) | TCCR0 | FOC0 | WGM00 | COM01 | COM00 | WGM01 | CS02 | CS01 | CS00 | 86 |
| 0x32 (0x52) | TCNT0 | Timer/Counter0 (8 Bits) | | | | | | | | 30 |
| 0x31 (0x51) | OSCCAL | Oscillator Calibration Register | | | | | | | | 59, 88, 135, 203, 223 |
| 0x30 (0x50) | SFIOH | ADTS2 | ADTS1 | ADTS0 | COM1B0 | FOC1A | FOC1B | WGM11 | WGM10 | 110 |
| 0x2F (0x4F) | TCCR1A | COM1A1 | COM1A0 | COM1B1 | COM1B0 | FOC1A | FOC1B | WGM11 | WGM10 | 113 |
| 0x2E (0x4E) | TCCR1B | ICNC1 | ICES1 | - | WGM13 | WGM12 | CS12 | CS11 | CS10 | 114 |
| 0x2D (0x4D) | TCNT1H | Timer/Counter1 - Counter Register High Byte | | | | | | | | 114 |
| 0x2C (0x4C) | TCNT1L | Timer/Counter1 - Counter Register Low Byte | | | | | | | | 114 |
| 0x2B (0x4B) | OCR1AH | Timer/Counter1 - Output Compare Register A High Byte | | | | | | | | 114 |
| 0x2A (0x4A) | OCR1AL | Timer/Counter1 - Output Compare Register A Low Byte | | | | | | | | 114 |
| 0x29 (0x49) | OCR1BH | Timer/Counter1 - Output Compare Register B High Byte | | | | | | | | 114 |
| 0x28 (0x48) | OCR1BL | Timer/Counter1 - Output Compare Register B Low Byte | | | | | | | | 114 |
| 0x27 (0x47) | ICR1H | Timer/Counter1 - Input Capture Register High Byte | | | | | | | | 114 |
| 0x26 (0x46) | ICR1L | Timer/Counter1 - Input Capture Register Low Byte | | | | | | | | 114 |
| 0x25 (0x45) | TCCR2 | FOC2 | WGM20 | COM21 | COM20 | WGM21 | CS22 | CS21 | CS20 | 128 |
| 0x24 (0x44) | TGNT2 | Timer/Counter2 (8 Bits) | | | | | | | | 131 |
| 0x23 (0x43) | OCR2 | Timer/Counter2 Output Compare Register | | | | | | | | 131 |
| 0x22 (0x42) | ASSR | - | - | - | WDCE | WDE | AS2 | TCN2UB | OCR2UB | TCR2UB |
| 0x21 (0x41) | WDTCR | - | - | - | - | - | USRR[11:8] | UCS21 | UCS20 | UCPOL |
| 0x20 (0x40) | UBRR1 | URSEL | UMSEL | UPM1 | UPM0 | USBS | UCS21 | UCS20 | UCPOL | 19 |
| 0x1F (0x3F) | UCSR0 | URSEL | UMSEL | UPM1 | UPM0 | USBS | UCS21 | UCS20 | UCPOL | 19 |
| 0x1E (0x3E) | EEAR1 | EEPROM Address Register Low Byte | | | | | | | | 19 |
| 0x1D (0x3D) | EEAR0 | EEPROM Address Register High Byte | | | | | | | | 19 |
| 0x1C (0x3C) | EEDR | EEPROM Data Register | | | | | | | | 19 |
| 0x1B (0x3B) | EECR | - | - | - | - | - | EERIE | EEMWE | EEMTE | 19 |
| 0x1A (0x3A) | PORTA | PORTA7 | PORTA6 | PORTA5 | PORTA4 | PORTA3 | PORTA2 | PORTA1 | PORTA0 | 66 |
| 0x19 (0x39) | DDRA | DDA7 | DDA6 | DDA5 | DDA4 | DDA3 | DDA2 | DDA1 | DDA0 | 66 |
| 0x18 (0x38) | PINA | PINA7 | PINA6 | PINA5 | PINA4 | PINA3 | PINA2 | PINA1 | PINA0 | 66 |
| 0x17 (0x37) | PORTB | PORTB7 | PORTB6 | PORTB5 | PORTB4 | PORTB3 | PORTB2 | PORTB1 | PORTB0 | 66 |
| 0x16 (0x36) | DDR B | DD B7 | DD B6 | DD B5 | DD B4 | DD B3 | DD B2 | DD B1 | DD B0 | 66 |
| 0x15 (0x35) | PIN B | PIN B7 | PIN B6 | PIN B5 | PIN B4 | PIN B3 | PIN B2 | PIN B1 | PIN B0 | 67 |
| 0x14 (0x34) | PORTC | PORTC7 | PORTC6 | PORTC5 | PORTC4 | PORTC3 | PORTC2 | PORTC1 | PORTC0 | 67 |
| 0x13 (0x33) | DDRC | DDC7 | DDC6 | DDC5 | DDC4 | DDC3 | DDC2 | DDC1 | DDC0 | 67 |
| 0x12 (0x32) | PINC | PINC7 | PINC6 | PINC5 | PINC4 | PINC3 | PINC2 | PINC1 | PINC0 | 67 |
| 0x11 (0x31) | PORTD | PORTD7 | PORTD6 | PORTD5 | PORTD4 | PORTD3 | PORTD2 | PORTD1 | PORTD0 | 67 |
| 0x10 (0x30) | DDRD | DDD7 | DDD6 | DDD5 | DDD4 | DDD3 | DDD2 | DDD1 | DDD0 | 67 |
| 0x0F (0x2F) | PIND | PIND7 | PIND6 | PIND5 | PIND4 | PIND3 | PIND2 | PIND1 | PIND0 | 143 |
| 0x0E (0x2E) | SPDR | SPI Data Register | | | | | | | | 143 |
| 0x0D (0x2D) | SPIF | WCOL | - | - | - | - | CPOL | CPHA | SPR1 | SPR0 |
| 0x0C (0x2C) | SPCR | SPIE | SPE | DORD | MSTR | CPOL | CPHA | SPR1 | SPR0 | 141 |
| 0x0B (0x2B) | UDR | USART I/O Data Register | | | | | | | | 165 |
| 0x0A (0x2A) | UCSRA | RXCIE | TXCIE | UDRIE | FE | DOR | PE | U2X | MPCM | 166 |
| 0x09 (0x29) | UCSRB | RXCIE | TXCIE | UDRIE | RXEN | TXEN | UCS22 | RXB8 | TXB8 | 169 |
| 0x08 (0x28) | UBRR1 | USART Baud Rate Register Low Byte | | | | | | | | 203 |
| 0x07 (0x27) | ACSR | ACD | ACBG | AC0 | AC1 | ACIE | ACIC | ACIS1 | ACIS0 | 219 |
| 0x06 (0x26) | ADMUX | REFS1 | REFS0 | ADLAR | MUX4 | MUX3 | MUX2 | MUX1 | MUX0 | 221 |
| 0x05 (0x25) | ADCSRA | ADEN | ADSC | ADATE | ADIF | ADIE | ADPS2 | ADPS1 | ADPS0 | 222 |
| 0x04 (0x24) | ADCH | ADC Data Register High Byte | | | | | | | | 222 |
| 0x03 (0x23) | ADCL | ADC Data Register Low Byte | | | | | | | | 183 |
| 0x02 (0x22) | TWDR | Two-wire Serial Interface Data Register | | | | | | | | 183 |
| 0x01 (0x21) | TWSR | TWS7 | TWS6 | TWS5 | TWS4 | TWS3 | TWS2 | TWS1 | TWS0 | 183 |

Register Summary (Continued)

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Page |
|-------------|------|---|-------|-------|-------|-------|-------|-------|-------|------|
| 0x00 (0x20) | TWBR | Two-wire Serial Interface Bit Rate Register | | | | | | | | 181 |

- Notes:
1. Refer to the USART description for details on how to access UBRRH and UCSRC.
 2. For compatibility with future devices, reserved bits should be written to zero if accessed. Reserved I/O memory addresses should never be written.
 3. Some of the status flags are cleared by writing a logical one to them. Note that the CBI and SBI instructions will operate on all bits in the I/O Register, writing a one back into any flag read as set, thus clearing the flag. The CBI and SBI instructions work with registers 0x00 to 0x1F only.





Instruction Set Summary

| Mnemonic | Operands | Description | Operation | Flags | #Clocks |
|--|----------|---|---|---------------|---------|
| ARITHMETIC AND LOGIC INSTRUCTIONS | | | | | |
| ADD | Rd, Rr | Add two Registers | $Rd \leftarrow Rd + Rr$ | Z, C, N, V, H | 1 |
| ADC | Rd, Rr | Add with Carry two Registers | $Rd \leftarrow Rd + Rr + C$ | Z, C, N, V, H | 1 |
| ADW | Rd, K | Add Immediate to Word | $RdH:RdL \leftarrow RdH:RdL + K$ | Z, C, N, V, S | 2 |
| SUB | Rd, Rr | Subtract two Registers | $Rd \leftarrow Rd - Rr$ | Z, C, N, V, H | 1 |
| SUBI | Rd, K | Subtract Constant from Register | $Rd \leftarrow Rd - K$ | Z, C, N, V, H | 1 |
| SBC | Rd, Rr | Subtract with Carry two Registers | $Rd \leftarrow Rd - Rr - C$ | Z, C, N, V, H | 1 |
| SBCI | Rd, K | Subtract with Carry Constant from Reg. | $Rd \leftarrow Rd - K - C$ | Z, C, N, V, S | 2 |
| SBIW | Rd, K | Subtract Immediate from Word | $RdH:RdL \leftarrow RdH:RdL - K$ | Z, N, V | 1 |
| AND | Rd, Rr | Logical AND Registers | $Rd \leftarrow Rd \& Rr$ | Z, N, V | 1 |
| ANDI | Rd, K | Logical AND Register and Constant | $Rd \leftarrow Rd \& K$ | Z, N, V | 1 |
| OR | Rd, Rr | Logical OR Registers | $Rd \leftarrow Rd \vee Rr$ | Z, N, V | 1 |
| ORI | Rd, K | Logical OR Register and Constant | $Rd \leftarrow Rd \vee K$ | Z, N, V | 1 |
| XOR | Rd, Rr | Exclusive OR Registers | $Rd \leftarrow Rd \oplus Rr$ | Z, C, N, V | 1 |
| XORI | Rd, K | Exclusive OR Register and Constant | $Rd \leftarrow Rd \oplus K$ | Z, C, N, V, H | 1 |
| COM | Rd | One's Complement | $Rd \leftarrow \text{bit00} \cdot Rd$ | Z, N, V | 1 |
| NEG | Rd | Two's Complement | $Rd \leftarrow Rd \vee K$ | Z, N, V | 1 |
| SBR | Rd, K | Set Bit(s) in Register | $Rd \leftarrow Rd \vee (0x\text{FF} - K)$ | Z, N, V | 1 |
| CBR | Rd, K | Clear Bit(s) in Register | $Rd \leftarrow Rd \& K$ | Z, N, V | 1 |
| INC | Rd | Increment | $Rd \leftarrow Rd + 1$ | Z, N, V | 1 |
| DEC | Rd | Decrement | $Rd \leftarrow Rd - 1$ | Z, N, V | 1 |
| DEC | Rd | Test for Zero or Minus | $Rd \leftarrow Rd \oplus Rd$ | Z, N, V | 1 |
| TST | Rd | Test for Zero or Minus | $Rd \leftarrow Rd \oplus Rd$ | Z, N, V | 1 |
| CLR | Rd | Clear Register | $Rd \leftarrow 0x\text{FF}$ | None | 2 |
| SET | Rd | Set Register | $Rd \leftarrow 0x\text{FF}$ | Z, C | 2 |
| SER | Rd | Set Register | $Rd \leftarrow 0x\text{FF}$ | Z, C | 2 |
| MUL | Rd, Rr | Multiply Unsigned | $R1:R0 \leftarrow Rd \times Rr$ | Z, C | 2 |
| MULS | Rd, Rr | Multiply Signed | $R1:R0 \leftarrow Rd \times Rr$ | Z, C | 2 |
| MULSU | Rd, Rr | Multiply Signed with Unaligned | $R1:R0 \leftarrow (Rd \times Rr) \ll 1$ | Z, C | 2 |
| FMUL | Rd, Rr | Fractional Multiply Unsigned | $R1:R0 \leftarrow (Rd \times Rr) \ll 1$ | Z, C | 2 |
| FMULS | Rd, Rr | Fractional Multiply Signed | $R1:R0 \leftarrow (Rd \times Rr) \ll 1$ | Z, C | 2 |
| FMULSU | Rd, Rr | Fractional Multiply Signed with Unaligned | $R1:R0 \leftarrow (Rd \times Rr) \ll 1$ | Z, C | 2 |
| BRANCH INSTRUCTIONS | | | | | |
| RJMP | k | Relative Jump | $PC \leftarrow PC + k + 1$ | None | 2 |
| IJMP | | Indirect Jump to (Z) | $PC \leftarrow Z$ | None | 3 |
| lJMP | | Indirect Jump to (Z) | $PC \leftarrow PC + k + 1$ | None | 3 |
| RCALL | k | Relative Subroutine Call | $PC \leftarrow Z$ | None | 4 |
| ICALL | | Indirect Call to (Z) | $PC \leftarrow \text{STACK}$ | None | 4 |
| ICALL | | Subroutine Return | $PC \leftarrow \text{STACK}$ | None | 4 |
| RET | | Interrupt Return | $PC \leftarrow \text{STACK}$ | None | 1/2/3 |
| RETI | | Interrupt Return | $PC \leftarrow \text{STACK}$ | None | 1/2/3 |
| CPSE | Rd, Rr | Compare, Stop if Equal | $\text{if } (Rd = Rr) \text{ then } PC \leftarrow PC + 2 \text{ or } 3$ | Z, N, V, C, H | 1 |
| CP | Rd, Rr | Compare | $Rd - Rr$ | Z, N, V, C, H | 1 |
| CP | Rd, Rr | Compare with Carry | $Rd - Rr - C$ | Z, N, V, C, H | 1 |
| CPC | Rd, Rr | Compare Register with Immediate | $Rd - K$ | None | 1/2/3 |
| CPI | Rd, K | Compare Register with Immediate | $Rd - K$ | None | 1/2/3 |
| SBRC | Rr, b | Skip if Bit in Register Cleared | $\text{if } (Rr(b)=0) \text{ then } PC \leftarrow PC + 2 \text{ or } 3$ | None | 1/2/3 |
| SBRS | Rr, b | Skip if Bit in Register Set | $\text{if } (Rr(b)=1) \text{ then } PC \leftarrow PC + 2 \text{ or } 3$ | None | 1/2/3 |
| SBIC | P, b | Skip if Bit in I/O Register Cleared | $\text{if } (P(b)=0) \text{ then } PC \leftarrow PC + 2 \text{ or } 3$ | None | 1/2/3 |
| SBIS | P, b | Skip if Bit in I/O Register Set | $\text{if } (P(b)=1) \text{ then } PC \leftarrow PC + 2 \text{ or } 3$ | None | 1/2 |
| BRSC | s, k | Branch if Status Flag Set | $\text{if } (SREG(s)=1) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRSS | s, k | Branch if Status Flag Set | $\text{if } (SREG(s)=0) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRBC | s, k | Branch if Status Flag Cleared | $\text{if } (Z = 1) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRBE | s, k | Branch if Status Flag Cleared | $\text{if } (Z = 0) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRNE | k | Branch if Not Equal | $\text{if } (Z = 1) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRNC | k | Branch if Not Carry | $\text{if } (C = 1) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRCS | k | Branch if Carry Set | $\text{if } (C = 0) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRCC | k | Branch if Carry Cleared | $\text{if } (C = 1) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRSH | k | Branch if Same or Higher | $\text{if } (C = 1) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRBH | k | Branch if Same or Higher | $\text{if } (C = 0) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRLO | k | Branch if Lower | $\text{if } (N = 1) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRHI | k | Branch if Lower | $\text{if } (N = 0) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRPL | k | Branch if Minus | $\text{if } (N = 0) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRMI | k | Branch if Minus | $\text{if } (N = 1) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRPL | k | Branch if Plus | $\text{if } (N \oplus V = 0) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRGE | k | Branch if Greater or Equal, Signed | $\text{if } (N \oplus V = 1) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRLE | k | Branch if Less Than Zero, Signed | $\text{if } (N \oplus V = 1) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRLT | k | Branch if Less Than Zero, Signed | $\text{if } (H = 1) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRHS | k | Branch if Half Carry Flag Set | $\text{if } (H = 0) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRHC | k | Branch if Half Carry Flag Cleared | $\text{if } (H = 1) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRNC | k | Branch if Half Carry Flag Cleared | $\text{if } (T = 1) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRIS | k | Branch if T Flag Set | $\text{if } (T = 0) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRIS | k | Branch if T Flag Cleared | $\text{if } (T = 1) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRIS | k | Branch if T Flag Cleared | $\text{if } (V = 1) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRIS | k | Branch if T Flag Cleared | $\text{if } (V = 0) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRIS | k | Branch if T Flag Cleared | $\text{if } (I = 1) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRIS | k | Branch if T Flag Cleared | $\text{if } (I = 0) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRIS | k | Branch if T Flag Cleared | $\text{if } (I = 1) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| BRIS | k | Branch if T Flag Cleared | $\text{if } (I = 0) \text{ then } PC \leftarrow PC + k + 1$ | None | 1/2 |
| DATA TRANSFER INSTRUCTIONS | | | | | |

| Mnemonics | Operands | Description | Operation | Flags | #Clocks |
|--------------------------------------|----------|-----------------------------------|--|------------|---------|
| | | | $Rd \leftarrow Rr$ | None | 1 |
| MOV | Rd, Rr | Move Between Registers | $Rd \leftarrow Rr$ | None | 1 |
| MOVW | Rd, Rr | Copy Register Word | $Rd \leftarrow Rr$ | None | 1 |
| LDI | Rd, K | Load Immediate | $Rd \leftarrow K$ | None | 2 |
| LD | Rd, X | Load Indirect | $Rd \leftarrow (X)$ | None | 2 |
| LD | Rd, X+ | Load Indirect and Post-Inc. | $X \leftarrow X + 1, Rd \leftarrow (X)$ | None | 2 |
| LD | Rd, -X | Load Indirect and Pre-Dec. | $Rd \leftarrow (X), X \leftarrow X - 1$ | None | 2 |
| LD | Rd, Y | Load Indirect | $Rd \leftarrow (Y)$ | None | 2 |
| LD | Rd, Y+ | Load Indirect and Post-Inc. | $Y \leftarrow Y + 1, Rd \leftarrow (Y)$ | None | 2 |
| LD | Rd, -Y | Load Indirect and Pre-Dec. | $Rd \leftarrow (Y), Y \leftarrow Y - 1$ | None | 2 |
| LDD | Rd, Y+q | Load Indirect with Displacement | $Rd \leftarrow (Y + q)$ | None | 2 |
| LD | Rd, Z | Load Indirect | $Rd \leftarrow (Z)$ | None | 2 |
| LD | Rd, Z+ | Load Indirect and Post-Inc. | $Z \leftarrow Z + 1, Rd \leftarrow (Z)$ | None | 2 |
| LD | Rd, -Z | Load Indirect and Pre-Dec. | $Rd \leftarrow (Z), Z \leftarrow Z - 1$ | None | 2 |
| LDD | Rd, Z+q | Load Indirect with Displacement | $Rd \leftarrow (Z + q)$ | None | 2 |
| LDS | Rd, k | Load Direct from SRAM | $(k) \leftarrow Rr$ | None | 2 |
| ST | X, Rr | Store Indirect | $(X) \leftarrow Rr, X \leftarrow X + 1$ | None | 2 |
| ST | X+, Rr | Store Indirect and Post-Inc. | $X \leftarrow X + 1, (X) \leftarrow Rr$ | None | 2 |
| ST | -X, Rr | Store Indirect and Pre-Dec. | $(X) \leftarrow Rr, X \leftarrow X - 1$ | None | 2 |
| ST | Y, Rr | Store Indirect | $(Y) \leftarrow Rr$ | None | 2 |
| ST | Y+, Rr | Store Indirect and Post-Inc. | $Y \leftarrow Y + 1, (Y) \leftarrow Rr$ | None | 2 |
| ST | -Y, Rr | Store Indirect and Pre-Dec. | $(Y) \leftarrow Rr, Y \leftarrow Y - 1$ | None | 2 |
| STD | Y+q, Rr | Store Indirect with Displacement | $(Y + q) \leftarrow Rr$ | None | 2 |
| ST | Z, Rr | Store Indirect | $(Z) \leftarrow Rr$ | None | 2 |
| ST | Z+, Rr | Store Indirect and Post-Inc. | $Z \leftarrow Z + 1, (Z) \leftarrow Rr$ | None | 2 |
| ST | -Z, Rr | Store Indirect and Pre-Dec. | $(Z) \leftarrow Rr, Z \leftarrow Z - 1$ | None | 2 |
| STD | Z+q, Rr | Store Indirect with Displacement | $(Z + q) \leftarrow Rr$ | None | 2 |
| STS | k, Rr | Store Direct to SRAM | $Rr \leftarrow (k)$ | None | 3 |
| LPM | | Load Program Memory | $Rd \leftarrow (Z)$ | None | 3 |
| LPM | Rd, Z | Load Program Memory | $Rd \leftarrow (Z), Z \leftarrow Z + 1$ | None | - |
| LPM | Rd, Z+ | Load Program Memory and Post-Inc. | $(Z) \leftarrow Rr, Z \leftarrow Z + 1$ | None | 1 |
| SPM | | Store Program Memory | $Rd \leftarrow P$ | None | 1 |
| IN | Rd, P | In Port | $P \leftarrow Rr$ | None | 2 |
| OUT | P, Rr | Out Port | $STACK \leftarrow Rr$ | None | 2 |
| PUSH | Rr | Push Register on Stack | $Rd \leftarrow STACK$ | None | 2 |
| POP | Rd | Pop Register from Stack | | None | 2 |
| BIT AND BIT-TEST INSTRUCTIONS | | | | | |
| SBI | P, b | Set Bit in I/O Register | $I/O(P, b) \leftarrow 1$ | None | 2 |
| CBI | P, b | Clear Bit in I/O Register | $I/O(P, b) \leftarrow 0$ | Z, C, N, V | 1 |
| LSL | Rd | Logical Shift Left | $Rd(n+1) \leftarrow Rd(n), Rd(0) \leftarrow 0$ | Z, C, N, V | 1 |
| LSR | Rd | Logical Shift Right | $Rd(n) \leftarrow Rd(n+1), Rd(7) \leftarrow 0$ | Z, C, N, V | 1 |
| ROL | Rd | Rotate Left Through Carry | $Rd(0) \leftarrow C, Rd(n+1) \leftarrow Rd(n), C \leftarrow Rd(7)$ | Z, C, N, V | 1 |
| ROR | Rd | Rotate Right Through Carry | $Rd(7) \leftarrow C, Rd(n) \leftarrow Rd(n+1), C \leftarrow Rd(0)$ | Z, C, N, V | 1 |
| ASR | Rd | Arithmetic Shift Right | $Rd(n) \leftarrow Rd(n+1), n=0..8$ | None | 1 |
| SWAP | Rd | Swap Nibbles | $Rd(3..0) \leftarrow Rd(7..4), Rd(7..4) \leftarrow Rd(3..0)$ | SREG(s) | 1 |
| BSET | s | Flag Set | $SREG(s) \leftarrow 1$ | SREG(s) | 1 |
| BCLR | s | Flag Clear | $SREG(s) \leftarrow 0$ | T | 1 |
| BCLP | Rr, b | Bit Store from Register to T | $T \leftarrow Rr(b)$ | None | 1 |
| BST | Rd, b | Bit Load from T to Register | $Rd(b) \leftarrow T$ | C | 1 |
| BLD | | Set Carry | $C \leftarrow 1$ | C | 1 |
| SEC | | Clear Carry | $C \leftarrow 0$ | N | 1 |
| CLC | | Set Negative Flag | $N \leftarrow 1$ | N | 1 |
| SEN | | Clear Negative Flag | $N \leftarrow 0$ | Z | 1 |
| CLN | | Set Zero Flag | $Z \leftarrow 1$ | Z | 1 |
| SEZ | | Clear Zero Flag | $Z \leftarrow 0$ | I | 1 |
| CLZ | | Global Interrupt Enable | $I \leftarrow 1$ | I | 1 |
| SEI | | Global Interrupt Disable | $I \leftarrow 0$ | S | 1 |
| CLI | | Set Signed Test Flag | $S \leftarrow 1$ | S | 1 |
| SEB | | Clear Signed Test Flag | $S \leftarrow 0$ | V | 1 |
| CLB | | Set Two's Complement Overflow | $V \leftarrow 1$ | V | 1 |
| SEV | | Clear Two's Complement Overflow | $V \leftarrow 0$ | T | 1 |
| CLV | | Set T in SREG | $T \leftarrow 1$ | T | 1 |
| SET | | Clear T in SREG | $T \leftarrow 0$ | H | 1 |
| CLT | | Set Half Carry Flag in SREG | $H \leftarrow 1$ | H | 1 |
| SEH | | Clear Half Carry Flag in SREG | $H \leftarrow 0$ | | 1 |
| CLH | | | | None | 1 |
| MCU CONTROL INSTRUCTIONS | | | | | |
| NOP | | No Operation | | | |





| Mnemonics | Operands | Description | Operation | Flags | #Clocks |
|-----------|----------|----------------|--|-------|---------|
| SLEEP | | Sleep | (see specific descr. for Sleep function) | None | 1 |
| WDR | | Watchdog Reset | (see specific descr. for WDR/Timer) | None | 1 |
| BREAK | | Break | For On-chip Debug Only | None | N/A |

Ordering Information

| Speed (MHz) | Power Supply | Ordering Code | Package ⁽¹⁾ | Operation Range | |
|--------------------------------|--------------------------------|-----------------|-------------------------------|-------------------------------|-----------------------------|
| 8 | 2.7 - 5.5V | ATmega8535L-8AC | 44A | Commercial (0°C to 70°C) | |
| | | ATmega8535L-8PC | 40P6 | | |
| | | ATmega8535L-8JC | 44J | | |
| | | ATmega8535L-8MC | 44M1 | | |
| | | ATmega8535L-8AJ | 44A | Industrial (-40°C to 85°C) | |
| | | ATmega8535L-8PI | 40P6 | | |
| | | ATmega8535L-8JI | 44J | | |
| | | ATmega8535L-8MI | 44M1 | | |
| | ATmega8535L-8AU ⁽²⁾ | 44A | | | |
| | ATmega8535L-8PU ⁽²⁾ | 40P6 | | | |
| | ATmega8535L-8JU ⁽²⁾ | 44J | | | |
| | ATmega8535L-8MU ⁽²⁾ | 44M1 | | | |
| | 16 | 4.5 - 5.5V | ATmega8535-16AC | 44A | Commercial (0°C to 70°C) |
| | | | ATmega8535-16PC | 40P6 | |
| ATmega8535-16JC | | | 44J | | |
| ATmega8535-16MC | | | 44M1 | | |
| ATmega8535-16AJ | | 44A | Industrial (-40°C to 85°C) | | |
| ATmega8535-16PI | | 40P6 | | | |
| ATmega8535-16JI | | 44J | | | |
| ATmega8535-16MI | | 44M1 | | | |
| ATmega8535-16AU ⁽²⁾ | | 44A | | | |
| ATmega8535-16PU ⁽²⁾ | | 40P6 | | | |
| ATmega8535-16JU ⁽²⁾ | 44J | | | | |
| ATmega8535-16MU ⁽²⁾ | 44M1 | | | | |

- Note: 1. This device can also be supplied in wafer form. Please contact your local Atmel sales office for detailed ordering information and minimum quantities.
2. Pb-free packaging alternative, complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green.

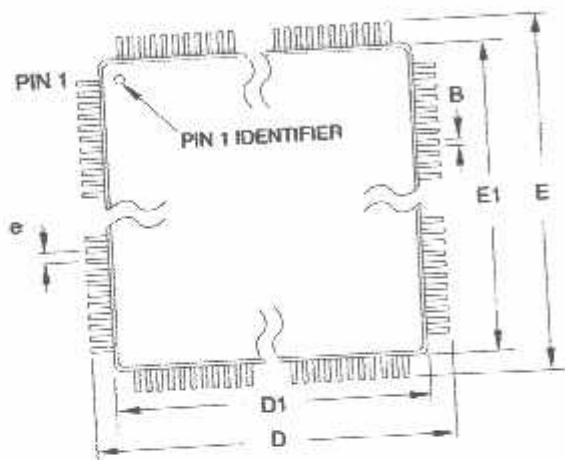
| Package Type | |
|--------------|---|
| 44A | 44-lead, Thin (1.0 mm) Plastic Gull Wing Quad Flat Package (TQFP) |
| 40P6 | 40-pin, 0.600" Wide, Plastic Dual Inline Package (PDIP) |
| 44J | 44-lead, Plastic J-leaded Chip Carrier (PLCC) |
| 44M1-A | 44-pad, 7 x 7 x 1.0 mm body, lead pitch 0.50 mm, Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF) |





Packaging Information

44A



COMMON DIMENSIONS
(Unit of Measure = mm)

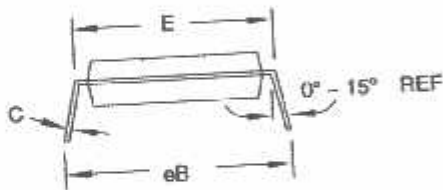
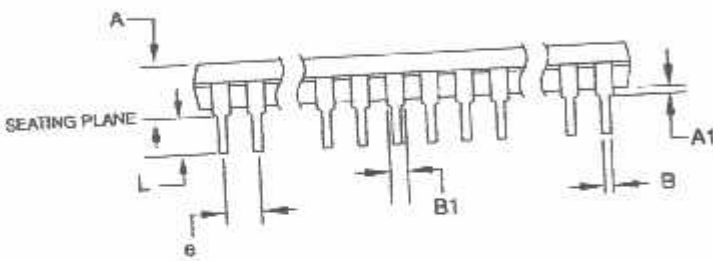
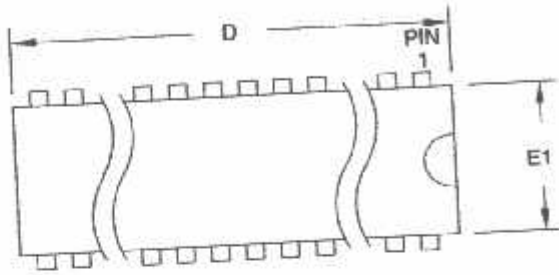
| SYMBOL | MIN | NOM | MAX | NOTE |
|--------|----------|-------|-------|--------|
| A | - | - | 1.20 | |
| A1 | 0.05 | - | 0.15 | |
| A2 | 0.95 | 1.00 | 1.05 | |
| D | 11.75 | 12.00 | 12.25 | |
| D1 | 9.90 | 10.00 | 10.10 | Note 2 |
| E | 11.75 | 12.00 | 12.25 | |
| E1 | 9.90 | 10.00 | 10.10 | Note 2 |
| B | 0.30 | - | 0.45 | |
| C | 0.09 | - | 0.20 | |
| L | 0.45 | - | 0.75 | |
| e | 0.80 TYP | | | |

- Notes:
1. This package conforms to JEDEC reference MS-026, Variation ACB.
 2. Dimensions D1 and E1 do not include mold protrusion. Allowable protrusion is 0.25 mm per side. Dimensions D1 and E1 are maximum plastic body size dimensions including mold mismatch.
 3. Lead coplanarity is 0.10 mm maximum.

10/5/2001

| | | | |
|--|--|--------------------|-------------|
| 2325 Orchard Parkway San Jose, CA 95131 | TITLE 44A, 44-lead, 10 x 10 mm Body Size, 1.0 mm Body Thickness, 0.8 mm Lead Pitch, Thin Profile Plastic Quad Flat Package (TQFP) | DRAWING NO. | REV. |
| | | 44A | B |

40P6



COMMON DIMENSIONS
(Unit of Measure = mm)

| SYMBOL | MIN | NOM | MAX | NOTE |
|--------|-----------|-----|--------|--------|
| A | - | - | 4.826 | |
| A1 | 0.381 | - | - | |
| D | 52.070 | - | 52.578 | Note 2 |
| E | 15.240 | - | 15.875 | |
| E1 | 13.462 | - | 13.970 | Note 2 |
| B | 0.356 | - | 0.559 | |
| B1 | 1.041 | - | 1.651 | |
| L | 3.048 | - | 3.556 | |
| C | 0.203 | - | 0.381 | |
| eB | 15.494 | - | 17.526 | |
| e | 2.540 TYP | | | |

- Notes:
1. This package conforms to JEDEC reference MS-011, Variation AC.
 2. Dimensions D and E1 do not include mold Flash or Protrusion. Mold Flash or Protrusion shall not exceed 0.25 mm (0.010").

09/28/01

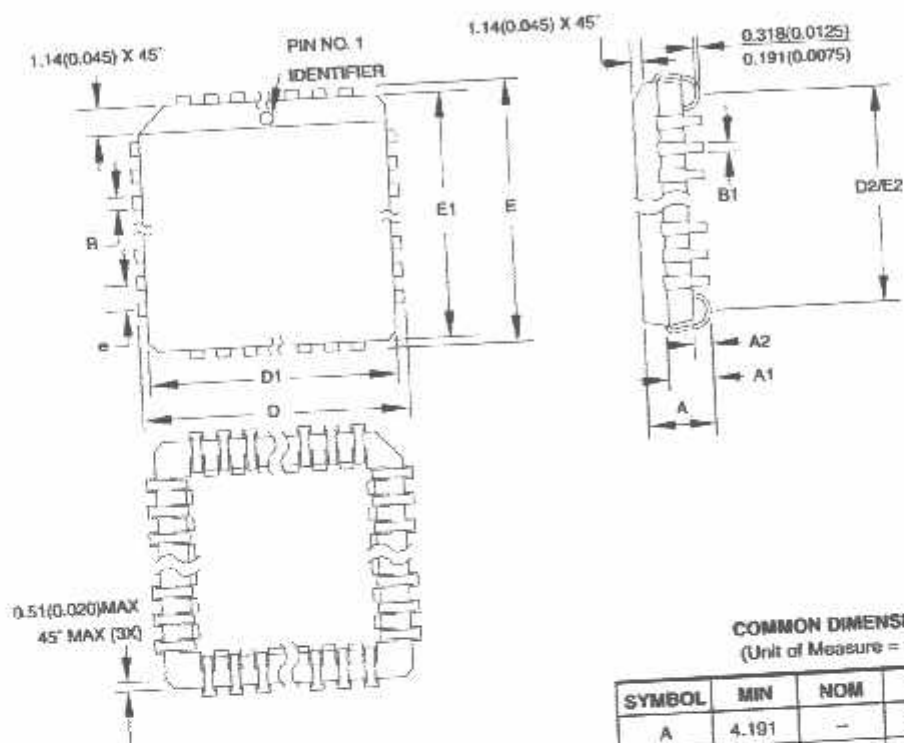


2325 Orchard Parkway
San Jose, CA 95131

TITLE
40P6, 40-lead (0.600"/15.24 mm Wide) Plastic Dual
Inline Package (PDIP)

| DRAWING NO. | REV. |
|-------------|------|
| 40P6 | B |




COMMON DIMENSIONS
 (Unit of Measure = mm)

| SYMBOL | MIN | NOM | MAX | NOTE |
|--------|-----------|-----|--------|--------|
| A | 4.191 | - | 4.572 | |
| A1 | 2.286 | - | 3.048 | |
| A2 | 0.508 | - | - | |
| D | 17.399 | - | 17.653 | |
| D1 | 16.510 | - | 16.662 | Note 2 |
| E | 17.399 | - | 17.653 | |
| E1 | 16.510 | - | 16.662 | Note 2 |
| D2/E2 | 14.985 | - | 16.002 | |
| B | 0.660 | - | 0.813 | |
| B1 | 0.330 | - | 0.533 | |
| e | 1.270 TYP | | | |

- Notes:
1. This package conforms to JEDEC reference MS-018, Variation AC.
 2. Dimensions D1 and E1 do not include mold protrusion. Allowable protrusion is .010" (0.254 mm) per side. Dimension D1 and E1 include mold mismatch and are measured at the extreme material condition at the upper or lower parting line.
 3. Lead coplanarity is 0.004" (0.102 mm) maximum.

10/04/01

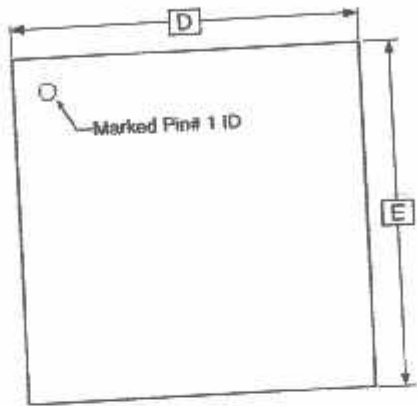

 2325 Orchard Parkway
 San Jose, CA 95131

TITLE
 44J, 44-lead, Plastic J-leaded Chip Carrier (PLCC)

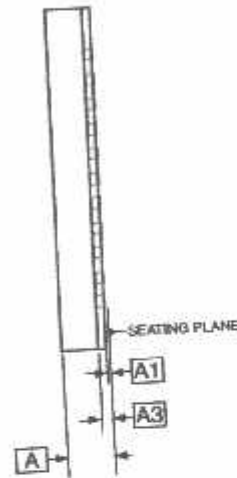
DRAWING NO.
 44J

REV.
 B

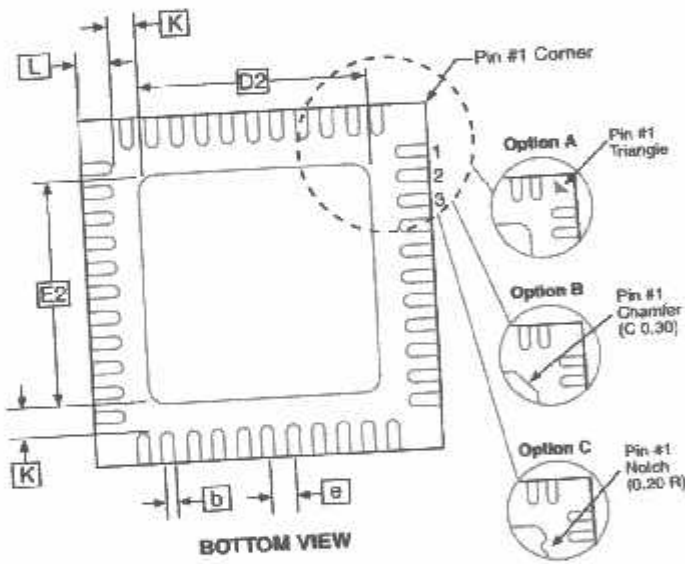
44M1-A



TOP VIEW



SIDE VIEW



BOTTOM VIEW

COMMON DIMENSIONS
(Unit of Measure = mm)

| SYMBOL | MIN | NOM | MAX | NOTE |
|--------|----------|------|------|------|
| A | 0.80 | 0.90 | 1.00 | |
| A1 | — | 0.02 | 0.05 | |
| A3 | 0.25 REF | | | |
| b | 0.18 | 0.23 | 0.30 | |
| D | 6.90 | 7.00 | 7.10 | |
| D2 | 5.00 | 5.20 | 5.40 | |
| E | 6.90 | 7.00 | 7.10 | |
| E2 | 5.00 | 5.20 | 5.40 | |
| e | 0.50 BSC | | | |
| L | 0.59 | 0.64 | 0.69 | |
| K | 0.20 | 0.26 | 0.41 | |

Note: JEDEC Standard MO-220, Fig. 1 (SAW Singulation) VKKD-3.

5/27/06



2325 Orchard Parkway
San Jose, CA 95131

TITLE
44M1, 44-pad, 7 x 7 x 1.0 mm Body, Lead Pitch 0.50 mm,
5.20 mm Exposed Pad, Micro Lead Frame Package (MLF)

DRAWING NO.
44M1

REV.
G





Errata

ATmega8535
Rev. A and B

The revision letter refer to the device revision.

- First Analog Comparator conversion may be delayed
- Asynchronous Oscillator does not stop in Power-down

1. **First Analog Comparator conversion may be delayed**

If the device is powered by a slow rising V_{CC} , the first Analog Comparator conversion will take longer than expected on some devices.

Problem Fix/Workaround

When the device has been powered or reset, disable then enable the Analog Comparator before the first conversion.

2. **Asynchronous Oscillator does not stop in Power-down**

The asynchronous oscillator does not stop when entering Power-down mode. This leads to higher power consumption than expected.

Problem Fix/Workaround

Manually disable the asynchronous timer before entering Power-down.

Datasheet Revision History

Please note that the referring page numbers in this section are referring to this document. The referring revision in this section are referring to the document revision.

Changes from Rev.
2502J- 08/06 to Rev.
2502K- 10/06

1. Updated TOP/BOTTOM description for all Timer/Counters Fast PWM mode.
2. Updated "Errata" on page 18.

Changes from Rev.
2502I- 06/06 to Rev.
2502J- 08/06

1. Updated "Ordering Information" on page 13.

Changes from Rev.
2502H- 04/06 to Rev.
2502I- 06/06

1. Updated code example "USART Initialization" on page 150.

Changes from Rev.
2502G- 04/05 to Rev.
2502H- 04/06

1. Added "Resources" on page 6.
2. Updated Table 7 on page 29, Table 17 on page 42 and Table 111 on page 258.
3. Updated "Serial Peripheral Interface – SPI" on page 136.
4. Updated note in "Bit Rate Generator Unit" on page 180.

Changes from Rev.
2502F- 06/04 to Rev.
2502G- 04/05

1. Removed "Preliminary" and TBD's.
2. Updated Table 37 on page 69 and Table 113 on page 261.
3. Updated "Electrical Characteristics" on page 255.
4. Updated "Ordering Information" on page 13.

Changes from Rev.
2502E-12/03 to Rev.
2502G-06/04

1. MLF-package alternative changed to "Quad Flat No-Lead/Micro Lead Frame Package QFN/MLF".

Changes from Rev.
2502E-12/03 to Rev.
2502F-06/04

1. Updated "Reset Characteristics" on page 37.
2. Updated SPH in "Stack Pointer" on page 12.
3. Updated C code in "USART Initialization" on page 150.
4. Updated "Errata" on page 18.

Changes from Rev.
2502D-09/03 to Rev.
2502E-12/03

1. Updated "Calibrated Internal RC Oscillator" on page 29.
2. Added section "Errata" on page 18.





Changes from Rev.
2502C-04/03 to Rev.
2502D-09/03

1. Removed "Advance Information" and some TBD's from the datasheet.
2. Added note to "Pinout ATmega8535" on page 2.
3. Updated "Reset Characteristics" on page 37.
4. Updated "Absolute Maximum Ratings" and "DC Characteristics" in "Electrical Characteristics" on page 255.
5. Updated Table 111 on page 258.
6. Updated "ADC Characteristics" on page 263.
7. Updated "ATmega8535 Typical Characteristics" on page 266.
8. Removed CALL and JMP instructions from code examples and "Instruction Set Summary" on page 10.

Changes from Rev.
2502B-09/02 to Rev.
2502C-04/03

1. Updated "Packaging Information" on page 14.
2. Updated Figure 1 on page 2, Figure 84 on page 179, Figure 85 on page 185, Figure 87 on page 191, Figure 98 on page 207.
3. Added the section "EEPROM Write During Power-down Sleep Mode" on page 22.
4. Removed the references to the application notes "Multi-purpose Oscillator" and "32 kHz Crystal Oscillator", which do not exist.
5. Updated code examples on page 44.
6. Removed ADHSM bit.
7. Renamed Port D pin ICP to ICP1. See "Alternate Functions of Port D" on page 64.
8. Added information about PWM symmetry for Timer 0 on page 79 and Timer 2 on page 126.
9. Updated Table 68 on page 169, Table 75 on page 190, Table 76 on page 193, Table 77 on page 196, Table 108 on page 253, Table 113 on page 261.
10. Updated description on "Bit 5 – TWSTA: TWI START Condition Bit" on page 182.
11. Updated the description in "Filling the Temporary Buffer (Page Loading)" and "Performing a Page Write" on page 231.
12. Removed the section description in "SPI Serial Programming Characteristics" on page 254.
13. Updated "Electrical Characteristics" on page 255.

14. Updated "ADC Characteristics" on page 263.
14. Updated "Register Summary" on page 8.
15. Various Timer 1 corrections.
16. Added WD_FUSE period in Table 108 on page 253.
1. Changed the Endurance on the Flash to 10,000 Write/Erase Cycles.

Changes from Rev.
2502A-06/02 to Rev.
2502B-09/02



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2502KS-AVR-10/06

| | | | | | | | | | | | | |
|------------|--|---------|--------------------|--------------------|-------|------|------|-------|-----|------|-------|-----|
| 2BB | | \$14.00 | 39.5 x 20.0 x 35.6 | 1.40 x 0.79 x 1.40 | 41.0 | 1.45 | 0.23 | 3.40 | 47 | 0.18 | 4.00 | 56 |
| STD | | | | | | | | | | | | |
| S03N F | | \$10.50 | 39.5 x 20.0 x 35.6 | 1.40 x 0.79 x 1.40 | 41.0 | 1.45 | 0.18 | 2.80 | 39 | 0.15 | 3.20 | 44 |
| 2BB | | \$14.00 | 39.5 x 20.0 x 35.6 | 1.40 x 0.79 x 1.40 | 41.0 | 1.45 | 0.18 | 2.80 | 39 | 0.15 | 3.20 | 44 |
| STD | | | | | | | | | | | | |
| S03N XF | | \$10.50 | 39.5 x 20.0 x 35.6 | 1.40 x 0.79 x 1.40 | 41.0 | 1.45 | 0.15 | 2.2 | 31 | 0.12 | 2.45 | 34 |
| 2BB | | \$14.00 | 39.5 x 20.0 x 35.6 | 1.40 x 0.79 x 1.40 | 41.0 | 1.45 | 0.15 | 2.2 | 31 | 0.12 | 2.45 | 34 |
| STD | | | | | | | | | | | | |
| S03N MG | | N/A | 39.5 x 20.0 x 35.6 | 1.40 x 0.79 x 1.40 | 64.0 | 2.26 | 0.23 | 3.4 | 47 | 0.18 | 4.20 | 58 |
| 2BB | | \$19.25 | 39.5 x 20.0 x 35.6 | 1.40 x 0.79 x 1.40 | 64.0 | 2.26 | 0.18 | 2.80 | 39 | 0.15 | 3.40 | 47 |
| STD | | | | | | | | | | | | |
| S03NF MG | | N/A | 39.5 x 20.0 x 35.6 | 1.40 x 0.79 x 1.40 | 64.0 | 2.26 | 0.15 | 2.50 | 35 | 0.12 | 3.00 | 42 |
| 2BB | | \$19.25 | 39.5 x 20.0 x 35.6 | 1.40 x 0.79 x 1.40 | 64.0 | 2.26 | 0.33 | 7.20 | 100 | 0.27 | 8.00 | 111 |
| STD | | | | | | | | | | | | |
| S03 NXF MG | | N/A | 39.5 x 20.0 x 39.5 | 1.56 x 0.79 x 1.56 | 46.0 | 1.62 | 0.33 | 7.20 | 100 | 0.27 | 8.00 | 111 |
| 2BB | | \$10.50 | 39.5 x 20.0 x 39.5 | 1.56 x 0.79 x 1.56 | 46.0 | 1.62 | 0.27 | 5.80 | 81 | 0.22 | 6.50 | 90 |
| STD | | | | | | | | | | | | |
| S03 T | | \$14.00 | 39.5 x 20.0 x 39.5 | 1.56 x 0.79 x 1.56 | 46.0 | 1.62 | 0.27 | 5.80 | 81 | 0.22 | 6.50 | 90 |
| 2BB | | \$10.50 | 39.5 x 20.0 x 39.5 | 1.56 x 0.79 x 1.56 | 46.0 | 1.62 | 0.27 | 5.80 | 81 | 0.22 | 6.50 | 90 |
| STD | | | | | | | | | | | | |
| S03 TF | | \$14.00 | 39.5 x 20.0 x 39.5 | 1.56 x 0.79 x 1.56 | 46.0 | 1.62 | 0.21 | 5.00 | 69 | 0.17 | 6.20 | 86 |
| 2BB | | \$10.50 | 39.5 x 20.0 x 39.5 | 1.56 x 0.79 x 1.56 | 46.0 | 1.62 | 0.21 | 5.00 | 69 | 0.17 | 6.20 | 86 |
| STD | | | | | | | | | | | | |
| S03 TXF | | \$14.00 | 39.5 x 20.0 x 39.5 | 1.56 x 0.79 x 1.56 | 46.0 | 1.62 | 0.21 | 5.00 | 69 | 0.17 | 6.20 | 86 |
| 2BB | | N/A | 39.5 x 20.0 x 39.5 | 1.56 x 0.79 x 1.56 | 73.00 | 2.57 | 0.33 | 7.40 | 102 | 0.27 | 8.60 | 119 |
| STD | | | | | | | | | | | | |
| S03 T MG | | \$19.25 | 39.5 x 20.0 x 39.5 | 1.56 x 0.79 x 1.56 | 73.00 | 2.57 | 0.27 | 6.00 | 83 | 0.22 | 6.95 | 97 |
| 2BB | | N/A | 39.5 x 20.0 x 39.5 | 1.56 x 0.79 x 1.56 | 73.00 | 2.57 | 0.27 | 6.00 | 83 | 0.22 | 6.95 | 97 |
| STD | | | | | | | | | | | | |
| S03 TF MG | | \$19.25 | 39.5 x 20.0 x 39.5 | 1.56 x 0.79 x 1.56 | 73.00 | 2.57 | 0.21 | 5.60 | 76 | 0.17 | 6.40 | 89 |
| 2BB | | N/A | 39.5 x 20.0 x 39.5 | 1.56 x 0.79 x 1.56 | 73.00 | 2.57 | 0.21 | 5.60 | 76 | 0.17 | 6.40 | 89 |
| STD | | | | | | | | | | | | |
| S03 TXF MG | | \$19.25 | 39.5 x 20.0 x 39.5 | 1.56 x 0.79 x 1.56 | 73.00 | 2.57 | 0.25 | 10.00 | 139 | 0.20 | 13.00 | 181 |
| 2BB | | N/A | 39.5 x 20.0 x 39.5 | 1.56 x 0.79 x 1.56 | 73.00 | 2.57 | 0.28 | 13.00 | 181 | 0.22 | 15.00 | 208 |
| STD | | | | | | | | | | | | |
| S03 TXF MG | | \$19.25 | 39.5 x 20.0 x 39.5 | 1.56 x 0.79 x 1.56 | 73.00 | 2.57 | 0.22 | 10.40 | 144 | 0.18 | 12.00 | 167 |
| 2BB | | N/A | 39.5 x 20.0 x 39.5 | 1.56 x 0.79 x 1.56 | 73.00 | 2.57 | 0.24 | 24.00 | 333 | 0.20 | 28.80 | 400 |
| STD | | | | | | | | | | | | |
| S03 TXF MG | | \$19.25 | 39.5 x 20.0 x 39.5 | 1.56 x 0.79 x 1.56 | 180.0 | 6.35 | 0.19 | 18.50 | 257 | 0.16 | 22.50 | 312 |
| 2BB | | N/A | 39.5 x 20.0 x 39.5 | 1.56 x 0.79 x 1.56 | 180.0 | 6.35 | 0.15 | 15.00 | 208 | 0.13 | 18.00 | 250 |
| STD | | | | | | | | | | | | |
| S666 N MG | | \$43.75 | 63.0 x 32.0 x 61.6 | 2.48 x 1.26 x 2.43 | 160.4 | 5.66 | 0.15 | 35.00 | 486 | 0.12 | 42.00 | 583 |
| 2BB | | N/A | 63.0 x 32.0 x 61.6 | 2.48 x 1.26 x 2.43 | 160.4 | 5.66 | 0.15 | 35.00 | 486 | 0.12 | 42.00 | 583 |
| STD | | | | | | | | | | | | |
| S666 NF | | \$38.50 | 63.0 x 32.0 x 61.6 | 2.48 x 1.26 x 2.43 | 190.0 | 6.70 | 0.12 | 26.00 | 361 | 0.10 | 31.00 | 431 |
| 2BB | | N/A | 63.0 x 32.0 x 61.6 | 2.48 x 1.26 x 2.43 | 190.0 | 6.70 | 0.12 | 26.00 | 361 | 0.10 | 31.00 | 431 |
| STD | | | | | | | | | | | | |
| S666 NXF | | \$38.50 | 63.0 x 32.0 x 61.6 | 2.48 x 1.26 x 2.43 | 190.0 | 6.70 | 0.12 | 26.00 | 361 | 0.10 | 31.00 | 431 |
| 2BB | | N/A | 63.0 x 32.0 x 61.6 | 2.48 x 1.26 x 2.43 | 190.0 | 6.70 | 0.12 | 26.00 | 361 | 0.10 | 31.00 | 431 |
| STD | | | | | | | | | | | | |
| S777 CG | | \$70.00 | 65.0 x 32.0 x 70.4 | 2.56 x 1.26 x 2.77 | 190.0 | 6.70 | 0.12 | 26.00 | 361 | 0.10 | 31.00 | 431 |
| 6BB | | N/A | 65.0 x 32.0 x 70.4 | 2.56 x 1.26 x 2.77 | 190.0 | 6.70 | 0.12 | 26.00 | 361 | 0.10 | 31.00 | 431 |
| STD | | | | | | | | | | | | |
| S777 FCG | | \$70.00 | 65.0 x 32.0 x 70.4 | 2.56 x 1.26 x 2.77 | 190.0 | 6.70 | 0.12 | 26.00 | 361 | 0.10 | 31.00 | 431 |
| 6BB | | N/A | 65.0 x 32.0 x 70.4 | 2.56 x 1.26 x 2.77 | 190.0 | 6.70 | 0.12 | 26.00 | 361 | 0.10 | 31.00 | 431 |
| STD | | | | | | | | | | | | |

GWS USA Quick Catalog - Servos and Accessories (Latest Update: July 18, 2006)

±1.5g - 6g Three Axis Low-g Micromachined Accelerometer

The MMA7260QT low cost capacitive micromachined accelerometer features signal conditioning, a 1-pole low pass filter, temperature compensation and g-Select which allows for the selection among 4 sensitivities. Zero-g offset full scale span and filter cut-off are factory set and require no external devices. Includes a Sleep Mode that makes it ideal for handheld battery powered electronics.

Features

- Selectable Sensitivity (1.5g/2g/4g/6g)
- Low Current Consumption: 500 μ A
- Sleep Mode: 3 μ A
- Low Voltage Operation: 2.2 V – 3.6 V
- 6mm x 6mm x 1.45mm QFN
- High Sensitivity (800 mV/g @ 1.5g)
- Fast Turn On Time
- Integral Signal Conditioning with Low Pass Filter
- Robust Design, High Shocks Survivability
- Pb-Free Terminations
- Environmentally Preferred Package
- Low Cost

Typical Applications

- HDD MP3 Player: Freefall Detection
- Laptop PC: Freefall Detection, Anti-Theft
- Cell Phone: Image Stability, Text Scroll, Motion Dialing, E-Compass
- Pedometer: Motion Sensing
- PDA: Text Scroll
- Navigation and Dead Reckoning: E-Compass Tilt Compensation
- Gaming: Tilt and Motion Sensing, Event Recorder
- Robotics: Motion Sensing

| ORDERING INFORMATION | | | |
|----------------------|-------------------|-----------------|---------------------|
| Device Name | Temperature Range | Package Drawing | Package |
| MMA7260QT | -40 to +105°C | 1622-02 | QFN-16, Tray |
| MMA7260QR2 | -40 to +105°C | 1622-02 | QFN-16, Tape & Reel |

MMA7260QT

MMA7260QT: XYZ AXIS
 ACCELEROMETER
 ±1.5g/2g/4g/6g

Bottom View



16 LEAD
 QFN
 CASE 1622-02

Top View



Figure 1. Pin Connections

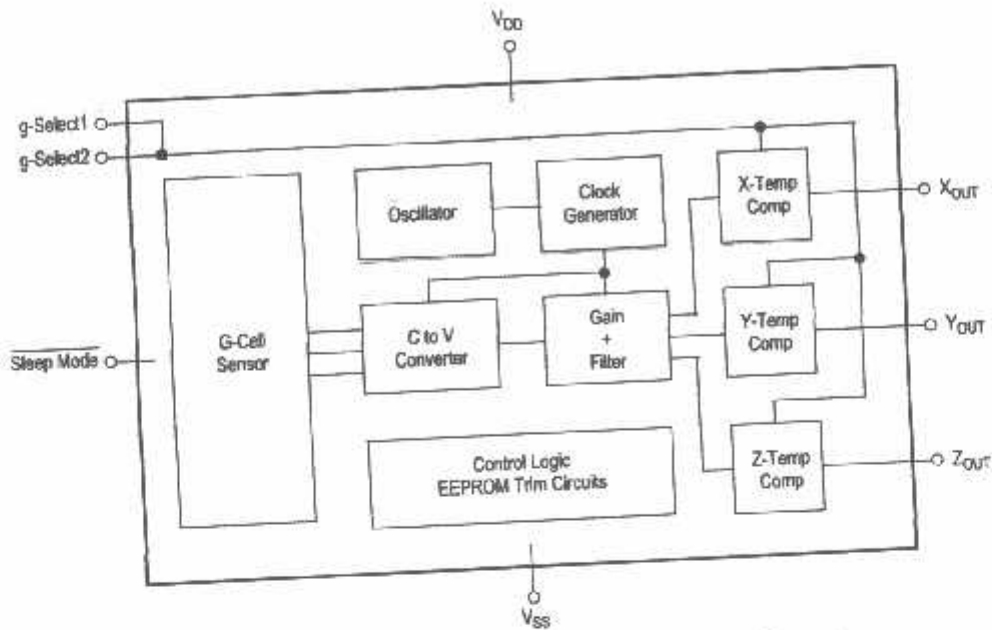


Figure 2. Simplified Accelerometer Functional Block Diagram

Table 1. Maximum Ratings
(Maximum ratings are the limits to which the device can be exposed without causing permanent damage.)

| Rating | Symbol | Value | Unit |
|---------------------------------|------------|--------------|------|
| Maximum Acceleration (all axis) | a_{max} | ± 5000 | g |
| Supply Voltage | V_{DD} | -0.3 to +3.6 | V |
| Drop Test ⁽¹⁾ | D_{drop} | 1.8 | m |
| Storage Temperature Range | T_{stg} | -40 to +125 | °C |

1. Dropped onto concrete surface from any axis.

ELECTRO STATIC DISCHARGE (ESD)

WARNING: This device is sensitive to electrostatic discharge.

Although the Freescale accelerometer contains internal 2000 volts ESD protection circuitry, extra precaution must be taken by the user to protect the chip from ESD. A charge of over 2000 volts can accumulate on the human body or associated test equipment. A charge of this magnitude can

alter the performance or cause failure of the chip. When handling the accelerometer, proper ESD precautions should be followed to avoid exposing the device to discharges which may be detrimental to its performance.

Table 2. Operating Characteristics
 Unless otherwise noted: $-40^{\circ}\text{C} \leq T_A \leq 105^{\circ}\text{C}$, $2.2\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, Acceleration = 0g, Loaded output⁽¹⁾

| Characteristic | Symbol | Min | Typ | Max | Unit |
|--|-------------------|------------------|------------|------------------|--------------------------------|
| Operating Range ⁽²⁾ | V_{DD} | 2.2 | 3.3 | 3.6 | V |
| Supply Voltage ⁽³⁾ | I_{DD} | — | 500 | 800 | μA |
| Supply Current | I_{DD} | — | 3.0 | 10 | μA |
| Supply Current at Sleep Mode ⁽⁴⁾ | T_A | -40 | — | +105 | $^{\circ}\text{C}$ |
| Operating Temperature Range | | | | | |
| Acceleration Range, X-Axis, Y-Axis, Z-Axis | gFS | — | ± 1.5 | — | g |
| g-Select1 & 2: 00 | gFS | — | ± 2.0 | — | g |
| g-Select1 & 2: 10 | gFS | — | ± 4.0 | — | g |
| g-Select1 & 2: 01 | gFS | — | ± 6.0 | — | g |
| g-Select1 & 2: 11 | gFS | — | — | — | g |
| Output Signal | | | | | |
| Zero-g ($T_A = 25^{\circ}\text{C}$, $V_{DD} = 3.3\text{ V}$) ⁽⁵⁾ | V_{OFF} | 1.485 | 1.65 | 1.815 | V |
| Zero-g ⁽⁴⁾ | V_{OFF, T_A} | $\pm 2.6^{(6)}$ | ± 0.8 | $\pm 3.8^{(7)}$ | $\text{mg}/^{\circ}\text{C}$ |
| X-axis | | $\pm 5.8^{(6)}$ | ± 5.8 | $\pm 5.9^{(7)}$ | |
| Y-axis | | $\pm 1.0^{(6)}$ | ± 0.8 | $\pm 0.8^{(7)}$ | |
| Z-axis | | | | | |
| Sensitivity ($T_A = 25^{\circ}\text{C}$, $V_{DD} = 3.3\text{ V}$) | | | | | |
| 1.5g | $S_{1.5g}$ | 740 | 800 | 860 | mV/g |
| 2g | S_{2g} | 555 | 600 | 645 | mV/g |
| 4g | S_{4g} | 277.5 | 300 | 322.5 | mV/g |
| 8g | S_{8g} | 185 | 200 | 215 | mV/g |
| Sensitivity ⁽⁴⁾ | S_{T_A} | $\pm 0.02^{(6)}$ | ± 0.02 | $\pm 0.02^{(7)}$ | $\%/^{\circ}\text{C}$ |
| X-axis | | $\pm 0.01^{(6)}$ | ± 0.01 | $\pm 0.01^{(7)}$ | |
| Y-axis | | $\pm 0.01^{(6)}$ | ± 0.01 | $\pm 0.01^{(7)}$ | |
| Z-axis | | | | | |
| Bandwidth Response | | | | | |
| XY | f_{-3dB} | — | 350 | — | Hz |
| Z | f_{-3dB} | — | 150 | — | Hz |
| Noise | | | | | |
| RMS (0.1 Hz – 1 kHz) ⁽⁴⁾ | Γ_{RMS} | — | 4.7 | — | mVrms |
| Power Spectral Density RMS (0.1 Hz – 1 kHz) ⁽⁴⁾ | Γ_{PSD} | — | 350 | — | $\mu\text{g}/\sqrt{\text{Hz}}$ |
| Control Timing | | | | | |
| Power-Up Response Time ⁽⁸⁾ | $t_{RESPONSE}$ | — | 1.0 | 2.0 | ms |
| Enable Response Time ⁽⁹⁾ | t_{ENABLE} | — | 0.5 | 2.0 | ms |
| Sensing Element: Resonant Frequency | | | | | |
| XY | f_{GCELL} | — | 6.0 | — | kHz |
| Z | f_{GCELL} | — | 3.4 | — | kHz |
| Internal Sampling Frequency | f_{CLK} | — | 11 | — | kHz |
| Output Stage Performance | | | | | |
| Full-Scale Output Range ($I_{OUT} = 30\ \mu\text{A}$) | V_{FSO} | $V_{SS}+0.25$ | — | $V_{DD}-0.25$ | V |
| Nonlinearity, X_{OUT} , Y_{OUT} , Z_{OUT} | NL _{OUT} | -1.0 | — | +1.0 | %FSO |
| Cross-Axis Sensitivity ⁽¹⁰⁾ | $V_{XY, XZ, YZ}$ | — | — | 5.0 | % |
| Ratiometric Error ⁽¹¹⁾ | error | — | — | — | % |

- For a loaded output, the measurements are observed after an RC filter consisting of a 1.0 k Ω resistor and a 0.1 μF capacitor on V_{DD} -GND.
- These limits define the range of operation for which the part will meet specification.
- Within the supply range of 2.2 and 3.6 V, the device operates as a fully calibrated linear accelerometer. Beyond these supply limits the device may operate as a linear device but is not guaranteed to be in calibration.
- This value is measured with g-Select in 1.5g mode.
- The device can measure both + and - acceleration. With no input acceleration the output is at midsupply. For positive acceleration the output will increase above $V_{DD}/2$. For negative acceleration, the output will decrease below $V_{DD}/2$.
- These values represent the 10th percentile, not the minimum.
- These values represent the 90th percentile, not the maximum.
- The response time between 10% of full scale V_{DD} input voltage and 90% of the final operating output voltage.
- The response time between 10% of full scale Sleep Mode input voltage and 90% of the final operating output voltage.
- A measure of the device's ability to reject an acceleration applied 90 from the true axis of sensitivity.
- Zero-g offset: ratiometric error can be typically >20% at $V_{DD} = 2.2\text{ V}$. Sensitivity ratiometric error can be typically >3% at $V_{DD} = 2.2$. Consult factory for additional information.

PRINCIPLE OF OPERATION

The Freescale accelerometer is a surface-micromachined integrated-circuit accelerometer.

The device consists of two surface micromachined capacitive sensing cells (g-cell) and a signal conditioning ASIC contained in a single integrated circuit package. The sensing elements are sealed hermetically at the wafer level using a bulk micromachined cap wafer.

The g-cell is a mechanical structure formed from semiconductor materials (polysilicon) using semiconductor processes (masking and etching). It can be modeled as a set of beams attached to a movable central mass that move between fixed beams. The movable beams can be deflected from their rest position by subjecting the system to an acceleration (Figure 3).

As the beams attached to the central mass move, the distance from them to the fixed beams on one side will increase by the same amount that the distance to the fixed beams on the other side decreases. The change in distance is a measure of acceleration.

The g-cell beams form two back-to-back capacitors (Figure 3). As the center beam moves with acceleration, the distance between the beams changes and each capacitor's value will change. ($C = \epsilon A/D$). Where A is the area of the beam, ϵ is the dielectric constant, and D is the distance between the beams.

The ASIC uses switched capacitor techniques to measure the g-cell capacitors and extract the acceleration data from the difference between the two capacitors. The ASIC also signal conditions and filters (switched capacitor) the signal, providing a high level output voltage that is ratiometric and proportional to acceleration.

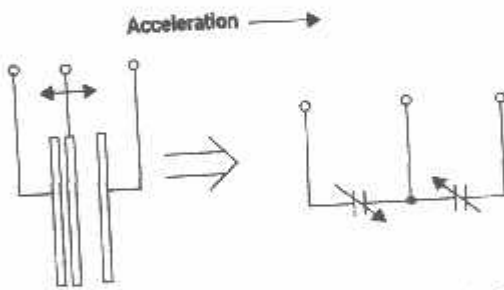


Figure 3. Simplified Transducer Physical Model

SPECIAL FEATURES

g-Select

The g-Select feature allows for the selection among 4 sensitivities present in the device. Depending on the logic input placed on pins 1 and 2, the device internal gain will be changed allowing it to function with a 1.5g, 2g, 4g, or 6g sensitivity (Table 3). This feature is ideal when a product has applications requiring different sensitivities for optimum performance. The sensitivity can be changed at anytime during the operation of the product. The g-Select1 and g-Select2 pins can be left unconnected for applications requiring only a 1.5g sensitivity as the device has an internal pull-down to keep it at that sensitivity (800mV/g).

Table 3. g-Select Pin Descriptions

| g-Select2 | g-Select1 | g-Range | Sensitivity |
|-----------|-----------|---------|-------------|
| 0 | 0 | 1.5g | 800 mV/g |
| 0 | 1 | 2g | 600 mV/g |
| 1 | 0 | 4g | 300 mV/g |
| 1 | 1 | 6g | 200 mV/g |

Sleep Mode

The 3 axis accelerometer provides a Sleep Mode that is ideal for battery operated products. When Sleep Mode is active, the device outputs are turned off, providing significant reduction of operating current. A low input signal on pin 12 (Sleep Mode) will place the device in this mode and reduce the current to 3 μ A typ. For lower power consumption, it is recommended to set g-Select1 and g-Select2 to 1.5g mode. By placing a high input signal on pin 12, the device will resume to normal mode of operation.

Filtering

The 3 axis accelerometer contains onboard single-pole switched capacitor filters. Because the filter is realized using switched capacitor techniques, there is no requirement for external passive components (resistors and capacitors) to set the cut-off frequency.

Ratiometricity

Ratiometricity simply means the output offset voltage and sensitivity will scale linearly with applied supply voltage. That is, as supply voltage is increased, the sensitivity and offset increase linearly; as supply voltage decreases, offset and sensitivity decrease linearly. This is a key feature when interfacing to a microcontroller or an A/D converter because it provides system level cancellation of supply induced errors in the analog to digital conversion process. Offset ratiometric error can be typically >20% at $V_{DD} = 2.2$ V. Sensitivity ratiometric error can be typically >3% at $V_{DD} = 2.2$ V. Consult factory for additional information.

BASIC CONNECTIONS

Pin Descriptions

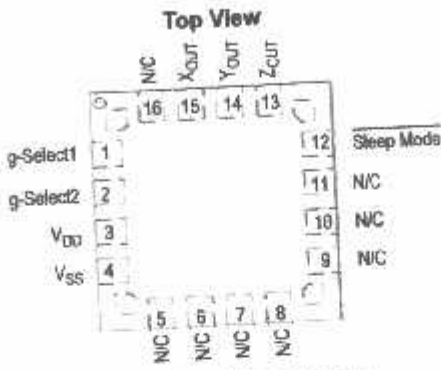


Figure 4. Pinout Description

Table 4. Pin Descriptions

| Pin No. | Pin Name | Description |
|---------|------------------|--|
| 1 | g-Select1 | Logic input pin to select g level. |
| 2 | g-Select2 | Logic input pin to select g level. |
| 3 | V _{DD} | Power Supply Input |
| 4 | V _{SS} | Power Supply Ground |
| 5 - 7 | N/C | No internal connection. Leave unconnected. |
| 8 - 11 | N/C | Unused for factory trim. Leave unconnected. |
| 12 | Sleep Mode | Logic input pin to enable product or Sleep Mode. |
| 13 | Z _{OUT} | Z direction output voltage. |
| 14 | Y _{OUT} | Y direction output voltage. |
| 15 | X _{OUT} | X direction output voltage. |
| 16 | N/C | No internal connection. Leave unconnected. |

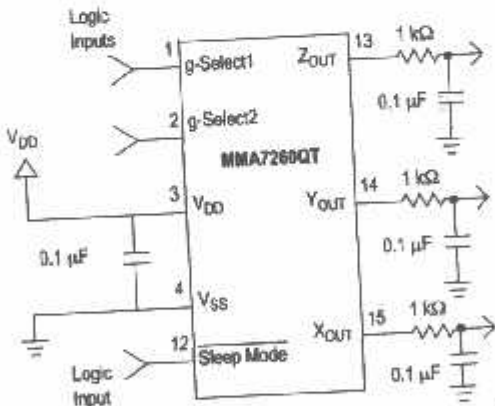


Figure 5. Accelerometer with Recommended Connection Diagram

PCB Layout

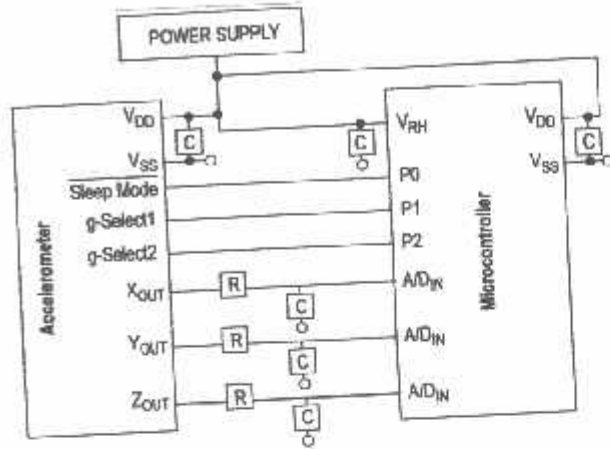


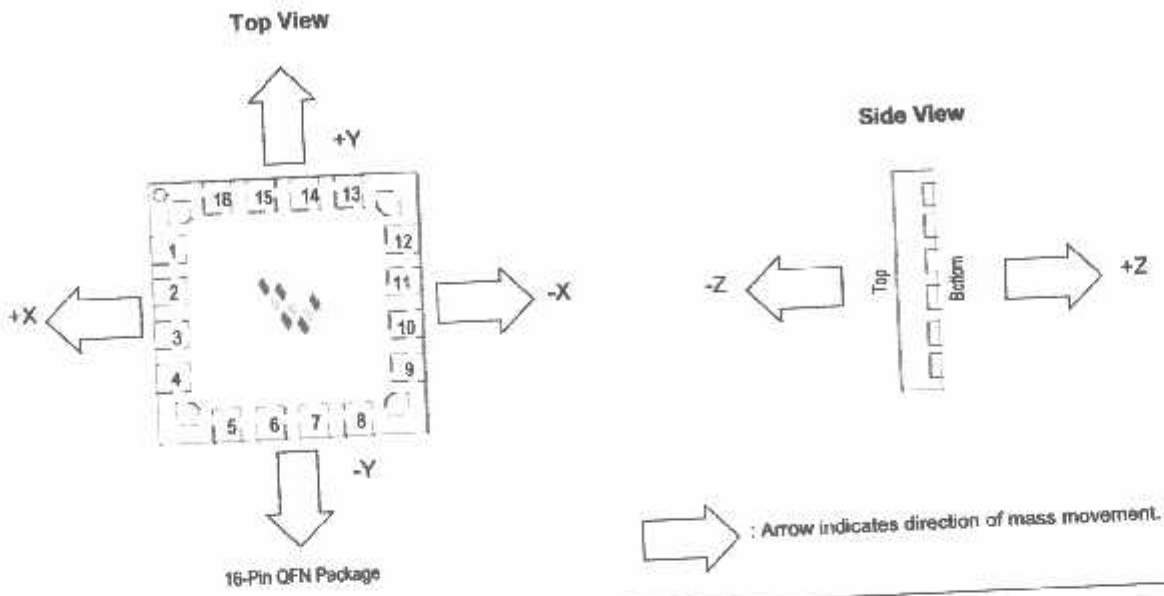
Figure 6. Recommended PCB Layout for Interfacing Accelerometer to Microcontroller

NOTES:

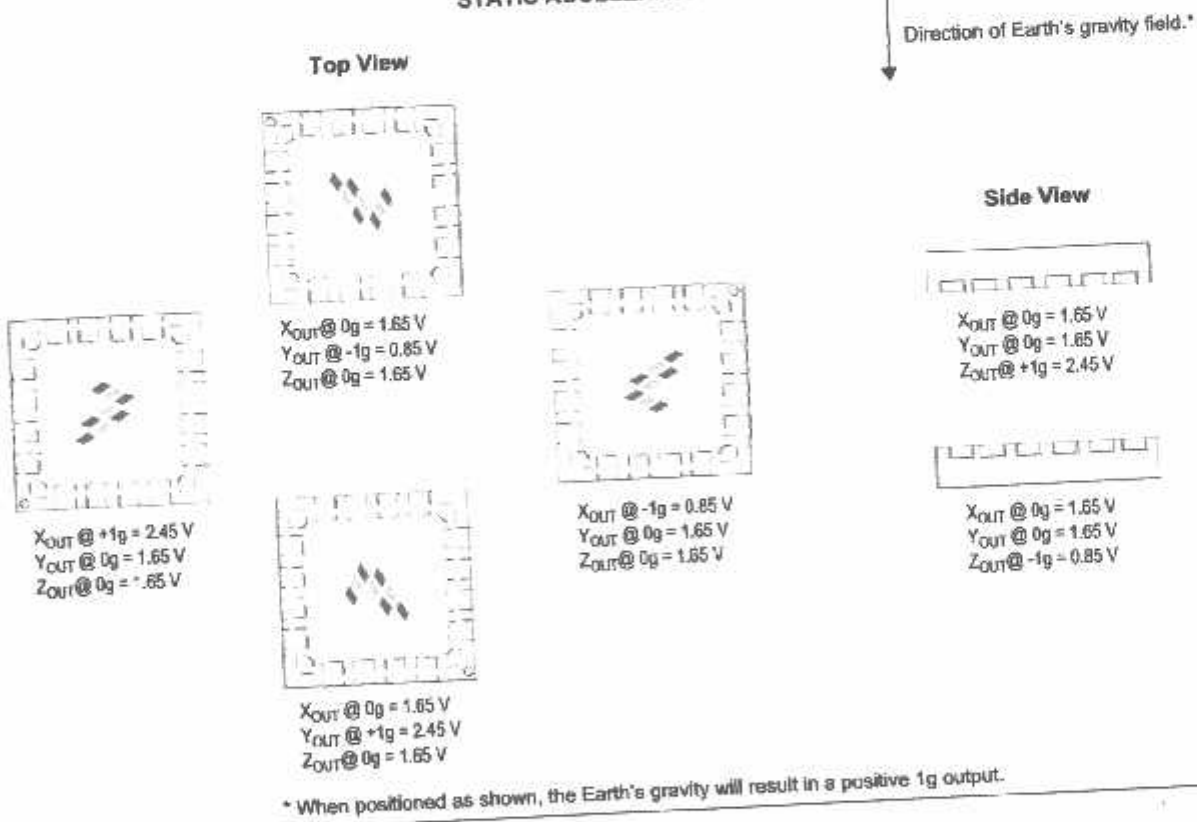
1. Verify V_{DD} line has the ability to reach 2.2 V in ≤ 0.1 ms as measured on the device at the V_{DD} pin. Rise times greater than this most likely will prevent start up operation.
2. Physical coupling distance of the accelerometer to the microcontroller should be minimal.
3. The flag underneath the package is internally connected to ground. It is not recommended for the flag to be soldered down.
4. Place a ground plane beneath the accelerometer to reduce noise, the ground plane should be attached to all of the open ended terminals shown in Figure 6.
5. Use an RC filter with 1.0 k Ω and 0.1 μ F on the outputs of the accelerometer to minimize clock noise (from the switched capacitor filter circuit).
6. PCB layout of power and ground should not couple power supply noise.
7. Accelerometer and microcontroller should not be a high current path.
8. A/D sampling rate and any external power supply switching frequency should be selected such that they do not interfere with the internal accelerometer sampling frequency (11 kHz for the sampling frequency). This will prevent aliasing errors.
9. PCB layout should not run traces or vias under the QFN part. This could lead to ground shorting to the accelerometer flag.

MMA7260QT

DYNAMIC ACCELERATION



STATIC ACCELERATION

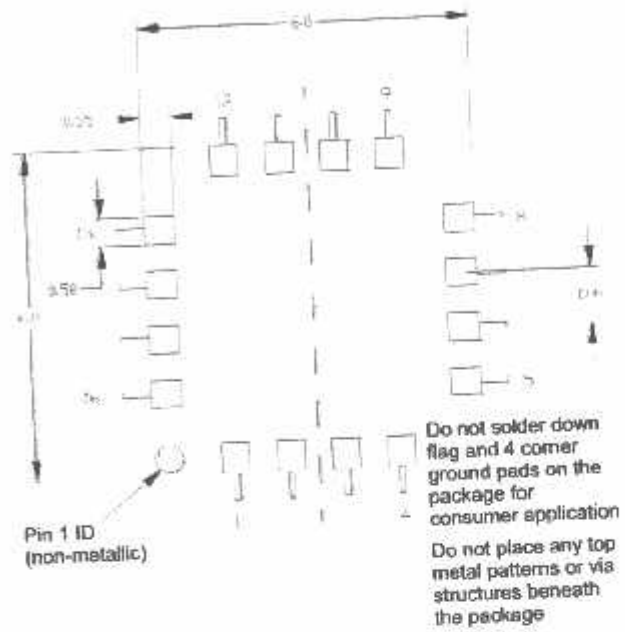


MINIMUM RECOMMENDED FOOTPRINT FOR SURFACE MOUNTED APPLICATIONS

Surface mount board layout is a critical portion of the total design. The footprint for the surface mount packages must be the correct size to ensure proper solder connection interface between the board and the package.

With the correct footprint, the packages will self-align when subjected to a solder reflow process. It is always recommended to design boards with a solder mask layer to avoid bridging and shorting between solder pads.

The flag underneath the package is internally connected to ground. It is not recommended for the flag to be soldered down.



Note: The die pad (flag) is not generally recommended to be soldered down for consumer product application. All dimensions are in mm.

Figure 7. PCB Footprint for 16-Lead QFN, 6x6 mm for Consumer Grade Products and Applications

PCB DESIGN GUIDELINES

The following are the recommended guidelines to follow for mounting QFN sensors for either automotive or consumer applications.

1. NSMD (Non Solder Mask Defined) is shown in Figure 8.
2. Solder mask opening = PCB land pad +0.1 mm.
3. Stencil aperture size = PCB land pad -0.025mm, as shown in Figure 9 with a 6mil stencil.
4. Do not place insertion components or vias at a distance less than 2mm from the package land area.
5. Signal trace connected to pads should be as symmetric as possible. Put dummy traces if there is NC pads, in order to have same length of exposed trace for all pads. Signal traces with 0.1mm width and

min. 0.5mm length for all PCB land pad near package are recommended as shown in Figure 8 and Figure 9. Wider trace can be continued after the 0.5mm zone.

6. Use a standard pick and place process and equipment (no hand soldering process).
7. It is recommended to use a cleanable solder paste with an additional cleaning step after SMT mount
8. It is recommended to avoid screwing down the PCB to fix it into an enclosure since this may cause the PCB to bend.
9. PC boards should be rated for multiple reflow of lead-free conditions with 260°C maximum temperature.

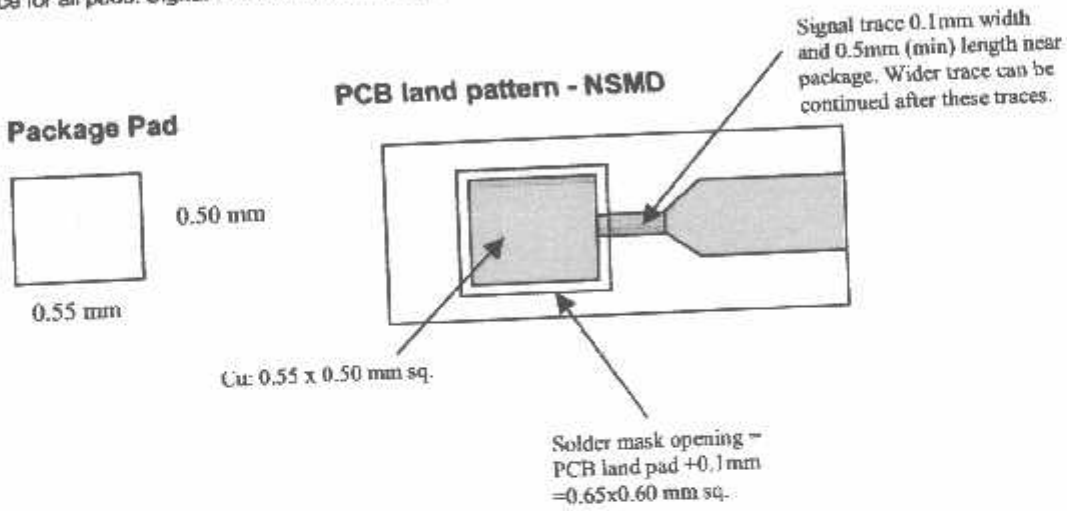


Figure 8. NSMD Solder Mask Design Guidelines

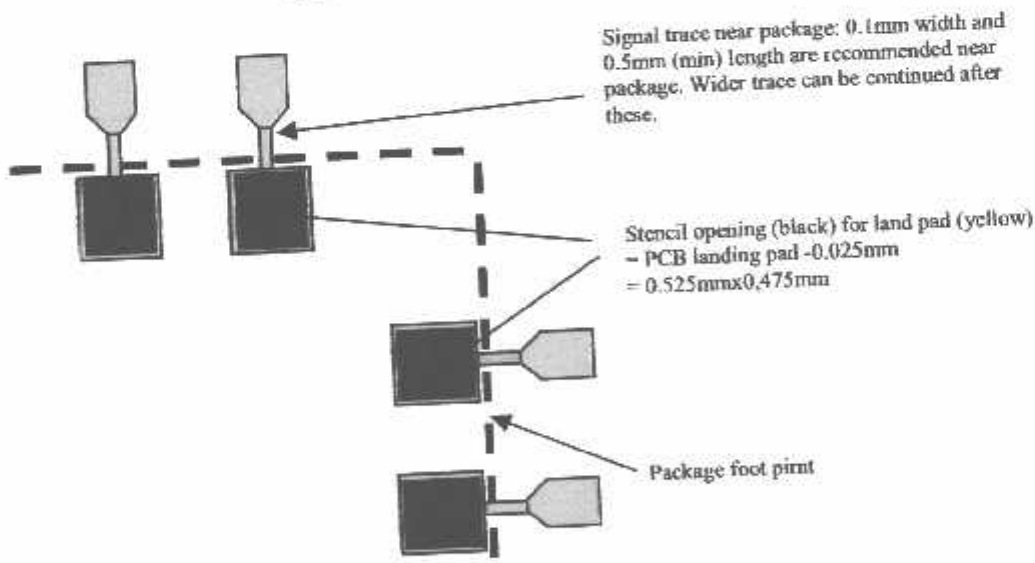
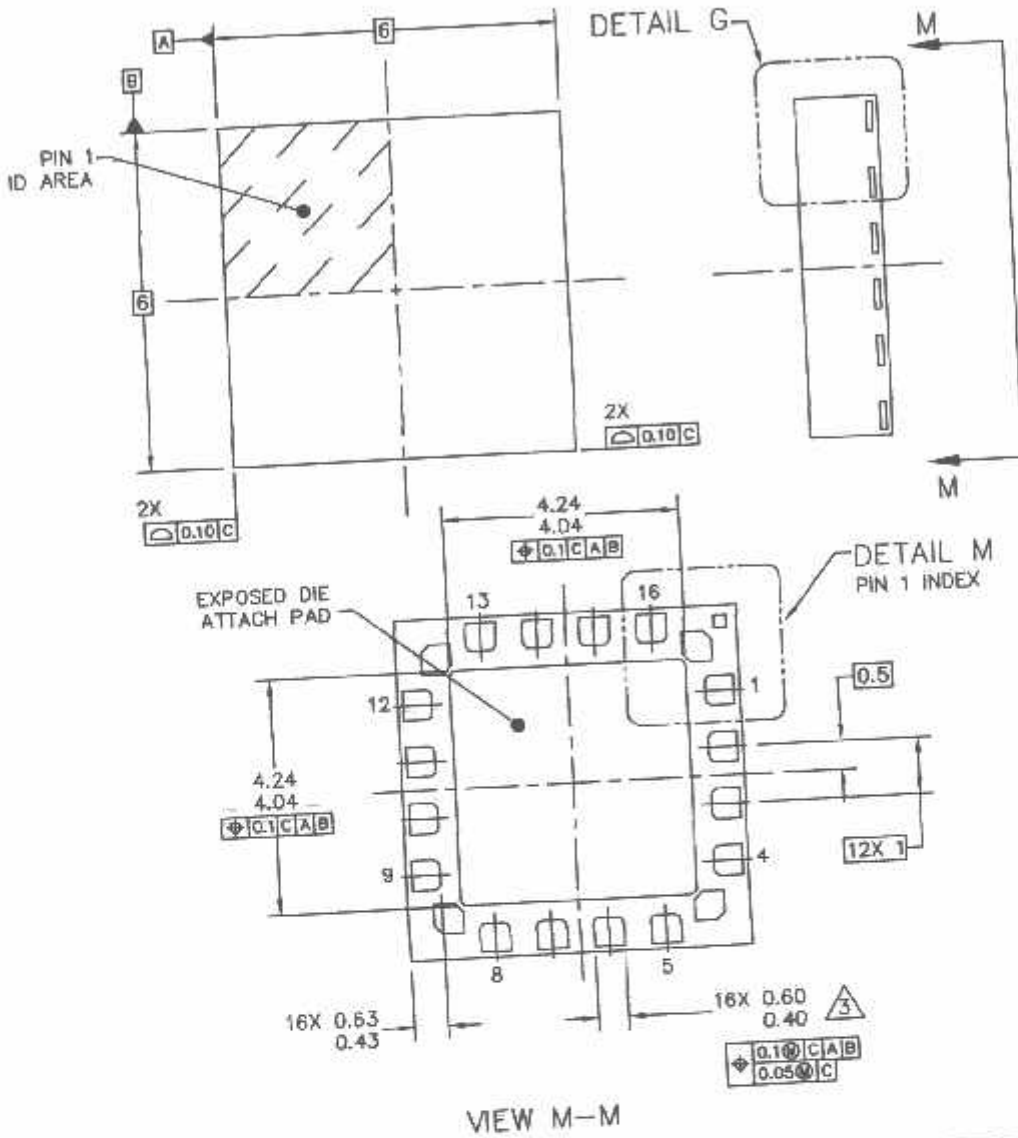


Figure 9. Stencil Design Guidelines

PACKAGE DIMENSIONS



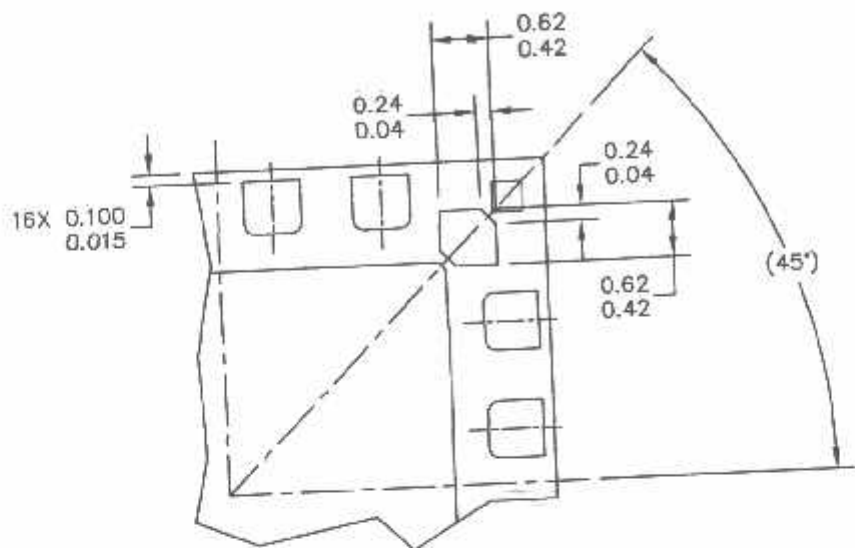
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| | DOCUMENT NO: 98ASA10651D | REV: B | 27 SEP 2006 |
| | CASE NUMBER: 1622-02 | STANDARD: NON-JEDEC | |

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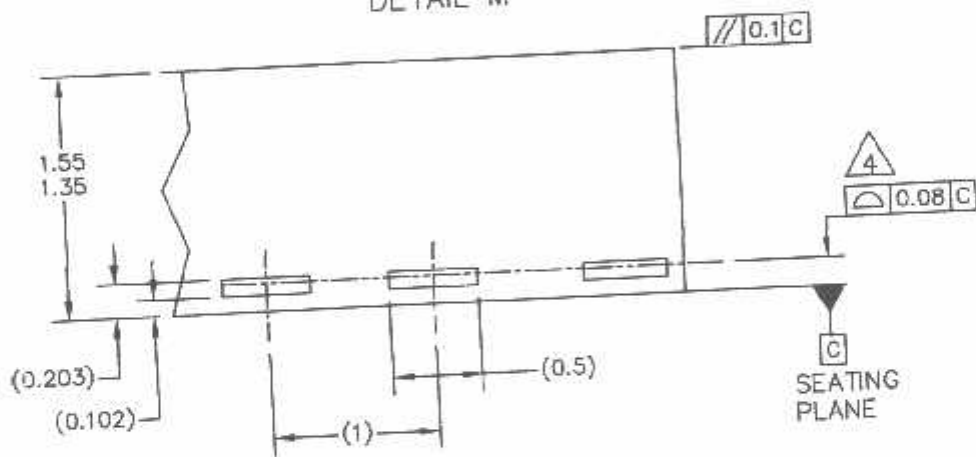
CASE 1622-02
 ISSUE B
 16-LEAD QFN

MMA7260QT

PACKAGE DIMENSIONS



DETAIL M



DETAIL G
VIEW ROTATED 90° CW

| | | | | |
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PACKAGE DIMENSIONS

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.
3. THIS DIMENSION APPLIES TO METALLIZED TERMINAL AND IS MEASURED BETWEEN 0.25MM AND 0.30MM FROM TERMINAL TIP.
4. COPLANARITY APPLIES TO THE EXPOSED HEAT SLUG, TERMINALS AND CORNER PADS.
5. RADIUS ON TERMINAL IS OPTIONAL.
6. MINIMUM METAL GAP SHOULD BE 0.2MM EXCEPT GAP BETWEEN CORNER PADS AND THE EXPOSED HEAT SLUG.

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