AN520

C-CODE EXAMPLE FOR MS56XX, MS57XX (EXCEPT ANALOG SENSOR), AND MS58XX SERIES PRESSURE SENSORS APPLICATION NOTE

INTRODUCTION

This application note describes the communication between a microcontroller and MEAS Switzerland's MS56XX, MS57xx and MS58xx pressure sensor modules series using SPI and I²C protocol. In these code examples we explain: microcontroller initialization, commands construction and calculation of pressure and temperature from the obtained data. For more information on specific pressure and temperature algorithm please refer to the specific sensor datasheet.
The code in these examples is developed for the ATMEL ATmega644p microcontroller. The compiler used is gcc from the WinAVR 20080610 bundle available freely on the Internet. All examples presented here can be implemented on any microcontroller with hardware implementation of the SPI and I²C protocol.

SPI PROTOCOL C-CODE EXAMPLE

Figure below shows an easy way to use sensors with the SPI bus. Please note a minimum of 100nF decoupling capacitor for the sensor and the PS pin (protocol select) connected to ground that defines the usage of the SPI protocol.

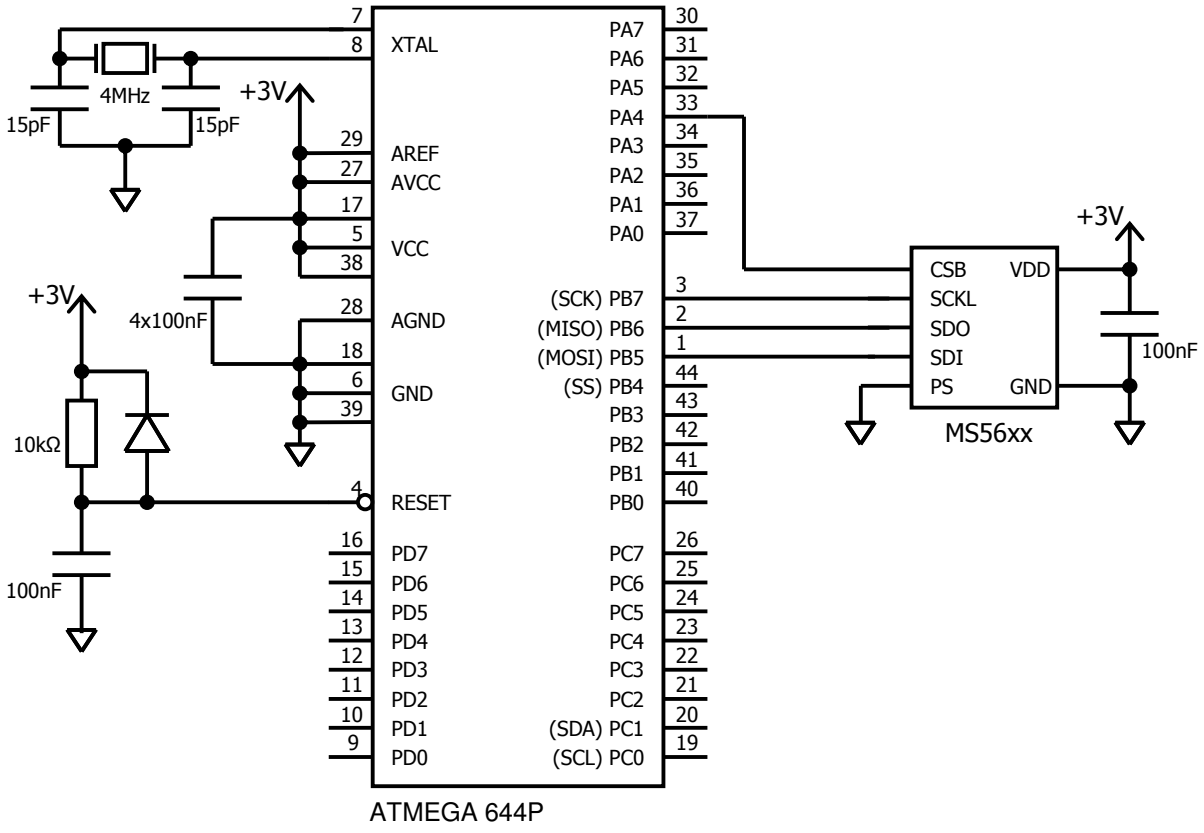

Figure 1: Circuit diagram of the hardware used for the SPI C-code testing

```
//!
//! @file an520_SPI.c,v
//!
//! Copyright (c) 2009 MEAS Switzerland
//!
//!
//!
//! @brief This C code is for starter reference only. It is written for the
//! MEAS Switzerland  MS56xx pressure sensor modules and Atmel Atmega644p
//! microcontroller.
//!
//! @version 1.0 $Id: an520_SPI.c,v 1.0
//!
//! @todo

//_____ M A C R O S

#define TRUE 1
#define FALSE 0

#define F_CPU 4000000UL  // 4 MHz XTAL

#define CMD_RESET        0x1E     // ADC reset command
#define CMD_ADC_READ 0x00     // ADC read command
#define CMD_ADC_CONV 0x40     // ADC conversion command
#define CMD_ADC_D1   0x00        // ADC D1 conversion
#define CMD_ADC_D2   0x10        // ADC D2 conversion
#define CMD_ADC_256  0x00        // ADC OSR=256
#define CMD_ADC_512  0x02        // ADC OSR=512
#define CMD_ADC_1024 0x04        // ADC OSR=1024
#define CMD_ADC_2048 0x06        // ADC OSR=2056
#define CMD_ADC_4096 0x08        // ADC OSR=4096
#define CMD_PROM_RD  0xA0     // Prom read command

#define csb_hi() (_SFR_BYTE(PORTA) &= ~_BV(3))  // setting CSB low
#define csb_lo() (_SFR_BYTE(PORTA) |=  _BV(3))  // setting CSB high


//_____ I N C L U D E S

#include <stdio.h>
#include <util/delay.h>
#include <avr/io.h>
#include <math.h>

//_____ D E F I N I T I O N S

void spi_send(char cmd);
void cmd_reset(void);
unsigned long cmd_adc(char cmd);
unsigned int cmd_prom(char coef_num);
unsigned char crc4(unsigned int n_prom[]);

//*************************************************************
//! @brief send 8 bit using SPI hardware interface
//!
//! @return 0
//*************************************************************
void spi_send(char cmd)
{
                        SPDR= cmd;       // put the byte in the SPI hardware buffer and start sending
```

```
                while (bit_is_clear(SPSR, 7));      // wait that the data is sent
}

//***************************************************
//! @brief send reset sequence
//!
//! @return 0
//***************************************************

void cmd_reset(void)
{
        csb_lo();                       // pull CSB low to start the command
        spi_send(CMD_RESET);    // send reset sequence
        _delay_ms(3);                           // wait for the reset sequence timing
        csb_hi();                       // pull CSB high to finish the command
}

//***************************************************
//! @brief preform adc conversion
//!
//! @return 24bit result
//***************************************************
unsigned long cmd_adc(char cmd)
{
        unsigned int ret;
        unsigned long temp=0;
        csb_lo();                                               // pull CSB low
        spi_send(CMD_ADC_CONV+cmd);                     // send conversion command
        switch (cmd & 0x0f)                                             // wait necessary conversion time
        {
                case CMD_ADC_256 : _delay_us(900); break;
                case CMD_ADC_512 : _delay_ms(3);   break;
                case CMD_ADC_1024: _delay_ms(4);   break;
                case CMD_ADC_2048: _delay_ms(6);   break;
                case CMD_ADC_4096: _delay_ms(10);  break;
        }

        csb_hi();                                       // pull CSB high to finish the conversion
        csb_lo();                                       // pull CSB low to start new command
        spi_send(CMD_ADC_READ);                                 // send ADC read command
        spi_send(0x00);                         // send 0 to read 1st byte (MSB)
        ret=SPDR;
        temp=65536*ret;
        spi_send(0x00);                         // send 0 to read 2nd byte
        ret=SPDR;
        temp=temp+256*ret;
        spi_send(0x00);                         // send 0 to read 3rd byte (LSB)
        ret=SPDR;
        temp=temp+ret;
        csb_hi();                                       // pull CSB high to finish the read command
        return temp;
}

//***************************************************
//! @brief Read calibration coefficients
//!
//! @return coefficient
//***************************************************
```

```
unsigned int cmd_prom(char coef_num)
{
        unsigned int ret;
        unsigned int rC=0;

        csb_lo();                                       // pull CSB low
        spi_send(CMD_PROM_RD+coef_num*2);               // send PROM READ command
        spi_send(0x00);                                 // send 0 to read the MSB
        ret=SPDR;
        rC=256*ret;
        spi_send(0x00);                                 // send 0 to read the LSB
        ret=SPDR;
        rC=rC+ret;
        csb_hi();                                       // pull CSB high
        return rC;
}

//************************************************************
//! @brief calculate the CRC code for details look into CRC CODE NOTES
//!
//! @return crc code
//************************************************************

unsigned char crc4(unsigned int n_prom[])
{
        int cnt;                                                // simple counter
        unsigned int n_rem;                                             // crc reminder
        unsigned int crc_read;                                  // original value of the crc
        unsigned char  n_bit;
        n_rem = 0x00;
        crc_read=n_prom[7];                                             //save read CRC
        n_prom[7]=(0xFF00 & (n_prom[7]));                       //CRC byte is replaced by 0
        for (cnt = 0; cnt < 16; cnt++)                  // operation is performed on bytes
        {           // choose LSB or MSB
                if (cnt%2==1) n_rem ^= (unsigned short) ((n_prom[cnt>>1]) & 0x00FF);
                else n_rem ^= (unsigned short) (n_prom[cnt>>1]>>8);
        for (n_bit = 8; n_bit > 0; n_bit--)
        {
                if (n_rem & (0x8000))
                {
                   n_rem = (n_rem << 1) ^ 0x3000;
                }
                else
                {
                   n_rem = (n_rem << 1);
                }
        }
        }
        n_rem=  (0x000F & (n_rem >> 12)); // // final 4-bit reminder is CRC code
        n_prom[7]=crc_read;                             // restore the crc_read to its original place
        return (n_rem ^ 0x00);
}


//************************************************************
//! @brief main program
//!
//! @return 0
//************************************************************
```

```
int main (void)
{

        unsigned long D1;               // ADC value of the pressure conversion
        unsigned long D2;               // ADC value of the temperature conversion
        unsigned int C[8];              // calibration coefficients
        double P;                       // compensated pressure value
        double T;                       // compensated temperature value
        double dT;                      // difference between actual and measured temperature
        double OFF;                     // offset at actual temperature
        double SENS;                    // sensitivity at actual temperature

        int i;
        unsigned char n_crc;        // crc value of the prom

        DDRA = 0xFE;                    // prepare the port A
        DDRB = 0xBF;                    // SDO input
        DDRC = 0x00;                    // I2C pins as input
        DDRD = 0x82;                // prepare the port D, RX out and TX out;
        PORTA= 0x10;
        PORTD= 0x20;

        //SPI settings:master, mode 0, fosc/4
        SPCR=(1<<SPE)|(1<<MSTR);
        //alternative SPI settings: master, mode 3, fosc/4
        //SPCR=(1<<SPE)|(1<<MSTR)|(1<<CPOL)|(1<<CPHA);

        cmd_reset();                                    // reset the module after powerup
        for (i=0;i<8;i++){ C[i]=cmd_prom(i);}       // read calibration coefficients
        n_crc=crc4(C);

        while(TRUE)                     // loop without stopping
        {


                D1=cmd_adc(CMD_ADC_D1+CMD_ADC_256);     // read uncompensated pressure
                D2=cmd_adc(CMD_ADC_D2+CMD_ADC_4096);    // read uncompensated temperature

                // calcualte 1st order pressure and temperature (MS5607 1st order algorithm)
                dT=D2-C[5]*pow(2,8);
                OFF=C[2]*pow(2,17)+dT*C[4]/pow(2,6);
                SENS=C[1]*pow(2,16)+dT*C[3]/pow(2,7);

                T=(2000+(dT*C[6])/pow(2,23))/100;
                P=(((D1*SENS)/pow(2,21)-OFF)/pow(2,15))/100;

                // place to use P, T, put them on LCD, send them trough RS232 interface...
        }

   return 0;
}
```

I2C PROTOCOL C-CODE EXAMPLE

Figure below shows an easy way to use sensors with the I2C bus. Please note a minimum of 100nF decoupling capacitor for the sensor and the PS pin (protocol select) connected to VDD that defines the usage of the I2C protocol. In this example the CSB is connected to ground which defines the I2C address to 0xEE.

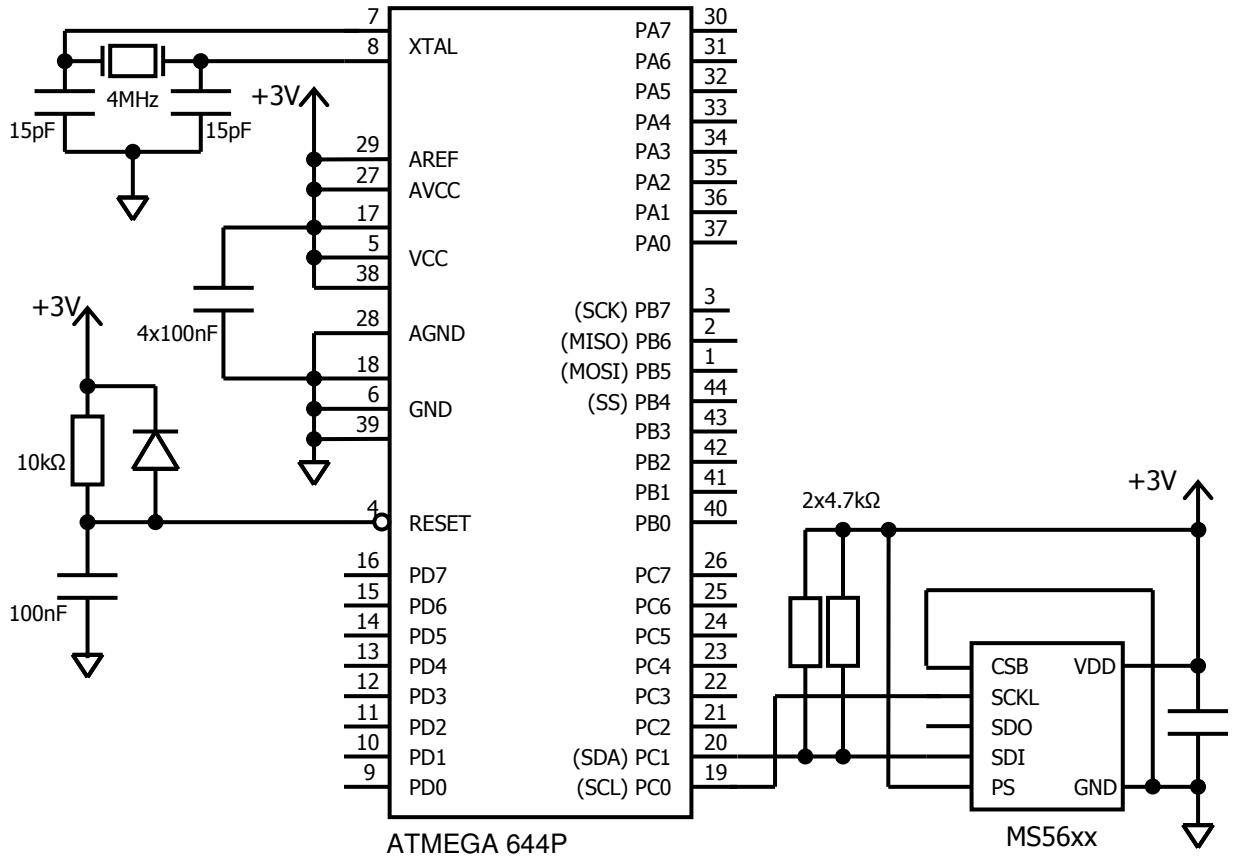

Figure 2: Circuit diagram of the hardware used for the I2C C-code testing

```
//!
//! @file an520_I2C.c,v
//!
//! Copyright (c) 2009 MEAS Switzerland
//!
//!
//!
//! @brief This C code is for starter reference only. It is written for the
//! MEAS Switzerland  MS56xx pressure sensor modules and Atmel Atmega644p
//! microcontroller.
//!
//! @version 1.0 $Id: an520_I2C.c,v 1.0
//!
//! @todo
```

```
//_____ M A C R O S


#define TRUE 1
#define FALSE 0

#define F_CPU    4000000UL          // 4 MHz external XTAL
#define SCL_CLOCK        100000L              // I2C clock in Hz
#define ADDR_W      0xEE             // Module address write mode
#define ADDR_R 0xEF                  // Module address read mode

#define CMD_RESET        0x1E                // ADC reset command
#define CMD_ADC_READ 0x00                    // ADC read command
#define CMD_ADC_CONV 0x40                    // ADC conversion command
#define CMD_ADC_D1   0x00          // ADC D1 conversion
#define CMD_ADC_D2   0x10          // ADC D2 conversion
#define CMD_ADC_256  0x00          // ADC OSR=256
#define CMD_ADC_512  0x02          // ADC OSR=512
#define CMD_ADC_1024 0x04          // ADC OSR=1024
#define CMD_ADC_2048 0x06          // ADC OSR=2048
#define CMD_ADC_4096 0x08          // ADC OSR=4096
#define CMD_PROM_RD  0xA0                    // Prom read command



//_____ I N C L U D E S

#include <stdio.h>
#include <util/delay.h>
#include <util/twi.h>
#include <avr/io.h>
#include <math.h>


//_____ D E F I N I T I O N S

unsigned char i2c_start(unsigned char address);
void i2c_stop(void);
unsigned char i2c_write( unsigned char data );
unsigned char i2c_readAck(void);
unsigned char i2c_readNak(void);
void cmd_reset(void);
unsigned long cmd_adc(char cmd);
unsigned int cmd_prom(char coef_num);
unsigned char crc4(unsigned int n_prom[]);

//*************************************************************
//! @brief send I2C start condition and the address byte
//!
//! @return 0
//*************************************************************
unsigned char i2c_start(unsigned char address)
{
        unsigned char   twst;

        TWCR = (1<<TWINT) | (1<<TWSTA) | (1<<TWEN); // send START condition
        while(!(TWCR & (1<<TWINT)));                    // wait until transmission completed
        twst = TW_STATUS & 0xF8;// check value of TWI Status Register. Mask prescaler bits.
        if ( (twst != TW_START) && (twst != TW_REP_START)) return 1;
        TWDR = address;                                 // send device address
        TWCR = (1<<TWINT) | (1<<TWEN);
        // wait until transmission completed and ACK/NACK has been received
```

```
        while(!(TWCR & (1<<TWINT)));
        twst = TW_STATUS & 0xF8;
        // check value of TWI Status Register. Mask prescaler bits.
        if ( (twst != TW_MT_SLA_ACK) && (twst != TW_MR_SLA_ACK) ) return 1;
        return 0;
}

//*************************************************************
//! @brief send I2C stop condition
//!
//! @return none
//*************************************************************
void i2c_stop(void)
{
        /* send stop condition */
        TWCR = (1<<TWINT) | (1<<TWEN) | (1<<TWSTO);
        // wait until stop condition is executed and bus released
        while(TWCR & (1<<TWSTO)); //THIS MAKES PROBLEM FOR IS2402

}

//*************************************************************
//! @brief send I2C stop condition
//!
//! @return 0
//*************************************************************
unsigned char i2c_write(unsigned char data)
{
        unsigned char   twst;
        TWDR = data; // send data to the previously addressed device
        TWCR = (1<<TWINT) | (1<<TWEN);
        while(!(TWCR & (1<<TWINT))); // wait until transmission completed
        twst = TW_STATUS & 0xF8; // check value of TWI Status Register. Mask prescaler bits
        if( twst != TW_MT_DATA_ACK) return 1;
        return 0;
}

//*************************************************************
//! @brief read I2C byte with acknowledgment
//!
//! @return read byte
//*************************************************************
unsigned char i2c_readAck(void)
{
        TWCR = (1<<TWINT) | (1<<TWEN) | (1<<TWEA);
while(!(TWCR & (1<<TWINT)));
        return TWDR;
}

//*************************************************************
//! @brief read I2C byte without acknowledgment
//!
//! @return read byte
//*************************************************************
unsigned char i2c_readNak(void)
{
        TWCR = (1<<TWINT) | (1<<TWEN);
        while(!(TWCR & (1<<TWINT)));
        return TWDR;
}

//*************************************************************
```

```
//! @brief send command using I2C hardware interface
//!
//! @return none
//*********************************************************
void i2c_send(char cmd)
{
        unsigned char ret;

        ret = i2c_start(ADDR_W); // set device address and write mode
        if ( ret )
        {//failed to issue start condition, possibly no device found */
        i2c_stop();
        }
        else
        {// issuing start condition ok, device accessible
        ret=i2c_write(cmd);
                i2c_stop();
        }
}

//*********************************************************
//! @brief send reset sequence
//!
//! @return none
//*********************************************************
void cmd_reset(void)
{
        i2c_send(CMD_RESET);                    // send reset sequence
        _delay_ms(3);                                   // wait for the reset sequence timing
}

//*********************************************************
//! @brief preform adc conversion
//!
//! @return 24bit result
//*********************************************************
unsigned long cmd_adc(char cmd)
{
        unsigned int ret;
        unsigned long temp=0;

        i2c_send(CMD_ADC_CONV+cmd);                     // send conversion command
        switch (cmd & 0x0f)                                     // wait necessary conversion time
        {
                case CMD_ADC_256 : _delay_us(900); break;
                case CMD_ADC_512 : _delay_ms(3);   break;
                case CMD_ADC_1024: _delay_ms(4);   break;
                case CMD_ADC_2048: _delay_ms(6);   break;
                case CMD_ADC_4096: _delay_ms(10);  break;
        }
        i2c_send(CMD_ADC_READ);
        ret = i2c_start(ADDR_R);                        // set device address and read mode
        if ( ret )
        {//failed to issue start condition, possibly no device found
        i2c_stop();
        }
        else
        {//issuing start condition ok, device accessible
                ret = i2c_readAck();                    // read MSB and acknowledge
                temp=65536*ret;
```

```
                ret = i2c_readAck();                    // read byte and acknowledge
        temp=temp+256*ret;
                ret = i2c_readNak();                    // read LSB and not acknowledge
                temp=temp+ret;
                i2c_stop();                                     // send stop condition
        }
        return temp;
}



//*******************************************************
//! @brief Read calibration coefficients
//!
//! @return coefficient
//*******************************************************
unsigned int cmd_prom(char coef_num)
{
        unsigned int ret;
        unsigned int rC=0;

        i2c_send(CMD_PROM_RD+coef_num*2);       // send PROM READ command
        ret = i2c_start(ADDR_R);                // set device address and read mode
        if ( ret )
        {//failed to issue start condition, possibly no device found
        i2c_stop();
        }
        else
        {//issuing start condition ok, device accessible
                ret = i2c_readAck();            // read MSB and acknowledge
        rC=256*ret;
                ret = i2c_readNak();            // read LSB and not acknowledge
                rC=rC+ret;
                i2c_stop();
        }
        return rC;
}

//*******************************************************
//! @brief calculate the CRC code
//!
//! @return crc code
//*******************************************************
unsigned char crc4(unsigned int n_prom[])
{
        int cnt;                                // simple counter
        unsigned int n_rem;                     // crc reminder
        unsigned int crc_read;                  // original value of the crc
        unsigned char  n_bit;
        n_rem = 0x00;
        crc_read=n_prom[7];                     //save read CRC
        n_prom[7]=(0xFF00 & (n_prom[7]));       //CRC byte is replaced by 0
        for (cnt = 0; cnt < 16; cnt++)          // operation is performed on bytes
        {// choose LSB or MSB
if (cnt%2==1) n_rem ^= (unsigned short) ((n_prom[cnt>>1]) & 0x00FF);
                else n_rem ^= (unsigned short) (n_prom[cnt>>1]>>8);
        for (n_bit = 8; n_bit > 0; n_bit--)
        {
   if (n_rem & (0x8000))
             {
                n_rem = (n_rem << 1) ^ 0x3000;
```

```
                }
                else
                {
                        n_rem = (n_rem << 1);
                }
        }
        }
        n_rem=  (0x000F & (n_rem >> 12));           // final 4-bit reminder is CRC code
        n_prom[7]=crc_read;                         // restore the crc_read to its original place
        return (n_rem ^ 0x0);
}

//************************************************************
//! @brief main program
//!
//! @return 0
//************************************************************
int main (void)
{
        unsigned long D1;                   // ADC value of the pressure conversion
        unsigned long D2;                   // ADC value of the temperature conversion
        unsigned int C[8];                  // calibration coefficients
        double P;                           // compensated pressure value
        double T;                           // compensated temperature value
        double dT;                          // difference between actual and measured temperature
        double OFF;                         // offset at actual temperature
        double SENS;                        // sensitivity at actual temperature
        int i;
        unsigned char n_crc;        // crc value of the prom

        // setup the ports
        DDRA  = 0xFE;
        DDRB  = 0x0F;               //SPI pins as input
        DDRC  = 0x03;               // I2C pins as output
        DDRD  = 0x82;               // RS out and tx out;

        PORTA = 0x1F;               // I2C pin high
        PORTB = 0xF0;
        PORTC = 0x01;
        PORTD = 0x00;

        // initialize the I2C hardware module
        TWSR = 0;                   // no prescaler
        TWBR = ((F_CPU/SCL_CLOCK)-16)/2;        // set the I2C speed

        D1=0;
        D2=0;
        cmd_reset();                                            // reset IC
        for (i=0;i<8;i++){ C[i]=cmd_prom(i);} // read coefficients
        n_crc=crc4(C);                                  // calculate the CRC
        for(;;)                                         // loop without stopping
        {
                D2=cmd_adc(CMD_ADC_D2+CMD_ADC_4096);        // read D2
                D1=cmd_adc(CMD_ADC_D1+CMD_ADC_4096);        // read D1

                // calcualte 1st order pressure and temperature (MS5607 1st order algorithm)
                dT=D2-C[5]*pow(2,8);
                OFF=C[2]*pow(2,17)+dT*C[4]/pow(2,6);
                SENS=C[1]*pow(2,16)+dT*C[3]/pow(2,7);

                T=(2000+(dT*C[6])/pow(2,23))/100;
                P=(((D1*SENS)/pow(2,21)-OFF)/pow(2,15))/100;
```

```
                    // place to use P, T, put them on LCD, send them trough RS232 interface...
            }


    return 0;
}
```

CRC CODE NOTES

The CRC code is calculated and written in factory with the LSB byte in the prom n_prom[7] set to 0x00 (see Coefficient table below). It is thus important to clear those bytes from the calculation buffer before proceeding with the CRC calculation itself:

```
n_prom[7]=(0xFF00 & (n_prom[7]));          //CRC byte is replaced by 0
```

As a simple test of the CRC code, the following coefficient table could be used:

```
unsigned int nprom[] = {0x3132,0x3334,0x3536,0x3738,0x3940,0x4142,0x4344,0x4500};
```

the resulting calculated CRC should be 0xB.

Add	DB15	DB14	DB13	DB12	DB11	DB10	DB9	DB8	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	16 bit reserved for manufacturer															
1	Coefficient 1 (16 bit unsigned)															
2	Coefficient 2 (16 bit unsigned)															
3	Coefficient 3 (16 bit unsigned)															
4	Coefficient 4 (16 bit unsigned)															
5	Coefficient 5 (16 bit unsigned)															
6	Coefficient 6 (16 bit unsigned)															
7									0	0	0	0	CRC (0x0)			

Table 1: Memory PROM mapping

REVISION HISTORY

Date	Revision	Type of changes
18.06.2009	000	Initial document
12.01.2010	001	Change to MEAS logo and layout; addition of CRC code notes
22.03.2011	002	Modification of the title, addition of: “MS57xx except analog sensor MS58xx series” Some characters were put in bold for more readability
20.06.2011	003	Insertion of the mention TM in the logo, modification of Shenzhen zip code
09.08.2011	004	Modification of the title from "AN520 C-code example for MS56xx, MS57xx except analog sensor and MS58xx series pressure sensors" to "AN520 C-code example for MS56xx, MS57xx (except analog sensor), and MS58xx series pressure sensors". Page 6, change picture in figure 2, one resistor on SDA and one on SCL. Page 7, change “ADDR_W 0xEF” in “ADDR_W 0xEE”

NORTH AMERICA
Measurement Specialties,
a TE Connectivity Company
45738 Northport Loop West
Fremont, CA 94538
Tel: 1-800-767-1888
Fax: 1-510-498-1578
Sales: customercare.frmt@te.com

EUROPE
MEAS Switzerland Sàrl
a TE Connectivity Company
Ch. Chapons-des-Prés 11
CH-2022 Bevaix
Tel: +41 32 847 9550
Fax: + 41 32 847 9569
Sales: customercare.bevx@te.com

ASIA
Measurement Specialties (China), Ltd.,
a TE Connectivity Company
No. 26 Langshan Road
Shenzhen High-Tech Park (North)
Nanshan District, Shenzhen 518057
China
Tel: +86 755 3330 5088
Fax: +86 755 3330 5099
Sales: customercare.shzn@te.com

te.com/sensorsolutions

ECN1531