University of British Columbia
Electrical and Computer Engineering
ELEC291/ELEC292

Project 1 – EFM8 board, FSM, EEPROM, and tips

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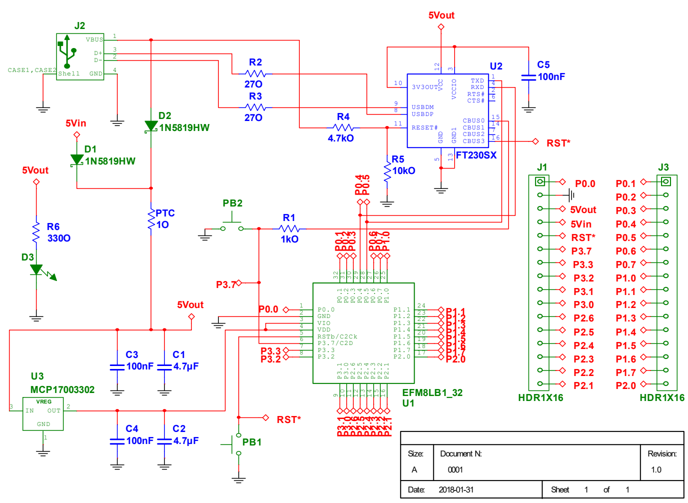
Objectives

- Introduction to the EFM8 board.
- Programming using Finite State Machines (FSMs) in assembly language.
- Using non-volatile memory (flash) for variable storage and initialization.
- Extra project tips.

The EFM8 Board

- Each student should have a EFM8 board for the second half of the course.
- Each student should assemble (or try to) a EFM8 board. Stencil + Solder Paste + SMDs + TH + Testing.
- The EFM8 board needs to be soldered in an reflow oven. You need a reflow oven controller!

EFM8 circuit



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EFM8 Bill of Materials (BOM)

Qty	Supplier's#	Reference	Man's #	Description
1	768-1135-1-ND	U2	FT230XS-R	IC USB SERIAL BASIC UART 16SSOP
1	MCP1700T3302ETTCT-ND	U3	MCP1700T-3302E/TT	IC REG LDO 3.3V 0.25A SOT23-3
1	336-3736-ND	U1	EFM8LB12F64E-B-QFP32	IC MCU 8BIT 64KB FLASH 32QFP
2	450-1759-1-ND	PB1, PB2	FSM4JSMATR	SWITCH TACTILE SPST-NO 0.05A 24V
2	A26509-16-ND	J1, J3	4-103741-0-16	CONN HEADR BRKWAY .100 16POS STR
1	ED2983-ND	J2	USB-B1HSB6	CONN USB TYPE B R/A BLACK
2	1N5819HW-FDICT-ND	D1, D2	1N5819HW-7-F	DIODE SCHOTTKY 40V 1A SOD123
3	399-1170-1-ND	C3, C4, C5	C0805C104K5RACTU	CAP CER 0.1UF 50V X7R 0805
2	311-22ARCT-ND	R2, R3	RC0805JR-0722RL	RES SMD 22 OHM 5% 1/8W 0805
1	160-1179-1-ND	D3	LTST-C170GKT	LED GREEN CLEAR 0805 SMD
1	311-330ARCT-ND	R6	RC0805JR-07330RL	RES SMD 330 OHM 5% 1/8W 0805
1	311-1.0KARCT-ND	R1	RC0805JR-071KL	RES SMD 1K OHM 5% 1/8W 0805
1	311-4.7KARCT-ND	R4	RC0805JR-074K7L	RES SMD 4.7K OHM 5% 1/8W 0805
2	478-8125-1-ND	C1, C2	F921A475MPA	CAP TANT 4.7UF 10V 20% 0805
1	507-1797-1-ND	PTC	0ZCJ0020FF2E	PTC RESTTBLE 0.20A 30V CHIP 1206
1	311-10KARCT-ND	R5	RC0805JR-0710KL	RES SMD 10K OHM 5% 1/8W 0805

Steps Assembling a PCB with SMDs.

- Step 1: Apply solder paste to the PCB. You will use a Mylar stencil. (The most critical step in the whole process!)
- Step 2: Place the SMT components into the PCB.
- Step 3: Reflow soldering. You will be using a toaster oven with a controller of your own design.
- Step 4: Hand soldering of TH (thru hole) components.

Testing the EFM8 Board

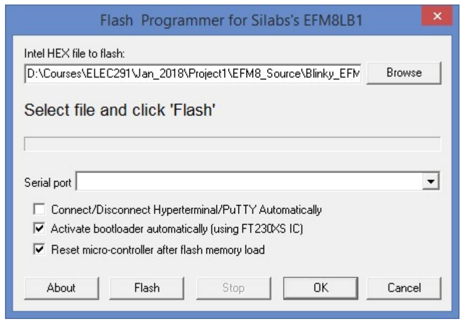
- Write a "blinky.asm" for the EFM8. Some things to take into account compared to the AT89LP51RC2 and AT89LP51RC2:
  - The default oscillator frequency is 6.000MHz. It can be configured for 12MHz, 24MHz, 48MHZ, and 72MHz… or many different values in between!
  - The number cycles per instruction is different.
  - The registers used to configure the ports are different. Check the datasheet!

blinky_EFM8.asm

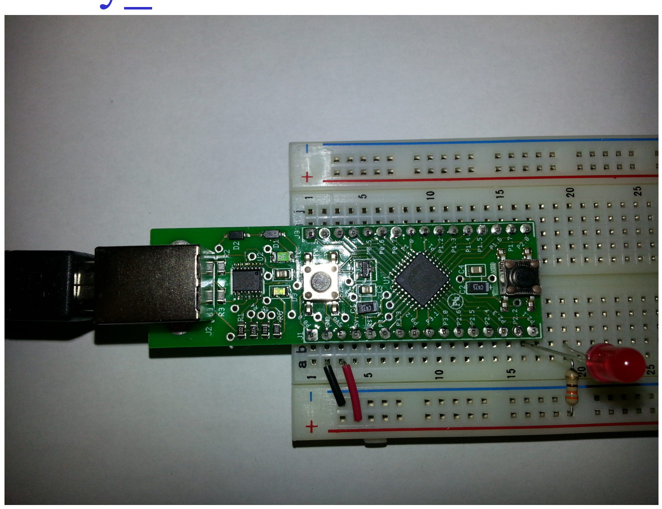
```
$MODEFM8LB1

CSEG at 0H
    ljmp main
Wait_half_second:
    ;For a 6MHz clock one machine cycle takes 1/6.0000MHz=166.666ns
    mov R2, #25
L3: mov R1, #250
L2: mov R0, #120
L1: djnz R0, L1 ; 4 machine cycles-> 4*166.666ns*120=80us
    djnz R1, L2 ; 80us*250=0.02s
    djnz R2, L3 ; 0.02s*25=0.5s
    ret
main:
    ; DISABLE WDT: provide Watchdog disable keys
    mov WDTCN, #0xDE ; First key
    mov WDTCN, #0xAD ; Second key
    mov SP, #7FH
    ; Enable crossbar and weak pull-ups
    mov XBR0, #0x00
    mov XBR1, #0x00
    mov XBR2, #0x40
    mov P2MDOUT, #0x02 ; make LED pin (P2.1) output push-pull
M0: cpl P2.1 ; Led off/on
    lcall Wait_half_second
    sjmp M0
end
```

Flashing HEX file into EFM8 Board

- In CrossIDE click fLash->Silabs EFM8LB1. Select the correct HEX file, make sure settings are like shown below, and then click ‘Flash’.



Testing the board with blinky_EFM8.asm in breadboard.

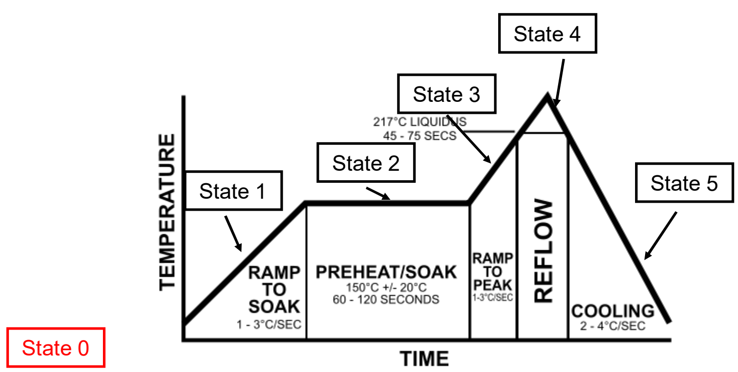


Finite State Machines in Assembly Language

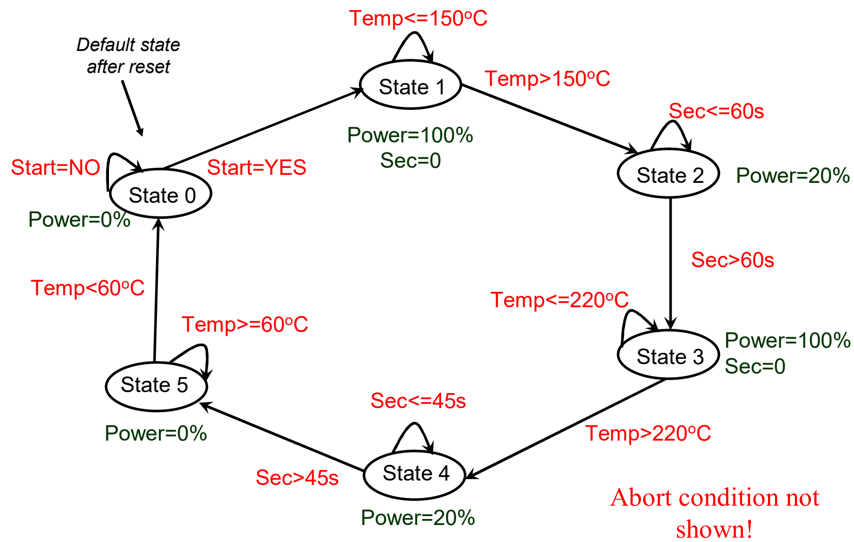
- A finite state machine (FSM) is a programming abstraction method that can be represented using a graph structure.
- We can draw the states as circles and the transitions as arrows.
- There is a finite number of states. The active state is called the current state.
- FSMs are easily implemented in assembly language!
- Many FMS can be run “concurrently”. (One after another really!)
- FSM are in principle non-blocking.

Reflow Profile States

http://en.wikipedia.org/wiki/Reflow_soldering



Reflow Profile FSM



Abort condition not shown!

FSM In assembly (some states only!)

```
FSM1:
    mov a, FSM1_state

FSM1_state0:
    cjne a, #0, FSM1_state1
    mov pwm, #0
    jb PB6, FSM1_state0_done
    jnb PB6, $ ; Wait for key release
    mov FSM1_state, #1
FSM1_state0_done:
    ljmp FSM1_FSM2

FSM1_state1:
    cjne a, #1, FSM1_state2
    mov pwm, #100
    mov sec, #0
    mov a, #150
    clr c
    subb a, temp
    jnc FSM1_state1_done
    mov FSM1_state, #2
FSM1_state1_done:
    ljmp FSM2
```

```
FSM1_state2:
    cjne a, #2, FSM1_state3
    mov pwm, #20
    mov a, #60
    clr c
    subb a, sec
    jnc FSM1_state2_done
    mov FSM1_state, #3
FSM1_state2_done:
    ljmp FSM2
         .
         .
         .
         .
         .
         .
         .
```

In assembly (some states only!) using variables…

```
FSM1:
    mov a, FSM1_state

FSM1_state0:
    cjne a, #0, FSM1_state1
    mov pwm, #0
    jb PB6, FSM1_state0_done
    jnb PB6, $ ; Wait for key release
    mov FSM1_state, #1
FSM1_state0_done:
    ljmp FSM2

FSM1_state1:
    cjne a, #1, FSM2_state2
    mov pwm, #100
    mov sec, #0
    mov a, temp_soak
    clr c
    subb a, temp
    jnc FSM1_state1_done
    mov FSM1_state, #2
FSM1_state1_done:
    ljmp FSM2
```

```
FSM1_state2:
    cjne a, #2, FSM1_state3
    mov pwm, #20
    mov a, time_soak
    clr c
    subb a, sec
    jnc FSM1_state2_done
    mov FSM1_state, #3
FSM1_state2_done:
    ljmp FSM2
        .
        .
        .
        .
        .
DSEG ; Before the state machine!
state: ds 1
temp_soak: ds 1
Time_soak: ds 1
Temp_refl: ds 1
Time_refl: ds 1
```

Variables need to be initialized!

About Variables

- Initialize variables before using them!
- It is easy to work with binary (8-bit) variables. Use “inc”, “dec”, to increment/decrement and ‘subb’ to compare.
- Small variables are easy to save and retrieve from non-volatile memory such as FLASH or EEPROM.
- If temperature measurements are too “noisy”, make several measurements and take the average!
- To convert 8-bit binary variable to decimal use either HEX2BCD (in the math32 library) or one of these smaller/faster 8051 subroutines:

Binary to decimal conversion of 8-bit numbers in the 8051

```
; Send eight bit number via serial port, passed in 'a'.
SendToSerialPort:
      mov b, #100
      div ab
      orl a, #0x30 ; Convert hundreds to ASCII
      lcall putchar ; Send to PuTTY/Python/Matlab
      mov a, b     ; Remainder is in register b
      mov b, #10
      div ab
      orl a, #0x30 ; Convert tens to ASCII
      lcall putchar ; Send to PuTTY/Python/Matlab
      mov a, b
      orl a, #0x30 ; Convert units to ASCII
      lcall putchar ; Send to PuTTY/Python/Matlab
      ret
```


Binary to decimal conversion of 8-bit numbers in the 8051

```
; Eight bit number to display passed in 'a'.
; Sends result to LCD
SendToLCD:
      mov b, #100
      div ab
      orl a, #0x30 ; Convert hundreds to ASCII
      lcall ?WriteData ; Send to LCD
      mov a, b     ; Remainder is in register b
      mov b, #10
      div ab
      orl a, #0x30 ; Convert tens to ASCII
      lcall ?WriteData; Send to LCD
      mov a, b
      orl a, #0x30 ; Convert units to ASCII
      lcall ?WriteData; Send to LCD
      ret
```

DIV AB

DIV AB

Function: Divide

Description: DIV AB divides the unsigned eight-bit integer in the accumulator by the unsigned eight-bit integer in register B. The accumulator receives the integer part of the quotient; register B receives the integer remainder. The carry and OV flags will be cleared. *Exception*: If B had originally contained 00H, the values returned in the accumulator and B register will be undefined and the overflow flag will be set. The carry flag is cleared in any case.

Example: The accumulator contains 251 (0FBH or 11111011B) and B contains 18 (12H or 00010010B). The instruction DIV AB will leave 13 in the accumulator (0DH or 00001101 B) and the value 17 (11H or 00010001B) in B, since 251 = (13x18) + 17. Carry and OV will both be cleared.

Operation: **DIV AB**
(A), (B) ¬ (A) / (B)

Encoding:

1	0	0	0	0	1	0	0

Non-Volatile Memory: AT89LP51RC2 Flash as EEPROM

Emulating EEPROM Using AT89LP On-Chip Flash Data Memory

AT89LP EEPROM Emulation

Application Note

1. Introduction

Many embedded systems rely on nonvolatile parameters that are preserved across reset or power-loss events. In some systems this static information is used to initialize the system to a correct state at start-up. In other systems it is used to log system history or accumulated data. Traditionally these tasks have been implemented using EEPROM; first with off-chip EEPROM and later in on-chip EEPROM as levels of system integration have increased.

This application note describes how to emulate the behavior of an on-chip EEPROM using the on-chip Flash data memory of Atmel's AT89LP series of microcontrollers. Flash data memory is an alternative to EEPROM that is well suited for large parameter sets. Flash access routines are provided in both MCS®51 assembly and the C programming language. These routines are meant to replace existing code; they do not take full advantage of Flash memory performance and are not recommended for new designs.

Why non-volatile memory?

- To save your reflow oven controller parameters so they are available automatically the next time you use it.
- To store other useful information.

Example: Writing Project Data to the AT89LP51RC2 Flash

```
loadbyte mac
    mov a, %0
    movx @dptr, a
    inc dptr
endmac

Save_Configuration:
    mov FCON, #0x08 ; Page Buffer Mapping Enabled (FPS = 1)
    mov dptr, #0x7f80 ; Last page of flash memory
    ; Save variables
    loadbyte(temp_soak) ; @0x7f80
    loadbyte(time_soak) ; @0x7f81
    loadbyte(temp_refl) ; @0x7f82
    loadbyte(time_refl) ; @0x7f83
    loadbyte(#0x55) ; First key value @0x7f84
    loadbyte(#0xAA) ; Second key value @0x7f85
    mov FCON, #0x00 ; Page Buffer Mapping Disabled (FPS = 0)
    orl EECON, #0b01000000 ; Enable auto-erase on next write sequence
    mov FCON, #0x50 ; Write trigger first byte
    mov FCON, #0xA0 ; Write trigger second byte
    ; CPU idles until writing of flash completes.
    mov FCON, #0x00 ; Page Buffer Mapping Disabled (FPS = 0)
    anl EECON, #0b10111111 ; Disable auto-erase
    ret
```

Example: Read From Flash; Get Saved Values

```
getbyte mac
    clr a
    movc a, @a+dptr
    mov %0, a
    inc dptr
Endmac

Load_Configuration:
    mov dptr, #0x7f84 ; First key value location.
    getbyte(R0) ; 0x7f84 should contain 0x55
    cjne R0, #0x55, Load_Defaults
    getbyte(R0) ; 0x7f85 should contain 0xAA
    cjne R0, #0xAA, Load_Defaults
    ; Keys are good.  Get stored values.
    mov dptr, #0x7f80
    getbyte(temp_soak) ; 0x7f80
    getbyte(time_soak) ; 0x7f81
    getbyte(temp_refl) ; 0x7f82
    getbyte(time_refl) ; 0x7f83
    ret
```

```
; Load defaults if 'keys'
; are incorrect
Load_Defaults:
   mov temp_soak, #150
   mov time_soak, #45
   mov temp_refl, #225
   mov time_refl, #30
   ret
```


Extra Tips…

- Are you using macros yet?

```
Change_8bit_Variable MAC
    jb %0, %2
    Wait_Milli_Seconds(#50) ; de-bounce
    jb %0, %2
    jnb %0, $
    jb SHIFT_BUTTON, skip%Mb
    dec %1
    sjmp skip%Ma
skip%Mb:
    inc %1
skip%Ma:
ENDMAC
```

```
    Change_8bit_Variable(MY_VARIABLE_BUTTON, my_variable, loop_c)
    Set_Cursor(2, 14)
    mov a, my_variable
    lcall SendToLCD
    lcall Save_Configuration
loop_c:
```

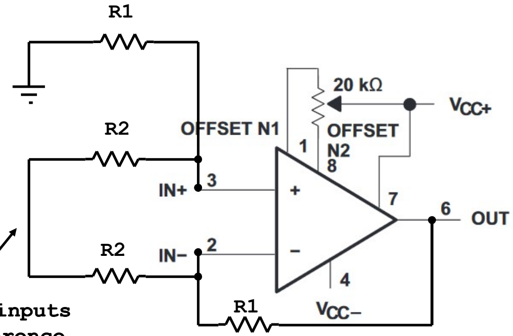
Extra tips…

- ‘Noisy’ measurements? Average!

```
Wait10us:
    mov R0, #74
    djnz R0, $
    ret

Average_CH0:
    Load_x(0)
    mov R5, #100
Sum_loop0:
    lcall Read_ADC_Channel
    mov y+3, #0
    mov y+2, #0
    mov y+1, R7
    mov y+0, R6
    lcall add32
    lcall Wait10us
    djnz R5, Sum_loop0
    load_y(100)
    lcall div32
    ret
```


Extra tips…

- Op-amp has to much offset? Zero it! (Should not be needed for OP07)



Connect inputs of difference amplifier

Figure 2. Input Offset-Voltage Null Circuit

Adjust pot until ‘OUT’ is near zero mV.

Extra tip

- There is ‘magic’ value of gain that will give you the temperature of the thermocouple (minus cold junction) directly when reading from the ADC!

The smallest component we are using is ‘0805’ size