



Downloading HEX Files to PIC16F87X PICmicro® Microcontrollers

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INTRODUCTION

The release of the PIC16F87X devices introduces the first mid-range family of devices from Microchip Technology that has the capability to read and write to internal program memory. This family has FLASH-based program memory, SRAM data memory and EEPROM data memory. The FLASH program memory allows for a truly reprogrammable system. Table 1 shows the features of the PIC16F87X family of devices.

ACCESSING MEMORY

The read and write operations are controlled by a set of Special Function Registers (SFRs). There are six SFRs required to access the FLASH program memory:

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

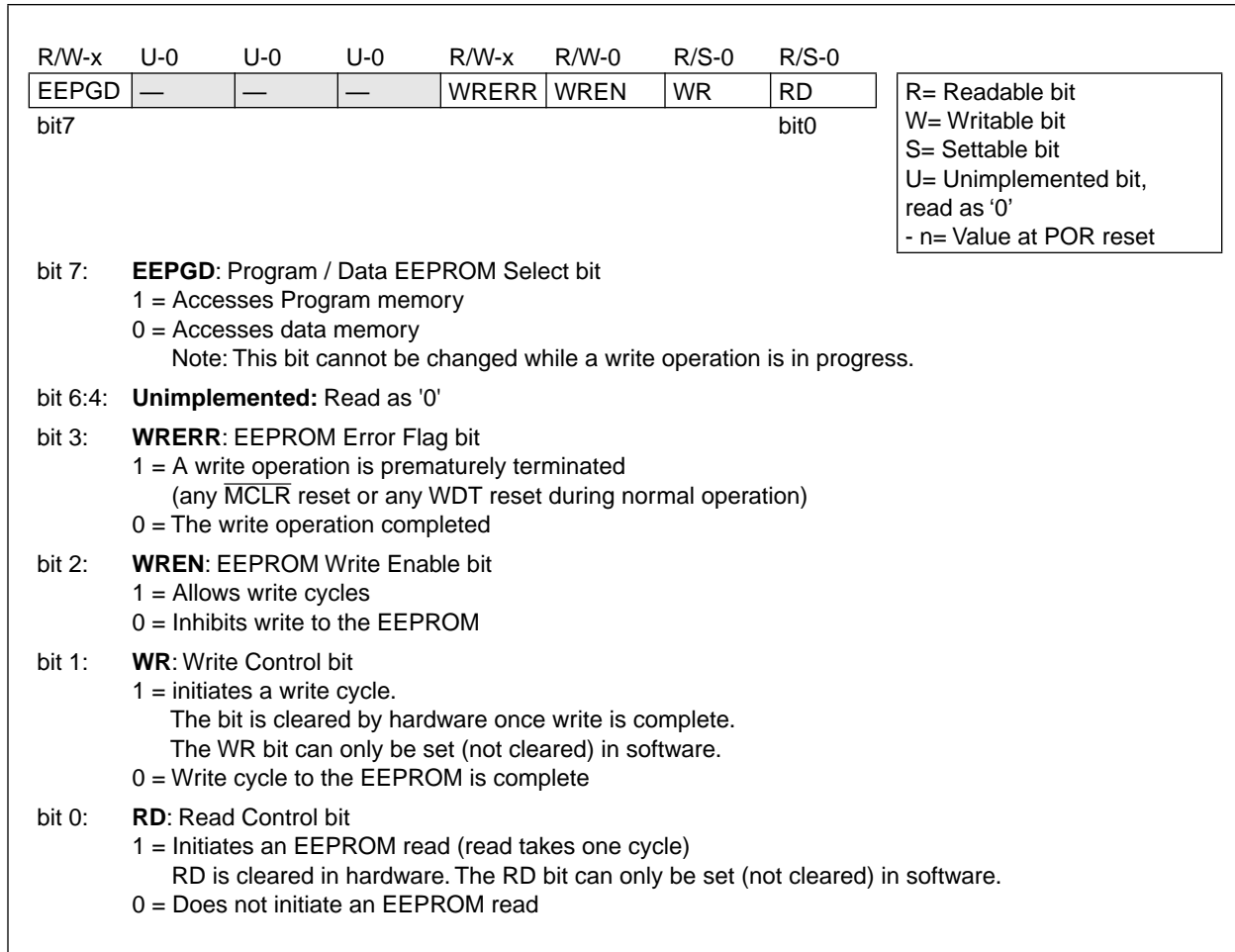
The registers EEADRH:EEADR holds the 12-bit address required to access a location in the 8K words of program memory. The registers EEDATH:EEDATA are used to hold the data values. When reading program memory, the EEPGD bit (EECON1<7>) must be set to indicate to the microcontroller that the operation is going to be on program memory. If the bit is cleared, the operation will be performed on data memory at the address pointed to by EEADR. The EEDATA register will hold the data. The EECON1 register also has bits for write enable and to initiate the read or write operation. There is also a bit to indicate a write error has occurred, possibly due to a reset condition happening while a write operation is in progress. Figure 1 shows the register map for EECON1.

The EECON2 register 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. Listing 1 shows the code snippet to initiate a write operation on the PIC16F87X devices.

TABLE 1 PIC16F87X FAMILY FEATURES

Table with 5 columns: Key Features, PIC16F873, PIC16F874, PIC16F876, PIC16F877. Rows include Operating Frequency, Resets, Flash Prog Memory, Data Memory, EEPROM Data Memory, Interrupts, I/O Ports, Timers, Capture/Compare/PWM modules, Serial Communications, Parallel Communications, and 10-bit Analog-to-Digital Module.

**FIGURE 1: EECON1 REGISTER**



## HEX FILE FORMAT

The data to be programmed into program memory will be read into the microcontroller using one of its standard interface modules: SPI, I<sup>2</sup>C™, USART, or PSP. Probably the simplest format to send the data to the microcontroller is in the standard HEX format used by the Microchip development tools. The formats supported are 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 INHX32 and therefore 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 both formats as shown below:

```
:BBAAAATTTHHHH...HHHCC
```

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. Divide this number by two to get the number of words per 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.

Since the PIC16F87X devices only have a maximum of 8K words, the linear address record '04' is ignored by the routine. The HEX file is composed of ASCII characters 0 through 9 and A to F and the end of each line has a carriage return and linefeed. The downloader code in the PICmicro microcontrollers must convert the ASCII characters to binary numbers to be used for programming.

## PICmicro Code

The sample downloader code does not specifically use one of the interface modules on the PIC16F87X device. Instead, a routine called `GetByte` retrieves a single character from the HEX file over the desired interface. It is up to the engineer to write this routine around the desired interface. Another routine `GetHEX8` calls `GetByte` twice to form a two digit hexadecimal number.

One issue that arises is how many times to reprogram a location that does not program correctly. The sample code provided simply exits the downloader routine and stores a value of `0xFF` in the `WREG` if a program memory location does not properly program on the first attempt. The engineer may optionally add code to loop several times if this event occurs.

Still another issue that is not specifically addressed in the sample code is to prevent the downloader from overwriting its own program memory address locations. The designer must add an address check to prevent this situation from happening.

Finally, the designer must account for situations where the download of new code into the microcontroller is interrupted by an external event such as power failure or reset. The system must be able to recover from such an event. This is not a trivial task, is very system dependent, and is therefore left up to the designer to provide the safeguards and recovery mechanisms.

Another error that could happen is a line checksum error. If the calculated line checksum does not match the line checksum from the HEX file, a value of 1 is returned in `WREG`. The part of the routine that calls the downloader should check for the errors `0xFF` (could not program a memory location) and 1. If program memory is programmed correctly and no errors have been encountered, the downloader routine returns a 0 in `WREG` to indicate success to the calling routine. Figure 2 shows the flowchart for the downloader routines. [Listing 2](#) shows the complete listing for the downloader code.

The routine `ASCII2HEX` converts the input character to a binary number. The routine does not provide any out of range error checking for incoming characters. Since the only valid characters in a HEX file are the colon (:), the numbers 0 through 9 and the letters A through F, the routine can be highly optimized. It first subtracts 48 from the character value. For the ASCII numbers 0 through 9, this results in a value from 0 to 9. If the character is A through F, the result is a number greater than 15. The routine checks to see if the upper nibble of the result is 0. If not 0, then the original value was A through F and the routine now subtracts an additional 43 from the character resulting in the binary values 10 through 15. The colon is not accounted for in this routine because the main part of the downloader code uses it as a line sync.

### LISTING 1: FLASH WRITE SEQUENCE

```

bsfSTATUS,RP1      ; Bank2
bcfSTATUS,RP0
movfAddrH,W        ; Load address into
movwfEEADRH        ; EEADRH:EEADR
movfAddrL,W
movwfEEADR
bsfSTATUS,RP0      ; Bank3
bsfEECON1,EEPGD    ; Set for Prog Mem
bsfEECON1,RD       ; read operation
bcfSTATUS,RP0      ; Bank2
nop
movfEEDATA,W       ; Data is read
...                 ; user can now
movfEEDATH,W       ; access memory
...

```

## LISTING 2: HEX DOWNLOAD CODE WRITTEN FOR MPASM

```
list p=16f877
#include "c:\progra~1\mplab\p16f877.inc"

DownloadCode                                ;Uses USART to receive data from PC
banksel      RCREG
DCStart
call         GetByte
movlw       ':'                                ;Wait for colon
subwf      RCREG,W
btfss      STATUS,Z
goto       DCStart

call         GetHex8                          ;Read byte count
movwf      ByteCount                         ;Store in register
movwf      LineChecksum                      ;Store in line checksum
bcf        STATUS,C
rrf        ByteCount,F                       ;Divide byte counter by 2 to get words

call         GetHex8                          ;Read high byte of 16-bit address
movwf      AddrH
addwf      LineChecksum,F                   ;Add high byte to line checksum
call         GetHex8                          ;Read low byte of 16-bit address
movwf      AddrL
addwf      LineChecksum,F                   ;Add low byte to line checksum

call         GetHex8                          ;Read record type
movwf      RecType
addwf      LineChecksum,F                   ;Add to line checksum

DataRec                                        ;Data reception
movf       RecType,F                         ;Check for data record (0h)
btfss     STATUS,Z
goto      EndOfFileRec                       ;Otherwise check for EOF

DRLoop
movf       ByteCount,F                       ;Check for bytecount = 0
btfsc     STATUS,Z
goto      DRckChecksum                      ;If zero, goto checksum validation
call      GetHex8                            ;Read lower byte of data (2 characters)
movwf     HexDataL                           ;Add received data to checksum
addwf     LineChecksum,F
call      GetHex8                            ;Read upper byte of data (2 characters)
movwf     HexDataH                           ;Add received data to checksum
addwf     LineChecksum,F

WriteDataSequence                            ;Write sequence to internal prog. mem FLASH
banksel   EEADRH
movf      AddrH,W                            ;Write address to EEADRH:EEADR registers
movwf     EEADRH
movf      AddrL,W
movwf     EEADR
movf      HexDataH,W                         ;Write data to EEDATH:EEDATA registers
movwf     EEDATH
movf      HexDataL,W
movwf     EEDATA
banksel   EECON1                             ;Write sequence
bsf       EECON1,EEPGD                       ;Set EEPGD to indicate program memory
bsf       EECON1,WREN                       ;Enable writes to memory
bcf       INTCON,GIE                        ;Make sure interrupts are disabled
movlw    0x55                               ;Required write sequence
movwf     EECON2
movlw    0xaa
movwf     EECON2
bsf       EECON1,WR                          ;Start internal write cycle
nop
```

```

nop
bcf          EECON1,WREN          ;Disable writes

banksel     EECON1                ;Read sequence
bsf         EECON1,EEPGD         ;Set EEPGD to indicate program memory
bsf         EECON1,RD            ;Enable reads from memory
bcf         STATUS,RP0
nop
movf        EEDATH,W              ;Compare memory value to HexDataH:HexDataL
subwf      HexDataH,W
btfss      STATUS,Z
retlw      0xff                    ;If upper byte not equal, return FFh
; to indicate programming failure
movf        EEDATA,W
subwf      HexDataL,W
btfss      STATUS,Z
retlw      0xff                    ;If lower byte not equal, return FFh
; to indicate programming failure

incf        AddrL,F              ;Increment address for next iteration
btfsc      STATUS,Z
incf        AddrH,F
decf        ByteCount,F          ;Decrement byte count
goto       DRLoop                ;Go back to check for ByteCount = 0

DRckChecksum                                ;Checksum verification
call       GetHex8                ;Read in checksum
addwf      LineChecksum,W         ;Add to calculated checksum
btfss      STATUS,Z              ;Result should be 0
retlw      1                      ; If not return 1 to indicate checksum fail
goto       DCStart                ;Do it again

EndOfFileRec                                ;End of File record (01h)
decf        RecType,W            ;If EOF record, decrement should = 0
btfss      STATUS,Z
goto       DCStart                ;Not valid record type, wait for next :
call       GetHex8                ;Read in checksum
addwf      LineChecksum,W         ;Add to calculated checksum
btfss      STATUS,Z              ;Result should be 0
retlw      1                      ; If not return 1 to indicate checksum fail
retlw      0                      ;Otherwise return 0 to indicate success

GetByte
; Insert your code here to retrieve a byte of data from
; the desired interface. In this case it is the USART on F877.
;clear CTS
;   banksel     PIR1
;GH4Waitbtfss PIR1,RCIF
;   goto       GH4Wait
;set CTS
nop
banksel     RCREG
movf        RCREG,W
return

GetHex8                                ;This function uses the USART
call       GetByte                ;Read a character from the USART
call       ASCII2Hex              ;Convert the character to binary
movwf      Temp                    ;Store result in high nibble
swapf      Temp,F

call       GetByte                ;Read a character from the USART
call       ASCII2Hex              ;Convert the character to binary
iorwf      Temp,F                  ;Store result in low nibble
movf        Temp,W                 ;Move result into WREG
return

```

# TB025

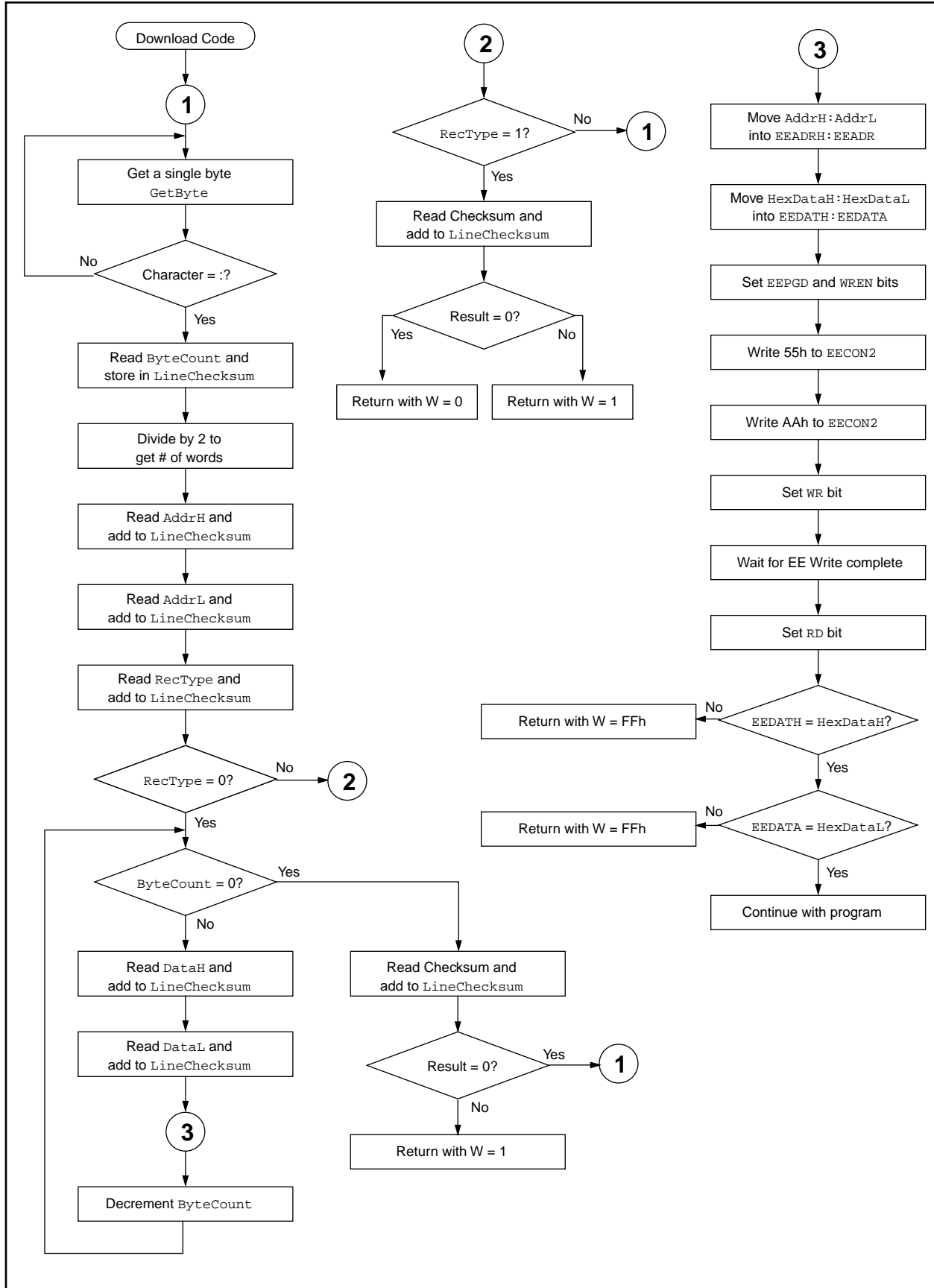
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```
ASCII2Hex                                ;Convert value to binary
    movwf    Temp1                        ;Subtract ASCII 0 from number
    movlw    '0'
    subwf    Temp1,F
    movlw    0xf0                          ;If number is 0-9 result, upper nibble
    andwf    Temp1,W                       ; should be zero
    btfsc    STATUS,Z
    goto     ASCIIOut
    movlw    'A'-'0'-0x0a                  ;Otherwise, number is A - F, so
    subwf    Temp1,F                       ;subtract off additional amount

ASCIIOut
    movf     Temp1,W                       ;Value should be 0 - 15
    return

end
```

**FIGURE 2: FLOWCHART**





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9/29/98



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