TB026

Calculating Program Memory Checksums Using a PIC16F87X

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INTRODUCTION

Many applications require the microcontroller to calculate a checksum on the program memory to determine if the contents have been corrupted. Until now, the only family of PICmicro® microcontrollers to have the capability to read from program memory are the PIC17CXXX devices. The PIC16F87X devices are the first 14-bit core PICmicro microcontrollers that are able to access program memory in the same fashion as used with data EEPROM memory. These devices are FLASH extensions of the popular PIC16C7X family. Table 1 shows a comparison between the two PICmicro microcontroller families.

TABLE 1: PIC16C7X vs. PIC16F87X

Feature	PIC16C7X	PIC16C87X
Pins	28 or 40	28 or 40
Timers	3	3
Interrupts	11 or 12	13 or 14
Communication	PSP, USART, SSP (SPI or I^{2}C Slave)	PSP, USART, SSP(SPI or I^{2}C Master/Slave)
Frequency	20 MHz	20 MHz
A/D	8-bit	10-bit
CCP	2	2
Program Mem.	4K or 8K EPROM	4K or 8K FLASH
RAM	192 or 368 bytes	192 or 368 bytes
Data EEPROM	None	128 or 256 bytes
Other	---	In-Circuit Debugger

ACCESSING MEMORY

The data EEPROM and FLASH Program memory are both accessed using the same method. An address and/or data value are stored in Special Function Registers (SFR) and then memory is accessed using control bits in other SFRs. There are six SFRs required to access memory:

- EECON1
- EECON2
- EEDATA
- EEDATH
- EEADR
- EEADRH

When interfacing to data EEPROM memory, the address is stored in the EEADR register and the data is accessed using the EEDATA register. The operation is controlled using the EECON1 and EECON2 registers. The register map for EECON1 is shown in Figure 1. EECON2 is not a physical register. Reading it will result in all '0's. This register is used exclusively in the EEPROM and FLASH write sequences.

When interfacing to FLASH program memory, the address is stored in the EEADRH:EEADR registers and the data is accessed using the EEDATH:EEDATA registers. Since the same set of control registers are used to access data and program memory, the EEPGD bit (EECON1<7>) is used to indicate to the microcontroller whether the operation is going to be on data memory (EEPGD = 0) or program memory (EEPGD = 1). Refer to Section 7.0 in the PIC16F87X data sheet (DS30292) for more information about using the EEPROM and FLASH memories.

FIGURE 1: EECON1 REGISTER

R/W-x	U-0	U-0	U-0	R/W-x	R/W-0	R/S-0	R/S-0
EEPGD	—	—	—	WRERR	WREN	WR	RD
bit7							bit0

R = Readable bit
W = Writable bit
S = Settable bit
U = Unimplemented bit, read as ‘0’
- n = Value at POR reset

bit 7: **EEPGD**: Program / Data EEPROM Select bit
1 = Accesses Program memory
0 = Accesses data memory
Note: This bit cannot be changed while a write operation is in progress.

bit 6:4: **Unimplemented:** Read as '0'

bit 3: **WRERR**: EEPROM Error Flag bit
1 = A write operation is prematurely terminated
(any $\overline{\text{MCLR}}$ reset or any WDT reset during normal operation)
0 = The write operation completed

bit 2: **WREN**: EEPROM Write Enable bit
1 = Allows write cycles
0 = Inhibits write to the EEPROM

bit 1: **WR**: Write Control bit
1 = initiates a write cycle. (The bit is cleared by hardware once write is complete.
The WR bit can only be set (not cleared) in software.
0 = Write cycle to the EEPROM is complete

bit 0: **RD**: Read Control bit
1 = Initiates an EEPROM read (read takes one cycle. RD is cleared in hardware.
The RD bit can only be set (not cleared) in software).
0 = Does not initiate an EEPROM read

HEX FILE FORMAT

Development tools from Microchip support the Intel HEX Format (INHX8M), Intel Split HEX Format (INHX8S), and the Intel HEX 32 Format (INHX32). The most commonly used formats are the INHX8M and the INHX32. These are the only formats discussed in this document. Please refer to Appendix A in the MPASM User's Guide (DS33014) for more information about HEX file formats. The difference between INHX8M and INHX32 is that INHX32 supports 32-bit addresses using a linear address record. The basic format of the hex file is the same between INHX8M and INHX32 as shown below:

```
:BBAAAATTHHHH...HHHHCC
```

Each data record begins with a 9 character prefix and always ends with a 2 character checksum. All records begin with a ':' regardless of the format. The individual elements are described below.

- **BB** - is a two digit hexadecimal byte count representing the number of data bytes that will appear on the line.
- **AAAA** - is a four digit hexadecimal address representing the starting address of the data record. Format is high byte first followed by low byte, the address is doubled because this format only supports 8-bits (to find the real PICmicro address, simply divide the value **AAAA** by 2).
- **TT** - is a two digit record type that will be '00' for data records, '01' for end of file records and '04' for extended address record (INHX32 only).
- **HHHH** - is a four digit hexadecimal data word. Format is low byte followed by high byte. There will be **BB**/2 data words following **TT**.
- **CC** - is a two digit hexadecimal checksum that is the two's complement of the sum of all the preceding bytes in the line record.

HEX File Preparation

The checksum used to verify program memory contents is a 14-bit number calculated only on the program memory contents of a HEX file. The reason that only 14-bits is used is because the PIC16F87X has 14-bit wide program memory.

The first step to obtaining the checksum is to get a complete HEX file that has all address locations specified. This can be easily accomplished in MPLAB by enabling the programmer, either PROMATE II or PICSTART PLUS, whichever one is available. Load the HEX file into MPLAB using the menus File -> Import -> Download to Memory. Then save the HEX file using File -> Export -> Save HEX File. Make sure that the Program Memory box is checked with a range of 0 to 8191 and the Configuration bits and IDs box are also checked. It is optional to check the EEPROM memory box depending on you application. This will create a complete HEX file including all program memory, configuration word, IDs, and optionally EEPROM memory.

The checksum provided by a programmer, such as PROMATE II or PICSTART PLUS, is not valid because the configuration word and device ID are included in the calculation. Therefore, a different program is required to calculate the program memory checksum. Once a complete HEX file has been obtained by the previously presented method, it must be processed and modified to contain the checksum. The program `CHECKSUM.EXE`, which is a DOS based program, reads in the HEX file, calculates the checksum, and outputs the new HEX file with checksum included. The checksum is calculated by:

1. Adding together the memory locations 0x0000 to 0x1FFE.
2. Mask off all but the lower 14-bits.
3. Take the 2's complement of Step 2.
4. Mask off all but the lower 14-bits.
5. Save this value into the HEX file at address 0x1FFF.

The program ignores all configuration word, ID, and EEPROM memory information in the HEX file and dumps it to the output file unchanged. The output file can then be programmed into the PIC16F87X device.

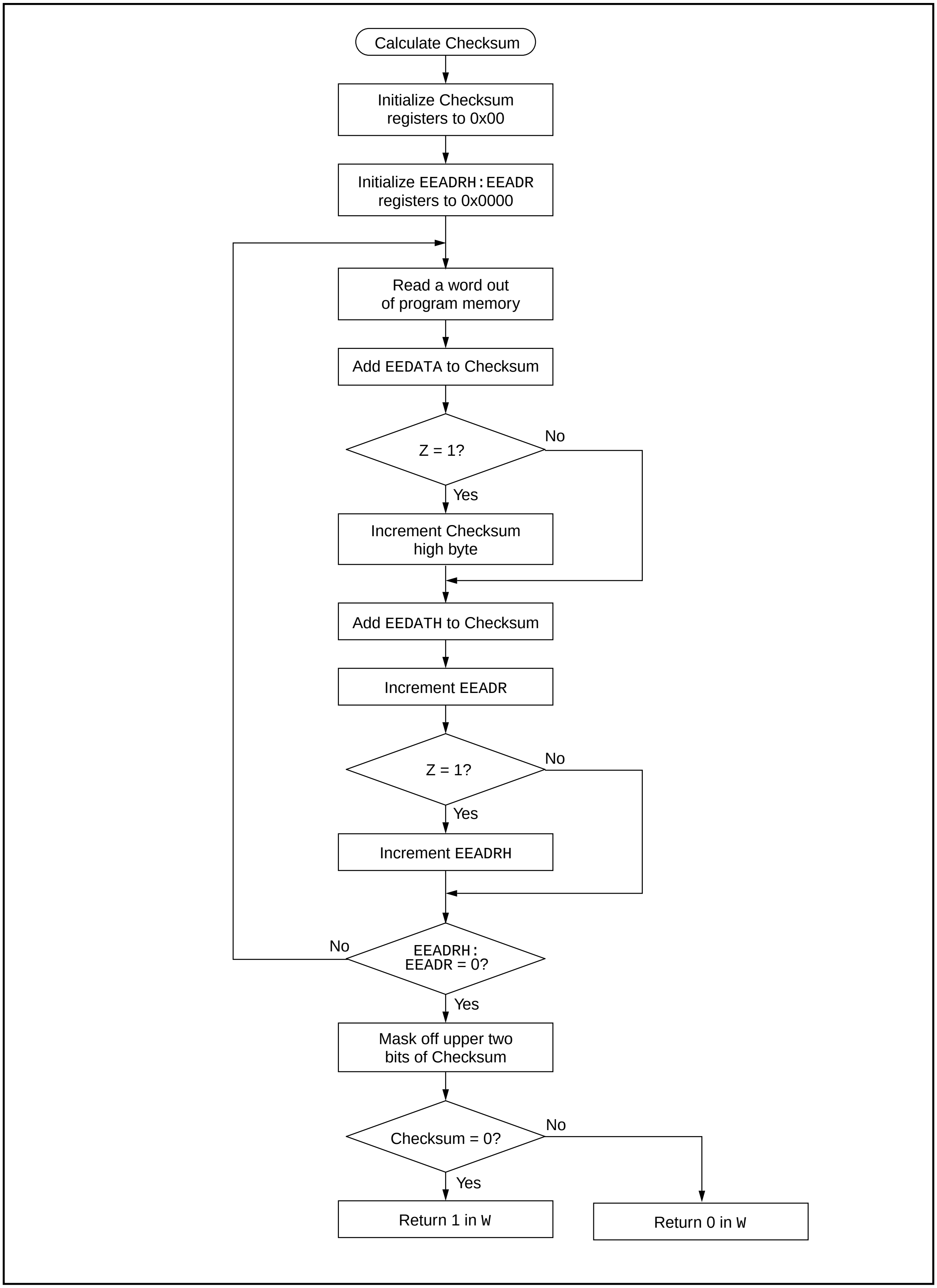
PICmicro Code

The code used by the PIC16F87X to calculate checksum uses 36 words of program memory and two data memory locations. The example code uses data memory locations 0x7E and 0x7F to store the calculated checksum. These locations are shared across all banks. The user can optionally change these locations and add banking into the routine. Figure 2 shows the flowchart for the routine. The checksum is created such that by adding up all program memory locations, a 14-bit result of 0x0000 is obtained. Since the calculation is done in 16-bits, the result will actually be 0x4000, but the upper two bits are masked off by the routine. Example 1 shows the code in MPASM to calculate the program memory checksum. If the program memory verifies, the routine returns a '1'. If a failure is detected, the routine returns a '0'.

LISTING 1: PROGRAM MEMORY CHECKSUM ROUTINE

```
CalcChecksum
    bsf     STATUS,RP1      ;Go to Bank 2
    bcf     STATUS,RP0
    clrf    ChecksumL       ;Clear the Checksum
    clrf    ChecksumH       ;registers
    clrf    EEADR           ;Set the Program Memory
    clrf    EEADRH          ; address to 0x0000
CLoop                       ;Loop for each location
    bsf     STATUS,RP0      ; to read memory location
    bsf     EECON1,EEPGD    ;Set for program memory
    bsf     EECON1,RD       ;Set for read operation
    bcf     STATUS,RP0      ;Go to Bank 2
    nop
    movf    EEDATA,W        ;Add low byte to Checksum
    addwf   ChecksumL,F
    btfsc   STATUS,C        ;Check for overflow
    incf    ChecksumH,F     ;Yes, increment Checksum
    movf    EEDATH,W        ;Add high byte
    addwf   ChecksumH,F
    incf    EEADR,F         ;Increment low address
    btfsc   STATUS,Z        ;Check for overflow
    incf    EEADRH,F        ;Increment high address
    movf    EEADRH,F        ;Check to see if
    btfss   STATUS,Z        ; address wrapped
    goto    CLoop           ; from 0x1fff to
    movf    EEADR,F         ; 0x0000
    btfss   STATUS,Z
    goto    CLoop
                            ;Checkcum calculation complete
    bcf     ChecksumH,7     ;Clear upper 2 bits
    bcf     ChecksumH,6     ; only 14-bit checksum
    movf    ChecksumH,F     ;Checksum should be 0
    btfss   STATUS,Z
    retlw0                  ;Checksum failed
    movf    ChecksumL,F
    btfss   STATUS,Z
    retlw0                  ;Checksum failed
    retlw1                  ;Checksum passed
```

FIGURE 1: FLOWCHART



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