AN512

Implementing Ohmmeter/Temperature Sensor

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INTRODUCTION

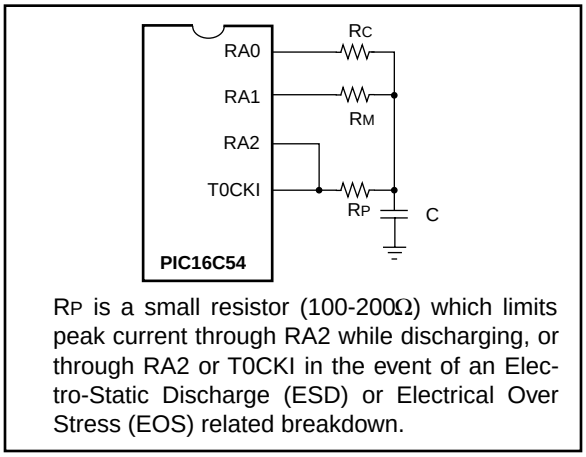
This application note describes a method for implementing an ohmmeter or resistance type temperature sensor using the PIC16C5X series of microcontrollers. The ohmmeter requires only two external components and is software and hardware configurable for resistance measurement with resolutions from 6-bits to 10-bits with measurement times of 250 µs (6-bits at 8 MHz) or longer. This method uses a software calibration technique that compensates for voltage, time, and temperature drift as well as component errors. PIC16C5X microcontrollers are ideal for simple analog applications because:

- Very low cost
- Few external components required
- Fully programmable. PIC16C5X Microcontrollers are offered as One Time Programmable (OTP) EPROM devices.
- Available off the shelf from distributors
- Calibration in software for improved measurement accuracy
- Power savings using PIC16C5X's Sleep mode.
- PIC16C5X's output pins have large, current source/sink capability to drive LED's directly.

THEORY OF OPERATION

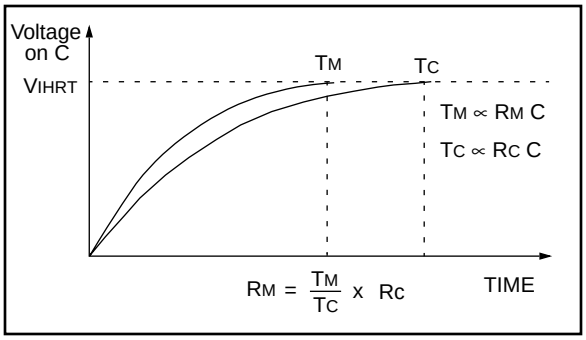
This application uses a capacitive charging circuit (Figure 1) to convert resistance to time, which can be easily measured using a microcontroller. First, a reference voltage (usually V_{DD}) is applied to a calibration resistor, Rc. The capacitor C is charged up until the threshold on the chip input trips. This generates a software calibration value that is used to calibrate out most circuit errors, including inaccuracies in the capacitor, changes in the input threshold voltage and temperature variations. After C is discharged, the reference voltage is applied to the resistance to be measured (or thermistor). The time to trip the threshold is then measured and compared to the calibration value to determine the actual resistance (Figure 2). In the temperature sensing mode, the temperature is calculated using a lookup table.

FIGURE 1: OHMMETER/TEMPERATURE SENSOR



R_P is a small resistor (100-200Ω) which limits peak current through RA2 while discharging, or through RA2 or T0CKI in the event of an Electro-Static Discharge (ESD) or Electrical Over Stress (EOS) related breakdown.

FIGURE 2: OHMMETER/TEMPERATURE SENSOR



CIRCUIT CONFIGURATION

The values of Rc and C are selected based upon the number of bits of resolution required. Rc should be approximately one half the largest value resistance to be measured and:

$$C = \frac{-T}{R_M \bullet IN\left(1 - \frac{V_T}{V_R}\right)}$$

Where:

V_R = Reference voltage
T = Time to do the number of bits of resolution desired
V_T = Threshold voltage of the PIC16C5X input being used
R_M = Maximum resistance value to be measured

Actual value for C should be slightly smaller than calculated to ensure that the PIC16C5X does not overcount during the measurement.

For example use R_M = 200k for 8-bit resolution with an 8 MHz clock, V_R = 5V, V_T = 3V, Rc = 100k and 6 instruction cycles per count:

T = 256 counts • 1/8 MHz • 4 clocks/instruction • 6 instructions/count = 768 µs
C = 4200 pF [Use 3900 pF]

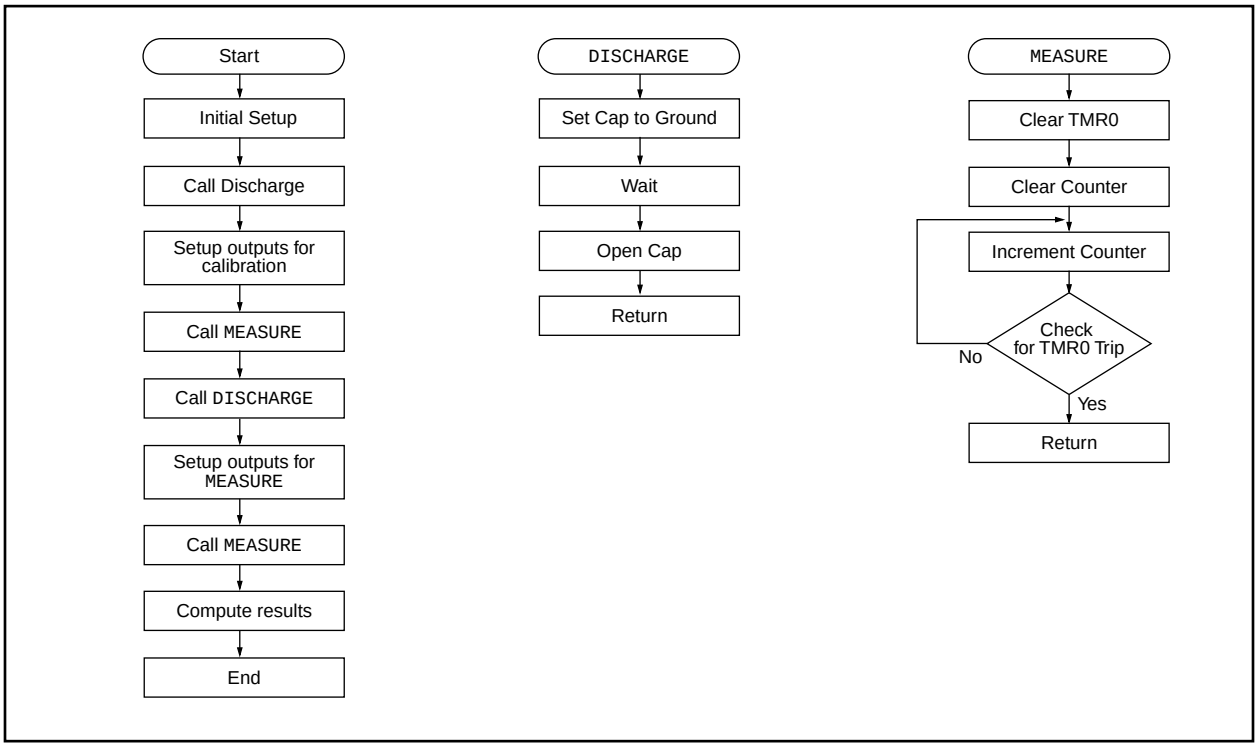
CIRCUIT PERFORMANCE

The calibration cycle removes all first order errors (offset, gain, C inaccuracy, power supply voltage and temperature) except R absolute accuracy. A low drift resistor should be selected for R and its value stored in software to reduce measurement errors. Other error sources are I/O pin leakage, resistor and capacitor non-linearities, input threshold uncertainty, and time measurement uncertainty (± one instruction cycle time). Measured performance shows the ohmmeter to be accurate within ±1% over one decade.

Example

The assembly code implementing the circuit of Figure 1 is listed in Appendix A. This code measures time up to 16-bits (65535 measure cycles) and calculates the results using 16-bit multiply and divide subroutines. In actual applications, it is more efficient to use 8-bit measurements if application accuracies permit. The math code will be substantially reduced and measurement time is reduced by the simpler code and shorter count.

FIGURE 3: TRANSMISSION FLOWCHART



Please check the Microchip BBS for the latest version of the source code. Microchip's Worldwide Web Address: www.microchip.com; Bulletin Board Support: MCHIPBBS using CompuServe® (CompuServe membership not required).

APPENDIX A: OHMETER SOURCE CODE

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MPASM 01.40 Released          OHMETER.ASM   1-16-1997  12:31:45         PAGE  1


LOC  OBJECT CODE     LINE SOURCE TEXT
  VALUE

                     00001         TITLE  'OHMETER/TEMPERATURE SENSING PROGRAM REV 3-29-90'
                     00002         LIST   P=16C54
                     00003 ;
                     00004 ;*****************************************************************
                     00005 ;
                     00006 ;       Program:          OHMETER.ASM
                     00007 ;       Revision Date:
                     00008 ;                         1-13-97      Compatibility with MPASMWIN 1.40
                     00009 ;
                     00010 ;*****************************************************************
                     00011 ;
  00000008           00012 ACCA    EQU     8
  0000000A           00013 ACCB    EQU     0A
  0000000C           00014 ACCC    EQU     0C
  0000000E           00015 ACCD    EQU     0E
  00000010           00016 ACCE    EQU     10
  00000012           00017 TCAL    EQU     12
  00000014           00018 TEMP    EQU     14
                     00019 ;
  00000001           00020 F       EQU     1
                     00021 ;
  0000002F           00022 RCALMS  EQU     2F            ;RCAL MSB VALUE IN HEX
  0000003C           00023 RCALLS  EQU     3C            ;RCAL LSB VALUE IN HEX
                     00024
01FF                 00025         ORG     1FF
01FF 0A58            00026         GOTO    OHMS
0000                 00027         ORG     0
                     00028
0000 0209            00029 MADD    MOVF    ACCA+1,W
0001 01EB            00030         ADDWF   ACCB+1, F     ;ADD LSB
0002 0603            00031         BTFSC   3,0           ;ADD IN CARRY
0003 02AA            00032         INCF    ACCB, F
0004 0208            00033         MOVF    ACCA,W
0005 01EA            00034         ADDWF   ACCB, F       ;ADD MSB
0006 0800            00035         RETLW   0
0007 0000            00036         NOP
                     00037
0008 0915            00038 MPY     CALL    SETUP         ;RESULTS IN B(16 MSB'S) AND C(16 LSB'S)
0009 032E            00039 MLOOP   RRF     ACCD, F       ;ROTATE D RIGHT
000A 032F            00040         RRF     ACCD+1, F
000B 0603            00041         SKPNC                 ;NEED TO ADD?
000C 0900            00042         CALL    MADD
000D 032A            00043         RRF     ACCB, F
000E 032B            00044         RRF     ACCB+1, F
000F 032C            00045         RRF     ACCC, F
0010 032D            00046         RRF     ACCC+1, F
0011 02F4            00047         DECFSZ  TEMP, F       ;LOOP UNTIL ALL BITS CHECKED
0012 0A09            00048         GOTO    MLOOP
0013 0800            00049         RETLW   0
                     00050
0014 0000            00051         NOP
0015 0C10            00052 SETUP   MOVLW   10
0016 0034            00053         MOVWF   TEMP
0017 020A            00054         MOVF    ACCB,W        ;MOVE B TO D
0018 002E            00055         MOVWF   ACCD
```

```
0019 020B          00056        MOVF    ACCB+1,W
001A 002F          00057        MOVWF   ACCD+1
001B 020C          00058        MOVF    ACCC,W
001C 0030          00059        MOVWF   ACCE
001D 020D          00060        MOVF    ACCC+1,W
001E 0031          00061        MOVWF   ACCE+1
001F 006A          00062        CLRF    ACCB
0020 006B          00063        CLRF    ACCB+1
0021 0800          00064        RETLW   0
                   00065
0022 0000          00066        NOP
0023 0915          00067 DIV    CALL    SETUP
0024 0C20          00068        MOVLW   20
0025 0034          00069        MOVWF   TEMP
0026 006C          00070        CLRF    ACCC
0027 006D          00071        CLRF    ACCC+1
0028 0403          00072 DLOOP  CLRC
0029 0371          00073        RLF     ACCE+1, F
002A 0370          00074        RLF     ACCE, f
002B 036F          00075        RLF     ACCD+1, F
002C 036E          00076        RLF     ACCD, F
002D 036D          00077        RLF     ACCC+1, F
002E 036C          00078        RLF     ACCC, F
002F 0208          00079        MOVF    ACCA,W
0030 008C          00080        SUBWF   ACCC,W        ;CHECK IF A>C
0031 0743          00081        SKPZ
0032 0A35          00082        GOTO    NOCHK
0033 0209          00083        MOVF    ACCA+1,W
0034 008D          00084        SUBWF   ACCC+1,W      ;IF MSB EQUAL THEN CHECK LSB
0035 0703          00085 NOCHK  SKPC                  ;CARRY SET IF C>A
0036 0A3E          00086        GOTO    NOGO
0037 0209          00087        MOVF    ACCA+1,W      ;C-A INTO C
0038 00AD          00088        SUBWF   ACCC+1, F
0039 0703          00089        BTFSS   3,0
003A 00EC          00090        DECF    ACCC, F
003B 0208          00091        MOVF    ACCA,W
003C 00AC          00092        SUBWF   ACCC, F
003D 0503          00093        SETC                  ;SHIFT A 1 INTO B (RESULT)
003E 036B          00094 NOGO   RLF     ACCB+1, F
003F 036A          00095        RLF     ACCB, F
0040 02F4          00096        DECFSZ  TEMP, F       ;LOOP UNTILL ALL BITS CHECKED
0041 0A28          00097        GOTO    DLOOP
0042 0800          00098        RETLW   0
                   00099
0043 0C0B          00100 DSCHRG MOVLW   B'00001011'   ;ACTIVATE RA2
0044 0005          00101        TRIS    5
0045 0CFF          00102        MOVLW   0FF
0046 0034          00103        MOVWF   TEMP
0047 02F4          00104 LOOP   DECFSZ  TEMP, F       ;WAIT
0048 0A47          00105        GOTO    LOOP
0049 0C0F          00106        MOVLW   B'00001111'   ;ALL OUTPUTS OFF
004A 0005          00107        TRIS    5
004B 0800          00108        RETLW   0
                   00109
004C 0061          00110 M_TIME CLRF    1             ;CLEAR TMR0
004D 0069          00111        CLRF    ACCA+1
004E 0068          00112        CLRF    ACCA
004F 03E9          00113 TLOOP  INCFSZ  ACCA+1, F
0050 0A54          00114        GOTO    ENDCHK
0051 03E8          00115        INCFSZ  ACCA, F
0052 0A54          00116        GOTO    ENDCHK
0053 0A56          00117        GOTO    END_M
0054 0701          00118 ENDCHK BTFSS   1,0           ;CHECK FOR TMR0 TRIP
0055 0A4F          00119        GOTO    TLOOP
0056 0201          00120 END_M  MOVF    1,W
0057 0800          00121        RETLW   0
```

```
                  00122
0058 0C03         00123 OHMS   MOVLW   B’00000011’   ;SET RA0 AND RA1 HIGH (ON WHEN ACTIVATED)
0059 0025         00124        MOVWF   5
005A 0C28         00125        MOVLW   B’00101000’   ;SELECT POSITIVE EDGE FOR TMR0
005B 0002         00126        OPTION
                  00127
005C 0943         00128 CAL    CALL    DSCHRG        ;DISCHARGE CAPACITOR
005D 0C0E         00129        MOVLW   B’00001110’   ;ACTIVATE RA0
005E 0005         00130        TRIS    5
005F 094C         00131        CALL    M_TIME        ;MEASURE TIME
0060 0209         00132        MOVF    ACCA+1,W
0061 0033         00133        MOVWF   TCAL+1        ;STORE LSB
0062 0208         00134        MOVF    ACCA,W
0063 0032         00135        MOVWF   TCAL          ;STORE MSB
                  00136
0064 0943         00137 MEAS   CALL    DSCHRG        ;DISCHARGE CAPACITOR
0065 0C0D         00138        MOVLW   B’00001101’   ;ACTIVATE RA1
0066 0005         00139        TRIS    5
0067 094C         00140        CALL    M_TIME        ;MEASURE TIME
                  00141
0068 0C3C         00142        MOVLW   RCALLS        ;CALIBRATION LSB VALUE
0069 002B         00143        MOVWF   ACCB+1
006A 0C2F         00144        MOVLW   RCALMS        ;CALIBRATION MSB VALUE
006B 002A         00145        MOVWF   ACCB
                  00146
006C 0908         00147        CALL    MPY           ;MULTIPLY ACCA(MEAS) * ACCB(RCAL)
006D 0213         00148        MOVF    TCAL+1,W
006E 0029         00149        MOVWF   ACCA+1
006F 0212         00150        MOVF    TCAL,W
0070 0028         00151        MOVWF   ACCA
                  00152
0071 0923         00153        CALL    DIV           ;DIVIDE ACCB(MEAS * R) BY ACCA(TCAL)
                  00154
0072 0A58         00155        GOTO OHMS
                  00156
                  00157        END

MEMORY USAGE MAP (‘X’ = Used,  ‘-’ = Unused)

0000 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
0040 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXX-------------
01C0 : ---------------- ---------------- ---------------- ---------------X

All other memory blocks unused.

Program Memory Words Used:   116
Program Memory Words Free:   396

Errors   :     0
Warnings :     0 reported,     0 suppressed
Messages :     0 reported,     0 suppressed
```

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