LAMPIRAN A

PROGRAM CODE VISION AVR
This program was produced by the

CodeWizardAVR V2.05.0 Evaluation

Automatic Program Generator

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Project : Realisasi Alat Ukur pH dan Tds Air Berbasis Mikrokontroler ATmega 16

Version :

Date    : 3/12/2013

Author  : Freeware, for evaluation and non-commercial use only

Company : Jurusan Teknik Elektro Universitas Kristen Maranatha

Comments:

Chip type : ATmega16

Program type : Application

AVR Core Clock frequency: 16.000000 MHz

Memory model : Small

External RAM size : 0

Data Stack size : 256

*******************************************************************************/
// Header Program

#include <mega16.h>

#include <delay.h>

#include <stdlib.h>

// Alphanumeric LCD Module functions

#include <alcd.h>

#define ADC_VREF_TYPE 0x40

// Inisialisasi Variabel-variabel yang digunakan

char PH[8];

char TDS[8];

char suhu[8];

float ppm,kadar_ph,celcius, Total1,Total2,Total3,Rata1,Rata2,Rata3,suhu_tds;

unsigned int Baca0,Baca6,Baca7;

int i;

// 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

void main(void)
{

// Declare your local variables here

// Input/Output Ports initialization

// Port A initialization

// Func7=In Func6=In Func5=In Func4=In Func3=In Func2=In Func1=In Func0=In
// State7=T State6=T State5=T State4=T State3=T State2=T State1=T State0=T
PORTA=0x00;
DDRA=0x00;

// Port B initialization

// Func7=In Func6=In Func5=In Func4=In Func3=In Func2=In Func1=In Func0=In
// State7=T State6=T State5=T State4=T State3=T State2=T State1=T State0=T
PORTB=0x00;
DDRB=0x00;

// Port C initialization

// Func7=In Func6=In Func5=In Func4=In Func3=In Func2=In Func1=In Func0=In
// State7=T State6=T State5=T State4=T State3=T State2=T State1=T State0=T

PORTC=0x00;
DDRC=0x00;

// Port D initialization

PORTD=0x00;
DDRD=0x00;

// Timer/Counter 0 initialization

// Clock source: System Clock

// Clock value: Timer 0 Stopped

// Mode: Normal top=0xFF

// OC0 output: Disconnected

TCCR0=0x00;
TCNT0=0x00;
OCR0=0x00;

// Timer/Counter 1 initialization

// Clock source: System Clock

// Clock value: Timer1 Stopped

// Mode: Normal top=0xFFFF

// OC1A output: Discon.

// OC1B output: Discon.
// Noise Canceler: Off

// Input Capture on Falling Edge

// Timer1 Overflow Interrupt: Off

// Input Capture Interrupt: Off

// Compare A Match Interrupt: Off

// Compare B Match Interrupt: Off

TCCR1A=0x00;
TCCR1B=0x00;
TCNT1H=0x00;
TCNT1L=0x00;
ICR1H=0x00;
ICR1L=0x00;
OCR1AH=0x00;
OCR1AL=0x00;
OCR1BH=0x00;
OCR1BL=0x00;

// Timer/Counter 2 initialization

// Clock source: System Clock

// Clock value: Timer2 Stopped

// Mode: Normal top=0xFF

// OC2 output: Disconnected

ASSR=0x00;
TCCR2=0x00;
TCNT2=0x00;
OCR2=0x00;

// External Interrupt(s) initialization

// INT0: Off

// INT1: Off

// INT2: Off

MCUCR=0x00;
MCUCSR=0x00;

// Timer(s)/Counter(s) Interrupt(s) initialization

TIMSK=0x00;

// USART initialization

// USART disabled

UCSRB=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: 125.000 kHz

// ADC Voltage Reference: AVCC pin
// ADC Auto Trigger Source: ADC Stopped

ADMUX=ADC_VREF_TYPE & 0xff;

ADCSRA=0x87;

// SPI initialization

// SPI disabled

SPCR=0x00;

// TWI initialization

// TWI disabled

TWCR=0x00;

// Alphanumeric LCD initialization

// Connections specified in the

// Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu:

// RS - PORTC Bit 0

// RD - PORTC Bit 1

// EN - PORTC Bit 2

// D4 - PORTC Bit 4

// D5 - PORTC Bit 5

// D6 - PORTC Bit 6

// D7 - PORTC Bit 7

// Characters/line: 16

lcd_init(16);

c lcd_clear();
lcd_gotoxy(0,0);
lcd_putsf("++PH dan TDS++");
lcd_gotoxy(0,1);
lcd_putsf("BY SANDI");
delay_ms(1000);

// Inisialisasi Awal untuk program rata-rata
i=0;
Total1=0;
Total2=0;
Total3=0;

while (1)
{
    i++;
    Baca0=read_adc(0); // Baca Adc (0)
    ppm=((float)Baca0*500/1024); // Rumus untuk Menghitung Nilai Tds
    Total1=Total1+ppm; // Menjumlahkan nilai ppm dan dimasukan ke variabel Total1
    Baca7=read_adc(7); // Baca Adc(7)
    kadar_ph=(-3.811*(float)Baca7*5/1024)+13.63; // Rumus Untuk Menghitung Nilai pH
    Total2=Total2+kadar_ph; // Menjumlahkan kadar_pH dan dimasukan ke variabel
    Total2
    Baca6=read_adc(6); // Baca Adc(6)
    celcius=((float)Baca6*500/1024); // Rumus Untuk Menghitung Nilai Suhu

    //Respons dari program
    lcd_gotoxy(0,3);
    lcd_putsf("Total1: 
    Total2: 
    Total3: 

    //Melakukan perhitungan
    //Fungsi display
    //Menampilkan hasil perhitungan
    //Terminasi program
}
Total3=Total3+celcius; //Menjumlahkan celcius dan dimasukan ke variabel Total3
delay_ms(200);
if(i==20)
{
Rata1=Total1/20; //rata-rata nilai Tds
Rata2=Total2/20; //rata-rata nilai pH
Rata3=Total3/20; //rata-rata nilai suhu
suhu_tds=((Rata1*((1+(0.0214*(Rata3-25)))))); //Rumus Menghitung koreksi suhu terhadap tds
delay_ms(100);
lcd_clear();
lcd_gotoxy(0,0);
lcd_puts("TDS= "); //menampilkan tulisan TDS pada baris 0 kolom 0
lcd_gotoxy(7,0);
lcd_puts("ppm/"); //menampilkan tulisan ppm/ pada baris 7 kolom 0
lcd_gotoxy(0,1);
lcd_puts("PH="); //menampilkan tulisan PH pada baris 0 kolom 1
lcd_gotoxy(13,0);
lcd_putchar(0xdf); //menampilkan karakter derajat
lcd_puts("C"); //menampilkan tulisan C
ftoa(suhu_tds,0,TDS); //mengubah tipe data float ke data array
ftoa(Rata2,2,PH);//mengubah tipe data float ke data array dengan nilai ph 2 angka dibelakang koma

ftoa(Rata3,0,suhu);//mengubah tipe data float ke data array

lcd_gotoxy(4,0);
lcd_puts(TDS); //menampilkan nilai TDS pada baris 4 kolom 0

lcd_gotoxy(3,1);
lcd_puts(PH); //menampilkan nilai pH pada baris 3 kolom 1

lcd_gotoxy(11,0);
lcd_puts(suhu);//menampilkan nilai suhu pada pada baris 11 kolom 0

//Kembali ke inisialisasi awal untuk program rata-rata

i=0;

Total1=0;

Total2=0 ;

Total3=0;

delay_ms(1000);

} ;

}


// Place your code here

}
LAMPIRAN B

TAMPILAN REALISASI ALAT UKUR PH DAN TDS AIR BERBASIS MIKROKONTROLER ATMEGA16
SENSOR TDS

MINIMUM SISTEM

SENSOR TEMPERATURE

ALAT UKUR DIST3 HANNA INSTRUMENT

SENSOR PH VERNIER-BTA

PENGUKURAN PH AIR SAMPEL C
PENGUKURAN PH AIR CUKA

PENGUKURAN PH AIR SABUN

PENGUKURAN HCL
PENGUKURAN PH DAN TDS AIR SAMPEL C

PENGUKURAN PH DAN TDS SAMPEL D
PENGUKURAN PH DAN TDS AIR SAMPEL A

PENGUKURAN PH DAN TDS AIR SAMPEL B
LAMPIRAN C

LAPORAN HASIL PENGUKURAN TDS DI PT SUCOFINDO
# LAPORAN HASIL ANALISA

**PENGERI ORDER** : SAMUI Patroli - Bandung  
**JENIS SAMPLE** : APL  
**TANGGAL TERIMA SAMPLE** : 11 April 2013  
**TANGGAL ANALISA** : 11 – 12 April 2013  
**ANALISA / UJI** : Total Dissolved Solid  
**KETERANGAN SAMPLE** : Sempoi dikirim oleh pelanggan dengan keterangan abd  
- Kemasan / Botol plastik  
- Volume : 4 X 600 mL  

**IDENTITAS SAMPLE** : "A, B, C & D"  

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sanksi</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>Metod*1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Dissolved Solid</td>
<td>mg/l</td>
<td>64</td>
<td>108</td>
<td>158</td>
<td>154</td>
<td>2540 C</td>
</tr>
</tbody>
</table>

*1: "**Sanksi" in the table, means penalties for certain values. The 2540 mg/l value exceeds the allowable limit."

Permenpan Sertifikat analisis ini diakui oleh Bapak Kepala Badan Analisa, yang ditanda tangan oleh Bapak...  
Bidang Konsultasi dan Jasa Lain

Yanti Dandini
LAMPIRAN D

DATASHEET SENSOR LM35, SENSOR PH VERNIER

BTA, AND MICROCONTROLLER ATMEGA 16
**LM35/LM35A/LM35C/LM35CA/LM35D**

**Precision Centigrade Temperature Sensors**

**General Description**

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1/3°C at room temperature and ±3/4°C over a full −55 to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuits especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 µA from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35 is rated to operate over a −55°C to +150°C temperature range, while the LM35C is rated for a −40°C to +110°C range (−10°C with improved accuracy). The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-202 package.

**Features**

- Calibrated directly in °Celsius (Centigrade)
- Linear + 10.0 mV/°C scale factor
- 0.5°C accuracy guaranteed (at +25°C)
- Rated for full −55°C to +150°C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60 µA current drain
- Low self-heating, 0.08°C in still air
- Nonlinearity only ±1/4°C typical
- Low impedance output, 0.1 Ω for 1 mA load

**Connection Diagrams**

- **TO-46** MetalCan Package*
- **TO-92** Plastic Package
- **SO-8** Small Outline Molded Package

*Case is connected to negative pin (GND)

Order Number LM35H, LM35AH, LM35CH, LM35CAH or LM35CAH
See NS Package Number H03H

Order Number LM35C, LM35CA or LM35DZ
See NS Package Number Z03A

Order Number LM35D
See NS Package Number M08A

**Typical Applications**

**FIGURE 1. Basic Centigrade Temperature Sensor (±2°C to +150°C)**

Choose $R_f = -V_s/50 \mu A$

$V_{OUT} = 1,500 \text{ mV at } +150^\circ C$

$= +250 \text{ mV at } +25^\circ C$

$= -550 \text{ mV at } -55^\circ C$

**FIGURE 2. Full-Range Centigrade Temperature Sensor**
### Absolute Maximum Ratings (Note 10)

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

- **Supply Voltage**: +35V to -0.2V
- **Output Voltage**: +5V to -1.0V
- **Output Current**: 10 mA
- **Storage Temp., TC-46 Package**: -60°C to +180°C
- **TC-92 Package**: -60°C to +150°C
- **SC-8 Package**: -65°C to +150°C
- **TC-202 Package**: -65°C to +150°C

- **Lead Temp.**
  - TO-46 Package (Soldering, 10 seconds): 300°C
  - TO-92 Package (Soldering, 10 seconds): 260°C
  - TO-202 Package (Soldering, 10 seconds): +230°C

- **SO Package (Note 12):**
  - Vapor Phase (60 seconds): 215°C
  - Infrared (15 seconds): 220°C
  - ESD Susceptibility (Note 11): 2500V

- **Specified Operating Temperature Range**: TMIN to TMAX

  (Note 2)
  - LM35, LM35A: -55°C to +150°C
  - LM35C, LM35CA: -40°C to +110°C
  - LM35D: 0°C to +100°C

### Electrical Characteristics (Note 1) (Note 6)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM35A</th>
<th>LM35CA</th>
<th>Units (Max.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Typical</td>
<td>Tested Limit (Note 4)</td>
<td>Design Limit (Note 5)</td>
</tr>
<tr>
<td>Accuracy (Note 7)</td>
<td>TA = +25°C</td>
<td>±0.2</td>
<td>±0.5</td>
<td>±0.2</td>
</tr>
<tr>
<td></td>
<td>TA = -10°C</td>
<td>±0.3</td>
<td>±0.5</td>
<td>±0.3</td>
</tr>
<tr>
<td></td>
<td>TA = TMAX</td>
<td>±0.4</td>
<td>±1.0</td>
<td>±0.4</td>
</tr>
<tr>
<td></td>
<td>TA = TMIN</td>
<td>±0.4</td>
<td>±1.0</td>
<td>±0.4</td>
</tr>
<tr>
<td>Nonlinearity (Note 8)</td>
<td>TMIN ≤ TA ≤ TMAX</td>
<td>±0.18</td>
<td>±0.35</td>
<td>±0.15</td>
</tr>
<tr>
<td>Sensor Gain (Average Slope)</td>
<td>TMIN ≤ TA ≤ TMAX</td>
<td>+10.0</td>
<td>+9.9, +10.1</td>
<td>+10.0</td>
</tr>
<tr>
<td>Load Regulation (Note 3) 0 ≤ IL ≤ 1 mA</td>
<td>TA = +25°C</td>
<td>±0.4</td>
<td>±1.0</td>
<td>±0.5</td>
</tr>
<tr>
<td></td>
<td>TMIN ≤ TA ≤ TMAX</td>
<td>±0.5</td>
<td>±3.0</td>
<td>±0.5</td>
</tr>
<tr>
<td>Line Regulation (Note 3) 4V ≤ VS ≤ 30V</td>
<td>TA = +25°C</td>
<td>±0.01</td>
<td>±0.06</td>
<td>±0.01</td>
</tr>
<tr>
<td></td>
<td>4V ≤ VS ≤ 30V</td>
<td>±0.02</td>
<td>±0.06</td>
<td>±0.02</td>
</tr>
<tr>
<td>Quiescent Current (Note 9)</td>
<td>VS = +5V, +25°C</td>
<td>56</td>
<td>67</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>VS = +5V</td>
<td>105</td>
<td>131</td>
<td>91</td>
</tr>
<tr>
<td></td>
<td>VS = +30V, +25°C</td>
<td>56.2</td>
<td>68</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>VS = +30V</td>
<td>105.5</td>
<td>133</td>
<td>91.5</td>
</tr>
<tr>
<td>Change of Quiescent Current (Note 3)</td>
<td>4V ≤ VS ≤ 30V</td>
<td>0.2</td>
<td>1.0</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>4V ≤ VS ≤ 30V</td>
<td>0.5</td>
<td>2.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Temperature Coefficient of Quiescent Current</td>
<td></td>
<td>+0.39</td>
<td>+0.5</td>
<td>+0.39</td>
</tr>
<tr>
<td>Minimum Temperature for Rated Accuracy</td>
<td>In circuit of Figure 1, IL = 0</td>
<td>+1.5</td>
<td>+2.0</td>
<td>+1.5</td>
</tr>
<tr>
<td>Long Term Stability</td>
<td>TJ = TMAX for 1000 hours</td>
<td>±0.08</td>
<td>±0.08</td>
<td>±0.08</td>
</tr>
</tbody>
</table>

**Note 1:** Unless otherwise noted, these specifications apply: -55°C ≤ Tj ≤ +150°C for the LM35 and LM35A; -40°C ≤ Tj ≤ +110°C for the LM35D and LM35CA; and 0°C ≤ Tj ≤ +100°C for the LM35E. VS = 5 Vdc and IL = 10 mA. In the circuit of Figure 2. These specifications also apply from +2°C to TMAX in the circuit of Figure 1. Specifications in **boldface** apply over the full rated temperature range.

**Note 2:** Thermal resistance of the TO-46 package is 400°C/W junction to ambient, and 24°C/W junction to case. Thermal resistance of the TO-92 package is 180°C/W junction to ambient. Thermal resistance of the small outline molded package is 220°C/W junction to ambient. Thermal resistance of the TO-202 package is 85°C/W junction to ambient. For additional thermal resistance information see table in the Applications section.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM35</th>
<th>LM35C, LM35D</th>
<th>Units (Max.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Typical</td>
<td>Tested Limit (Note 4)</td>
<td>Design Limit (Note 5)</td>
</tr>
<tr>
<td>Accuracy,</td>
<td>$T_A = +25^\circ C$</td>
<td>$\pm 0.4$</td>
<td>$\pm 1.0$</td>
<td>$\pm 0.4$</td>
</tr>
<tr>
<td>LM35, LM35C, (Note 7)</td>
<td>$T_A = -10^\circ C$</td>
<td>$\pm 0.5$</td>
<td>$\pm 0.9$</td>
<td>$\pm 0.5$</td>
</tr>
<tr>
<td></td>
<td>$T_A = T_{MAX}$</td>
<td>$\pm 0.3$</td>
<td>$\pm 1.5$</td>
<td>$\pm 0.8$</td>
</tr>
<tr>
<td></td>
<td>$T_A = T_{MIN}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accuracy,</td>
<td>$T_A = +25^\circ C$</td>
<td>$\pm 0.5$</td>
<td>$\pm 0.8$</td>
<td>$\pm 0.5$</td>
</tr>
<tr>
<td>LM35D</td>
<td>$T_A = T_{MAX}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$T_A = T_{MIN}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonlinearity (Note 8)</td>
<td>$T_{MN} \leq T_A \leq T_{MAX}$</td>
<td>$\pm 0.3$</td>
<td>$\pm 0.5$</td>
<td>$\pm 0.2$</td>
</tr>
<tr>
<td>Sensor Gain (Average Slope)</td>
<td>$T_{MN} \leq T_A \leq T_{MAX}$</td>
<td>$+10.0$</td>
<td>$+9.8$, $+10.2$</td>
<td>$+10.0$</td>
</tr>
<tr>
<td>Load Regulation (Note 3)</td>
<td>$0 \leq I_L \leq 1 \text{ mA}$</td>
<td>$\pm 0.4$</td>
<td>$\pm 2.0$</td>
<td>$\pm 0.4$</td>
</tr>
<tr>
<td>(Note 3)</td>
<td>$T_{A} = +25^\circ C$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Line Regulation (Note 3)</td>
<td>$4 \leq V_S \leq 30 \text{ V}$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.1$</td>
<td>$\pm 0.01$</td>
</tr>
<tr>
<td></td>
<td>$T_A = +25^\circ C$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quiescent Current (Note 9)</td>
<td>$V_S = +5 \text{ V}, +25^\circ C$</td>
<td>56</td>
<td>80</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>$V_S = +5 \text{ V}$</td>
<td>56.2</td>
<td>82</td>
<td>56.2</td>
</tr>
<tr>
<td></td>
<td>$V_S = +30 \text{ V}, +25^\circ C$</td>
<td>105.5</td>
<td>158</td>
<td>91</td>
</tr>
<tr>
<td></td>
<td>$V_S = +30 \text{ V}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change of Quiescent Current (Note 3)</td>
<td>$4 \leq V_S \leq 30 \text{ V}$</td>
<td>0.2</td>
<td>2.0</td>
<td>0.2</td>
</tr>
<tr>
<td>Temperature Coefficient of Quiescent Current</td>
<td>$T_A = +25^\circ C$</td>
<td>$+0.39$</td>
<td>$+0.7$</td>
<td>$+0.39$</td>
</tr>
<tr>
<td></td>
<td>$4 \leq V_S \leq 30 \text{ V}$</td>
<td>$+0.5$</td>
<td>2.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Minimum Temperature for Rated Accuracy</td>
<td>$T_J = T_{MAX}$ for 1000 hours</td>
<td>$+1.5$</td>
<td>$+2.0$</td>
<td>$+1.5$</td>
</tr>
<tr>
<td>Long Term Stability</td>
<td>$T_J = T_{MAX}$ for 1000 hours</td>
<td>$\pm 0.08$</td>
<td>$\pm 0.08$</td>
<td></td>
</tr>
</tbody>
</table>

Note 3: Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the internal dissipation by the thermal resistance.

Note 4: Tested Limits are guaranteed and 100% tested in production.

Note 5: Design Limits are guaranteed (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.

Note 6: Specifications in **boldface** apply over the full rated temperature range.

Note 7: Accuracy is defined as the error between the output voltage and 10mV/°C times the device’s case temperature, at specified conditions of voltage, current, and temperature (expressed in °C).

Note 8: Nonlinearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the device’s rated temperature range.

Note 9: Quiescent current is defined in the circuit of Figure 1.

Note 10: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions. See Note 1.

Note 11: Human body model, 100 pF discharged through a 1.5 kΩ resistor.

Note 12: See AN-450 “Surface Mounting Methods and Their Effect on Product Reliability” or the section titled “Surface Mount” found in a current National Semiconductor Linear Data Book for other methods of soldering surface mount devices.
Applications

The LM35 can be applied easily in the same way as other integrated-circuit temperature sensors. It can be glued or cemented to a surface and its temperature will be within about 0.01°C of the surface temperature.

This assumes that the ambient air temperature is almost the same as the surface temperature; if the air temperature were much higher or lower than the surface temperature, the actual temperature of the LM35 die would be at an intermediate temperature between the surface temperature and the air temperature. This is especially true for the TO-92 plastic package, where the copper leads are the principal thermal path to carry heat into the device, so its temperature might be closer to the air temperature than to the surface temperature.

To minimize this problem, be sure that the wiring to the LM35, as it leaves the device, is held at the same temperature as the surface of interest. The easiest way to do this is to cover up these wires with a bead of epoxy which will insulate that the leads and wires are all at the same temperature as the surface, and that the LM35 die’s temperature will not be affected by the air temperature.

Temperature Rise of LM35 Due To Self-heating (Thermal Resistance)

<table>
<thead>
<tr>
<th>Package</th>
<th>No Heat Sink</th>
<th>Small Heat Sink*</th>
<th>No Heat Sink</th>
<th>Small Heat Sink*</th>
</tr>
</thead>
<tbody>
<tr>
<td>TO-46</td>
<td>400°C/W</td>
<td>100°C/W</td>
<td>180°C/W</td>
<td>140°C/W</td>
</tr>
<tr>
<td>TO-44</td>
<td>60°C/W</td>
<td>40°C/W</td>
<td>90°C/W</td>
<td>70°C/W</td>
</tr>
<tr>
<td>SO-8</td>
<td>50°C/W</td>
<td>30°C/W</td>
<td>45°C/W</td>
<td>40°C/W</td>
</tr>
</tbody>
</table>

| Temperature Rise of LM35 Due To Self-heating (Thermal Resistance) (Continued) |

* Wavefield type 201, or 1” disc of 0.029” sheet brass, soldered to case, or similar.
** TO-92 and SO-8 packages glued and leads soldered to 1” square of %” printed circuit board with 2 oz. foil or similar.

Typical Applications (Continued)

![Figure 3. LM35 with Decoupling from Capacitive Load](tlh/5516-19)

**HEAVY CAPACITIVE LOAD, WIRING, ETC.**

LM35

2k

OUT

TO A HIGH-IMPEDANCE LOAD

**CAPACITIVE LOADS**

Like most micropower circuits, the LM35 has a limited ability to drive heavy capacitive loads. The LM35 by itself is able to drive 50 pF without special precautions. If heavier loads are anticipated, it is easy to isolate or decouple the load with a resistor; see Figure 3. Or you can improve the tolerance of capacitance with a series R-C damper from output to ground; see Figure 4.

When the LM35 is applied with a 200Ω load resistor as shown in Figure 5, 6, or 8, it is relatively immune to wiring capacitance because the capacitance forms a bypass from ground to input, not on the output. However, as with any linear circuit connected to wires in a hostile environment, its performance can be affected adversely by intense electromagnetic sources such as relays, radio transmitters, motors with arcing brushes, SCR transients, etc., as its wiring can act as a receiving antenna and its internal junctions can act as rectifiers. For best results in such cases, a bypass capacitor from Vᵢ to ground and a series R-C damper such as 751Ω in series with 0.2 or 1 pF from output to ground are often useful. These are shown in Figures 13, 14, and 16.

![Figure 4. LM35 with R-C Damper](tlh/5516-20)

**HEAVY CAPACITIVE LOAD, WIRING, ETC.**

LM35

0.1 µF BYPASS (OPTIMAL)

1 µF

OUT

Tuned Circuit
Typical Applications (Continued)

FIGURE 5. Two-Wire Remote Temperature Sensor (Grounded Sensor)

FIGURE 7. Temperature Sensor, Single Supply, −55° to +150°C

FIGURE 8. Two-Wire Remote Temperature Sensor (Output Referred to Ground)

FIGURE 9. 4-To-20 mA Current Source (0°C to +100°C)

FIGURE 10. Fahrenheit Thermometer
Typical Applications (Continued)

FIGURE 11. Centigrade Thermometer (Analog Meter)

FIGURE 12. Expanded Scale Thermometer
(50° to 80° Fahrenheit, for Example Shown)

FIGURE 13. Temperature To Digital Converter (Serial Output) (+128°C Full Scale)

FIGURE 14. Temperature To Digital Converter (Parallel TRI-STATE® Outputs for Standard Data Bus to μP Interface) (128°C Full Scale)
Typical Applications (Continued)

**FIGURE 15. Bar-Graph Temperature Display (Dot Mode)**

**FIGURE 16. LM35 With Voltage-To-Frequency Converter And Isolated Output**
(2°C to +150°C; 20 Hz to 1500 Hz)
pH Sensor
(Order Code PH-BTA)

Our pH Sensor can be used for any lab or demonstration that can be done with a traditional pH meter. This sensor offers the additional advantages of automated data collection, graphing, and data analysis. Typical activities using our pH sensor include studies of household acids and bases, acid-base titrations, monitoring pH change during chemical reactions or in an aquarium as a result of photosynthesis, investigations of acid rain and buffering, and investigations of water quality in streams and lakes.

Collecting Data with the pH Sensor
This sensor can be used with the following interfaces to collect data:
- Vernier LabQuest® as a standalone device or with a computer
- Vernier LabQuest® Mini with a computer
- Vernier LabPro® with a computer, TI graphing calculator, or Palm® handheld
- Vernier Go!® Link
- Vernier EasyLink®
- Vernier SensorDAQ®
- CBL 2™

Here is the general procedure to follow when using the pH Sensor:
1. Connect the pH Sensor to the interface.
2. Start the data-collection software.
3. The software will identify the pH Sensor and load a default data-collection setup. You are now ready to collect data.

Important: Do not fully submerge the sensor. The handle is not waterproof.

Data-Collection Software
This sensor can be used with an interface and the following data-collection software.
- Logger Pro 3 This computer program is used with LabQuest, LabQuest Mini, LabPro, or Go!Link.
- Logger Pro 2 This computer program is used with ULI or Serial Box Interface.
- Logger Lite This computer program is used with LabQuest, LabQuest Mini, LabPro, or Go!Link.
- LabQuest App This program is used when LabQuest is used as a standalone device.
- EasyData App This calculator application for the TI-83 Plus and TI-84 Plus can be used with CBL 2, LabPro, and Vernier EasyLink. We recommend version 2.0 or newer, which can be downloaded from the Vernier web site.

NOTE: This product is to be used for educational purposes only. It is not appropriate for industrial, medical, research, or commercial applications.

pH Electrode Specifications
Type: Sealed, gel-filled, epoxy body, Ag/AgCl
Response time: 90% of final reading in 1 second
Temperature range: 5 to 80°C
12 mm OD
Range: pH 0–14
13-bit Resolution (SensorDAQ): 0.0025 pH units
12-bit Resolution (LabQuest, LabQuest Mini, Go!Link, LabPro, ULI, SBI): 0.005 pH units
10-bit Resolution (CBL 2): 0.02 pH units
Isopotential pH: pH 7 (point at which temperature has no effect)
Output: 59.2 mV/pH at 25°C
Stored Calibration Values:
  - Intercept (k0): 13.720
  - Slope (k): -3.838

How the pH Sensor Works
The pH Amplifier inside the handle is a circuit which allows a standard combination pH electrode (such as the Vernier 7120B) to be monitored by a lab interface. The cable from the pH Amplifier ends in a BTA plug.

The pH Sensor will produce a voltage of 1.75 volts in a pH 7 buffer. The voltage will increase by about 0.25 volts for every pH number decrease. The voltage will decrease by about 0.25 volts/pH number as the pH increases.

The Vernier gel-filled pH Sensor is designed to make measurements in the pH range of 0 to 14. A polycarbonate body that extends below the glass sensing bulb of the

---

1 These are average calibration values. Actual values may vary because sensors are individually calibrated by Vernier before shipping.
electrode makes this probe ideal for the demands of a middle school, high school, or university level science class or for making measurements in the environment. The gel-filled reference half cell is sealed—it never needs to be refilled.

This sensor is equipped with circuitry that supports auto-ID. When used with LabQuest, LabQuest Mini, LabPro, Go! Link, SensorDAQ, EasyLink, or CBL 2, the data-collection software identifies the sensor and uses pre-defined parameters to configure an experiment appropriate to the recognized sensor.

Preparing for Use
To prepare the electrode to make pH measurements, follow this procedure:

- Remove the storage bottle from the electrode by first unscrewing the lid, then removing the bottle and lid. Thoroughly rinse the lower section of the probe, especially the region of the bulb, using distilled or deionized water.
- When the probe is not being stored in the storage bottle, it can be stored for short periods of time (up to 24 hours) in pH-4 or pH-7 buffer solution. It should never be stored in distilled water.
- Connect the pH Sensor to your lab interface, load or perform a calibration (as described in the next section), and you are ready to make pH measurements.

Note: Do not completely submerge the sensor. The handle is not waterproof.

When you are finished making measurements, rinse the tip of the electrode with distilled water. Slide the cap onto the electrode body, then screw the cap onto the storage bottle. Note: When the level of storage solution left in the bottle gets low, you can replenish it with small amounts of tap water the first few times you use the probe (but not indefinitely). A better solution is to prepare a quantity of pH-4 buffer/KCl storage solution (see the section on Maintenance and Storage) and use it to replace lost solution.

Do I Need to Calibrate the pH Sensor?
We feel that you should not have to perform a new calibration when using the pH Sensor for most experiments in the classroom. We have set the sensor to match our stored calibration before shipping it. You can simply use the appropriate calibration file that is stored in your data-collection program from Vernier in any of these ways:

1. If you ordered the PH-BTA version of the sensor, and you are using it with a LabQuest, LabQuest Mini, LabPro or CBL 2 interface, then a calibration (in pH) is automatically loaded when the pH Sensor is connected. Note: Each pH Sensor (PH-BTA version) is calibrated at Vernier. This custom calibration is then stored on the sensor. This means that when you first use it, you will see pH readings that are accurate to ±0.1 pH units, without calibration! With time, you may see some minor loss of the initial custom calibration accuracy, but for most purposes (see below), it should not be necessary to calibrate the pH Sensor.

2. If you are using Logger Pro software (version 2.0 or newer) on a Macintosh or Windows computer, open an experiment file for the pH Sensor, and its stored calibration will be loaded at the same time. Note: If you have an earlier version of Logger Pro, a free upgrade is available from our web site.

3. Any version of the DataMate or EasyData program (with LabPro or CBL 2) has stored calibrations for this sensor.

4. Any version of Data Pro has stored calibrations for this sensor.

If you are performing a chemistry experiment, or doing water quality testing that requires a very accurate calibration, you can calibrate the Vernier pH Electrode following this procedure:

- Use the 2-point calibration option of the Vernier data-collection program. Rinse the tip of the electrode in distilled water. Place the electrode into one of the buffer solutions (e.g., pH 4). When the voltage reading displayed on the computer or calculator screen stabilizes, enter a pH value, “4”.
- For the next calibration point, rinse the electrode and place it into a second buffer solution (e.g., pH 7). When the displayed voltage stabilizes, enter a pH value, “7”.
- Rinse the electrode with distilled water and place it in the sample.

pH Buffer Solutions
In order to do a calibration of the pH Sensor, or to confirm that a saved pH calibration is accurate, you need to have a supply of pH buffer solutions that cover the range of pH values you will be measuring. We recommend buffer solutions of pH 4, 7, and 10.

- Vernier sells a pH buffer kit (order code PHK). The kit has 12 tablets: four tablets each of buffer pH 4, 7, and 10. Each tablet is added to 100 mL of distilled or deionized water to prepare respective pH buffer solutions.
- Flinn Scientific (www.flinnsci.com, Tel. 800-452-1261) sells a wide variety of buffer tablets and prepared buffer solutions.

You can prepare your own buffer solutions using the following recipes:

<table>
<thead>
<tr>
<th>pH</th>
<th>Buffer Solution 1</th>
<th>Buffer Solution 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.00</td>
<td>Add 2.0 mL of 0.1 M HCl to 1000 mL of 0.1 M potassium hydrogen phthalate.</td>
<td></td>
</tr>
<tr>
<td>7.00</td>
<td>Add 582 mL of 0.1 M NaOH to 1000 mL of 0.1 M potassium dihydrogen phosphate.</td>
<td></td>
</tr>
<tr>
<td>10.00</td>
<td>Add 214 mL of 0.1 M NaOH to 1000 mL of 0.05 M sodium bicarbonate.</td>
<td></td>
</tr>
</tbody>
</table>

Maintenance and Storage
Short-term storage (up to 24 hours): Place the electrode in pH-4 or pH-7 buffer solution.

Long-term storage (more than 24 hours): Store the electrode in a buffer pH-4/KCl storage solution in the storage bottle. The pH Electrode is shipped in this solution. Vernier sells 500 mL bottles of replacement pH Storage Solution (order code PH-SS), or you can prepare additional storage solution by adding 10 g of solid potassium chloride (KCl) to 100 mL of buffer pH-4 solution. Flinn Scientific (800-452-1261) sells a Buffer Solution Preservative (order code B0175) that can be added to this storage solution. By storing the electrode in this solution, the reference portion of the electrode is kept moist. Keeping the reference junction moist adds to electrode longevity and retains electrode response time when the unit is placed back into
service. If the electrode is inadvertently stored dry (we don’t recommend this!), immerse the unit in soaking solution for a minimum of eight hours prior to service.

When testing a pH Sensor, it is best to place it into a known buffer solution. This allows you to see if the sensor is reading correctly (e.g., in a buffer pH 7, is the sensor reading close to pH 7). Do not place your sensor into distilled water to check for readings—distilled water can have a pH reading anywhere between 5.5 and 7.0, due to variable amounts of carbon dioxide dissolved from the atmosphere. Furthermore, due to a lack of ions, the pH values reported with the sensor in distilled water will be erratic.

If your pH Sensor is reading slightly off of the known buffer pH (e.g., reads 6.7 in a buffer 7), you may simply need to calibrate the sensor. You can calibrate the sensor in two buffer solutions for two calibration points. If you do not remember or know how to perform a calibration, refer to the booklet that came with the pH sensor.

If your readings are off by several pH values, the pH readings do not change when moved from one buffer solution to another different buffer, or the sensor’s response seems slow, the problem may be more serious. Sometimes a method called "shocking" is used to revive pH electrodes. To shock your pH Sensor, perform the following:

1. Let the pH Electrode soak for 4-8 hours in an HCl solution between 0.1 and 1.0 M.
2. Rinse off the electrode and let it sit in some buffer pH 7 for an hour or so.
3. Rinse the electrode and give it another try.

Mold growth in the buffer/KCl storage solution can be prevented by adding a commercial growth inhibitor. This mold will not harm the electrode and can easily be removed using a light detergent solution.

This sensor is designed to be used in aqueous solutions. The polycarbonate body of the sensor can be damaged by many organic solvents. In addition, do not use the sensor in solutions containing: perchlorates, silver ions, sulfide ions, biological samples with high concentrations of proteins, or Tris buffered solutions. Do not use it in hydrofluoric acid or in acid or base solutions with a concentration greater than 1.0 molar. The electrode may be used to measure the pH of sodium hydroxide solutions with a concentration near 1.0 molar, but should not be left in this concentration of sodium hydroxide for periods longer than 5 minutes. Using or storing the electrode at very high temperatures or very low temperatures (near 0°C) can damage it beyond repair.

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3 Vernier now offers Tris-Compatible Flat pH Sensor which features a double junction electrode, so it can be used with proteins, sulfides, and Tris buffers. Order code FPH-BTA.
Features

- High-performance, Low-power AVR® 8-bit Microcontroller
- Advanced RISC Architecture
  - 131 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
  - 16K 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
- JTAG (IEEE std. 1149.1 Compliant) Interface
  - Boundary-scan Capabilities According to the JTAG Standard
  - Extensive On-chip Debug Support
  - Programming of Flash, EEPROM, Fuses, and Lock Bits through the JTAG Interface
- 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 in TQFP Package Only
    - 2 Differential Channels with Programmable Gain at 1x, 10x, or 200x
  - 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, and 44-pad QFN/MLF
- Operating Voltages
  - 2.7 - 5.5V for ATmega16L
  - 4.5 - 5.5V for ATmega16
- Speed Grades
  - 0 - 8 MHz for ATmega16L
  - 0 - 18 MHz for ATmega16
- Power Consumption @ 1 MHz, 3V, and 25°C for ATmega16L
  - Active: 1.1 mA
  - Idle Mode: 0.35 mA
  - Power-down Mode: < 1 μA

Summary

ATmega16
ATmega16L

Note: Not recommended for new designs.
Pin Configurations

Figure 1. Pinout ATmega16

Disclaimers
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.

ATmega16(L)
Overview

The ATmega16 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega16 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

Block Diagram

Figure 2. Block Diagram

[Diagram of ATmega16 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 ATmega16 provides the following features: 16K bytes of In-System Programmable Flash Program memory with Read-While-Write capabilities, 512 bytes EEPROM, 1K byte SRAM, 32 general purpose I/O lines, 32 general purpose working registers, a JTAG interface for Boundary-scan, On-chip Debugging support and programming, 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 (TQFP package only), 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 USART, Two-wire interface, A/D Converter, 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 External 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 ATmega16 is a powerful microcontroller that provides a highly-flexible and cost-effective solution to many embedded control applications.

The ATmega16 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.

**Pin Descriptions**

**VCC**
Digital supply voltage.

**GND**
Ground.

**Port A (PA7..PA0)**
Port A serves as the analog inputs to the A/D Converter.

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.
Port B (PB7..PB0) 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. Port B also serves the functions of various special features of the ATmega16 as listed on page 58.

Port C (PC7..PC0) 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. If the JTAG interface is enabled, the pull-up resistors on pins PC5(TDI), PC3(TMS) and PC2(TCK) will be activated even if a reset occurs. Port C also serves the functions of the JTAG interface and other special features of the ATmega16 as listed 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 ATmega16 as listed on page 63.

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.

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 VCC, even if the ADC is not used. If the ADC is used, it should be connected to VCC through a low-pass filter.

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

<table>
<thead>
<tr>
<th>Address</th>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Page</th>
</tr>
</thead>
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<td>SBR3</td>
<td></td>
<td>T</td>
<td>H</td>
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<td>E</td>
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<td>SP6</td>
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<td>INT1</td>
<td>INT2</td>
<td></td>
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<td></td>
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Notes:

1. When the OCDEN Fuse is unprogrammed, the OSCCAL Register is always accessed on this address. Refer to the debugger specific documentation for details on how to use the OCNR Register.
2. Refer to the USART description for details on how to access UBRRH and UCSRC.
3. For compatibility with future devices, reserved bits should be written to zero if accessed. Reserved I/O memory addresses should never be written.
4. 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 $00 to $1F only.