AN621

PIC14000 Calibration Parameters

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Caution:

When using a WINDOWED DEVICE, the calibration data will be lost if the device is erased. Care should be exercised to insure that factory calibration data is not lost. Microchip does not recommend using code protection in a windowed device.

Due to the photosensitivity of semiconductors, the analog peripherals may not function properly if the window protection label is not in place during device operation.

INTRODUCTION

This application note discusses the PIC14000 calibration constants and calibration procedures.

The PIC14000 has several analog peripherals. Like all CMOS circuitry the parametric values vary with process, temperature, voltage, and time.

The PIC14000 has been designed to minimize the effect of these variations. In addition, each device is calibrated at factory test by measuring several key parameters and storing these values into EPROM at specified locations.The customer's application program may access this data and use it to mathematically compensate for device variations.

Collectively, these data values are referred to as calibration constants. They are listed in Table 4-1 in the PIC14000 Data Sheet (DS40122A).

CALIBRATION DATA

The PIC14000 calibration constants are shown in Table 1.

TABLE 1: CALIBRATION CONSTANTS

Parameter	Symbol
A/D Slope reference ratio	KREF
Bandgap reference voltage	KBG
Temperature sensor voltage	VTHERM
Temperature sensor voltage slope	KTC
Internal oscillator frequency multiplier	FOSC
Watch Dog Timer (WDT) time-out	TWDT

Table 2 show an example of PIC14000 calibration constants and their locations.

The first four parameters in the table are in 32-bit floating point representation. Each parameter has an exponent byte, and three bytes of mantissa. (For information on floating point algorithms, refer to AN575.) The last two parameters are single-byte numbers.

TABLE 2: TYPICAL CALIBRATION CONSTANTS

Constant	Address	Value	Byte 1	Byte 2	Byte 3	Byte 4
KREF	0FC0:0FC3	0.1259	7C	00	F8	DD
KBG	0FC4:0FC7	1.1842	7F	17	93	02
VTHERM	0FC8:0FCB	1.0766	7F	09	CC	CD
KTC	0FCC:0FCF	0.0037	76	75	B3	3C
FOSC	0FD0	4.65	A5	—	—	—
TWDT	0FD2	16	10	—	—	—

Note: For the 4-byte constants, Byte 1 is the exponent, while Byte 2, 3, and 4 specify Mantissa High Byte, Middle Byte, and Low Byte, respectively. For the 1-Byte constants, the value occupies only Byte 1.

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USING CALIBRATION DATA

The calibration constants should be used by the application firmware to obtain the best accuracy.

KREF and KBG are used in A/D conversions. For further details, see AN624.

VTHERM and KTC are used for the internal temperature sensor. To use these parameters to calculate temperature, see AN624.

FOSC is a 1-byte value that represents the measured internal oscillator frequency. The internal oscillator frequency can be calculated as follows:

$$f = \left(3 + \frac{FOSC}{100}\right) MHz$$

FOSC can be used to compensate device internal clock variations for time critical applications such as USART baud rate generation.

TWDT is a 1-byte value that is the watchdog time-out in milliseconds without using the postscaler counter. The postscaler counter can extend the WDT time out up to 2.5 seconds. See the PIC14000 Data Sheet, Section 6, for further details

PARAMETER VARIATION

Table 3 lists the “Maximum Parameter Variation” attainable when the calibration data is not used. This data is based on measurement over the temperature range of -40°C to +85°C and over the operating VDD range of 2.7V to 6.0V, unless otherwise specified. For further details, refer to the PIC14000 Data Sheet.

TABLE 3: MAXIMUM PARAMETER VARIATION WITHOUT CALIBRATION (PRELIMINARY)

Symbol	Parameter	Maximum Variation
KREF	A/D slope reference ratio	+/- 2.2%
KBG	Bandgap reference voltage	+/- 4.2%
VTHERM	Temperature sensor voltage	+/- 12.4% (Note 1)
KTC	Temperature sensor coefficient	+/- 5%
TEMPINT	Calculated temperature	+/- 35°C
TWDT	WDT Timeout Period	+/- 60% (Note 2)

Note 1: At 25°C, +/- 2°C, over VDD range.
2: 7 msec to 33 msec over temperature, VDD = 5.0V

If these accuracies are adequate for the task at hand, no further calibrations are necessary. If greater accuracy is needed, the calibration constants must be used.

Table 4 lists the “Expected Parameter Variation with Calibration.” This data is based on measurements using the calibration data (measured at 25°C) over the temperature range of 0°C to +50°C and at the operating VDD = 5.0V unless otherwise specified. For further details, refer to the PIC14000 Data Sheet.

TABLE 4: EXPECTED VARIATION OF PARAMETERS WITH CALIBRATION (PRELIMINARY)

Symbol	Parameter	Maximum Variation
KREF	A/D slope reference ratio	+/- 0.13%
KBG	Bandgap reference voltage	+/- 0.058%
VTHERM	Temperature sensor voltage	+/- 0.71% (Note 1)
KTC	Temperature sensor coefficient	Calculated as the slope between 25°C and TMAX (NOTE 2)
TEMPINT	Calculated temperature	+/- 2°C (Note 3)
TWDT	WDT Timeout Period	+/- 13.8%

Note 1: At 25° C, +/- 2°C.
2: Tmax = 70°C for commercial temperature, 85°C for industrial temperature.
3: Refer to AN624 for description of TEMPINT.

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PROGRAMMING THE PIC14000

Non-Windowed Parts

Non-windowed parts are programmed just like any PIC16CXX processor. The calibration area is write-protected during factory calibration and will not be overwritten by PRO MATE.

Windowed Parts

Caution:

Windowed parts must not be write-protected. If the parts are erased by ultraviolet light, the calibration parameters are lost and can not be reprogrammed once the part has been write-protected.

Calibration data must be read out and saved before erasing a windowed part. There is no way to recreate these values, so if they are lost the part can no longer be calibrated.

The calibration data is read by the PRO MATE just like the rest of the code space. After reading, it must be saved as a Hex file. The entire memory space will be saved from 0 to 0xFFF. There is no way to save a part of the memory space.

To erase a windowed part:

1. Read part into the PRO MATE buffer.
2. If 000h - 0FBFh is not blank, use the Fill Prog Buffer command to set all bits to '1'.
3. Save the buffer content as a Hex file.

   Note:

   The calibration data, and hence this file, will be different for each PIC14000. Don't forget to label the file and the part!
4. Use ultraviolet light to erase the part.
5. Load the saved Hex file (in step 3) into the PRO MATE buffer.
6. Program the part.

The part is now at the same state as it was when the factory shipped it. Load your code and program in the usual fashion.

If desired, after the calibration data file has been loaded to PRO MATE, the application program may be loaded and the whole part programmed at once.

Checksum

The checksum bytes listed in the data sheet are only for use by the PIC14000 programmer. There is no way for an application program to utilize this checksum data. Note that there are special bytes added to this space so that the checksum of the entire calibration space totals zero. This means that the calibration factors, which vary from part to part, will not affect the user's code checksum, which may be used for program verification.

PROGRAM EXAMPLES

At the end of this application note are two code samples that may be used to access the calibration data. The first reads the entire table and stores the values in RAM. The second program can be used to restore calibration parameters, if accidentally erased.

SUMMARY

This application note has discussed the calibration constants programmed at Microchip Technology Inc. into the PIC14000. It has discussed the effect of these calibration constants on system accuracy. It has also covered the erasing and reprogramming procedures.

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PIC14000 CALIBRATION CONSTANTS

```
    list    p=14000, n=74, st=off
    errorlevel -306;suppress reporting of message "Crossing page boundary -- ensure page bits are
set"
                ;from list file

    include p14000.inc

    __CONFIG _CPC_ON & _CPU_OFF & _CPP_OFF & _PWRTE_ON & _WDT_OFF & _FOSC_RC

    ; __CONFIG is a MPASM directive used to embed the Configuration Word setup into.HEX file
    ; See PIC14000 Data Book for additional information on the Configuration Word

;*************************************************************************************************
;*  The code listed below can be implemented to read the 64 bytes of data located in the PIC14000
;*  Calibration Space (0FC0h - 0FFFh). The data bytes read will be saved to 64 consecutive RAM
;*  locations starting at location "CAL_ARRAY".
;*
;*************************************************************************************************


; REGISTER EQUATES

        ORG 0x20
TABLE_OFFSET    RES .1                  ;reserve 1 byte for table offset
KREF_PNTR       RES .4                  ;reserve 4 bytes for cal data
KBG_PNTR        RES .4                  ;reserve 4 bytes for cal data
VTHRM_PNTR      RES .4                  ;reserve 4 bytes for cal data
KTC_PNTR        RES .4                  ;reserve 4 bytes for cal data
KIN_PNTR        RES .40                 ;reserve 40 bytes for cal data
CAL_DATA_CHKSUM_PNTRRES.8  ;reserve 8 bytes for cal data

CAL_ARRAY   SET     KREF_PNTR

;*****  COPIES CALIBRATION DATA TO RAM
        ORG     0x00
        clrf    INTCON                  ;ensure INTCON is cleared
        clrf    PCLATH                  ;ensure PCLATH is cleared
        clrf    STATUS                  ;
        goto    start                   ;

        ORG 0x04
isr     goto    isr                     ;do nothing


start   movlw   high  read_cal_table;move high byte of read_cal-table
        movwf   PCLATH                  ;address into PCLATH
        call    read_cal_table     ;
        clrf    PCLATH                  ;reset PCLATH
stop    goto    stop                    ;wait here


        ORG 0xF00
read_cal_table clrfTABLE_OFFSET       ;initialize table offset register
        movlw   CAL_ARRAY               ;call routine for moving cal space data
                                        ;into RAM
        movwf   FSR                     ;initialize RAM array pointer

next_constantmovfTABLE_OFFSET,w       ;move array offset value into W Reg.
        call    cal_table               ;get a byte of CAL data
        movwf   INDF                    ;save constant to RAM
        incf    FSR,f                   ;increment RAM cal-array pointer
        incf    TABLE_OFFSET,f          ;point to next calibration data word
        movlw   0x3B                    ;
```


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```
        subwf   TABLE_OFFSET,w          ;test if all valid cal data has been read
        btfss   STATUS,Z                ;test if result of subtract (compare) is zero
        goto    next_constant           ;go read another table element
        return


        ORG     0xFBF

cal_table   addwf   PCL,f               ;Add table offset to PC

        END
```

CALIBRATION DATA TABLE

```
    list    p=14000,n=74,st=off
    errorlevel -306;suppress reporting of message “Crossing page boundary -- ensure page bits are
set”
                ;from list file

    include p14000.inc

    __CONFIG _CPC_ON & _CPU_OFF & _CPP_OFF & _PWRTE_ON & _WDT_OFF & _FOSC_RC

    ; __CONFIG is a MPASM directive used to embedd the Configuration Word setup into.HEX file
    ; See PIC14000 Data Book for additional information on the Configuration Word

;*************************************************************************************************
;* TITLE:   Calibration data table
;* PURPOSE: Create a hex file of the calibration data to program into the PIC14000
;* DESCRIPTION:
;*  This table is only needed if you erase, accidentally or otherwise, the existing
;*  calibration data that was preprogrammed in the PIC14000.
;*    In order to get the calibration data, you have to read the PIC14000 (before
;* you erase it) and save the data in a hex or text file.  So, it is a good idea
;* to read the cal data and save it before you start your development work.
;*
;*************************************************************************************************


        ORG 0xFC0                   ;Start of calibration data

;           ---------------------------------------Microchip modified IEEE754
;           |     | mantissa | mantissa | mantissa |32-bit floating point format
;           |exp  | hi byte  | mid byte | low byte |(see appnote AN575)
;           ---------------------------------------
Kref    DT   0x7B,   0x64,      0xC3,      0xEE;A/D Slope Ref.
Kbg     DT   0x7F,   0x13,      0x35,      0x40;Bandgap Ref. Voltage
Vthrm   DT   0x7F,   0x07,      0xC8,      0xB5;Temperature Sensor Voltage
Ktc     DT   0x76,   0x75,      0xB3,      0x3C;Volts / (degree Celsius)
Kin     DT   0x69                  ;Fosc (unsigned byte)

fill_startFILL(retlw 0xFF), (CAL_DATA_CHKSUM - fill_start);FD1 - FF8 = retlw 0xFF


        org 0xFF9                   ;cal data checksum address

CAL_DATA_CHKSUM               ;calibration data checksum FC0H-FF8H
        DT  0xC3,0xB5
        FILL0x3FFF,3          ;next three words are not unused
        org 0xFFE

        DW  0x12D6                  ;special checksum data
                                    ;makes calibration space (FC0H-FCDH)
                                    ;checksum equal 0000H.  Hence,
                                    ;the cal data has no effect on the
                                    ;device checksum calculation

        DW  0x0000                  ;Checksum of cal space = 0000H
        end
```


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NOTES:

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