# SISTEM PERINGATAN DINI KEBOCORAN GAS ELPIJI DENGAN MENGGUNAKAN SENSOR HS-133 BERBASIS MIKROKONTROLER ATmega8

Skripsi

Untuk memenuhi sebagian persyaratan

Mencapai derajat Sarjana S-1

Program Studi Fisika

Diajukan oleh:

FURKONUDIN

06620010

**Kepada**

**PROGRAM STUDI FISIKA**

**FAKULTAS SAINS DAN TEKNOLOGI**

**UNIVERSITAS ISLAM NEGERI SUNAN KALIJAGA**

**YOGYAKARTA**

**2011**

Universitas Islam Negeri Sunan Kalijaga **FM-UINSK-BM-05-07/R0**

## PENGESAHAN SKRIPSI/TUGAS AKHIR

Nomor : UIN.02/D.ST/PP.01.1/456/2011

| | | |
|---|---|---|
| Skripsi/Tugas Akhir dengan judul | : | Sistem Peringatan Dini Kebocoran Gas Elpiji dengan Menggunakan Sensor HS-133 Berbasis Mikrokontroler ATMega8 |
| Yang dipersiapkan dan disusun oleh | : | |
| Nama | : | Furkonudin |
| NIM | : | 06620010 |
| Telah dimunaqasyahkan pada | : | 1 Maret 2011 |
| Nilai Munaqasyah | : | A - |

Dan dinyatakan telah diterima oleh Fakultas Sains dan Teknologi UIN Sunan Kalijaga

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UIN Sunan Kalijaga
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## PERNYATAAN

Dengan ini saya menyatakan bahwa skripsi ini tidak terdapat karya yang pernah diajukan untuk memperoleh gelar kesarjanaan disuatu Perguruan Tinggi, dan sepanjang pengetahuan saya juga tidak terdapat karya atau pendapat yang pernah ditulis atau diterbitkan oleh orang lain, kecuali yang secara tertulis diacu dalam naskah ini dan disebutkan dalam daftar pustaka.

Yogyakarta, 16 Februari 2011


Furkonudin

# KATA PENGANTAR

Assalamu'alaikum Wr.Wb

Alhamdulillahirobbil 'alamin, penulis bersyukur kehadirat Allah SWT yang Maha Pengasih dan Penyayang serta senantiasa mencurahkan Rahmat dan Hidayah kepada hamba-Nya sehingga penulisan Skripsi ini dapat terselesaikan. Semoga keselamatan dan kesejahteraan senantiasa terlimpah kepada Nabi Muhammad SAW, yang telah memandu manusia menuju jalan kebenaran di dunia dan akhirat.

Dalam penyusunan Skripsi ini, penulis banyak mendapatkan bantuan dari berbagai pihak, mulai dari persiapan hingga Skripsi ini selesai dikerjakan. Untuk itu dalam kesempatan ini penulis mengucapkan terimakasih kepada:

1. Bapak Prof. Dr. Musa Asyarie, selaku Rektor UIN Sunan Kalijaga Yogyakarta.
2. Prof. Drs. H. Akh. Minhaji, M.A.,Ph.D selaku Dekan Fakultas Sains dan Teknologi UIN Sunan Kalijaga Yogyakarta.
3. Bapak Thaqibul Fikri Niyartama, M.Si selaku Kepala Jurusan Program Studi Fisika, sekaligus sebagai Dosen Penasehat Akademik Penulis.
4. Ibu Widayanti, M.Si selaku Dosen Pembimbing I penulisan skripsi penulis, terimakasih atas waktu dan saran yang telah diberikan.
5. Ibu Retno Rahmawati, M.Si selaku Dosen Pembimbing II penulisan skripsi penulis, terimakasih atas motivasi untuk segera lulus, saran dan koreksi yang telah diberikan.

6. Dosen Program Studi Fisika Fakultas Sains dan Teknologi UIN Sunan Kalijaga Yogyakarta yang telah mengajarkan dan membagikan ilmunya.
7. Seluruh staf dan karyawan dibagian Tata Usaha Fakultas Sains dan Teknologi UIN Sunan Kalijaga Yogyakarta.
8. Ayah dan ibunda tercinta yang selalu memberi dukungan, do'a dan nasihat kepada penulis, nasihat ayah dan ibu kan ku ingat dan kukerjakan.
9. Kang Amir yang menjadi motivator bagiku untuk dapat terus menuntut ilmu.
10. Adikku I'ing dan Amy mengingatmu membuatku malu tuk berlama-lama duduk dibangku kuliah.
11. Chayang Roik yang setia menemani walau bagaimanapun keadaanku.
12. Seluruh teman-teman Fisika angkatan 2006, *Yamyam Suriba, Jheng Tom2, Say, Mumun, Pak Danang, Muse, Fuad, Dyas, Madeceng,* semoga kebersamaan kita selama ini akan terus terjalin.

Dengan segala keterbatasan penulis menyadari bahwa masih banyak kekurangan dalam penyusunan skripsi ini. Untuk itu Saran dan kritik yang *konstruktif* dari semua pihak sangat penulis harapkan demi perbaikan dan peningkatan skripsi ini.

Akhirnya, penulis hanya bisa mendoakan semoga Allah membalas semua kebaikan-kebaikan mereka selama ini. Aamiin….

Yogyakarta, 16 Februari 2011

Penulis

**PERSEMBAHAN**

## *Motto:*

1. *"Jadikanlah sabar dan sholat sebagai penolongmu. Dan sesungguhnya yang demikian itu sungguh berat, kecuali bagi orang-orang yang khusyu".*
   *(Qs. Al-Baqarah : 45).*
2. *"Allah tidak membebani seseorang melainkan sesuai dengan kesanggupannya, dia mendapat pahala dari kebaikan yang dilakukannya dan mendapat siksa dari kejahatan yang diperbuatnya"*
   *(QS Al-Baqarah : 286)*
3. *Sebelum tidur, maafkan seluruh manusia, cuci hati dengan pemaafan sebanyak tujuh kali, dan untuk yang kedelapan kalinya lumurilah dengan ampunan, niscaya akan mendapatkan kedamaian hati.*
4. *Ilmu itu teman akrab dalam kesepian, sahabat dalam keterasingan, pengawas dalam kesendirian, penunjuk jalan kearah yang benar, penolong disaat sulit dan simpanan setelah kematian*

***Skripsi ini kupersembahkan untuk***

1. *Ayah dan ibunda tercinta*
2. *Kang Amir dan kedua adikku "Amy" n "I'ing"*
3. *Chayang Roik yang setia menemani bagaimanapun keadaanku*
4. *Seluruh Ummat manusia yang peduli dan ingin maju dengan pendidikan*

## DAFTAR ISI

# DAFTAR TABEL

## DAFTAR GAMBAR

## DAFTAR LAMPIRAN

**SISTEM PERINGATAN DINI KEBOCORAN GAS ELPIJI DENGAN MENGGUNAKAN SENSOR HS-133 BERBASIS MIKROKONTROLER ATmega8**

*Furkonudin*
*06620010*

## INTISARI

Telah berhasil dibuat seperangkat sistem sensor peringatan dini kebocoran gas elpiji dengan menggunakan sensor HS-133. Sistem sensor ini mampu mendeteksi dan menampilkan konsentrasi gas elpiji yang terdeteksi melalui LCD dalam satuan ppm. Sistem sensor yang menggunakan sensor HS-133 yang telah dihasilkan dari penelitian ini kemudian dikarakterisasi agar dapat digunakan sebagai alat pendeteksi gas elpiji.

Penelitian ini menggunakan mikrokontroler ATmega8 sebagai sistem kontrol dari sinyal masukan dan keluaran. Hasil akuisisi data dari penelitian ini dianalisis dengan menggunakan pendekatan metode kuadrat terkecil (*least square*).

Dari hasil analisis data diperoleh variabel karakterisasi antara lain: nilai sensitivitas sebesar 0,000107 *Volt/ppm*, galat taksiran standar sebesar 0,419338, *error repeatability* sebesar 5,645%, jangkauan pengukuran sampai dengan 20.000 *ppm*, dan *Zero of Set* sebesar 0,6 *Volt*.

Kata kunci: *Gas elpiji, Sensor HS-133, Mikrokontroler ATmega8*

# BAB I

# PENDAHULUAN

## I.1 Latar Belakang Masalah

Maraknya kebakaran dan kecelakaan yang disebabkan oleh bocor dan meledaknya tabung gas elpiji akhir-akhir ini, menjadi hal yang menakutkan bagi masyarakat pengguna gas tersebut. Maraknya kejadian tersebut tidak hanya menimbulkan kontroversi tapi juga kecaman dari berbagai kalangan terhadap pemerintah yang telah melakukan konversi gas. Bagi sebagian kalangan, pemerintah dianggap telah mengirimkan bom waktu bagi rakyatnya. Elpiji sudah tidak lagi menjadi barang mewah, dan telah menjelma menjadi barang kebutuhan rumah tangga modern. Meskipun demikian, kewaspadaan saat menggunakan elpiji tidak boleh dilupakan. Apalagi belakangan ini telah banyak beredar tabung gas palsu tanpa logo SNI (Standar Nasional Indonesia). Salah satu resiko penggunaan gas elpiji adalah terjadinya kebocoran pada tabung atau instalasi gas tersebut.

Pusat Laboratorium Forensik (Puslabfor) Mabes Polri menyatakan, kasus ledakan yang dipicu tabung gas elpiji ukuran 3 Kg diberbagai wilayah di Indonesia murni disebabkan karena faktor *human error*. Ito Sumardi (2010) menjelaskan selain faktor *human error*, ditemukan laporan kebocoran tabung gas yang disebabkan tabung sudah mengalami korosi. Penyebab lainnya adalah adanya upaya pengoplosan yang membuat rusaknya aksesori seperti selang, *valve*, dan regulator pada tabung gas.

Pada awalnya, gas elpiji tidak berbau, tetapi bila demikian akan sulit dideteksi apabila terjadi kebocoran pada tabung gas. Menyadari hal tersebut, Pertamina menambahkan gas *mercaptane,* yang baunya khas dan menusuk hidung. Langkah itu sangat berguna untuk mendeteksi bila terjadi kebocoran tabung gas. Melalui gas *mercaptane* tersebut masyarakat sudah dapat menghindari ledakan gas LPG, yaitu dengan cara pendeteksian bau gas dengan indra pencium/hidung. Namun karena keterbatasan dari indra pencium tersebut, bau gas yang tercium terkadang tidak dihiraukan dan tidak menjadikannya waspada. Akibatnya kecelakaan yang diakibatkan oleh kebocoran tabung gas pun tidak dapat dihindari.

Elpiji merupakan campuran dari berbagai *hidrokarbon,* sebagai hasil penyulingan minyak mentah yang berbentuk gas. Dengan menambah tekanan atau menurunkan suhunya sehingga elpiji menjadi berbentuk cair. Gas elpiji terkenal dengan sifatnya yang mudah terbakar sehingga kebocoran peralatan elpiji beresiko tinggi terhadap kebakaran. Dikarenakan sifatnya yang sensitif, maka perlu adanya perhatian khusus terhadap bahan bakar jenis ini.

Pada penelitian sebelumnya telah dibuat suatu alat yang dapat mendeteksi kebocoran gas elpiji. Namun pada penelitian tersebut hanya sebatas membunyikan sirine sebagai tanda peringatan dan hanya mampu menampilkan level kondisi (level aman, level waspada, level bahaya) pada tampilan *display*nya. Pada penelitian ini dibuat sistem pendeteksi bau gas dengan fasilitas *display* LCD (*Liquid Cristal Display*) yang menampilkan konsentrasi gas berbasiskan mikrokontroler ATmega8 dan sensor HS-133.

Sistem ini memiliki kelebihan dalam sistem komunikasi yaitu memberikan informasi konsentrasi gas, agar dapat selalu diamati oleh pengguna. Selain itu sistem juga dilengkapi dengan *buzzer* sebagai sirine dan LED indikator jika terdeteksi adanya gas.

## I.2 Rumusan Masalah

Berdasarkan latar belakang di atas dapat dirumuskan suatu masalah yang relevan dengan judul yang ada yaitu:

1. Bagaimanakah membuat seperangkat sistem peringatan dini kebocoran gas elpiji dengan menggunakan sensor HS-133?
2. Bagaimanakah karakteristik sensor HS-133 yang dihasilkan dari penelitian ini agar dapat digunakan sebagai alat pendeteksi gas elpiji?

## I.3 Batasan Masalah

Berdasarkan rumusan masalah diatas, maka penelitian ini dibatasi pada hal-hal berikut ini:

1. Sensor yang digunakan dalam penelitian ini adalah sensor HS-133.
2. Sistem berbasis mikrokontroller ATmega8 yang bertugas untuk mengatur seluruh kegiatan sistem yang dirakit.
3. Tanda bahaya dari kebocoran gas akan ditampilkan melalui LCD berupa nilai konsentrasi gas dengan satuan *ppm (part per million)* dan *buzzer* sebagai sistem peringatan dini.

## I.4 Tujuan Penelitian

Adapun tujuan penelitian ini adalah sebagai berikut:

1. Merancang dan mengimplementasikan suatu sistem yang dapat memantau dan mendeteksi adanya kebocoran gas elpiji dengan menggunakan sensor HS-133
2. Mengkarakterisasi sistem sensor HS-133 yang dihasilkan dari penelitian ini agar dapat digunakan sebagai alat pendeteksi gas elpiji.

## I.5 Manfaat Penelitian

Manfaat dari penelitian ini antara lain sebagai berikut:

1. Menanggulangi kebakaran yang diakibatkan oleh kebocoran gas elpiji.
2. Menghindari kecelakaan akibat kebocoran dan meledaknya tabung gas elpiji
3. Mengurangi *human error* akibat salah dalam melakukan pengukuran konsentrasi gas.

## I.6 Keaslian Penelitian

Dengan ini saya menyatakan bahwa skripsi ini tidak terdapat karya yang pernah diajukan untuk memperoleh gelar kesarjanaan di suatu Perguruan Tinggi, dan sepanjang pengetahuan saya juga tidak terdapat karya atau pendapat yang pernah ditulis atau diterbitkan oleh orang lain, kecuali yang secara tertulis diacu dalam naskah ini dan disebutkan dalam daftar pustaka.

# BAB V

# KESIMPULAN

## V.1 Kesimpulan

Berdasarkan hasil penelitian dan pembahasan yang telah diberikan pada bab sebelumnya, maka dapat diambil beberapa kesimpulan yaitu:

1. Telah berhasil dibuat seperangkat sistem peringatan dini kebocoran gas elpiji dengan menggunakan sensor HS-133 yang mampu mendeteksi sekaligus menampilkan nilai konsentrasi gas elpiji yang terdeteksi dalam satuan ppm.
2. Dari hasil karakterisasi terhadap sistem sensor pada penelitian ini diperoleh beberapa variabel karakteristik antara lain: nilai sensitivitas sebesar 0,000107 *Volt/ppm* dan galat taksiran standar sebesar 0,419338, *error repeatability* sebesar 5,645%, jangkauan pengukuran sampai dengan 20.000 *ppm*, dan *Zero of Set* sebesar 0,6 *Volt*.

## V.2 Saran

Berdasarkan hasil penelitian yang telah diperoleh disadari bahwa sistem deteksi kebocoran gas LPG yang telah dibuat memiliki beberapa kekurangan. Oleh sebab itu, untuk mengembangkannya menjadi alat yang akurat dan presisi disarankan untuk dilakukan beberapa hal sebagai berikut:

1. Sebaiknya hasil pengukuran konsentrasi gas LPG dibandingkan dengan alat ukur yang sudah terkalibrasi agar sistem sensor ini dapat digunakan sebagai alat ukur konsentrasi LPG.
2. Agar diperoleh hasil karakterisasi sistem sensor yang baik, sebaiknya menggunakan sumber gas yang memiliki konsentrasi di atas 30.000 ppm dan perubaha konsentrasinya tidak *fluktuatif*.
3. Disarankan untuk menambahkan sistem informasi kebocoran gas melalui sms agar kondisi gas dapat selalu terpantau secara *real time*.

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# LAMPIRAN

**LAMPIRAN 1**

**Universitas Islam Negeri Sunan Kalijaga** **FM-UINSK-BM-05-03/RO**

**SURAT PERSETUJUAN SKRIPSI/TUGAS AKHIR**

Hal : Persetujuan Skripsi
Lamp :

Kepada
Yth. Dekan Fakultas Sains dan Teknologi
UIN Sunan Kalijaga Yogyakarta
Di Yogyakarta

*Assalamu'alaikum wr.wb.*

Setelah membaca, meneliti, memberikan petunjuk dan mengoreksi serta mengadakan perbaikan seperlunya, maka kami selaku pembimbing berpendapat bahwa skripsi saudara:

Nama : Furkonudin
NIM : 06620010
Judul Skrispsi : Sistem Peringatan Dini Kebocoran Gas Elpiji Dengan Menggunakan Sensor HS-133 Berbasis Mikrokontroler ATmega8

Sudah dapat diajukan kembali kepada Fakultas Sains dan Teknologi, Jurusan/Program Studi Fisika UIN Sunan Kalijaga Yogyakarta sebagai salah satu syarat untuk memperoleh gelar Sarjana Strata Satu.

Dengan ini kami mengarap agar Skripsi/Tugas Akhir Saudara tersebut diatas dapat segera dimunaqosyahkan. Atas perhatiannya kami ucapkan terima kasih.

Yogyakarta, 16 Februari 2011

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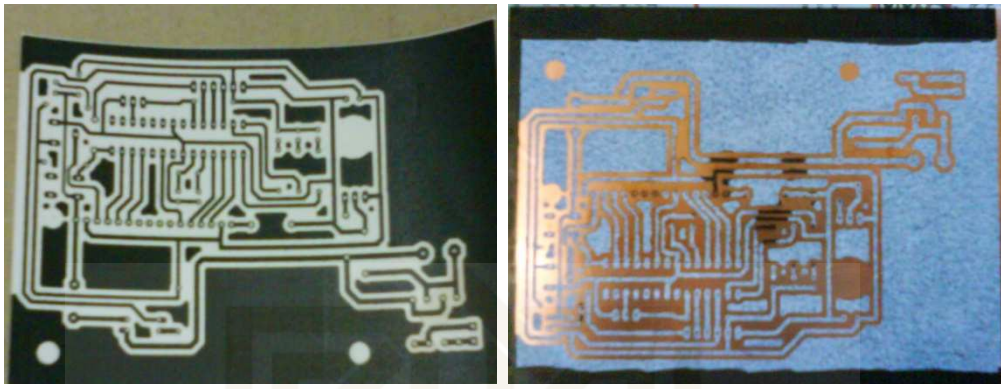
## LAMPIRAN 2. PERHITUNGAN KARAKTERISTIK SENSOR DENGAN METODE *LEAST SQUARE*

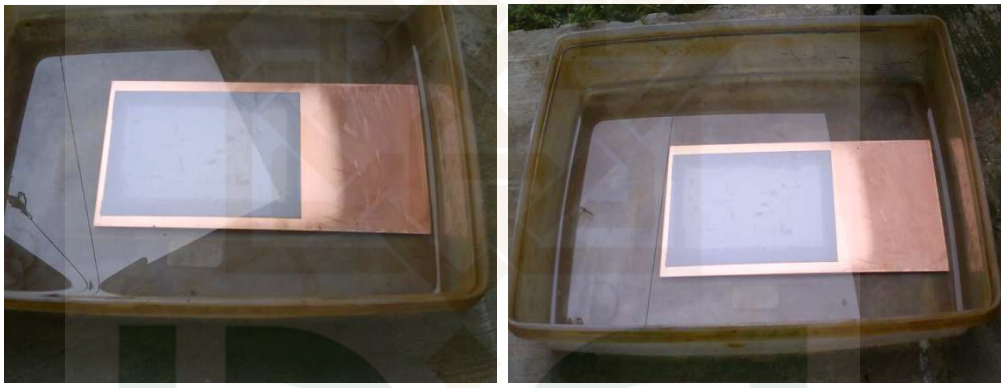
| No | Xi | Yi | Xi.Yi | Xi^2 | $Yi - \overline{Yi}$ | $(Yi - \overline{Yi})^2$ | Yi-ao-a1Xi | (Yi-ao-a1Xi)^2 |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0,60 | 0 | 0 | -1,59 | 2,52 | -0,78527685 | 0,616659732 |
| 2 | 122 | 0,80 | 97,6 | 14884 | -1,39 | 1,92 | -0,598387176 | 0,358067213 |
| 3 | 245 | 1,00 | 245 | 60025 | -1,19 | 1,41 | -0,411604964 | 0,169418646 |
| 4 | 312 | 1,10 | 343,2 | 97344 | -1,09 | 1,18 | -0,318804897 | 0,101636562 |
| 5 | 1037 | 1,40 | 1451,8 | 1075369 | -0,79 | 0,62 | -0,09671462 | 0,009353718 |
| 6 | 1524 | 1,60 | 2438,4 | 2322576 | -0,59 | 0,34 | 0,050951538 | 0,002596059 |
| 7 | 2021 | 1,80 | 3637,8 | 4084441 | -0,39 | 0,15 | 0,197543079 | 0,039023268 |
| 8 | 2881 | 2,00 | 5762 | 8300161 | -0,19 | 0,03 | 0,305126028 | 0,093101893 |
| 9 | 5161 | 2,50 | 12902,5 | 26635921 | 0,31 | 0,10 | 0,56011338 | 0,313726999 |
| 10 | 5968 | 2,56 | 15254,208 | 35617024 | 0,37 | 0,14 | 0,529391799 | 0,280255676 |
| 11 | 6694 | 2,60 | 17404,4 | 44809636 | 0,41 | 0,17 | 0,495374613 | 0,245396008 |
| 12 | 7903 | 2,67 | 21124,719 | 62457409 | 0,49 | 0,24 | 0,438453433 | 0,192241413 |
| 13 | 9032 | 2,75 | 24838 | 81577024 | 0,56 | 0,32 | 0,394129188 | 0,155337817 |
| 14 | 10000 | 2,80 | 28000 | 100000000 | 0,61 | 0,38 | 0,340106274 | 0,115672278 |
| 15 | 12619 | 2,85 | 36014,626 | 159239161 | 0,67 | 0,45 | 0,112664115 | 0,012693203 |
| 16 | 14048 | 2,88 | 40500,384 | 197346304 | 0,70 | 0,49 | -0,011898637 | 0,000141578 |
| 17 | 15238 | 2,91 | 44312,104 | 232196644 | 0,72 | 0,52 | -0,114778045 | 0,013174 |
| 18 | 16190 | 2,93 | 47388,13 | 262116100 | 0,74 | 0,55 | -0,198081571 | 0,039236309 |
| 19 | 18095 | 2,97 | 53669,77 | 327429025 | 0,78 | 0,61 | -0,363796086 | 0,132347592 |
| 20 | 20000 | 3,01 | 60200 | 400000000 | 0,82 | 0,68 | -0,524510601 | 0,275111371 |
| | | | | | | | | |
| ∑ | 149090 | 43,73 | 415584,641 | 1945379048 | | 12,80 | | 3,165191333 |
| **Rerata** | 7454,5 | 2,19 | | 97268952,4 | | | | |
| **(∑Xi)^2** | 22227828100 | | | | | | | |
| **Slope (a1)** | 0,000107462 | Sensitivitas | 0,000107462 | V/ppm | | | | |
| **ao** | 1,38527685 | | | | | | | |

| | |
|---|---|
| **Jumlah Total kuadrat (St)** | 12,79609255 |
| **Jmlh kuadrat residual(Sr)** | 3,165191333 |
| **Deviasi standar total (Sy)** | 0,820657392 |
| **Galat stndr taksiran (Sy/x)** | 0,419337529 |
| **koefisien korelasi (r^2)** | 0,752643917 |
| **Intersep (ao)** | 1,38527685 |

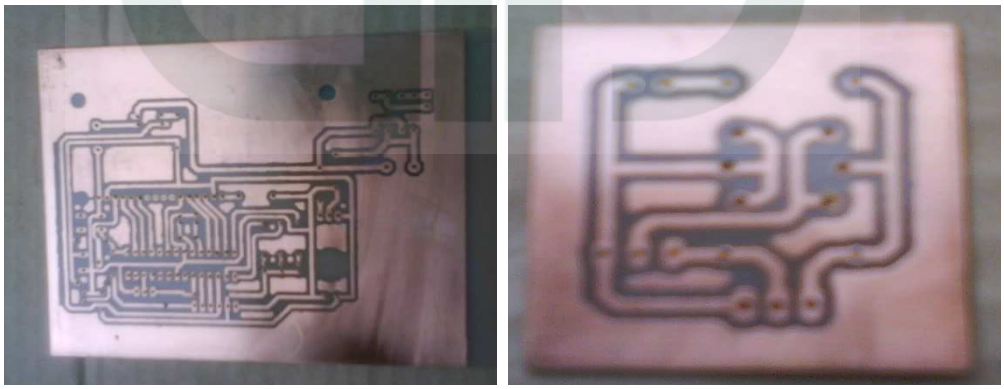
# LAMPIRAN 3
# PROSES PEMBUATAN ALAT



*Gambar 3.1 Layout dan Sablon PCB*

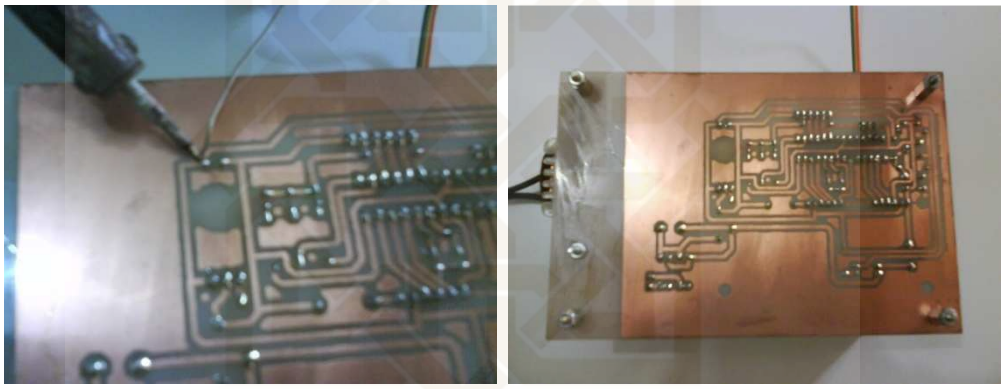


*Gambar 3.2 Proses Pelarutan PCB*

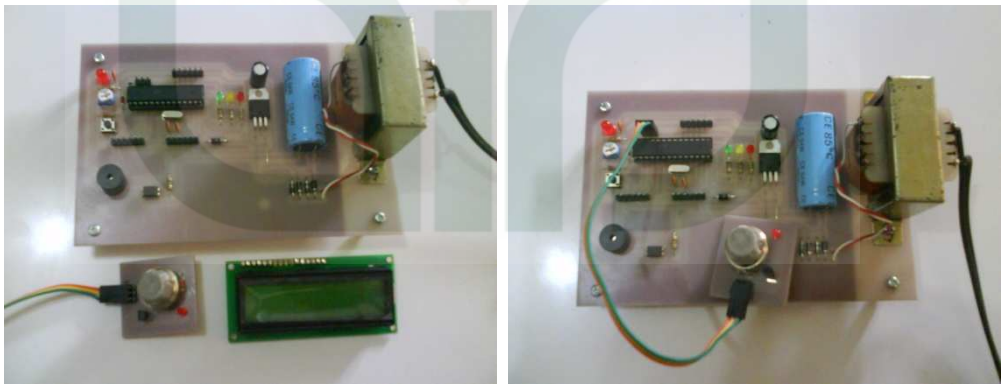


*Gambar 3.3 PCB Setelah  Dilarutkan Dalam Larutan Feri Cloride*

*Gambar 3.4 Proses Pemasangan Komponen*



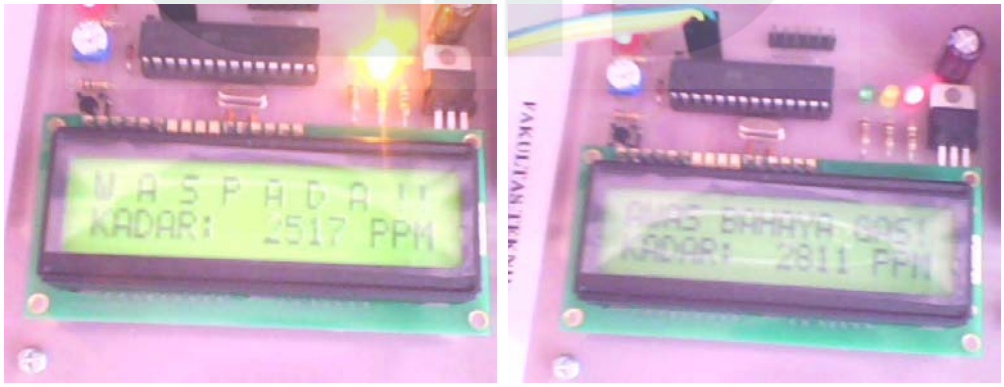
*Gambar 3.5 Proses Penyolderan Komponen*



*Gambar 3.6 Gambar Keseluruhan Komponen Setelah Dipasang*


*Gambar 3.7 Sistem Siap Digunakan*

*Gambar 3.8 Pengujian Sistem*




*Gambar 3.9 Tampilan Saat Sistem Mendeteksi Gas Elpiji*

**LAMPIRAN 4**
**LISTING PROGRAM MENGGUNAKAN BAHASA C**

```
/*****************************************************
Project         : Sensor LPG
Version         : 1.0
Author          : Furqonudin
NIM             : 06620010

Chip type                 : ATmega8
Program type              : Application
AVR Core Clock frequency  : 8.000000 MHz
Memory model              : Small
External RAM size         : 0
Data Stack size           : 256
*****************************************************/

#include <mega8.h>
#include <stdio.h>
#include <delay.h>

#define Alarm      PORTB.3
#define LED_Hijau   PORTB.2
#define LED_Kuning  PORTB.1
#define LED_Merah   PORTB.0

// Alphanumeric LCD Module functions
#asm
   .equ __lcd_port=0x12 ;PORTD
#endasm
#include <lcd.h>
```

```
#define ADC_VREF_TYPE 0x40

// Read the AD conversion result
unsigned int read_adc(unsigned char adc_input)
{
ADMUX=adc_input | (ADC_VREF_TYPE & 0xff);
// Delay needed for the stabilization of the ADC input voltage
delay_us(10);
// Start the AD conversion
ADCSRA|=0x40;
// Wait for the AD conversion to complete
while ((ADCSRA & 0x10)==0);
ADCSRA|=0x10;
return ADCW;
}

// Declare your global variables here
unsigned int PPM, V_Load;
const unsigned PPM_Limit=2000;
unsigned char Ulang_Cek;
unsigned char buffer_lcd[16];

flash char Text1[17] ="  DETEKTOR GAS  ";
flash char Text2[17] ="Oleh: Furqonudin";
flash char Text3[17] ="W A S P A D A !!";
flash char Text4[17] ="AWAS BAHAYA GAS!";

//
unsigned int Detect_LPG (void);
```

```
void main(void)
{
// Declare your local variables here

// Input/Output Ports initialization
// Port B initialization
PORTB=0x0F;
DDRB=0x0F;    //Output: PB0 ... PB3

// Port C initialization
PORTC=0x00;
DDRC=0x00;

// Port D initialization
PORTD=0x00;
DDRD=0x00;
// Analog Comparator initialization
// Analog Comparator: Off
// Analog Comparator Input Capture by Timer/Counter 1: Off
ACSR=0x80;
SFIOR=0x00;

// ADC initialization
// ADC Clock frequency: 1000.000 kHz
// ADC Voltage Reference: AREF pin
ADMUX=ADC_VREF_TYPE & 0xff;
ADCSRA=0x83;

// System initialization
lcd_init(16);
PPM = 0;
```

```
LED_Hijau=0;        //LED Nyala (On)
LED_Kuning=1;       //LED Padam (Off)
LED_Merah=1;
Alarm = 1;
//Tampilan Awal LCD
  lcd_clear();
  lcd_gotoxy(0,0);
  lcd_putsf(Text1);
  lcd_gotoxy(0,1);
  lcd_putsf(Text2);
delay_ms(2000);
  lcd_clear();
while (1)
      {
        Detect_LPG();
        while (PPM<(PPM_Limit/2)) {
          lcd_clear();
          delay_ms(300);
          lcd_gotoxy(0,0);
          lcd_putsf(Text1);
          lcd_gotoxy(0,1);
          lcd_putsf(Text2);
          delay_ms(300);
          Detect_LPG();
          }
//Ada LPG Bocor > batas toleransi (dalam 1 -  3 s)
        for (Ulang_Cek=0;Ulang_Cek<6;Ulang_Cek++) {
          Detect_LPG();
          if (PPM>PPM_Limit) {
            lcd_clear();
            delay_ms(250);
```

```
            sprintf(buffer_lcd,"KADAR: %5i PPM",PPM);
            lcd_gotoxy(0,0);
            lcd_putsf(Text3);
            lcd_gotoxy(0,1);
            lcd_puts(buffer_lcd);
            LED_Hijau=1;
            LED_Kuning=0;
            delay_ms(250);
            LED_Kuning=1;
            }
          //
          else {
            lcd_clear();
            delay_ms(200);
            lcd_gotoxy(0,0);
            lcd_putsf(Text1);
            lcd_gotoxy(0,1);
            lcd_putsf(Text2);
            LED_Hijau=0;
            LED_Kuning=1;
            delay_ms(200);
            }
          }
//Jika PPM > PPM_Limit selama 3s, nyatakan "bahaya"
        while (PPM>PPM_Limit){
          lcd_clear();
          delay_ms(250);
          sprintf(buffer_lcd,"KADAR: %5i PPM",PPM);
          lcd_gotoxy(0,0);
          lcd_putsf(Text4);
          lcd_gotoxy(0,1);
```

```
        lcd_puts(buffer_lcd);
        LED_Hijau=1;
        LED_Kuning=1;
        LED_Merah=~LED_Merah;
        Alarm=0;
        delay_ms(250);
        Alarm=1;
        Detect_LPG();
        }
      LED_Hijau=0;
      LED_Kuning=1;
      LED_Merah=1;
      Alarm=1;
      lcd_clear();
    };
}

unsigned int Detect_LPG (void)
{
 const float a1=2.91262, a2=11.88811;      // Konstanta Slope
 const float a3=20.97902, a4=80.64516;
 const float a5=238.09524;

 PORTC.3=1;
 V_Load = read_adc(3);                //+(0x7A);       //V_BE = 600mV = 7Ah
 if (V_Load<12) {
  V_Load=0;
  PPM =0;                          //Teg Input < 0.6V
  }
  //
 else {
```

```
  V_Load+=122;                    //Teg Input > 0.6V
  }
 //
 if (V_Load>573) PPM = (V_Load-573)*a5;    //Teg Input>2.8V?
 else
  if (V_Load>511) PPM = (V_Load-511)*a4;  //Teg Input>2.5V?
 else
  if (V_Load>368) PPM = (V_Load-368)*a3;  //Teg Input>1.8V?
 else
  if (V_Load>225) PPM = (V_Load-225)*a2;  //Teg Input>1.1V?
 else
  { PPM = (V_Load-122)*a1; }              //Teg Input>0.6V?
 return PPM;
}
```

# LAMPIRAN 5

## KODE ASCII BAHASA C

| Dec | Hx | Oct | Char | Dec | Hx | Oct | Html | Chr | Dec | Hx | Oct | Html | Chr | Dec | Hx | Oct | Html | Chr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 000 | NUL (null) | 32 | 20 | 040 |   | Space | 64 | 40 | 100 | @ | @ | 96 | 60 | 140 | ` | ` |
| 1 | 1 | 001 | SOH (start of heading) | 33 | 21 | 041 | ! | ! | 65 | 41 | 101 | A | A | 97 | 61 | 141 | a | a |
| 2 | 2 | 002 | STX (start of text) | 34 | 22 | 042 | " | " | 66 | 42 | 102 | B | B | 98 | 62 | 142 | b | b |
| 3 | 3 | 003 | ETX (end of text) | 35 | 23 | 043 | # | # | 67 | 43 | 103 | C | C | 99 | 63 | 143 | c | c |
| 4 | 4 | 004 | EOT (end of transmission) | 36 | 24 | 044 | $ | $ | 68 | 44 | 104 | D | D | 100 | 64 | 144 | d | d |
| 5 | 5 | 005 | ENQ (enquiry) | 37 | 25 | 045 | % | % | 69 | 45 | 105 | E | E | 101 | 65 | 145 | e | e |
| 6 | 6 | 006 | ACK (acknowledge) | 38 | 26 | 046 | & | & | 70 | 46 | 106 | F | F | 102 | 66 | 146 | f | f |
| 7 | 7 | 007 | BEL (bell) | 39 | 27 | 047 | ' | ' | 71 | 47 | 107 | G | G | 103 | 67 | 147 | g | g |
| 8 | 8 | 010 | BS (backspace) | 40 | 28 | 050 | ( | ( | 72 | 48 | 110 | H | H | 104 | 68 | 150 | h | h |
| 9 | 9 | 011 | TAB (horizontal tab) | 41 | 29 | 051 | ) | ) | 73 | 49 | 111 | I | I | 105 | 69 | 151 | i | i |
| 10 | A | 012 | LF (NL line feed, new line) | 42 | 2A | 052 | * | * | 74 | 4A | 112 | J | J | 106 | 6A | 152 | j | j |
| 11 | B | 013 | VT (vertical tab) | 43 | 2B | 053 | + | + | 75 | 4B | 113 | K | K | 107 | 6B | 153 | k | k |
| 12 | C | 014 | FF (NP form feed, new page) | 44 | 2C | 054 | , | , | 76 | 4C | 114 | L | L | 108 | 6C | 154 | l | l |
| 13 | D | 015 | CR (carriage return) | 45 | 2D | 055 | - | - | 77 | 4D | 115 | M | M | 109 | 6D | 155 | m | m |
| 14 | E | 016 | SO (shift out) | 46 | 2E | 056 | . | . | 78 | 4E | 116 | N | N | 110 | 6E | 156 | n | n |
| 15 | F | 017 | SI (shift in) | 47 | 2F | 057 | / | / | 79 | 4F | 117 | O | O | 111 | 6F | 157 | o | o |
| 16 | 10 | 020 | DLE (data link escape) | 48 | 30 | 060 | 0 | 0 | 80 | 50 | 120 | P | P | 112 | 70 | 160 | p | p |
| 17 | 11 | 021 | DC1 (device control 1) | 49 | 31 | 061 | 1 | 1 | 81 | 51 | 121 | Q | Q | 113 | 71 | 161 | q | q |
| 18 | 12 | 022 | DC2 (device control 2) | 50 | 32 | 062 | 2 | 2 | 82 | 52 | 122 | R | R | 114 | 72 | 162 | r | r |
| 19 | 13 | 023 | DC3 (device control 3) | 51 | 33 | 063 | 3 | 3 | 83 | 53 | 123 | S | S | 115 | 73 | 163 | s | s |
| 20 | 14 | 024 | DC4 (device control 4) | 52 | 34 | 064 | 4 | 4 | 84 | 54 | 124 | T | T | 116 | 74 | 164 | t | t |
| 21 | 15 | 025 | NAK (negative acknowledge) | 53 | 35 | 065 | 5 | 5 | 85 | 55 | 125 | U | U | 117 | 75 | 165 | u | u |
| 22 | 16 | 026 | SYN (synchronous idle) | 54 | 36 | 066 | 6 | 6 | 86 | 56 | 126 | V | V | 118 | 76 | 166 | v | v |
| 23 | 17 | 027 | ETB (end of trans. block) | 55 | 37 | 067 | 7 | 7 | 87 | 57 | 127 | W | W | 119 | 77 | 167 | w | w |
| 24 | 18 | 030 | CAN (cancel) | 56 | 38 | 070 | 8 | 8 | 88 | 58 | 130 | X | X | 120 | 78 | 170 | x | x |
| 25 | 19 | 031 | EM (end of medium) | 57 | 39 | 071 | 9 | 9 | 89 | 59 | 131 | Y | Y | 121 | 79 | 171 | y | y |
| 26 | 1A | 032 | SUB (substitute) | 58 | 3A | 072 | : | : | 90 | 5A | 132 | Z | Z | 122 | 7A | 172 | z | z |
| 27 | 1B | 033 | ESC (escape) | 59 | 3B | 073 | ; | ; | 91 | 5B | 133 | [ | [ | 123 | 7B | 173 | { | { |
| 28 | 1C | 034 | FS (file separator) | 60 | 3C | 074 | < | < | 92 | 5C | 134 | \ | \ | 124 | 7C | 174 | | | \| |
| 29 | 1D | 035 | GS (group separator) | 61 | 3D | 075 | = | = | 93 | 5D | 135 | ] | ] | 125 | 7D | 175 | } | } |
| 30 | 1E | 036 | RS (record separator) | 62 | 3E | 076 | > | > | 94 | 5E | 136 | ^ | ^ | 126 | 7E | 176 | ~ | ~ |
| 31 | 1F | 037 | US (unit separator) | 63 | 3F | 077 | ? | ? | 95 | 5F | 137 | _ | _ | 127 | 7F | 177 | &#127; | DEL |

Source: www.LookupTables.com

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 128 | Ç | 144 | É | 161 | í | 177 | ▒ | 193 | ┴ | 209 | ╤ | 225 | ß | 241 | ± |
| 129 | ü | 145 | æ | 162 | ó | 178 | ▓ | 194 | ┬ | 210 | ╥ | 226 | Γ | 242 | ≥ |
| 130 | é | 146 | Æ | 163 | ú | 179 | │ | 195 | ├ | 211 | ╙ | 227 | π | 243 | ≤ |
| 131 | â | 147 | ô | 164 | ñ | 180 | ┤ | 196 | ─ | 212 | ╘ | 228 | Σ | 244 | ⌠ |
| 132 | ä | 148 | ö | 165 | Ñ | 181 | ╡ | 197 | ┼ | 213 | ╒ | 229 | σ | 245 | ⌡ |
| 133 | à | 149 | ò | 166 | ª | 182 | ╢ | 198 | ╞ | 214 | ╓ | 230 | µ | 246 | ÷ |
| 134 | å | 150 | û | 167 | º | 183 | ╖ | 199 | ╟ | 215 | ╫ | 231 | τ | 247 | ≈ |
| 135 | ç | 151 | ù | 168 | ¿ | 184 | ╕ | 200 | ╚ | 216 | ╪ | 232 | Φ | 248 | ° |
| 136 | ê | 152 | ÿ | 169 | ⌐ | 185 | ╣ | 201 | ╔ | 217 | ┘ | 233 | Θ | 249 | ∙ |
| 137 | ë | 153 | Ö | 170 | ¬ | 186 | ║ | 202 | ╩ | 218 | ┌ | 234 | Ω | 250 | · |
| 138 | è | 154 | Ü | 171 | ½ | 187 | ╗ | 203 | ╦ | 219 | █ | 235 | δ | 251 | √ |
| 139 | ï | 156 | £ | 172 | ¼ | 188 | ╝ | 204 | ╠ | 220 | ▄ | 236 | ∞ | 252 | ⁻ |
| 140 | î | 157 | ¥ | 173 | ¡ | 189 | ╜ | 205 | ═ | 221 | ▌ | 237 | φ | 253 | ² |
| 141 | ì | 158 | ₧ | 174 | « | 190 | ╛ | 206 | ╬ | 222 | ▐ | 238 | ε | 254 | ■ |
| 142 | Ä | 159 | ƒ | 175 | » | 191 | ┐ | 207 | ╧ | 223 | ▀ | 239 | ∩ | 255 | |
| 143 | Å | 160 | á | 176 | ░ | 192 | └ | 208 | ╨ | 224 | α | 240 | ≡ | | |

Source: www.LookupTables.com

LAMPIRAN 6

# LPG gas sensor HS-133 specifications

## 1.Characteristics

1.1 High sensitive, good selectivity to fume and alcohol.
1.2 Long period using life and reliable stability.

## 2. Application

2.1 Gas leakage detecting in family and industry
2.2 Suitable for detecting equipments of LPG、isobutane、propane、methane.

## 3. Structure

3.1 Structure and configuration of HS-133 as below Fig. 1

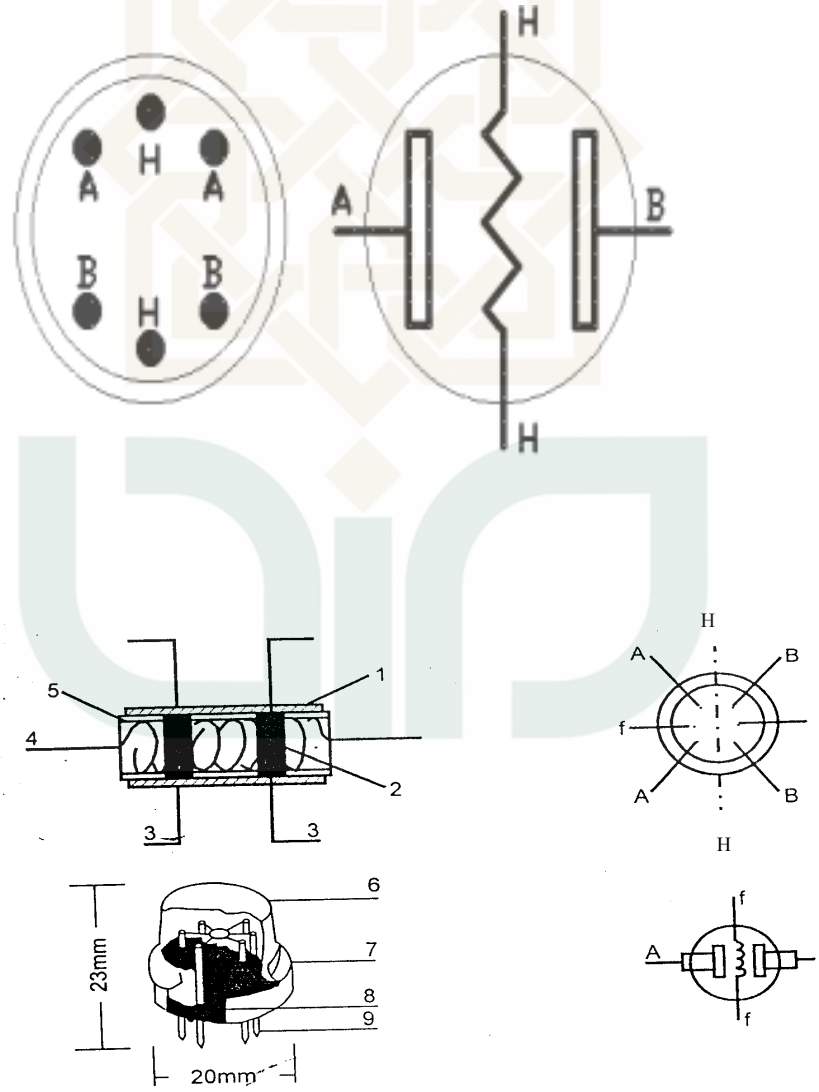



**Fig.1**

| series | Parts | Materials |
|---|---|---|
| 1 | gas sensing layer | $SnO_2$ |
| 2 | measurement electrode | Au |
| 3 | measurement electrode ignited line | Pt |
| 4 | Heater | Ni-Cr alloy |
| 5 | tubular ceramic basic body | $Al_2 O_3$ |
| 6 | anti-explosion network | 100 dual layer atainless steel (SUS316) |
| 7 | clamp ring | materials valcanized Ni |
| 8 | basic seat | bakelite |
| 9 | tube foot | materils valcanized Ni |

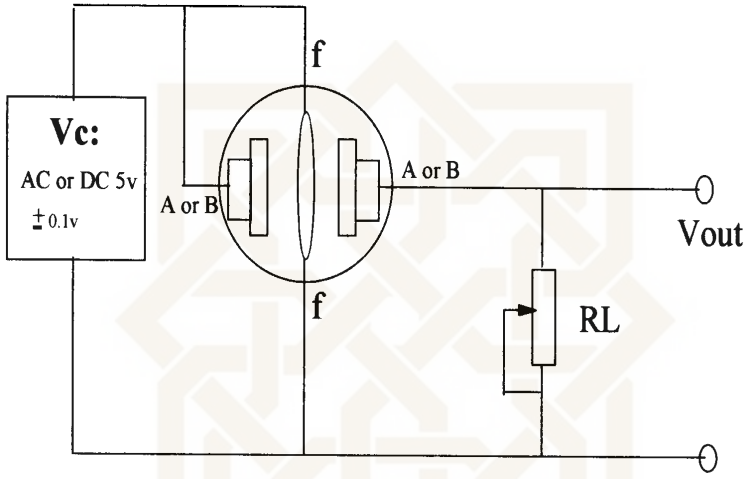



Fig:2

3.2 HS-133 have 6 pins, 4 of them are used to catch signals, and other 2 are used for providing heating current. Electric parameter measurement circuit is shown as Fig.2

## 4. Property

### 4.1 Standard work condition

| Symbol | Parameter name | Technical condition | Remarks |
|---|---|---|---|
| Vc | circuit voltage | 5V | AC OR DC |
| $V_H$ | Heating voltage | 5V | ACOR DC |
| $P_L$ | load resistance | can be adjustable | Ps <25mW |
| $R_H$ | heater resistance | 33 Ω ±5% | room Tem |
| $P_H$ | heating consumption | less than 800mw | |

4.2 Environment condition

| Symbol | Parameter name | Technical condition | Remarks |
|---|---|---|---|
| Tao | Uaing Tem | -20℃-50℃ | |
| Tas | storage Tem | -20℃-70℃ | |
| RH | related humidity | less than 95%Rh | |

| | | | |
|---|---|---|---|
| $O_2$ | oxygen concentration | 21%(standard condition)Oxygen co-ncentration can affect sensitivity | minimum value is over 2% |

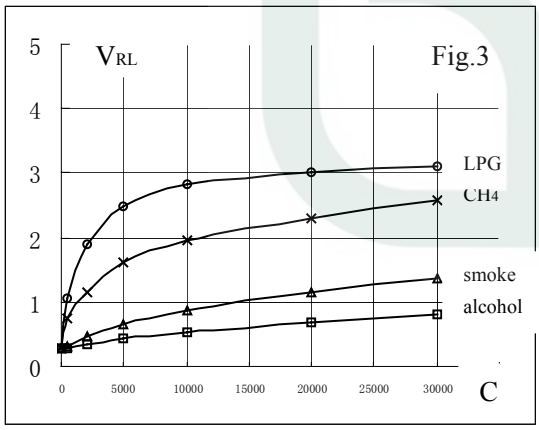
4.3 Sensitivity characteristic

| Symbol | Parameter name | Technical parameter | | Remark |
|---|---|---|---|---|
| Rs | sensing body resistance | 2kΩ-20kΩ (2000ppm isobutane ) | | Detecting concentration scope: 300ppm-10000ppm isobutane or LPG |
| α (5000/1000) isobutane | concentration slope rate | ≤0.6 | | |
| standard detecting condition | Temp: 20℃±2℃ Vc:5V±0.1 Humidity: 65%±5% Vh: 5V±0.1 | | | |
| preheat time | over 24 hour | | | |

4.4 Machinary characteristic

| Project | Condition | Property |
|---|---|---|
| Vibration | frequency 100cpm | Should be conformed to given sensitivity characteristic |
| | vertical vibrating amplitude | |
| | time 1 hour | |
| Punch | Acceleration 100G | |
| | punch times 5 | |

## 5. Sensitivity characteristic curve of HS-133



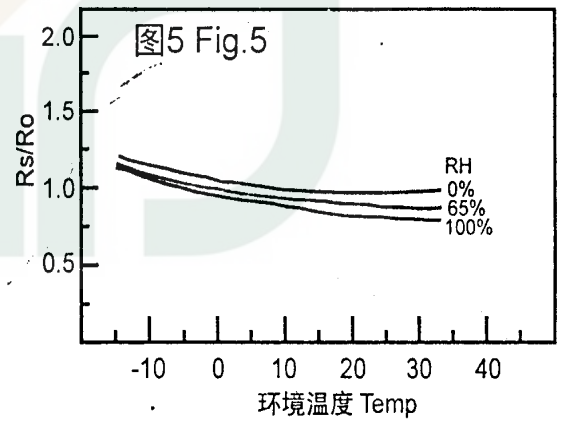




Fig 3 is relation curve of $V_{RL}$ and gas concentration.
in their: Temp: 20℃、 Humidity: 65%、 $O_2$ concentration 21% RL =5kΩ

Fig 4 is relation curve between surface resistance of HS-133 and environment related humidity.
Under the conditions of:
$R_o$ = 20℃, RH= 0% in 2000ppmLPG
Rs = resistance value in other Temp.

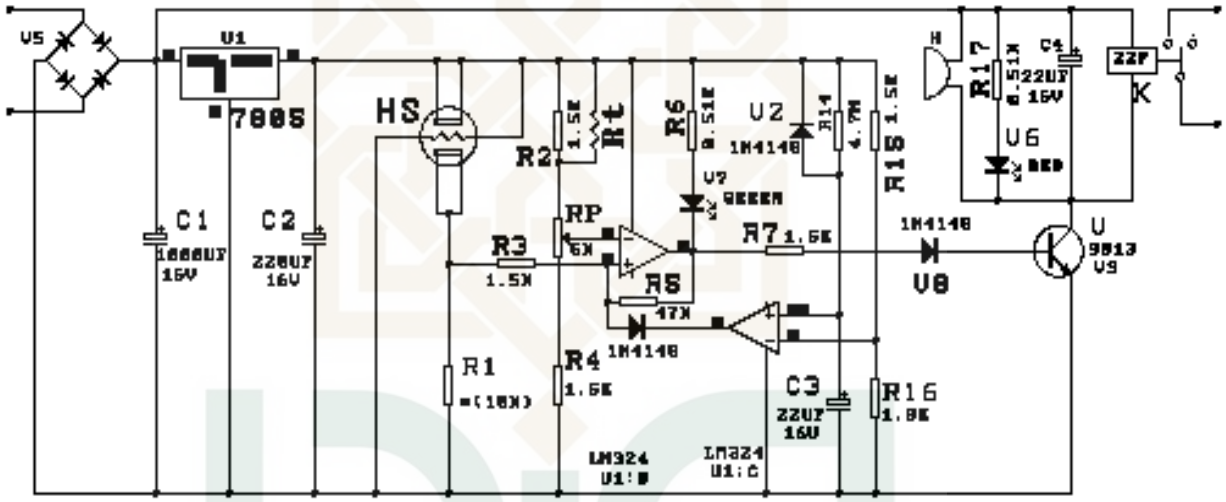
## 6. Sensitvity adjustment

Resistance value will be changing in the different spices and different concentration gas. So, when user operating the components, sensitivity adjustment is necessary. We suggest that use 300ppm-2000ppm isobutane<i-$C_4H_{10}$ >or LPG as standard sensitivity adjustment concentration gas.

Adjustment steps:

a. Input HS-133 to application circuits.
b. Before test the long storage HS-133 we suggest the pre-heating time should not be shorter than 24 hours in order to guarantee HS-133 property can reach stability completely.
c. In the detecting gas concentration, adjust the load resistance RL until suitable signal output.

## 7. **Application circuit which have temperature compensation function.**



## 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
- High Endurance Non-volatile Memory segments
  - 8K Bytes of In-System Self-programmable Flash program memory
  - 512 Bytes EEPROM
  - 1K Byte Internal SRAM
  - Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
  - Data retention: 20 years at 85°C/100 years at 25°C(1)
  - Optional Boot Code Section with Independent Lock Bits
    In-System Programming by On-chip Boot Program
    True Read-While-Write Operation
  - Programming Lock for Software Security
- Peripheral Features
  - Two 8-bit Timer/Counters with Separate Prescaler, one Compare Mode
  - One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
  - Real Time Counter with Separate Oscillator
  - Three PWM Channels
  - 8-channel ADC in TQFP and QFN/MLF package
    Eight Channels 10-bit Accuracy
  - 6-channel ADC in PDIP package
    Six Channels 10-bit Accuracy
  - 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
  - Five Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, and Standby
- I/O and Packages
  - 23 Programmable I/O Lines
  - 28-lead PDIP, 32-lead TQFP, and 32-pad QFN/MLF
- Operating Voltages
  - 2.7 - 5.5V (ATmega8L)
  - 4.5 - 5.5V (ATmega8)
- Speed Grades
  - 0 - 8 MHz (ATmega8L)
  - 0 - 16 MHz (ATmega8)
- Power Consumption at 4 Mhz, 3V, 25°C
  - Active: 3.6 mA
  - Idle Mode: 1.0 mA
  - Power-down Mode: 0.5 µA

# 8-bit AVR® with 8K Bytes In-System Programmable Flash

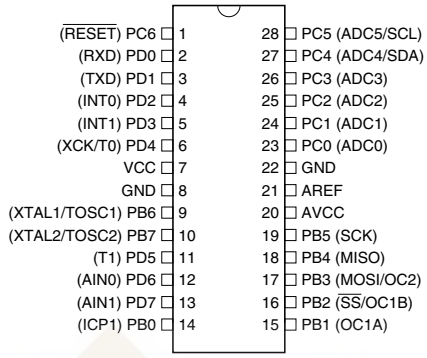
# ATmega8
# ATmega8L

## Summary

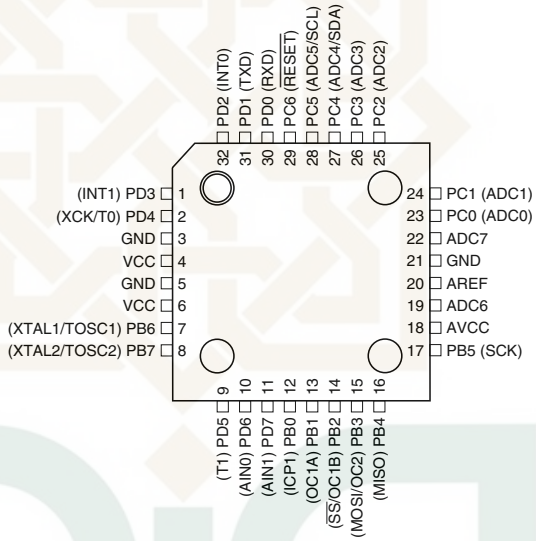
Rev. 2486XS–AVR–06/10

# Pin Configurations

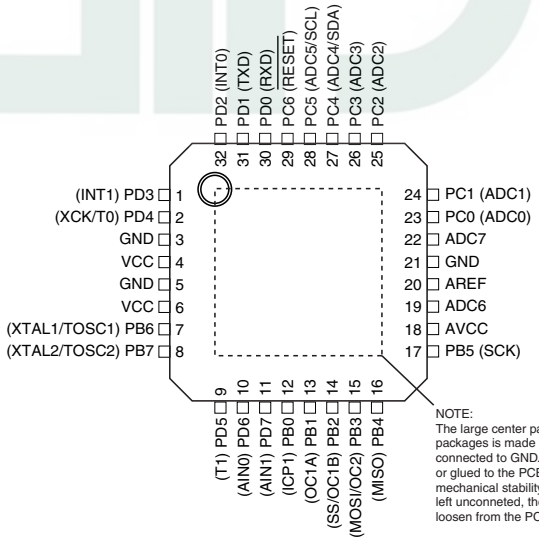
PDIP




TQFP Top View




MLF Top View



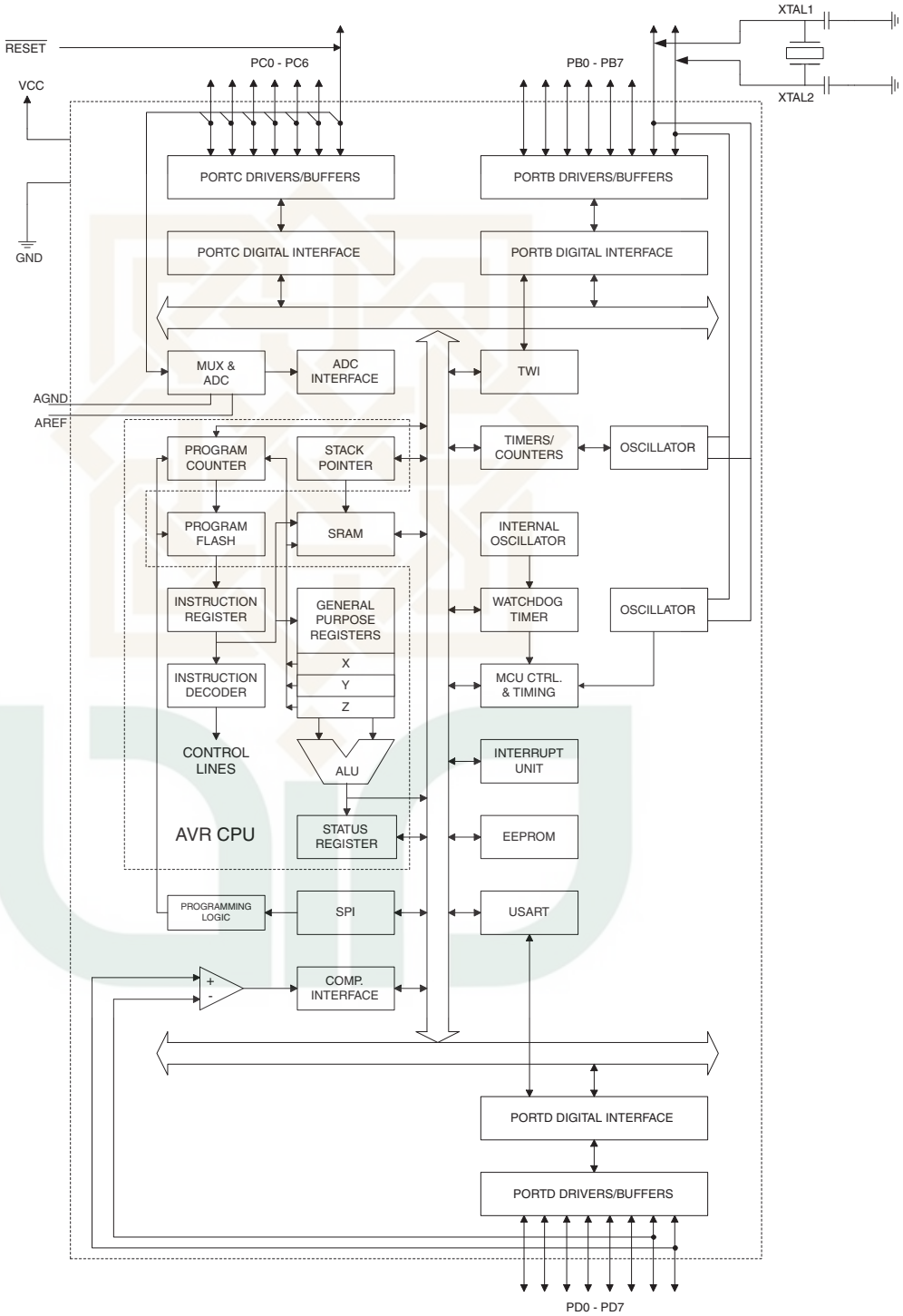

NOTE:
The large center pad underneath the MLF packages is made of metal and internally connected to GND. It should be soldered or glued to the PCB to ensure good mechanical stability. If the center pad is left unconneted, the package might loosen from the PCB.

## Overview

The ATmega8 is a low-power CMOS 8-bit microcontroller based on the AVR RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega8 achieves throughputs approaching 1 MIPS per MHz, allowing the system designer to optimize power consumption versus processing speed.

## Block Diagram

**Figure 1.** Block Diagram



The AVR core combines a rich instruction set with 32 general purpose working registers. All the 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 ATmega8 provides the following features: 8K bytes of In-System Programmable Flash with Read-While-Write capabilities, 512 bytes of EEPROM, 1K byte of SRAM, 23 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, a 6-channel ADC (eight channels in TQFP and QFN/MLF packages) with 10-bit accuracy, a programmable Watchdog Timer with Internal Oscillator, an SPI serial port, and five 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.

The device is manufactured using Atmel's high density non-volatile memory technology. The Flash Program memory can be reprogrammed In-System through an SPI serial interface, by a conventional non-volatile 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 ATmega8 is a powerful microcontroller that provides a highly-flexible and cost-effective solution to many embedded control applications.

The ATmega8 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.

## Disclaimer

Typical values contained in this datasheet 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.

## Pin Descriptions

**VCC** Digital supply voltage.

**GND** Ground.

**Port B (PB7..PB0) XTAL1/XTAL2/TOSC1/ TOSC2** 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.

Depending on the clock selection fuse settings, PB6 can be used as input to the inverting Oscillator amplifier and input to the internal clock operating circuit.

Depending on the clock selection fuse settings, PB7 can be used as output from the inverting Oscillator amplifier.

If the Internal Calibrated RC Oscillator is used as chip clock source, PB7..6 is used as TOSC2..1 input for the Asynchronous Timer/Counter2 if the AS2 bit in ASSR is set.

The various special features of Port B are elaborated in “Alternate Functions of Port B” on page 58 and “System Clock and Clock Options” on page 25.

**Port C (PC5..PC0)** Port C is an 7-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.

**PC6/$\overline{\text{RESET}}$** If the RSTDISBL Fuse is programmed, PC6 is used as an I/O pin. Note that the electrical characteristics of PC6 differ from those of the other pins of Port C.

If the RSTDISBL Fuse is unprogrammed, PC6 is used as a 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 38. Shorter pulses are not guaranteed to generate a Reset.

The various special features of Port C are elaborated on page 61.

**Port D (PD7..PD0)** 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.

Port D also serves the functions of various special features of the ATmega8 as listed on page 63.

**$\overline{\text{RESET}}$** 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 38. Shorter pulses are not guaranteed to generate a reset.

**$AV_{CC}$**

$AV_{CC}$ is the supply voltage pin for the A/D Converter, Port C (3..0), and ADC (7..6). 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. Note that Port C (5..4) use digital supply voltage, $V_{CC}$.

**AREF**

AREF is the analog reference pin for the A/D Converter.

**ADC7..6 (TQFP and QFN/MLF Package Only)**

In the TQFP and QFN/MLF package, ADC7..6 serve as analog inputs to the A/D converter. These pins are powered from the analog supply and serve as 10-bit ADC channels.

## Resources

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

## Data Retention

Reliability Qualification results show that the projected data retention failure rate is much less than 1 PPM over 20 years at 85°C or 100 years at 25°C.

# 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 | T | H | S | V | N | Z | C | 11 |
| 0x3E (0x5E) | SPH | – | – | – | – | – | SP10 | SP9 | SP8 | 13 |
| 0x3D (0x5D) | SPL | SP7 | SP6 | SP5 | SP4 | SP3 | SP2 | SP1 | SP0 | 13 |
| 0x3C (0x5C) | Reserved | | | | | | | | | |
| 0x3B (0x5B) | GICR | INT1 | INT0 | – | – | – | – | IVSEL | IVCE | 49, 67 |
| 0x3A (0x5A) | GIFR | INTF1 | INTF0 | – | – | – | – | – | – | 68 |
| 0x39 (0x59) | TIMSK | OCIE2 | TOIE2 | TICIE1 | OCIE1A | OCIE1B | TOIE1 | – | TOIE0 | 72, 102, 122 |
| 0x38 (0x58) | TIFR | OCF2 | TOV2 | ICF1 | OCF1A | OCF1B | TOV1 | – | TOV0 | 73, 102, 122 |
| 0x37 (0x57) | SPMCR | SPMIE | RWWSB | – | RWWSRE | BLBSET | PGWRT | PGERS | SPMEN | 213 |
| 0x36 (0x56) | TWCR | TWINT | TWEA | TWSTA | TWSTO | TWWC | TWEN | – | TWIE | 171 |
| 0x35 (0x55) | MCUCR | SE | SM2 | SM1 | SM0 | ISC11 | ISC10 | ISC01 | ISC00 | 33, 66 |
| 0x34 (0x54) | MCUCSR | – | – | – | – | WDRF | BORF | EXTRF | PORF | 41 |
| 0x33 (0x53) | TCCR0 | – | – | – | – | – | CS02 | CS01 | CS00 | 72 |
| 0x32 (0x52) | TCNT0 | Timer/Counter0 (8 Bits) | | | | | | | | 72 |
| 0x31 (0x51) | OSCCAL | Oscillator Calibration Register | | | | | | | | 31 |
| 0x30 (0x50) | SFIOR | – | – | – | – | ACME | PUD | PSR2 | PSR10 | 58, 75, 123, 193 |
| 0x2F (0x4F) | TCCR1A | COM1A1 | COM1A0 | COM1B1 | COM1B0 | FOC1A | FOC1B | WGM11 | WGM10 | 96 |
| 0x2E (0x4E) | TCCR1B | ICNC1 | ICES1 | – | WGM13 | WGM12 | CS12 | CS11 | CS10 | 100 |
| 0x2D (0x4D) | TCNT1H | Timer/Counter1 – Counter Register High byte | | | | | | | | 101 |
| 0x2C (0x4C) | TCNT1L | Timer/Counter1 – Counter Register Low byte | | | | | | | | 101 |
| 0x2B (0x4B) | OCR1AH | Timer/Counter1 – Output Compare Register A High byte | | | | | | | | 101 |
| 0x2A (0x4A) | OCR1AL | Timer/Counter1 – Output Compare Register A Low byte | | | | | | | | 101 |
| 0x29 (0x49) | OCR1BH | Timer/Counter1 – Output Compare Register B High byte | | | | | | | | 101 |
| 0x28 (0x48) | OCR1BL | Timer/Counter1 – Output Compare Register B Low byte | | | | | | | | 101 |
| 0x27 (0x47) | ICR1H | Timer/Counter1 – Input Capture Register High byte | | | | | | | | 102 |
| 0x26 (0x46) | ICR1L | Timer/Counter1 – Input Capture Register Low byte | | | | | | | | 102 |
| 0x25 (0x45) | TCCR2 | FOC2 | WGM20 | COM21 | COM20 | WGM21 | CS22 | CS21 | CS20 | 117 |
| 0x24 (0x44) | TCNT2 | Timer/Counter2 (8 Bits) | | | | | | | | 119 |
| 0x23 (0x43) | OCR2 | Timer/Counter2 Output Compare Register | | | | | | | | 119 |
| 0x22 (0x42) | ASSR | – | – | – | – | AS2 | TCN2UB | OCR2UB | TCR2UB | 119 |
| 0x21 (0x41) | WDTCR | – | – | – | WDCE | WDE | WDP2 | WDP1 | WDP0 | 43 |
| 0x20[1] (0x40)[1] | UBRRH | URSEL | – | – | – | UBRR[11:8] | | | | 158 |
| | UCSRC | URSEL | UMSEL | UPM1 | UPM0 | USBS | UCSZ1 | UCSZ0 | UCPOL | 156 |
| 0x1F (0x3F) | EEARH | – | – | – | – | – | – | – | EEAR8 | 20 |
| 0x1E (0x3E) | EEARL | EEAR7 | EEAR6 | EEAR5 | EEAR4 | EEAR3 | EEAR2 | EEAR1 | EEAR0 | 20 |
| 0x1D (0x3D) | EEDR | EEPROM Data Register | | | | | | | | 20 |
| 0x1C (0x3C) | EECR | – | – | – | – | EERIE | EEMWE | EEWE | EERE | 20 |
| 0x1B (0x3B) | Reserved | | | | | | | | | |
| 0x1A (0x3A) | Reserved | | | | | | | | | |
| 0x19 (0x39) | Reserved | | | | | | | | | |
| 0x18 (0x38) | PORTB | PORTB7 | PORTB6 | PORTB5 | PORTB4 | PORTB3 | PORTB2 | PORTB1 | PORTB0 | 65 |
| 0x17 (0x37) | DDRB | DDB7 | DDB6 | DDB5 | DDB4 | DDB3 | DDB2 | DDB1 | DDB0 | 65 |
| 0x16 (0x36) | PINB | PINB7 | PINB6 | PINB5 | PINB4 | PINB3 | PINB2 | PINB1 | PINB0 | 65 |
| 0x15 (0x35) | PORTC | – | PORTC6 | PORTC5 | PORTC4 | PORTC3 | PORTC2 | PORTC1 | PORTC0 | 65 |
| 0x14 (0x34) | DDRC | – | DDC6 | DDC5 | DDC4 | DDC3 | DDC2 | DDC1 | DDC0 | 65 |
| 0x13 (0x33) | PINC | – | PINC6 | PINC5 | PINC4 | PINC3 | PINC2 | PINC1 | PINC0 | 65 |
| 0x12 (0x32) | PORTD | PORTD7 | PORTD6 | PORTD5 | PORTD4 | PORTD3 | PORTD2 | PORTD1 | PORTD0 | 65 |
| 0x11 (0x31) | DDRD | DDD7 | DDD6 | DDD5 | DDD4 | DDD3 | DDD2 | DDD1 | DDD0 | 65 |
| 0x10 (0x30) | PIND | PIND7 | PIND6 | PIND5 | PIND4 | PIND3 | PIND2 | PIND1 | PIND0 | 65 |
| 0x0F (0x2F) | SPDR | SPI Data Register | | | | | | | | 131 |
| 0x0E (0x2E) | SPSR | SPIF | WCOL | – | – | – | – | – | SPI2X | 131 |
| 0x0D (0x2D) | SPCR | SPIE | SPE | DORD | MSTR | CPOL | CPHA | SPR1 | SPR0 | 129 |
| 0x0C (0x2C) | UDR | USART I/O Data Register | | | | | | | | 153 |
| 0x0B (0x2B) | UCSRA | RXC | TXC | UDRE | FE | DOR | PE | U2X | MPCM | 154 |
| 0x0A (0x2A) | UCSRB | RXCIE | TXCIE | UDRIE | RXEN | TXEN | UCSZ2 | RXB8 | TXB8 | 155 |
| 0x09 (0x29) | UBRRL | USART Baud Rate Register Low byte | | | | | | | | 158 |
| 0x08 (0x28) | ACSR | ACD | ACBG | ACO | ACI | ACIE | ACIC | ACIS1 | ACIS0 | 194 |
| 0x07 (0x27) | ADMUX | REFS1 | REFS0 | ADLAR | – | MUX3 | MUX2 | MUX1 | MUX0 | 205 |
| 0x06 (0x26) | ADCSRA | ADEN | ADSC | ADFR | ADIF | ADIE | ADPS2 | ADPS1 | ADPS0 | 207 |
| 0x05 (0x25) | ADCH | ADC Data Register High byte | | | | | | | | 208 |
| 0x04 (0x24) | ADCL | ADC Data Register Low byte | | | | | | | | 208 |
| 0x03 (0x23) | TWDR | Two-wire Serial Interface Data Register | | | | | | | | 173 |
| 0x02 (0x22) | TWAR | TWA6 | TWA5 | TWA4 | TWA3 | TWA2 | TWA1 | TWA0 | TWGCE | 174 |

## Register Summary (Continued)

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Page |
|---|---|---|---|---|---|---|---|---|---|---|
| 0x01 (0x21) | TWSR | TWS7 | TWS6 | TWS5 | TWS4 | TWS3 | – | TWPS1 | TWPS0 | 173 |
| 0x00 (0x20) | TWBR | Two-wire Serial Interface Bit Rate Register | | | | | | | | 171 |

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

| Mnemonics | Operands | Description | Operation | Flags | #Clocks |
|---|---|---|---|---|---|
| **ARITHMETIC AND LOGIC INSTRUCTIONS** | | | | | |
| ADD | Rd, Rr | Add two Registers | Rd ← Rd + Rr | Z,C,N,V,H | 1 |
| ADC | Rd, Rr | Add with Carry two Registers | Rd ← Rd + Rr + C | Z,C,N,V,H | 1 |
| ADIW | Rdl,K | Add Immediate to Word | Rdh:Rdl ← Rdh:Rdl + K | Z,C,N,V,S | 2 |
| SUB | Rd, Rr | Subtract two Registers | Rd ← Rd - Rr | Z,C,N,V,H | 1 |
| SUBI | Rd, K | Subtract Constant from Register | Rd ← Rd - K | Z,C,N,V,H | 1 |
| SBC | Rd, Rr | Subtract with Carry two Registers | Rd ← Rd - Rr - C | Z,C,N,V,H | 1 |
| SBCI | Rd, K | Subtract with Carry Constant from Reg. | Rd ← Rd - K - C | Z,C,N,V,H | 1 |
| SBIW | Rdl,K | Subtract Immediate from Word | Rdh:Rdl ← Rdh:Rdl - K | Z,C,N,V,S | 2 |
| AND | Rd, Rr | Logical AND Registers | Rd ← Rd • Rr | Z,N,V | 1 |
| ANDI | Rd, K | Logical AND Register and Constant | Rd ← Rd • K | Z,N,V | 1 |
| OR | Rd, Rr | Logical OR Registers | Rd ← Rd v Rr | Z,N,V | 1 |
| ORI | Rd, K | Logical OR Register and Constant | Rd ← Rd v K | Z,N,V | 1 |
| EOR | Rd, Rr | Exclusive OR Registers | Rd ← Rd ⊕ Rr | Z,N,V | 1 |
| COM | Rd | One's Complement | Rd ← 0xFF – Rd | Z,C,N,V | 1 |
| NEG | Rd | Two's Complement | Rd ← 0x00 – Rd | Z,C,N,V,H | 1 |
| SBR | Rd,K | Set Bit(s) in Register | Rd ← Rd v K | Z,N,V | 1 |
| CBR | Rd,K | Clear Bit(s) in Register | Rd ← Rd • (0xFF - K) | Z,N,V | 1 |
| INC | Rd | Increment | Rd ← Rd + 1 | Z,N,V | 1 |
| DEC | Rd | Decrement | Rd ← Rd – 1 | Z,N,V | 1 |
| TST | Rd | Test for Zero or Minus | Rd ← Rd • Rd | Z,N,V | 1 |
| CLR | Rd | Clear Register | Rd ← Rd ⊕ Rd | Z,N,V | 1 |
| SER | Rd | Set Register | Rd ← 0xFF | None | 1 |
| MUL | Rd, Rr | Multiply Unsigned | R1:R0 ← Rd x Rr | Z,C | 2 |
| MULS | Rd, Rr | Multiply Signed | R1:R0 ← Rd x Rr | Z,C | 2 |
| MULSU | Rd, Rr | Multiply Signed with Unsigned | R1:R0 ← Rd x Rr | Z,C | 2 |
| FMUL | Rd, Rr | Fractional Multiply Unsigned | R1:R0 ← (Rd x Rr) << 1 | Z,C | 2 |
| FMULS | Rd, Rr | Fractional Multiply Signed | R1:R0 ← (Rd x Rr) << 1 | Z,C | 2 |
| FMULSU | Rd, Rr | Fractional Multiply Signed with Unsigned | R1:R0 ← (Rd x Rr) << 1 | Z,C | 2 |
| **BRANCH INSTRUCTIONS** | | | | | |
| RJMP | k | Relative Jump | PC ← PC + k + 1 | None | 2 |
| IJMP | | Indirect Jump to (Z) | PC ← Z | None | 2 |
| RCALL | k | Relative Subroutine Call | PC ← PC + k + 1 | None | 3 |
| ICALL | | Indirect Call to (Z) | PC ← Z | None | 3 |
| RET | | Subroutine Return | PC ← STACK | None | 4 |
| RETI | | Interrupt Return | PC ← STACK | I | 4 |
| CPSE | Rd,Rr | Compare, Skip if Equal | if (Rd = Rr) PC ← PC + 2 or 3 | None | 1 / 2 / 3 |
| CP | Rd,Rr | Compare | Rd – Rr | Z, N,V,C,H | 1 |
| CPC | Rd,Rr | Compare with Carry | Rd – Rr – C | Z, N,V,C,H | 1 |
| CPI | Rd,K | Compare Register with Immediate | Rd – K | Z, N,V,C,H | 1 |
| SBRC | Rr, b | Skip if Bit in Register Cleared | if (Rr(b)=0) PC ← PC + 2 or 3 | None | 1 / 2 / 3 |
| SBRS | Rr, b | Skip if Bit in Register is Set | if (Rr(b)=1) PC ← PC + 2 or 3 | None | 1 / 2 / 3 |
| SBIC | P, b | Skip if Bit in I/O Register Cleared | if (P(b)=0) PC ← PC + 2 or 3 | None | 1 / 2 / 3 |
| SBIS | P, b | Skip if Bit in I/O Register is Set | if (P(b)=1) PC ← PC + 2 or 3 | None | 1 / 2 / 3 |
| BRBS | s, k | Branch if Status Flag Set | if (SREG(s) = 1) then PC←PC+k + 1 | None | 1 / 2 |
| BRBC | s, k | Branch if Status Flag Cleared | if (SREG(s) = 0) then PC←PC+k + 1 | None | 1 / 2 |
| BREQ | k | Branch if Equal | if (Z = 1) then PC ← PC + k + 1 | None | 1 / 2 |
| BRNE | k | Branch if Not Equal | if (Z = 0) then PC ← PC + k + 1 | None | 1 / 2 |
| BRCS | k | Branch if Carry Set | if (C = 1) then PC ← PC + k + 1 | None | 1 / 2 |
| BRCC | k | Branch if Carry Cleared | if (C = 0) then PC ← PC + k + 1 | None | 1 / 2 |
| BRSH | k | Branch if Same or Higher | if (C = 0) then PC ← PC + k + 1 | None | 1 / 2 |
| BRLO | k | Branch if Lower | if (C = 1) then PC ← PC + k + 1 | None | 1 / 2 |
| BRMI | k | Branch if Minus | if (N = 1) then PC ← PC + k + 1 | None | 1 / 2 |
| BRPL | k | Branch if Plus | if (N = 0) then PC ← PC + k + 1 | None | 1 / 2 |
| BRGE | k | Branch if Greater or Equal, Signed | if (N ⊕ V= 0) then PC ← PC + k + 1 | None | 1 / 2 |
| BRLT | k | Branch if Less Than Zero, Signed | if (N ⊕ V= 1) then PC ← PC + k + 1 | None | 1 / 2 |
| BRHS | k | Branch if Half Carry Flag Set | if (H = 1) then PC ← PC + k + 1 | None | 1 / 2 |
| BRHC | k | Branch if Half Carry Flag Cleared | if (H = 0) then PC ← PC + k + 1 | None | 1 / 2 |
| BRTS | k | Branch if T Flag Set | if (T = 1) then PC ← PC + k + 1 | None | 1 / 2 |
| BRTC | k | Branch if T Flag Cleared | if (T = 0) then PC ← PC + k + 1 | None | 1 / 2 |
| BRVS | k | Branch if Overflow Flag is Set | if (V = 1) then PC ← PC + k + 1 | None | 1 / 2 |
| BRVC | k | Branch if Overflow Flag is Cleared | if (V = 0) then PC ← PC + k + 1 | None | 1 / 2 |
| **Mnemonics** | **Operands** | **Description** | **Operation** | **Flags** | **#Clocks** |

## Instruction Set Summary (Continued)

| | | | | | |
|---|---|---|---|---|---|
| BRIE | k | Branch if Interrupt Enabled | if ( I = 1) then PC ← PC + k + 1 | None | 1 / 2 |
| BRID | k | Branch if Interrupt Disabled | if ( I = 0) then PC ← PC + k + 1 | None | 1 / 2 |
| **DATA TRANSFER INSTRUCTIONS** | | | | | |
| MOV | Rd, Rr | Move Between Registers | Rd ← Rr | None | 1 |
| MOVW | Rd, Rr | Copy Register Word | Rd+1:Rd ← Rr+1:Rr | None | 1 |
| LDI | Rd, K | Load Immediate | Rd ← K | None | 1 |
| LD | Rd, X | Load Indirect | Rd ← (X) | None | 2 |
| LD | Rd, X+ | Load Indirect and Post-Inc. | Rd ← (X), X ← X + 1 | None | 2 |
| LD | Rd, - X | Load Indirect and Pre-Dec. | X ← X - 1, Rd ← (X) | None | 2 |
| LD | Rd, Y | Load Indirect | Rd ← (Y) | None | 2 |
| LD | Rd, Y+ | Load Indirect and Post-Inc. | Rd ← (Y), Y ← Y + 1 | None | 2 |
| LD | Rd, - Y | Load Indirect and Pre-Dec. | Y ← Y - 1, Rd ← (Y) | None | 2 |
| LDD | Rd,Y+q | Load Indirect with Displacement | Rd ← (Y + q) | None | 2 |
| LD | Rd, Z | Load Indirect | Rd ← (Z) | None | 2 |
| LD | Rd, Z+ | Load Indirect and Post-Inc. | Rd ← (Z), Z ← Z+1 | None | 2 |
| LD | Rd, -Z | Load Indirect and Pre-Dec. | Z ← Z - 1, Rd ← (Z) | None | 2 |
| LDD | Rd, Z+q | Load Indirect with Displacement | Rd ← (Z + q) | None | 2 |
| LDS | Rd, k | Load Direct from SRAM | Rd ← (k) | None | 2 |
| ST | X, Rr | Store Indirect | (X) ← Rr | None | 2 |
| ST | X+, Rr | Store Indirect and Post-Inc. | (X) ← Rr, X ← X + 1 | None | 2 |
| ST | - X, Rr | Store Indirect and Pre-Dec. | X ← X - 1, (X) ← Rr | None | 2 |
| ST | Y, Rr | Store Indirect | (Y) ← Rr | None | 2 |
| ST | Y+, Rr | Store Indirect and Post-Inc. | (Y) ← Rr, Y ← Y + 1 | None | 2 |
| ST | - Y, Rr | Store Indirect and Pre-Dec. | Y ← Y - 1, (Y) ← Rr | None | 2 |
| STD | Y+q,Rr | Store Indirect with Displacement | (Y + q) ← Rr | None | 2 |
| ST | Z, Rr | Store Indirect | (Z) ← Rr | None | 2 |
| ST | Z+, Rr | Store Indirect and Post-Inc. | (Z) ← Rr, Z ← Z + 1 | None | 2 |
| ST | -Z, Rr | Store Indirect and Pre-Dec. | Z ← Z - 1, (Z) ← Rr | None | 2 |
| STD | Z+q,Rr | Store Indirect with Displacement | (Z + q) ← Rr | None | 2 |
| STS | k, Rr | Store Direct to SRAM | (k) ← Rr | None | 2 |
| LPM | | Load Program Memory | R0 ← (Z) | None | 3 |
| LPM | Rd, Z | Load Program Memory | Rd ← (Z) | None | 3 |
| LPM | Rd, Z+ | Load Program Memory and Post-Inc | Rd ← (Z), Z ← Z+1 | None | 3 |
| SPM | | Store Program Memory | (Z) ← R1:R0 | None | - |
| IN | Rd, P | In Port | Rd ← P | None | 1 |
| OUT | P, Rr | Out Port | P ← Rr | None | 1 |
| PUSH | Rr | Push Register on Stack | STACK ← Rr | None | 2 |
| POP | Rd | Pop Register from Stack | Rd ← STACK | None | 2 |
| BIT AND BIT-TEST INSTRUCTIONS | | | | | |
| SBI | P,b | Set Bit in I/O Register | I/O(P,b) ← 1 | None | 2 |
| CBI | P,b | Clear Bit in I/O Register | I/O(P,b) ← 0 | None | 2 |
| LSL | Rd | Logical Shift Left | Rd(n+1) ← Rd(n), Rd(0) ← 0 | Z,C,N,V | 1 |
| LSR | Rd | Logical Shift Right | Rd(n) ← Rd(n+1), Rd(7) ← 0 | Z,C,N,V | 1 |
| ROL | Rd | Rotate Left Through Carry | Rd(0)←C,Rd(n+1)← Rd(n),C←Rd(7) | Z,C,N,V | 1 |
| ROR | Rd | Rotate Right Through Carry | Rd(7)←C,Rd(n)← Rd(n+1),C←Rd(0) | Z,C,N,V | 1 |
| ASR | Rd | Arithmetic Shift Right | Rd(n) ← Rd(n+1), n=0..6 | Z,C,N,V | 1 |
| SWAP | Rd | Swap Nibbles | Rd(3..0)←Rd(7..4),Rd(7..4)←Rd(3..0) | None | 1 |
| BSET | s | Flag Set | SREG(s) ← 1 | SREG(s) | 1 |
| BCLR | s | Flag Clear | SREG(s) ← 0 | SREG(s) | 1 |
| BST | Rr, b | Bit Store from Register to T | T ← Rr(b) | T | 1 |
| BLD | Rd, b | Bit load from T to Register | Rd(b) ← T | None | 1 |
| SEC | | Set Carry | C ← 1 | C | 1 |
| CLC | | Clear Carry | C ← 0 | C | 1 |
| SEN | | Set Negative Flag | N ← 1 | N | 1 |
| CLN | | Clear Negative Flag | N ← 0 | N | 1 |
| SEZ | | Set Zero Flag | Z ← 1 | Z | 1 |
| CLZ | | Clear Zero Flag | Z ← 0 | Z | 1 |
| SEI | | Global Interrupt Enable | I ← 1 | I | 1 |
| CLI | | Global Interrupt Disable | I ← 0 | I | 1 |
| SES | | Set Signed Test Flag | S ← 1 | S | 1 |
| CLS | | Clear Signed Test Flag | S ← 0 | S | 1 |
| SEV | | Set Twos Complement Overflow. | V ← 1 | V | 1 |
| CLV | | Clear Twos Complement Overflow | V ← 0 | V | 1 |
| SET | | Set T in SREG | T ← 1 | T | 1 |
| **Mnemonics** | **Operands** | **Description** | **Operation** | **Flags** | **#Clocks** |

## Instruction Set Summary (Continued)

| | | | | | |
|---|---|---|---|---|---|
| CLT | | Clear T in SREG | T ← 0 | T | 1 |
| SEH | | Set Half Carry Flag in SREG | H ← 1 | H | 1 |
| CLH | | Clear Half Carry Flag in SREG | H ← 0 | H | 1 |
| MCU CONTROL INSTRUCTIONS | | | | | |
| NOP | | No Operation | | None | 1 |
| SLEEP | | Sleep | (see specific descr. for Sleep function) | None | 1 |
| WDR | | Watchdog Reset | (see specific descr. for WDR/timer) | None | 1 |

## Ordering Information

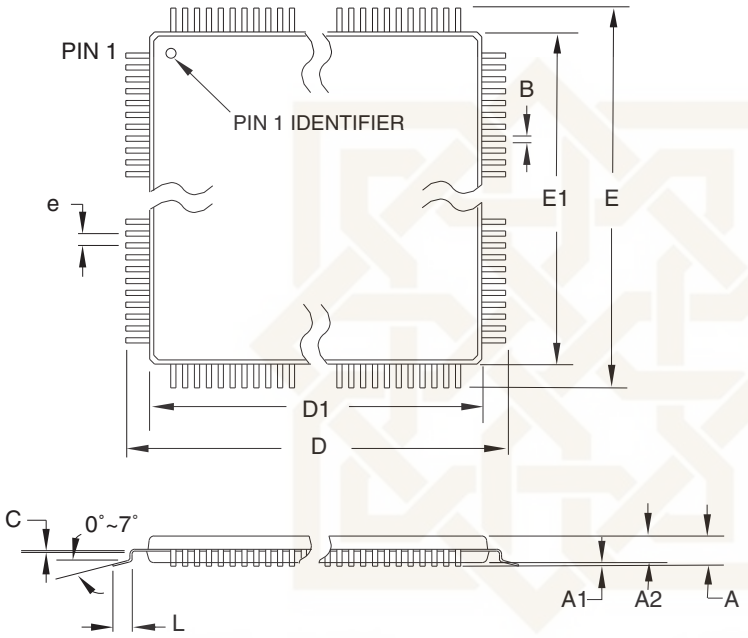
| Speed (MHz) | Power Supply | Ordering Code[2] | Package[1] | Operation Range |
|---|---|---|---|---|
| 8 | 2.7 - 5.5 | ATmega8L-8AU<br>ATmega8L-8PU<br>ATmega8L-8MU | 32A<br>28P3<br>32M1-A | Industrial<br>(-40°C to 85°C) |
| 16 | 4.5 - 5.5 | ATmega8-16AU<br>ATmega8-16PU<br>ATmega8-16MU | 32A<br>28P3<br>32M1-A | |

Notes: 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 complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green.

| Package Type | |
|---|---|
| **32A** | 32-lead, Thin (1.0 mm) Plastic Quad Flat Package (TQFP) |
| **28P3** | 28-lead, 0.300” Wide, Plastic Dual Inline Package (PDIP) |
| **32M1-A** | 32-pad, 5 x 5 x 1.0 body, Lead Pitch 0.50 mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF) |

# Packaging Information

## 32A




**COMMON DIMENSIONS**
(Unit of Measure = mm)

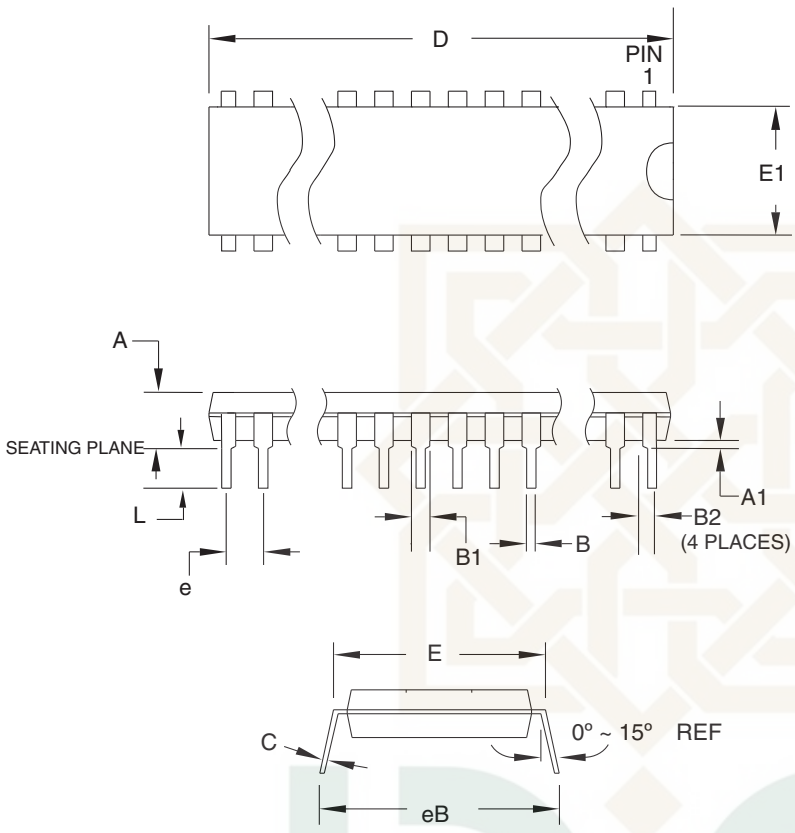
| SYMBOL | MIN | NOM | MAX | NOTE |
|---|---|---|---|---|
| A | – | – | 1.20 | |
| A1 | 0.05 | – | 0.15 | |
| A2 | 0.95 | 1.00 | 1.05 | |
| D | 8.75 | 9.00 | 9.25 | |
| D1 | 6.90 | 7.00 | 7.10 | Note 2 |
| E | 8.75 | 9.00 | 9.25 | |
| E1 | 6.90 | 7.00 | 7.10 | Note 2 |
| B | 0.30 | – | 0.45 | |
| C | 0.09 | – | 0.20 | |
| L | 0.45 | – | 0.75 | |
| e | 0.80 TYP | | | |

Notes:
1. This package conforms to JEDEC reference MS-026, Variation ABA.
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

| | TITLE | DRAWING NO. | REV. |
|---|---|---|---|
| 2325 Orchard Parkway<br>San Jose, CA 95131 | **32A,** 32-lead, 7 x 7 mm Body Size, 1.0 mm Body Thickness, 0.8 mm Lead Pitch, Thin Profile Plastic Quad Flat Package (TQFP) | 32A | B |

## 28P3




**COMMON DIMENSIONS**
(Unit of Measure = mm)

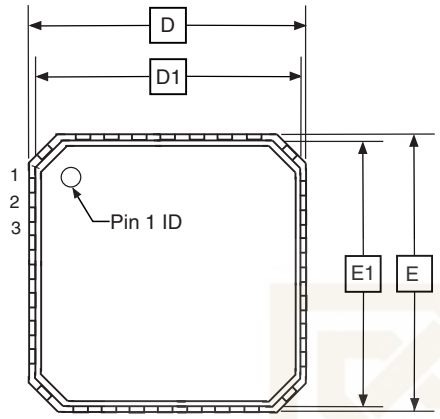
| SYMBOL | MIN | NOM | MAX | NOTE |
|---|---|---|---|---|
| A | – | – | 4.5724 | |
| A1 | 0.508 | – | – | |
| D | 34.544 | – | 34.798 | Note 1 |
| E | 7.620 | – | 8.255 | |
| E1 | 7.112 | – | 7.493 | Note 1 |
| B | 0.381 | – | 0.533 | |
| B1 | 1.143 | – | 1.397 | |
| B2 | 0.762 | – | 1.143 | |
| L | 3.175 | – | 3.429 | |
| C | 0.203 | – | 0.356 | |
| eB | – | – | 10.160 | |
| e | 2.540 TYP | | | |

Note: 1. Dimensions D and E1 do not include mold Flash or Protrusion. Mold Flash or Protrusion shall not exceed 0.25 mm (0.010").

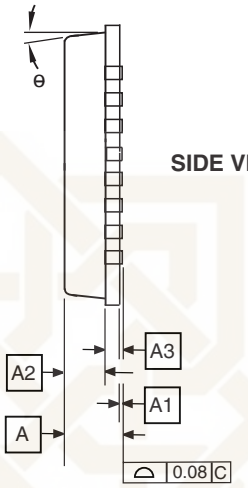
09/28/01

| | TITLE | DRAWING NO. | REV. |
|---|---|---|---|
| 2325 Orchard Parkway<br>San Jose, CA 95131 | **28P3**, 28-lead (0.300"/7.62 mm Wide) Plastic Dual Inline Package (PDIP) | 28P3 | B |

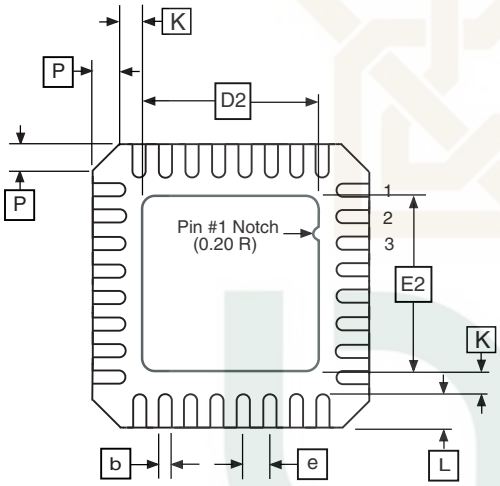
## 32M1-A




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 | |
| A2 | – | 0.65 | 1.00 | |
| A3 | | 0.20 REF | | |
| b | 0.18 | 0.23 | 0.30 | |
| D | 4.90 | 5.00 | 5.10 | |
| D1 | 4.70 | 4.75 | 4.80 | |
| D2 | 2.95 | 3.10 | 3.25 | |
| E | 4.90 | 5.00 | 5.10 | |
| E1 | 4.70 | 4.75 | 4.80 | |
| E2 | 2.95 | 3.10 | 3.25 | |
| e | | 0.50 BSC | | |
| L | 0.30 | 0.40 | 0.50 | |
| P | – | – | 0.60 | |
| θ | – | – | 12° | |
| K | 0.20 | – | – | |

Note: JEDEC Standard MO-220, Fig. 2 (Anvil Singulation), VHHD-2.

5/25/06

| | TITLE | DRAWING NO. | REV. |
|---|---|---|---|
| 2325 Orchard Parkway<br>San Jose, CA 95131 | **32M1-A**, 32-pad, 5 x 5 x 1.0 mm Body, Lead Pitch 0.50 mm,<br>3.10 mm Exposed Pad, Micro Lead Frame Package (MLF) | 32M1-A | E |

## Errata

The revision letter in this section refers to the revision of the ATmega8 device.

### ATmega8 Rev. D to I, M

- **First Analog Comparator conversion may be delayed**
- **Interrupts may be lost when writing the timer registers in the asynchronous timer**
- **Signature may be Erased in Serial Programming Mode**
- **CKOPT Does not Enable Internal Capacitors on XTALn/TOSCn Pins when 32 KHz Oscillator is Used to Clock the Asynchronous Timer/Counter2**
- **Reading EEPROM by using ST or STS to set EERE bit triggers unexpected interrupt request**

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 theAnalog Comparator before the first conversion.

2. **Interrupts may be lost when writing the timer registers in the asynchronous timer**

   The interrupt will be lost if a timer register that is synchronized to the asynchronous timer clock is written when the asynchronous Timer/Counter register(TCNTx) is 0x00.

   **Problem Fix / Workaround**

   Always check that the asynchronous Timer/Counter register neither have the value 0xFF nor 0x00 before writing to the asynchronous Timer Control Register(TCCRx), asynchronous Timer Counter Register(TCNTx), or asynchronous Output Compare Register(OCRx).

3. **Signature may be Erased in Serial Programming Mode**

   If the signature bytes are read before a chiperase command is completed, the signature may be erased causing the device ID and calibration bytes to disappear. This is critical, especially, if the part is running on internal RC oscillator.

   **Problem Fix / Workaround:**

   Ensure that the chiperase command has exceeded before applying the next command.

4. **CKOPT Does not Enable Internal Capacitors on XTALn/TOSCn Pins when 32 KHz Oscillator is Used to Clock the Asynchronous Timer/Counter2**

   When the internal RC Oscillator is used as the main clock source, it is possible to run the Timer/Counter2 asynchronously by connecting a 32 KHz Oscillator between XTAL1/TOSC1 and XTAL2/TOSC2. But when the internal RC Oscillator is selected as the main clock source, the CKOPT Fuse does not control the internal capacitors on XTAL1/TOSC1 and XTAL2/TOSC2. As long as there are no capacitors connected to XTAL1/TOSC1 and XTAL2/TOSC2, safe operation of the Oscillator is not guaranteed.

   **Problem Fix / Workaround**

   Use external capacitors in the range of 20 - 36 pF on XTAL1/TOSC1 and XTAL2/TOSC2. This will be fixed in ATmega8 Rev. G where the CKOPT Fuse will control internal capacitors also when internal RC Oscillator is selected as main clock source. For ATmega8 Rev. G, CKOPT = 0 (programmed) will enable the internal capacitors on XTAL1 and XTAL2. Customers who want compatibility between Rev. G and older revisions, must ensure that CKOPT is unprogrammed (CKOPT = 1).

5. **Reading EEPROM by using ST or STS to set EERE bit triggers unexpected interrupt request.**

   Reading EEPROM by using the ST or STS command to set the EERE bit in the EECR register triggers an unexpected EEPROM interrupt request.

   **Problem Fix / Workaround**

   Always use OUT or SBI to set EERE in EECR.

## Datasheet Revision History

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

### Changes from Rev. 2486W- 02/10 to Rev. 2486X- 06/10

1. Updated "DC Characteristics" on page 242 with new $V_{OL}$ maximum value (0.9V and 0.6V).

### Changes from Rev. 2486V- 05/09 to Rev. 2486W- 02/10

1. Updated "ADC Characteristics" on page 248 with $V_{INT}$ maximum value (2.9V).

### Changes from Rev. 2486U- 08/08 to Rev. 2486V- 05/09

1. Added "Not recommended for new designs" on page 1.
2. Updated "Errata" on page 17.
3. Updated the last page with Atmel's new adresses.

### Changes from Rev. 2486T- 05/08 to Rev. 2486U- 08/08

1. Updated "DC Characteristics" on page 242 with $I_{CC}$ typical values.

### Changes from Rev. 2486S- 08/07 to Rev. 2486T- 05/08

1. Updated Table 98 on page 240.
2. Updated "Ordering Information" on page 292.
   - Commercial Ordering Code removed.
   - No Pb-free packaging option removed.

### Changes from Rev. 2486R- 07/07 to Rev. 2486S- 08/07

1. Updated "Features" on page 1.
2. Added "Data Retention" on page 7.
3. Updated "Errata" on page 17.
4. Updated "Slave Mode" on page 129.

### Changes from Rev. 2486Q- 10/06 to Rev. 2486R- 07/07

1. Added text to Table 81 on page 218.
2. Fixed typo in "Peripheral Features" on page 1.
3. Updated Table 16 on page 42.
4. Updated Table 75 on page 206.
5. Removed redundancy and updated typo in Notes section of "DC Characteristics" on page 242.

**Changes from Rev. 2486P- 02/06 to Rev. 2486Q- 10/06**

1. Updated "Timer/Counter Oscillator" on page 32.
2. Updated "Fast PWM Mode" on page 89.
3. Updated code example in "USART Initialization" on page 138.
4. Updated Table 37 on page 97, Table 39 on page 98, Table 42 on page 117, Table 44 on page 118, and Table 98 on page 240.
5. Updated "Errata" on page 17.

**Changes from Rev. 2486O-10/04 to Rev. 2486P- 02/06**

1. Added "Resources" on page 7.
2. Updated "External Clock" on page 32.
3. Updated "Serial Peripheral Interface – SPI" on page 124.
4. Updated Code Example in "USART Initialization" on page 138.
5. Updated Note in "Bit Rate Generator Unit" on page 170.
6. Updated Table 98 on page 240.
7. Updated Note in Table 103 on page 248.
8. Updated "Errata" on page 17.

**Changes from Rev. 2486N-09/04 to Rev. 2486O-10/04**

1. Removed to instances of "analog ground". Replaced by "ground".
2. Updated Table 7 on page 29, Table 15 on page 38, and Table 100 on page 244.
3. Updated "Calibrated Internal RC Oscillator" on page 30 with the 1 MHz default value.
4. Table 89 on page 225 and Table 90 on page 225 moved to new section "Page Size" on page 225.
5. Updated descripton for bit 4 in "Store Program Memory Control Register – SPMCR" on page 213.
6. Updated "Ordering Information" on page 13.

**Changes from Rev. 2486M-12/03 to Rev. 2486N-09/04**

1. Added note to MLF package in "Pin Configurations" on page 2.
2. Updated "Internal Voltage Reference Characteristics" on page 42.
3. Updated "DC Characteristics" on page 242.
4. ADC4 and ADC5 support 10-bit accuracy. Document updated to reflect this.
   Updated features in "Analog-to-Digital Converter" on page 196.
   Updated "ADC Characteristics" on page 248.
5. Removed reference to "External RC Oscillator application note" from "External RC Oscillator" on page 28.

**Changes from Rev. 2486L-10/03 to Rev. 2486M-12/03**

1. Updated "Calibrated Internal RC Oscillator" on page 30.

**Changes from Rev. 2486K-08/03 to Rev. 2486L-10/03**

1. Removed "Preliminary" and TBDs from the datasheet.
2. Renamed ICP to ICP1 in the datasheet.
3. Removed instructions CALL and JMP from the datasheet.
4. Updated $t_{RST}$ in Table 15 on page 38, $V_{BG}$ in Table 16 on page 42, Table 100 on page 244 and Table 102 on page 246.
5. Replaced text "XTAL1 and XTAL2 should be left unconnected (NC)" after Table 9 in "Calibrated Internal RC Oscillator" on page 30. Added text regarding XTAL1/XTAL2 and CKOPT Fuse in "Timer/Counter Oscillator" on page 32.
6. Updated Watchdog Timer code examples in "Timed Sequences for Changing the Configuration of the Watchdog Timer" on page 45.
7. Removed bit 4, ADHSM, from "Special Function IO Register – SFIOR" on page 58.
8. Added note 2 to Figure 103 on page 215.
9. Updated item 4 in the "Serial Programming Algorithm" on page 238.
10. Added $t_{WD\_FUSE}$ to Table 97 on page 239 and updated Read Calibration Byte, Byte 3, in Table 98 on page 240.
11. Updated Absolute Maximum Ratings* and DC Characteristics in "Electrical Characteristics" on page 242.

**Changes from Rev. 2486J-02/03 to Rev. 2486K-08/03**

1. Updated $V_{BOT}$ values in Table 15 on page 38.
2. Updated "ADC Characteristics" on page 248.
3. Updated "ATmega8 Typical Characteristics" on page 249.
4. Updated "Errata" on page 17.

**Changes from Rev. 2486I-12/02 to Rev. 2486J-02/03**

1. Improved the description of "Asynchronous Timer Clock – clkASY" on page 26.
2. Removed reference to the "Multipurpose Oscillator" application note and the "32 kHz Crystal Oscillator" application note, which do not exist.
3. Corrected OCn waveforms in Figure 38 on page 90.
4. Various minor Timer 1 corrections.
5. Various minor TWI corrections.

6. Added note under “Filling the Temporary Buffer (Page Loading)” on page 216 about writing to the EEPROM during an SPM Page load.

7. Removed ADHSM completely.

8. Added section “EEPROM Write during Power-down Sleep Mode” on page 23.

9. Removed XTAL1 and XTAL2 description on page 5 because they were already described as part of “Port B (PB7..PB0) XTAL1/XTAL2/TOSC1/TOSC2” on page 5.

10. Improved the table under “SPI Timing Characteristics” on page 246 and removed the table under “SPI Serial Programming Characteristics” on page 241.

11. Corrected PC6 in “Alternate Functions of Port C” on page 61.

12. Corrected PB6 and PB7 in “Alternate Functions of Port B” on page 58.

13. Corrected 230.4 Mbps to 230.4 kbps under “Examples of Baud Rate Setting” on page 159.

14. Added information about PWM symmetry for Timer 2 in “Phase Correct PWM Mode” on page 113.

15. Added thick lines around accessible registers in Figure 76 on page 169.

16. Changed “will be ignored” to “must be written to zero” for unused Z-pointer bits under “Performing a Page Write” on page 216.

17. Added note for RSTDISBL Fuse in Table 87 on page 223.

18. Updated drawings in “Packaging Information” on page 14.

**Changes from Rev. 2486H-09/02 to Rev. 2486I-12/02**

1. Added errata for Rev D, E, and F on page 17.

**Changes from Rev. 2486G-09/02 to Rev. 2486H-09/02**

1. Changed the Endurance on the Flash to 10,000 Write/Erase Cycles.

**Changes from Rev. 2486F-07/02 to Rev. 2486G-09/02**

1. Updated Table 103, “ADC Characteristics,” on page 248.

**Changes from Rev. 2486E-06/02 to Rev. 2486F-07/02**

1. Changes in “Digital Input Enable and Sleep Modes” on page 55.

2. Addition of OCS2 in “MOSI/OC2 – Port B, Bit 3” on page 59.

3. The following tables have been updated:
   Table 51, “CPOL and CPHA Functionality,” on page 132, Table 59, “UCPOL Bit Settings,” on page 158, Table 72, “Analog Comparator Multiplexed Input(1),” on page 195, Table 73,

"ADC Conversion Time," on page 200, Table 75, "Input Channel Selections," on page 206, and Table 84, "Explanation of Different Variables used in Figure 103 and the Mapping to the Z-pointer," on page 221.

4. **Changes in "Reading the Calibration Byte" on page 234.**

5. **Corrected Errors in Cross References.**

**Changes from Rev. 2486D-03/02 to Rev. 2486E-06/02**

1. **Updated Some Preliminary Test Limits and Characterization Data**

   The following tables have been updated:

   Table 15, "Reset Characteristics," on page 38, Table 16, "Internal Voltage Reference Characteristics," on page 42, DC Characteristics on page 242, Table , "ADC Characteristics," on page 248.

2. **Changes in External Clock Frequency**

   Added the description at the end of "External Clock" on page 32.

   Added period changing data in Table 99, "External Clock Drive," on page 244.

3. **Updated TWI Chapter**

   More details regarding use of the TWI bit rate prescaler and a Table 65, "TWI Bit Rate Prescaler," on page 173.

**Changes from Rev. 2486C-03/02 to Rev. 2486D-03/02**

1. **Updated Typical Start-up Times.**

   The following tables has been updated:

   Table 5, "Start-up Times for the Crystal Oscillator Clock Selection," on page 28, Table 6, "Start-up Times for the Low-frequency Crystal Oscillator Clock Selection," on page 28, Table 8, "Start-up Times for the External RC Oscillator Clock Selection," on page 29, and Table 12, "Start-up Times for the External Clock Selection," on page 32.

2. **Added "ATmega8 Typical Characteristics" on page 249.**

**Changes from Rev. 2486B-12/01 to Rev. 2486C-03/02**

1. **Updated TWI Chapter.**

   More details regarding use of the TWI Power-down operation and using the TWI as Master with low TWBRR values are added into the datasheet.

   Added the note at the end of the "Bit Rate Generator Unit" on page 170.

   Added the description at the end of "Address Match Unit" on page 170.

2. **Updated Description of OSCCAL Calibration Byte.**

   In the datasheet, it was not explained how to take advantage of the calibration bytes for 2, 4, and 8 MHz Oscillator selections. This is now added in the following sections:

   Improved description of "Oscillator Calibration Register – OSCCAL" on page 31 and "Calibration Byte" on page 225.

3. **Added Some Preliminary Test Limits and Characterization Data.**

   Removed some of the TBD's in the following tables and pages:

   Table 3 on page 26, Table 15 on page 38, Table 16 on page 42, Table 17 on page 44, "TA = -40×C to 85×C, VCC = 2.7V to 5.5V (unless otherwise noted)" on page 242, Table 99 on page 244, and Table 102 on page 246.

4. **Updated Programming Figures.**
   Figure 104 on page 226 and Figure 112 on page 237 are updated to also reflect that $AV_{CC}$ must be connected during Programming mode.

5. **Added a Description on how to Enter Parallel Programming Mode if RESET Pin is Disabled or if External Oscillators are Selected.**
   Added a note in section “Enter Programming Mode” on page 228.

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