LAMPIRAN A
GAMBAR RANGKAIAN PERANCANGAN ALAT PEMBERI MAKAN IKAN OTOMATIS DAN PEMANTAU KEADAAN AKUARIUM BERBASIS MIKROKONTROLER ATMega8535
LAMPIRAN B
LISTING KODE PROGRAM

/*******************************************************************************/
Project : fish automatic feeder and aquarium conditions monitor
Date    : 21/05/2013
Author  : Recky_su
Company : Elektro USU

Chip type               : ATmega8535
Program type            : Application
AVR Core Clock frequency: 8,000000 MHz
Memory model            : Small
External RAM size       : 0
Data Stack size         : 128
*******************************************************************************/

#include <mega8535.h>
#include <delay.h>
define menu    PINC.4 // menu
define up      PINC.5 // tombol 1 / up
define down    PINC.6 // tombol 2 / down
define suhu    PINC.7 // tombol 3 dan tombol suhu

// I2C Bus functions
asm
  .equ __i2c_port=0x15 ;PORTC
  .equ __sda_bit=1
  .equ __scl_bit=0
endasm
#include <i2c.h>

// DS1307 Real Time Clock functions
#include <ds1307.h>

// Alphanumeric LCD Module functions
asm
  .equ __lcd_port=0x18 ;PORTB
endasm
#include <lcd.h>

// Standard Input/Output functions
#include <stdio.h>
#include <stdlib.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);

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Universitas Sumatera Utara
ADCSRA|=0x10;
return ADCW;
}

// Declare your global variables here
unsigned int ADC_, f=0, flag1=0, flag2=0, u=1;
unsigned char dd, mm, yy, s, m, h;
unsigned char a=0, b=0, c=0, o=0;
int i;
float suhu;
char buffer[33];
eeprom unsigned int data_jadwal=0, p1=0;

// External Interrupt 0 service routine
interrupt [EXT_INT0] void ext_int0_isr(void)
{
// Place your code here
if(PIND.2==0 && u==0)
{
    PORTC.2=0;
    lcd_clear();
lcd_gotoxy(0,0);
lcd_putsf("PLN ON");
delay_ms(1500);
printf("AT+CMGS=");  // kirim sms
putchar('"');
printf("085265768503");
putchar('"');
putchar(0x0D);  //CR (enter)
printf("PLN ON");
putchar(0xA1);  //CTRL-Z
putchar(0x0D);
lcd_clear();
lcd_gotoxy(0,0);
lcd_putsf("krm sms PLN ON");
delay_ms(5000);
p1=2; u=1;
delay_ms(500);
}

if(PIND.2==1 && u==1)
{
delay_ms(200);
delay_ms(200);
PORTC.2=1;
lcd_clear();
lcd_gotoxy(0,0);
lcd_putsf("PLN OFF");
delay_ms(1500);
printf("AT+CMGS=");  // kirim sms
putchar('"');
printf("085265768503");
putchar('"');
putchar(0x0D);  //CR / enter
printf("PLN OFF");
putchar(0xA1);  //CTRL-Z
putchar(0x0D);  //CR / enter
lcd_clear();
lcd_gotoxy(0,0);
}
void baca_suhu()
{
    ADC_ = read_adc(0);
    suhu = (float)ADC_*500/1024;
    sprintf(buffer,"ADC = %i",ADC_);
    lcd_clear();
    lcd_gotoxy(0,0);
    lcd_puts(buffer);
    lcd_gotoxy(7,1);
    ftoa(suhu, 2, buffer);
    lcd_puts(buffer);
    lcd_gotoxy(13,1);
    lcd_putsf("C");
    delay_ms(5000);
}

void set_waktu()
{
    if(menu==0)
    {
        delay_ms(200);
        delay_ms(200);
        lcd_clear();
        lcd_gotoxy(0,0);
        lcd_putsf("Set Jam");
        delay_ms(2000);
        a=1;
    }
    while(a==1)  //set jam
    {
        if (up==0) //up jam
        {
            delay_ms(200);
            b++;
            if(b>23) b=0;
            lcd_clear();
            lcd_gotoxy(0,0);
            sprintf(buffer,"Jam :%02u",b);
            lcd_puts(buffer);
        }
        if (down==0) //down jam
        {
            delay_ms(200);
            b--;
            if(b>24) b=23;
            lcd_clear();
            lcd_gotoxy(0,0);
            sprintf(buffer,"Jam :%02u",b);
            lcd_puts(buffer);
        }
    }
}

lcd_putsf("krm sms PLN OFF");
p1=1; u=0;
delay_ms(500);
}
delay_ms(500);
}
if (menu==0)
{
    delay_ms(200);
    delay_ms(200);
    lcd_clear();
    lcd_gotoxy(0,0);
    lcd_putsf("Set Menit");
    delay_ms(1000);
    a=2;
}
}
}
while(a==2)
{
    if (up==0)//up menit
    {
        delay_ms(200);
        c++;
        if(c>59) c=0;
        lcd_clear();
        lcd_gotoxy(0,1);
        sprintf(buffer,"Menit:%02u",c);
        lcd_puts(buffer);
    }
    if (down==0)//down menit
    {
        delay_ms(200);
        c--;
        if(c>60) c=59;
        lcd_clear();
        lcd_gotoxy(0,1);
        sprintf(buffer,"Menit:%02u",c);
        lcd_puts(buffer);
    }
    if (menu==0)
    {
        lcd_clear();
        lcd_gotoxy(0,1);
        lcd_putsf("Oke");
        delay_ms(1000);
        a=3;
    }
    if(a==3)
    {
        lcd_clear();
        lcd_gotoxy(0,0);
        h=b; m=c; s=o;
        rtc_set_time(b,c,o); //setting waktu real time
        sprintf(buffer,"%02u:%02u:00",b,c,o);
        lcd_puts(buffer);
        o=0;
        delay_ms(3000);
        a=0;
        delay_ms(200);
    }
}

void set_jadwal()
{

delay_ms(200);
lcd_clear();
lcd_gotoxy(0,0);
lcd_putsf("1. 1 X   3. 3 X");
lcd_gotoxy(0,1);
lcd_putsf("2. 2 X");
delay_ms(2000);
while(a==1)
{
    //set jadwal 1 kali
    if(up==0)
    {
        delay_ms(200);
        delay_ms(200);
        lcd_clear();
lcd_gotoxy(0,0);
lcd_putsf("1 kali feeding");
lcd_gotoxy(0,1);
lcd_putsf("Pukul 18:09:10");
delay_ms(2000);
f=1;
    data_jadwal=f;
a=0;
    }
    //set jadwal 2 kali
    if(down==0)
    {
        delay_ms(200);
        delay_ms(200);
        lcd_clear();
lcd_gotoxy(0,0);
lcd_putsf("2 kali feeding");
delay_ms(1000);
lcd_clear();
lcd_gotoxy(0,0);
lcd_putsf("Pkl 18:09:10");
lcd_gotoxy(0,1);
lcd_putsf("Pkl 18:09:30");
delay_ms(2000);
f=2;
    data_jadwal=f;
a=0;
    }
    //set jadwal 3 kali
    if(suhu1==0)
    {
        delay_ms(200);
        delay_ms(200);
        lcd_clear();
lcd_gotoxy(0,0);
lcd_putsf("3 kali feeding");
delay_ms(1000);
lcd_clear();
lcd_gotoxy(0,0);
lcd_putsf("1. Pkl 18:09:10");
lcd_gotoxy(0,1);
lcd_putsf("2. Pkl 18:09:30");
delay_ms(1500);
    lcd_clear();
}
void feeding()
{
    lcd_clear();
    lcd_gotoxy(0,0);
    lcd_putsf("kasih makan");
    delay_ms(2000);
    for(i=0;i<=8;i++) //aktifkan servo untuk memberikan makan
    {
        OCR1A=250; //KASIH 500
        delay_ms(500);
        OCR1A=1000;
        delay_ms(500);
        i++;
    }
    delay_ms(500);
    printf("AT+CMGS=");
    putchar('"');
    printf("085265768503");
    putchar('"');
    printf("feeding telah dilakukan");
    putchar(0x0D); //CR / enter
    printf("feeding telah dilakukan");
    putchar(0x1A); //CTRL-Z
    putchar(0x0D); //CR / enter
    lcd_clear();
    lcd_gotoxy(0,0);
    lcd_putsf("krm sms feeding");
    delay_ms(5000);
}

void main(void)
{
    PORTA=0x00;
    DDRA=0x00;  //PORTA.0 SEBAGAI ADC MENGUKUR SUHU
    PORTB=0x00;
    DDRB=0x00;  //LCD
    PORTC=0b11110000; // PINC4-7 DI SET SEBAGAI INPUT BUTTON
    DDRC=0b00001100; // PORTC.2 DI SET SEBAGAI OUTPUT LED TANDA PLN
    ON/OFF
    PORTD=0b0110100000; // PIN.2 dan 3 DI SET INPUT UNTUK DETEKSI
    LISTRIK PLN ON/OFF
    DDRD=0b000100000; //PORTD.5 DI SET OUTPUT UNTUK GERAKIN SERVO
    // 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: 1000,000 kHz
// Mode: Ph. & fr. cor. PWM top=ICR1
// OC1A output: Non-Inv.
// OC1B output: Non-Inv.
// 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=0xA0;
TCCR1B=0x12;
TCNT1H=0x00;
TCNT1L=0x00;
ICR1H=0x27; //input capture register 1 High diisi dengan nilai 27h
ICR1L=0x10; //input capture register 1 Low diisi dengan nilai 10h
OCR1AH=0x00;
OCR1AL=0x00;
OCR1BH=0x00;
OCR1BL=0x00;

// External Interrupt(s) initialization
// INT0: On
// INT0 Mode: Rising Edge
// INT1: On
// INT1 Mode: Rising Edge
// INT2: Off
GICR|=0xC0;
MCUCR=0x0F;
MCUCSR=0x00;
GIFR=0xC0;

// USART initialization
// Communication Parameters: 8 Data, 1 Stop, No Parity
// USART Receiver: On
// USART Transmitter: On
// USART Mode: Asynchronous
// USART Baud Rate: 9600
UCSRA=0x00;
UCSRB=0x18;
UCSRC=0x86;
UBRRH=0x00;
UBRRL=0x33;

// 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: AVCC pin
// ADC High Speed Mode: On
// ADC Auto Trigger Source: Free Running
ADMUX=ADC_VREF_TYPE & 0xff;
ADCSRA=0xA3;
SFIOR|=0x0F;
SFIOR|=0x10;

// DS1307 Real Time Clock initialization
// Square wave output on pin SQW/OUT: Off
// SQW/OUT pin state: 0
// RTC Bus initialization
rtc_init(0,0,0);

// Global enable interrupts
#asm("sei")

// LCD initialization
lcd_init(16);
lcd_clear();
lcd_gotoxy(0,0);
lcd_putsf("<==autofeeder==>");
lcd_gotoxy(0,1);
lcd_putsf("by: @recky_su-"晠;
delay_ms(2000);
rtc_set_time(22,13,0);
rtc_set_date(22,10,13);

while (1)
{
    // Place your code here
    rtc_get_time(&h,&m,&s);
    rtc_get_date(&dd,&mm,&yy);
    lcd_clear();
    // meletakkan tanggal
    lcd_gotoxy(0,0);
    sprintf(buffer,"Tanggal:%02u/%02u/%02u",dd,mm,yy);
    lcd_puts(buffer);
    // meletakkan waktu
    lcd_gotoxy(0,1);
    sprintf(buffer,"Waktu: %02u:%02u:%02u",h,m,s);
    lcd_puts(buffer);
    delay_ms(1000);

    // PENGECEKAN DATA PLN pada EEPROM//
    if (p1==1) PORTC.2=1; // PLN OFF
    else PORTC.2=0; // PLN ON

    // RUTIN BACA SUHU
    ADC_= read_adc(0);
suhu= (float)ADC_*500/1024;
    if (suhu>=30 && flag1==0)
    {
        PORTC.3=1; // hidupkan chiller
        PORTD.7=0; // matikan heater
        lcd_clear();
lcd_gotoxy(0,0);
```c
lcd_putsf("Heater OFF");
lcd_gotoxy(0,1);
lcd_putsf("Chiller ON");
delay_ms(2000);
printf("AT+CMTGSM=");
putchar('"');
printf("085265768503");
putchar('"');
putchar(0x0D);  //CR / enter
printf("suhu di atas normal, chiller dihidupkan");
putchar(0x1A);  //CTRL-Z
putchar(0x0D);  //CR / enter
lcd_clear();
lcd_gotoxy(0,0);
lcd_putsf("sms T UP");
delay_ms(4000);
flag1=1;
}
else if((suhu>20 && suhu<30) && flag1==1)
{
    PORTC.3=0; //matikan chiller
    PORTD.7=0; //matikan heater
    lcd_clear();
lcd_gotoxy(0,0);
lcd_putsf("Heater OFF");
lcd_gotoxy(0,1);
lcd_putsf("Chiller OFF");
delay_ms(2000);
printf("AT+CMTGSM=");
putchar('"');
printf("085265768503");
putchar('"');
putchar(0x0D);  //CR / enter
printf("suhu normal");
putchar(0x1A);  //CTRL-Z
putchar(0x0D);  //CR / enter
lcd_clear();
lcd_gotoxy(0,0);
lcd_putsf("sms T normal");
delay_ms(2000);
flag1=0;
flag2=1;
}
else if(suhu<=20 && flag2==1)
{
    PORTC.3=0; //matikan chiller
    PORTD.7=1; //hidupkan heater
    lcd_clear();
lcd_gotoxy(0,0);
lcd_putsf("Heater ON");
lcd_gotoxy(0,1);
lcd_putsf("Chiller OFF");
delay_ms(2000);
printf("AT+CMTGSM=");
putchar('"');
printf("085265768503");
putchar('"');
```

putchar(0x0D);  //CR / enter
printf("suhu down, heater dihidupkan");
putchar(0x1A);  //CTRL-Z
putchar(0x0D);  //CR / enter
lcd_clear();
lcd_gotoxy(0,0);
lcd_putsf("sms T DOWN");
delay_ms(4000);
flag1=1;
flag2=0;
}
if (menu==0)
{
delay_ms(200);
lcd_clear();
lcd_gotoxy(7,0);
lcd_putsf("Menu");
delay_ms(1000);
lcd_clear();
lcd_gotoxy(0,0);
lcd_putsf("1. Set Waktu");
lcd_gotoxy(0,1);
lcd_putsf("2. Set Jadwal");
delay_ms(2000);
a=1;
}
while(a==1)
{
if (up==0) set_waktu();
if (down==0) set_jadwal();
}

//menampilkan suhu ke LCD jika push button ditekan
if(suhu1==0) baca_suhu();

//DATA JADWAL di EEPROM/
if (data_jadwal==1)
{
  if (h==8 && m==0 && s==0) feeding();
}
if (data_jadwal==2)
{
  if (h==8 && m==0 && s==0) feeding();
  if (h==13 && m==0 && s==0) feeding();
}
if (data_jadwal==3)
{
  if (h==8 && m==0 && s==0) feeding();
  if (h==13 && m==0 && s==0) feeding();
  if (h==19 && m==0 && s==0) feeding();
}
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 MHz Throughput at 16 MHz
  - On-chip 2-cycle Multiplier
- Nonvolatile Program and Data Memories
  - 8K Bytes of In-System Self-Programmable Flash
  - Endurance: 10,000 Write/Erase Cycles
  - Optional Boot Code Section with Independent Lock Bits
  - In-System Programming by On-chip Boot Program
  - True Read-While-Write Operation
  - 512 Bytes EEPROM
    - Endurance: 100,000 Write/Erase Cycles
  - 512 Bytes Internal SRAM
  - Programming Lock for Software Security
- Peripheral Features
  - Two 8-bit Timer/Counters with Separate Prescalers and Compare Modes
  - One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
  - Real Time Counter with Separate Oscillator
  - Four PWM Channels
  - 6-channel, 10-bit ADC
    - 8 Single-ended Channels
    - 7 Differential Channels for TQFP Package Only
    - 2 Differential Channels with Programmable Gain at 1x, 10x, or 200x for TQFP Package Only
  - Byte-oriented Two-wire Serial Interface
  - Programmable Serial USART
  - Master/Slave SPI Serial Interface
  - Programmable Watchdog Timer with Separate On-chip Oscillator
  - On-chip Analog Comparator
- Special Microcontroller Features
  - Power-on Reset and Programmable Brown-out Detection
  - Internal Calibrated RC Oscillator
  - External and Internal Interrupt Sources
  - Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby and Extended Standby
- I/O and Packages
  - 32 Programmable I/O Lines
  - 40-pin PDIP, 44-lead TQFP, 44-lead PLCC, and 44-pin QFN/MLF
- Operating Voltages
  - 2.7 – 5.5V for ATmega8535L
  - 4.5 – 5.5V for ATmega8535
- Speed Grades
  - 0 - 8 MHz for ATmega8535L
  - 0 - 16 MHz for ATmega8535
Pin Configurations

Figure 1. Pinout ATmega8535

NOTE: MLF Bottom pad should be soldered to ground.

Disclaimer

Typical values contained in this data sheet are based on simulations and characterization of other AVR microcontrollers manufactured on the same process technology. Min and Max values will be available after the device is characterized.
DS1307
64 x 8, Serial, I²C Real-Time Clock

GENERAL DESCRIPTION
The DS1307 serial real-time clock (RTC) is a low-power, full binary-coded decimal (BCD) clock/calendar plus 58 bytes of NV SRAM. Address and data are transferred serially through an I²C, bidirectional bus. The clock/calendar provides seconds, minutes, hours, day, date, month, and year information. The end of the month date is automatically adjusted for months with fewer than 31 days, including corrections for leap year. The clock operates in either the 24-hour or 12-hour format with AM/PM indicator. The DS1307 has a built-in power-sense circuit that detects power failures and automatically switches to the backup supply. Timekeeping operation continues while the part operates from the backup supply.

FEATURES
- Real-Time Clock (RTC) Counts Seconds, Minutes, Hours, Date of the Month, Month, Day of the week, and Year with Leap-Year Compensation Valid Up to 2100
- 58-Byte, Battery-Backed, General-Purpose RAM with Unlimited Writes
- I²C Serial Interface
- Programmable Square-Wave Output Signal
- Automatic Power-Fail Detect and Switch Circuitry
- Consumes Less than 500nA in Battery-Backup Mode with Oscillator Running
- Optional Industrial Temperature Range: -40°C to +85°C
- Available in 8-Pin Plastic DIP or SO
- Underwriters Laboratories (UL) Recognized

TYPICAL OPERATING CIRCUIT

PIN CONFIGURATIONS

ORDERING INFORMATION

<table>
<thead>
<tr>
<th>PART</th>
<th>TEMP RANGE</th>
<th>VOLTAGE (V)</th>
<th>PIN-PACKAGE</th>
<th>TOP MARK*</th>
</tr>
</thead>
<tbody>
<tr>
<td>DS1307+</td>
<td>0°C to +70°C</td>
<td>5.0</td>
<td>8 PDIP (300 mils)</td>
<td>DS1307</td>
</tr>
<tr>
<td>DS1307N+</td>
<td>-40°C to +85°C</td>
<td>5.0</td>
<td>8 PDIP (300 mils)</td>
<td>DS1307N</td>
</tr>
<tr>
<td>DS1307Z+</td>
<td>0°C to +70°C</td>
<td>5.0</td>
<td>8 SO (150 mils)</td>
<td>DS1307</td>
</tr>
<tr>
<td>DS1307ZN+</td>
<td>-40°C to +85°C</td>
<td>5.0</td>
<td>8 SO (150 mils)</td>
<td>DS1307N</td>
</tr>
<tr>
<td>DS1307Z+T&amp;R</td>
<td>0°C to +70°C</td>
<td>5.0</td>
<td>8 SO (150 mils) Tape and Reel</td>
<td>DS1307</td>
</tr>
<tr>
<td>DS1307ZN+T&amp;R</td>
<td>-40°C to +85°C</td>
<td>5.0</td>
<td>8 SO (150 mils) Tape and Reel</td>
<td>DS1307N</td>
</tr>
</tbody>
</table>

*Denotes a lead-free/QRoHS-compliant package.
*A “-” anywhere on the top mark indicates a lead-free package. An “N” anywhere on the top mark indicates an Industrial temperature range device.

For pricing, delivery, and ordering information, please contact Maxim Direct at 1-888-629-4642, or visit Maxim’s website at www.maximintegrated.com.
**ABSOLUTE MAXIMUM RATINGS**
Voltage Range on Any Pin Relative to Ground ........................................... -0.5V to +7.0V
Operating Temperature Range (Noncondensing)
Commercial .......................................................... 0°C to +70°C
Industrial .......................................................... -40°C to +85°C
Storage Temperature Range .......................................................... -65°C to +125°C
Soldering Temperature (DIP, leads) ......................................................... +260°C for 10 seconds
Soldering Temperature (surface mount) .................................................. Refer to the JPCA/JEDEC J-STD-020 Specification.

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

**RECOMMENDED DC OPERATING CONDITIONS**
\( (T_A = 0°C \text{ to } +70°C, T_A = -40°C \text{ to } +85°C) \) (Notes 1, 2)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage</td>
<td>( V_{CC} )</td>
<td></td>
<td>4.5</td>
<td>5.0</td>
<td>5.5</td>
<td>V</td>
</tr>
<tr>
<td>Logic 1 Input</td>
<td>( V_{IL} )</td>
<td></td>
<td>-1</td>
<td></td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td>Logic 0 Input</td>
<td>( V_{IH} )</td>
<td></td>
<td>2.2</td>
<td>5.0</td>
<td>5.5</td>
<td>V</td>
</tr>
<tr>
<td>( V_{BAT} ) Battery Voltage</td>
<td>( V_{BAT} )</td>
<td></td>
<td>2.0</td>
<td>3.0</td>
<td>3.5</td>
<td>V</td>
</tr>
</tbody>
</table>

**DC ELECTRICAL CHARACTERISTICS**
\( (V_{CC} = 4.5V \text{ to } 5.5V; T_A = 0°C \text{ to } +70°C, T_A = -40°C \text{ to } +85°C) \) (Notes 1, 2)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Leakage (SCL)</td>
<td>( I_{L} )</td>
<td></td>
<td>-1</td>
<td></td>
<td>1</td>
<td>µA</td>
</tr>
<tr>
<td>I/O Leakage (SDA, SQW/OUT)</td>
<td>( I_{O} )</td>
<td></td>
<td>-1</td>
<td></td>
<td>1</td>
<td>µA</td>
</tr>
<tr>
<td>Logic 0 Output (( I_{OL} = 5mA ))</td>
<td>( V_{OL} )</td>
<td></td>
<td>0.4</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Active Supply Current (( f_{OSC} = 100kHz ))</td>
<td>( I_{CC} )</td>
<td></td>
<td>1.5</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>Standby Current</td>
<td>( I_{CCS} )</td>
<td>(Note 3)</td>
<td>200</td>
<td></td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td>( V_{BAT} ) Leakage Current</td>
<td>( I_{BATCHG} )</td>
<td></td>
<td>5</td>
<td>10</td>
<td></td>
<td>nA</td>
</tr>
<tr>
<td>Power-Fail Voltage (( V_{BAT} = 3.0V ))</td>
<td>( V_{OFF} )</td>
<td></td>
<td>1.216 \times \frac{V_{BAT}}{2} \text{ to } 1.284 \times \frac{V_{BAT}}{2}</td>
<td></td>
<td></td>
<td>V</td>
</tr>
</tbody>
</table>

**DC ELECTRICAL CHARACTERISTICS**
\( (V_{CC} = 0V, V_{BAT} = 3.0V; T_A = 0°C \text{ to } +70°C, T_A = -40°C \text{ to } +85°C) \) (Notes 1, 2)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{BAT} ) Current (OSC ON); SQW/OUT OFF</td>
<td>( I_{BAT1} )</td>
<td></td>
<td>300</td>
<td>500</td>
<td></td>
<td>nA</td>
</tr>
<tr>
<td>( V_{BAT} ) Current (OSC ON); SQW/OUT ON (32kHz)</td>
<td>( I_{BAT2} )</td>
<td></td>
<td>480</td>
<td>800</td>
<td></td>
<td>nA</td>
</tr>
<tr>
<td>( V_{BAT} ) Data-Retention Current (Oscillator Off)</td>
<td>( I_{BATOR} )</td>
<td></td>
<td>10</td>
<td>100</td>
<td></td>
<td>nA</td>
</tr>
</tbody>
</table>

**WARNING**: Negative undershoots below -0.3V while the part is in battery-backed mode may cause loss of data.
### AC ELECTRICAL CHARACTERISTICS

\( V_{CC} = 4.5\text{V to } 5.5\text{V}; \; T_A = 0^\circ C \text{ to } +70^\circ C, \; T_A = -40^\circ C \text{ to } +85^\circ C. \)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCL Clock Frequency</td>
<td>( f_{SCL} )</td>
<td></td>
<td>0</td>
<td>100</td>
<td></td>
<td>kHz</td>
</tr>
<tr>
<td>Bus Free Time Between a STOP and START Condition</td>
<td>( t_{BUF} )</td>
<td>(Note 4)</td>
<td>4.7</td>
<td></td>
<td></td>
<td>( \mu \text{s} )</td>
</tr>
<tr>
<td>Hold Time (Repeated) START Condition</td>
<td>( t_{HOLD} )</td>
<td>(Note 5, 6)</td>
<td>4.7</td>
<td></td>
<td></td>
<td>( \mu \text{s} )</td>
</tr>
<tr>
<td>LOW Period of SCL Clock</td>
<td>( t_{LOW} )</td>
<td></td>
<td>4.7</td>
<td></td>
<td></td>
<td>( \mu \text{s} )</td>
</tr>
<tr>
<td>HIGH Period of SCL Clock</td>
<td>( t_{HIGH} )</td>
<td></td>
<td>4.0</td>
<td></td>
<td></td>
<td>( \mu \text{s} )</td>
</tr>
<tr>
<td>Setup Time for a Repeated START Condition</td>
<td>( t_{SU} )</td>
<td></td>
<td>4.7</td>
<td></td>
<td></td>
<td>( \mu \text{s} )</td>
</tr>
<tr>
<td>Data Hold Time</td>
<td>( t_{HIH} )</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td>( \mu \text{s} )</td>
</tr>
<tr>
<td>Data Setup Time</td>
<td>( t_{SU} )</td>
<td></td>
<td>250</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>Rise Time of Both SDA and SCL Signals</td>
<td>( t_{R} )</td>
<td></td>
<td>1000</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>Fall Time of Both SDA and SCL Signals</td>
<td>( t_{F} )</td>
<td></td>
<td>300</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>Setup Time for STOP Condition</td>
<td>( t_{BU} )</td>
<td></td>
<td>4.7</td>
<td></td>
<td></td>
<td>( \mu \text{s} )</td>
</tr>
</tbody>
</table>

### CAPACITANCE

\( T_A = \pm 25^\circ \text{C} \)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pin Capacitance (SDA, SCL)</td>
<td>( C_{\text{IO}} )</td>
<td></td>
<td>10</td>
<td></td>
<td></td>
<td>pF</td>
</tr>
<tr>
<td>Capacitance Load for Each Bus Line</td>
<td>( C_{\text{S}} )</td>
<td>(Note 7)</td>
<td>400</td>
<td></td>
<td></td>
<td>pF</td>
</tr>
</tbody>
</table>

**Note 1:** All voltages are referenced to ground.

**Note 2:** Limits at -40\(^\circ\)C are guaranteed by design and are not production tested.

**Note 3:** \( V_{CC} \) specified with \( V_{DD} = 5.0\text{V} \) and SDA, SCL = 5.0\text{V}.

**Note 4:** After this period, the first clock pulse is generated.

**Note 5:** A device must internally provide a hold time of at least 300ns for the SDA signal (referred to the \( V_{HIH} \text{MIN} \) of the SCL signal) to bridge the undefined region of the falling edge of SCL.

**Note 6:** The maximum \( t_{HIH} \text{DAT} \) only has to be met if the device does not stretch the LOW period \( (t_{LOW}) \) of the SCL signal.

**Note 7:** \( C_{S} \)—total capacitance of one bus line in pF.
LM35
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°C at room temperature and ±1°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 circuitry 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 (±1°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-220 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°C typical
- Low impedance output, 0.1 Ω for 1 mA load

Typical Applications

![Basic Centigrade Temperature Sensor](image1)

**FIGURE 1. Basic Centigrade Temperature Sensor**

(+2°C to +150°C)

![Full-Range Centigrade Temperature Sensor](image2)

**FIGURE 2. Full-Range Centigrade Temperature Sensor**

- Choose R1 = +V supply
- Vout = +150 mV at +150°C
- +150 mV at +25°C
- +100 mV at +85°C
- -100 mV at +5°C

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### Absolute Maximum Ratings (Note 10)

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

<table>
<thead>
<tr>
<th>Supply Voltage</th>
<th>+35V to -0.2V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Voltage</td>
<td>+5V to -1.0V</td>
</tr>
<tr>
<td>Output Current</td>
<td>10 mA</td>
</tr>
</tbody>
</table>

Storage Temp:
- TO-92 Package: -60°C to +160°C
- TO-220 Package: -65°C to +150°C

Lead Temp:
- TO-92 Package: -65°C to +150°C

<table>
<thead>
<tr>
<th>Lead Temp.</th>
<th>(Soldering, 10 seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>300°C</td>
</tr>
</tbody>
</table>

### Specified Operating Temperature Range: \( T_{\text{MIN}} \) to \( T_{\text{MAX}} \) (Note 2)
- LM35, LM35A: -55°C to +150°C
- LM35C, LM35CA: -40°C to +110°C
- LM35D: 0°C to +100°C

### Electrical Characteristics (Notes 1, 6)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM35A</th>
<th>LM35CA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Typical</td>
<td>Design Limit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Note 4)</td>
<td>(Note 5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tested Limit</td>
<td>Tested Limit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Note 4)</td>
<td>(Note 5)</td>
</tr>
<tr>
<td>Accuracy (Note 7)</td>
<td>( T_a = +25°C )</td>
<td>±0.2</td>
<td>±0.2</td>
</tr>
<tr>
<td></td>
<td>( T_a = +10°C )</td>
<td>±0.3</td>
<td>±0.3</td>
</tr>
<tr>
<td></td>
<td>( T_a = T_{\text{MAX}} )</td>
<td>±1.0</td>
<td>±0.4</td>
</tr>
<tr>
<td></td>
<td>( T_a = T_{\text{MIN}} )</td>
<td>±1.0</td>
<td>±0.4</td>
</tr>
<tr>
<td>Nonlinearity (Note 8)</td>
<td>( T_{\text{MIN}} \leq T_a \leq T_{\text{MAX}} )</td>
<td>±0.18</td>
<td>±0.35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>±0.15</td>
<td>±0.3</td>
</tr>
<tr>
<td>Sensor Gain (Average Slope)</td>
<td>( T_{\text{MIN}} \leq T_a \leq T_{\text{MAX}} )</td>
<td>+10.0</td>
<td>+9.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>±0.9</td>
<td>±0.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>±10.1</td>
<td>±10.1</td>
</tr>
<tr>
<td>Load Regulation (Note 3)</td>
<td>( 0 \leq I_1 \leq 1 ) mA</td>
<td>±0.5</td>
<td>±0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>±3.0</td>
<td>±3.0</td>
</tr>
<tr>
<td></td>
<td>( T_a = +25°C )</td>
<td>±0.01</td>
<td>±0.01</td>
</tr>
<tr>
<td>Line Regulation (Note 3)</td>
<td>( V_{\text{GND}} \geq 30V )</td>
<td>±0.02</td>
<td>±0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>±0.1</td>
<td>±0.1</td>
</tr>
<tr>
<td></td>
<td>( 4V \leq V_{\text{GND}} \leq 30V )</td>
<td>±0.01</td>
<td>±0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>±0.05</td>
<td>±0.05</td>
</tr>
<tr>
<td></td>
<td>( V_{\text{GND}} = +5V ), ( +25°C )</td>
<td>56</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>( V_{\text{GND}} = +5V )</td>
<td>105</td>
<td>91</td>
</tr>
<tr>
<td></td>
<td>( V_{\text{GND}} = +30V ), ( +25°C )</td>
<td>66.2</td>
<td>56.2</td>
</tr>
<tr>
<td></td>
<td>( V_{\text{GND}} = +30V )</td>
<td>105.5</td>
<td>91.5</td>
</tr>
<tr>
<td>Change of Quiescent Current (Note 3)</td>
<td>( 4V \leq V_{\text{GND}} \leq 30V ), ( +25°C )</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>
| Temperature Coefficient of Quiescent Current
|                                |                      | ±0.39          | ±0.39          |
|                                |                      | ±0.5           | ±0.5           |
|                                |                      | ±0.5           | ±0.5           |
|                                |                      | ±1.5           | ±2.0           |
| Minimum Temperature for Rated Accuracy
|                                | In circuit of Figure 1, I_1 = 0 | +1.5           | ±2.0           |
| Long Term Stability
|                                | \( T_{\text{MAX}} \) for 1000 hours | ±0.08          | ±0.08          |
|                                |                      | ±0.08          | ±0.08          |

Units (Max.):
- °C
- mV/°C
- mV/V
- mV/mA
- μA/°C
- μA
### Electrical Characteristics

(Notes 1, 6)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM35 Typical</th>
<th>Tested Limit (Note 4)</th>
<th>Design Limit (Note 5)</th>
<th>LM35C, LM35D Typical</th>
<th>Tested Limit (Note 4)</th>
<th>Design Limit (Note 5)</th>
<th>Units (Max.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy,</td>
<td>$T_A = +25^\circ\text{C}$</td>
<td>$\pm 0.4$</td>
<td>$\pm 1.0$</td>
<td>$\pm 0.4$</td>
<td>$\pm 1.0$</td>
<td>$\pm 0.4$</td>
<td>$\pm 1.0$</td>
<td>$^\circ\text{C}$</td>
</tr>
<tr>
<td>LM35, LM35C</td>
<td>$T_A = 10^\circ\text{C}$</td>
<td>$\pm 0.5$</td>
<td>$\pm 0.5$</td>
<td>$\pm 0.5$</td>
<td>$\pm 1.5$</td>
<td>$\pm 1.5$</td>
<td>$\pm 1.5$</td>
<td>$^\circ\text{C}$</td>
</tr>
<tr>
<td>(Note 7)</td>
<td>$T_A = T_{\text{MAX}}$</td>
<td>$\pm 0.8$</td>
<td>$\pm 0.8$</td>
<td>$\pm 0.8$</td>
<td>$\pm 2.0$</td>
<td>$\pm 2.0$</td>
<td>$\pm 2.0$</td>
<td>$^\circ\text{C}$</td>
</tr>
<tr>
<td>Accuracy, LM35D</td>
<td>$T_A = +25^\circ\text{C}$</td>
<td>$\pm 0.8$</td>
<td>$\pm 0.8$</td>
<td>$\pm 0.8$</td>
<td>$\pm 1.5$</td>
<td>$\pm 1.5$</td>
<td>$\pm 1.5$</td>
<td>$^\circ\text{C}$</td>
</tr>
<tr>
<td>(Note 7)</td>
<td>$T_A = T_{\text{MAX}}$</td>
<td>$\pm 0.9$</td>
<td>$\pm 0.9$</td>
<td>$\pm 0.9$</td>
<td>$\pm 2.0$</td>
<td>$\pm 2.0$</td>
<td>$\pm 2.0$</td>
<td>$^\circ\text{C}$</td>
</tr>
<tr>
<td>Nonlinearity</td>
<td>$T_{\text{MIN}} \leq T \leq T_{\text{MAX}}$</td>
<td>$\pm 0.3$</td>
<td>$\pm 0.5$</td>
<td>$\pm 0.2$</td>
<td>$\pm 0.5$</td>
<td>$\pm 0.2$</td>
<td>$\pm 0.5$</td>
<td>$^\circ\text{C}$</td>
</tr>
<tr>
<td>Sensor Gain</td>
<td>$T_{\text{MAX}} \leq T \leq T_{\text{MAX}}$</td>
<td>$+10.0$</td>
<td>$+0.8$</td>
<td>$+10.0$</td>
<td>$+0.8$</td>
<td>$+10.0$</td>
<td>$+0.8$</td>
<td>mV/C</td>
</tr>
<tr>
<td>(Average Slope)</td>
<td>$T_{\text{MIN}} \leq T \leq T_{\text{MAX}}$</td>
<td>$+9.8$</td>
<td>$+10.2$</td>
<td>$+9.8$</td>
<td>$+10.2$</td>
<td>$+9.8$</td>
<td>$+10.2$</td>
<td>mV/mA</td>
</tr>
<tr>
<td>Load Regulation</td>
<td>$T_A = +25^\circ\text{C}$</td>
<td>$+0.4$</td>
<td>$\pm 2.0$</td>
<td>$+0.4$</td>
<td>$\pm 2.0$</td>
<td>$+0.4$</td>
<td>$\pm 2.0$</td>
<td>mV/mA</td>
</tr>
<tr>
<td>(Note 3)</td>
<td>$T_{\text{MIN}} \leq T \leq T_{\text{MAX}}$</td>
<td>$+0.5$</td>
<td>$\pm 5.0$</td>
<td>$+0.5$</td>
<td>$\pm 5.0$</td>
<td>$+0.5$</td>
<td>$\pm 5.0$</td>
<td>mV/mA</td>
</tr>
<tr>
<td>Line Regulation</td>
<td>$T_A = +25^\circ\text{C}$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.02$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.02$</td>
<td>$\pm 0.02$</td>
<td>$\pm 0.02$</td>
<td>mV/V</td>
</tr>
<tr>
<td>(Note 3)</td>
<td>$V_{ES} \leq 30V$</td>
<td>$0.01$</td>
<td>$0.02$</td>
<td>$0.01$</td>
<td>$0.02$</td>
<td>$0.01$</td>
<td>$0.02$</td>
<td>mV/V</td>
</tr>
<tr>
<td>Quiescent Current</td>
<td>$V_A = +6V$, $V_B = +25^\circ\text{C}$</td>
<td>$56$</td>
<td>$80$</td>
<td>$56$</td>
<td>$80$</td>
<td>$56$</td>
<td>$80$</td>
<td>$\mu\text{A}$</td>
</tr>
<tr>
<td>(Note 5)</td>
<td>$V_B = +6V$, $V_B = +30V$, $V_B = +25^\circ\text{C}$</td>
<td>$105$</td>
<td>$158$</td>
<td>$91$</td>
<td>$141$</td>
<td>$91.5$</td>
<td>$141$</td>
<td>$\mu\text{A}$</td>
</tr>
<tr>
<td>Change of</td>
<td>$V_A = +30V$, $V_B = +25^\circ\text{C}$</td>
<td>$56.2$</td>
<td>$82$</td>
<td>$56.2$</td>
<td>$82$</td>
<td>$56.2$</td>
<td>$82$</td>
<td>$\mu\text{A}$</td>
</tr>
<tr>
<td>Quiescent Current</td>
<td>$4V &lt; V &lt; 30V$, $+25^\circ\text{C}$</td>
<td>$0.5$</td>
<td>$2.0$</td>
<td>$0.5$</td>
<td>$2.0$</td>
<td>$0.5$</td>
<td>$2.0$</td>
<td>$\mu\text{A}$</td>
</tr>
<tr>
<td>Temperature</td>
<td></td>
<td>$+0.39$</td>
<td>$+0.7$</td>
<td>$+0.39$</td>
<td>$+0.7$</td>
<td>$+0.39$</td>
<td>$+0.7$</td>
<td>$\mu\text{A}/^\circ\text{C}$</td>
</tr>
<tr>
<td>Coefficient of</td>
<td></td>
<td>$+0.1$</td>
<td>$+0.2$</td>
<td>$+0.1$</td>
<td>$+0.2$</td>
<td>$+0.1$</td>
<td>$+0.2$</td>
<td>$\mu\text{A}/^\circ\text{C}$</td>
</tr>
<tr>
<td>Quiescent Current</td>
<td>In circuit of $R_{L} = 0$</td>
<td>$+1.5$</td>
<td>$+2.0$</td>
<td>$+1.5$</td>
<td>$+2.0$</td>
<td>$+1.5$</td>
<td>$+2.0$</td>
<td>$^\circ\text{C}$</td>
</tr>
<tr>
<td>Minimum Temperature for Rated Accuracy</td>
<td>$T_{J} = T_{\text{MAX}}$ for 1000 hours</td>
<td>$\pm 0.08$</td>
<td>$\pm 0.08$</td>
<td>$\pm 0.08$</td>
<td>$\pm 0.08$</td>
<td>$\pm 0.08$</td>
<td>$\pm 0.08$</td>
<td>$^\circ\text{C}$</td>
</tr>
</tbody>
</table>

**Note 1:** Unless otherwise noted, these specifications apply at $+25^\circ\text{C}$ for the LM35 and LM35A, $+40^\circ\text{C}$ for the LM35C and LM35CA, and $0^\circ\text{C}$ for the LM35D. $V_{IN} = +5\text{Vdc}$ and $I_{\text{LOAD}} = 5\text{mA}$. In the circuit of Figure 2. These specifications also apply from $-25^\circ\text{C}$ to $+25^\circ\text{C}$ in the circuit of Figure 1. Specifications in boldface apply over the full rated temperature range.

**Note 2:** Thermal resistances of the TO-46 package are 45°C/W junction-to-ambient, 5°C/W junction-to-case. Thermal resistances of the TO-92 package are 180°C/W junction-to-ambient. Thermal resistances of the TO-220 package are 30°C/W junction-to-ambient. For additional thermal resistance information see table in the Applications section.

**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 $10\text{mV/}^\circ\text{C}$ 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 charged through a 1.5 kΩ resistor.

**Note 12:** See AN-490 “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.
LM78XX Series Voltage Regulators

General Description
The LM78XX series of three terminal regulators is available with several fixed output voltages making them useful in a wide range of applications. One of these is local on card regulation, eliminating the distribution problems associated with single point regulation. The voltages available allow these regulators to be used in logic systems, instrumentation, HiFi, and other solid state electronic equipment. Although designed primarily as fixed voltage regulators these devices can be used with external components to obtain adjustable voltages and currents.

The LM78XX series is available in an aluminum TO-3 package which will allow over 1.0A load current if adequate heat sinking is provided. Current limiting is included to limit the peak output current to a safe value. Safe area protection for the output transistor is provided to limit internal power dissipation. If internal power dissipation becomes too high for the heat sinking provided, the thermal shutdown circuit takes over preventing the IC from overheating.

Considerable effort was expanded to make the LM78XX series of regulators easy to use and minimize the number of external components. It is not necessary to bypass the output, although this does improve transient response. Input bypassing is needed only if the regulator is located far from the filter capacitor of the power supply.

For output voltage other than 5V, 12V and 15V the LM117 series provides an output voltage range from 1.2V to 57V.

Features
- Output current in excess of 1A
- Internal thermal overload protection
- No external components required
- Output transistor safe area protection
- Internal short circuit current limit
- Available in the aluminum TO-3 package

Voltage Range
- LM7805C: 5V
- LM7812C: 12V
- LM7815C: 15V

Connection Diagrams

Metal Can Package
TO-3 (K) | Plastic Package
TO-220 (T)
Aluminum | Bottom View
Order Number LM7805CK, LM7812CK or LM7815CK
See NS Package Number K02A

Top View
Order Number LM7805CT, LM7812CT or LM7815CT
See NS Package Number T03B
### Electrical Characteristics LM78XXC (Note 2)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Input Voltage (unless otherwise noted)</th>
<th>5V</th>
<th>12V</th>
<th>15V</th>
<th>10V</th>
<th>19V</th>
<th>23V</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Typ</td>
<td>Max</td>
<td>Min</td>
<td>Typ</td>
<td>Max</td>
<td>Min</td>
<td>Typ</td>
</tr>
<tr>
<td>$V_{o}$</td>
<td>Output Voltage</td>
<td>4.8</td>
<td>5.0</td>
<td>5.2</td>
<td>11.5</td>
<td>12.0</td>
<td>12.5</td>
<td>14.4</td>
<td>15.0</td>
</tr>
<tr>
<td>$P_{D}$</td>
<td>Output Power</td>
<td>4.75</td>
<td>5.25</td>
<td>5.25</td>
<td>11.4</td>
<td>12.6</td>
<td>12.6</td>
<td>14.25</td>
<td>15.75</td>
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<tr>
<td>$V_{IN}$</td>
<td>Line Regulation</td>
<td>(7.5 $\leq V_{IN} &lt; 20$)</td>
<td>(14.5 $\leq V_{IN} &lt; 27$)</td>
<td>(17.5 $\leq V_{IN} &lt; 30$)</td>
<td>V</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{O}$</td>
<td>Load Regulation</td>
<td>3</td>
<td>50</td>
<td>120</td>
<td>4</td>
<td>120</td>
<td>150</td>
<td>mV</td>
<td></td>
</tr>
<tr>
<td>$V_{IN}$</td>
<td>Load Regulation</td>
<td>(7 $\leq V_{IN} &lt; 25$)</td>
<td>(14.5 $\leq V_{IN} &lt; 30$)</td>
<td>(17.5 $\leq V_{IN} &lt; 30$)</td>
<td>V</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{O}$</td>
<td>Quiescent Current</td>
<td>10</td>
<td>50</td>
<td>120</td>
<td>6</td>
<td>50</td>
<td>150</td>
<td>mV</td>
<td></td>
</tr>
<tr>
<td>$V_{IN}$</td>
<td>Quiescent Current</td>
<td>25</td>
<td>50</td>
<td>120</td>
<td>25</td>
<td>50</td>
<td>150</td>
<td>mV</td>
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<tr>
<td>$I_{O}$</td>
<td>Quiescent Current</td>
<td>5</td>
<td>8</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>mA</td>
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<td></td>
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<tr>
<td>$V_{IN}$</td>
<td>Quiescent Current</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>mA</td>
<td></td>
<td></td>
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<tr>
<td>$V_{IN}$</td>
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<td>0.5</td>
<td>0.5</td>
<td>mA</td>
<td></td>
<td></td>
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<tr>
<td>$Y_{N}$</td>
<td>Output Noise Voltage</td>
<td>40</td>
<td>75</td>
<td>90</td>
<td>μV</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>$\Delta V_{N}$</td>
<td>Ripple Rejection</td>
<td>62</td>
<td>80</td>
<td>72</td>
<td>dB</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$f = 120$</td>
<td>Hz</td>
<td>62</td>
<td>55</td>
<td>72</td>
<td>dB</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{IN}$</td>
<td>Ripple Rejection</td>
<td>(6 $\leq V_{IN} &lt; 15$)</td>
<td>(15 $\leq V_{IN} &lt; 25$)</td>
<td>(16.5 $\leq V_{IN} &lt; 28.5$)</td>
<td>V</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>$R_{D}$</td>
<td>Dropout Voltage</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>mΩ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$f = 1$</td>
<td>kHz</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>mΩ</td>
<td></td>
<td></td>
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</tr>
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</table>
**Electrical Characteristics LM78XXC** (Note 2) *(Continued)*

$0^\circ \text{C} \leq T_j \leq 125^\circ \text{C}$ unless otherwise noted.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Input Voltage (unless otherwise noted)</th>
<th>Conditions</th>
<th>5V</th>
<th>12V</th>
<th>15V</th>
<th>Units</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Min</td>
<td>Typ</td>
<td>Max</td>
<td>Min</td>
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<tr>
<td>Short-Circuit Current</td>
<td></td>
<td>$T_j = 25^\circ \text{C}$</td>
<td>2.1</td>
<td>1.5</td>
<td>1.2</td>
<td>A</td>
</tr>
<tr>
<td>Peak Output Current</td>
<td></td>
<td>$T_j = 25^\circ \text{C}$</td>
<td>2.4</td>
<td>2.4</td>
<td>2.4</td>
<td>A</td>
</tr>
<tr>
<td>Average TC of $V_{OUT}$</td>
<td></td>
<td>$0^\circ \text{C} \leq T_j \leq +125^\circ \text{C}$, $I_O = 5 \text{ mA}$</td>
<td>0.6</td>
<td>1.5</td>
<td>1.8</td>
<td>mV/°C</td>
</tr>
<tr>
<td>$V_{IN}$</td>
<td></td>
<td>$T_j = 25^\circ \text{C}$, $I_O \leq 1 \text{ A}$</td>
<td>7.5</td>
<td>14.6</td>
<td>17.7</td>
<td>V</td>
</tr>
</tbody>
</table>

**Note 1:** Thermal resistance of the TO-220 package (K, KC) is typically 4°C/W junction to case and 36°C/W case to ambient. Thermal resistance of the TO-220 package (T) is typically 4°C/W junction to case and 36°C/W case to ambient.

**Note 2:** All characteristics are measured with capacitor across the input of 0.022 μF and a capacitor across the output of 0.1 μF. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ($t_1 \leq 10 \text{ ms}, \text{ duty cycle} \leq 5\%$). Output voltage changes due to changes in internal temperature must be taken into account separately.

**Note 3:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. For guaranteed specifications and the test conditions, see **Electrical Characteristics**.
MAX232, MAX232I
DUAL EIA-232 DRIVERS/RECEIVERS

- Meets or Exceeds TIA/EIA-232-F and ITU Recommendation V.28
- Operates From a Single 5-V Power Supply With 1.0-μF Charge-Pump Capacitors
- Operates Up To 120 kbit/s
- Two Drivers and Two Receivers
- ±30-V Input Levels
- Low Supply Current . . . 8 mA Typical
- ESD Protection Exceeds JESD 22
  - 2000-V Human-Body Model (A114-A)
- Upgrade With Improved ESD (15-kV HBM) and 0.1-μF Charge-Pump Capacitors Is Available With the MAX202
- Applications
  - TIA/EIA-232-F, Battery-Powered Systems, Terminals, Modems, and Computers

Description/ordering information

The MAX232 is a dual driver/receiver that includes a capacitive voltage generator to supply TIA/EIA-232-F voltage levels from a single 5-V supply. Each receiver converts TIA/EIA-232-F inputs to 5-V TTL/CMOS levels. These receivers have a typical threshold of 1.3 V, a typical hysteresis of 0.5 V, and can accept ±30-V inputs. Each driver converts TTL/CMOS input levels into TIA/EIA-232-F levels. The driver, receiver, and voltage-generator functions are available as cells in the Texas Instruments LinASIC™ library.

ORDERING INFORMATION

<table>
<thead>
<tr>
<th>T_A</th>
<th>PACKAGE1</th>
<th>ORDERABLE PART NUMBER</th>
<th>TOP-SIDE MARKING</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°C to 70°C</td>
<td>PDIP (N)</td>
<td>Tube of 25</td>
<td>MAX232N</td>
</tr>
<tr>
<td></td>
<td>SOIC (D)</td>
<td>Tube of 40</td>
<td>MAX232D</td>
</tr>
<tr>
<td></td>
<td>SOIC (CW)</td>
<td>Tube of 40</td>
<td>MAX232DW</td>
</tr>
<tr>
<td></td>
<td>SCP (NS)</td>
<td>Tube of 2000</td>
<td>MAX232NSR</td>
</tr>
<tr>
<td>-40°C to 85°C</td>
<td>PDIP (N)</td>
<td>Tube of 25</td>
<td>MAX232IN</td>
</tr>
<tr>
<td></td>
<td>SOIC (D)</td>
<td>Tube of 40</td>
<td>MAX232IN</td>
</tr>
<tr>
<td></td>
<td>SOIC (CW)</td>
<td>Tube of 40</td>
<td>MAX232IDW</td>
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</tbody>
</table>

1 Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

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### Function Tables

#### EACH DRIVER

<table>
<thead>
<tr>
<th>INPUT TIN</th>
<th>OUTPUT TOUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
</tr>
</tbody>
</table>

*H* = high level, *L* = low level

#### EACH RECEIVER

<table>
<thead>
<tr>
<th>INPUT RIN</th>
<th>OUTPUT ROUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
</tr>
</tbody>
</table>

*H* = high level, *L* = low level

---

**logic diagram (positive logic)**

```
T1IN  11       14  T1OUT
      |           |
      V         V
T2IN  10       13  R1IN
      |           |
      V         V
R1OUT 12       13  R1IN
               |
               V
R2OUT  9        8  R2IN
```
APPLICATION INFORMATION

† C3 can be connected to VCC or GND.

NOTES:
A. Resistor values shown are nominal.
B. Nonpolarized ceramic capacitors are acceptable. If polarized tantalum or electrolytic capacitors are used, they should be connected as shown. In addition to the 1-µF capacitors shown, the MAX202 can operate with 0.1-µF capacitors.

Figure 4. Typical Operating Circuit
ANNOUNCED SPECIFICATION OF HS-422 STANDARD DELUXE SERVO

1. TECHNICAL VALUES
   - CONTROL SYSTEM: +PULSE WIDTH CONTROL 1500usec NEUTRAL
   - OPERATING VOLTAGE RANGE: 4.8V TO 6.0V
   - OPERATING TEMPERATURE RANGE: -20 TO +60°C
   - TEST VOLTAGE: AT 4.8V AT 6.0V
   - STALL TORQUE: 0.21sec/60° AT NO LOAD 0.16sec/60° AT NO LOAD
   - OPERATING SPEED: 3.3kg.cm(45.82oz.in) 4.1kg.cm(56.53oz.in)
   - OPERATING ANGLE: 45° ONE SIDE PULSE TRAVELING 400usec
   - DIRECTION: CLOCK WISE/PULSE TRAVELING 1500 TO 1900usec
   - CURRENT DRAIN: 8mA IDLE AND 150mA NO LOAD RUNNING
   - DEAD BAND WIDTH
   - CONNECTOR WIRE LENGTH
   - DIMENSIONS: 40.6x19.8x36.6mm(1.59x0.77x1.44in)
   - WEIGHT: 45.5g(1.6oz)

2. FEATURES
   - 3-POLE FERRITE MOTOR
   - LONG LIFE POTENTIOMETER
   - DUAL OILITE BUSHING
   - INDIRECT POTENTIOMETER DRIVE

3. APPLICATIONS
   - AIRCRAFT 20-60 SIZE
   - 30 SIZE HELICOPTERS
   - STEERING AND THROTTLE SERVO FOR CARS
   - TRUCK AND BOATS