COE 306, Term 171

 Introduction to Embedded Systems

**Assignment# 1 Solution**

**Due date: Sunday, Oct. 8, 2017**

# Look for a consumer product, e.g. a toy or a small home appliance that incorporates an embedded system. It will be good if you can find a locally available product, and include pictures showing its computer components.

# *Note:* You may need to disassemble the product to be able to verify that it does incorporate an embedded system. If this is the case, please exercise caution and follow safety procedures to avoid any injuries. If unsure about the safety of an action, consult lecture or lab instructors.

* 1. What feature of the product suggested to you that it may incorporate an embedded system?
	2. What is the model number of the microcontroller chip used in this product?
	3. What is the architecture of this microcontroller?
	4. What are the main specifications of this microcontroller? On-chip memory, integrated peripheral devices, maximum frequency, power rating (volts, amperes, watts), any other notable specifications.
	5. Provide the URL of the microcontroller datasheet.
	6. Include a picture of the product in its original condition, and another picture of its main board, showing the main microcontroller.

# Consider the C code given below:

**volatile** **static** **int** sum = 0; // assume sum is a memory variable

 **for** (**int** i=0; i<8; i++){

 **if** (i<4)

 sum = sum + 2\*i;

 **else**

 sum = sum + 3\*i;

 }

1. Write the given C code in ARM assembly without the use of conditional instructions except branch. Simulate your program using VisUAL ARM emulator and include a snapshot to show that your program produced the correct result of sum.

mov r3, #0 ; i=0

 adr r2, Sum

FOR cmp r3, # 3 ; if (i<4)

 ldr r1, [r2] ; load sum

 add r1, r1, r3, lsl#1 ; sum = sum + 2\*i;

 ble Skip

 add r1, r1, r3 ; sum = sum + 3\*i;

Skip str r1, [r2] ; store sum

 add r3, r3, #1 ; i++

 cmp r3, #8 ; i<8

 bne FOR

Sum DCD 0 ; sum declaration



1. Write the given C code in ARM assembly with the use of conditional instructions. Simulate your program using VisUAL ARM emulator and include a snapshot to show that your program produced the correct result of sum.

 mov r3, #0 ; i=0

 adr r2, Sum

FOR cmp r3, #3 ; if (i<4)

 ldr r1, [r2] ; load sum

 add r1, r1, r3, lsl #1 ; sum = sum + 2\*i;

 addgt r1, r1, r3 ; sum = sum + 3\*i;

 str r1, [r2] ; store sum

 add r3, r3, #1 ; i++

 cmp r3, #8 ; i<8

bne FOR

Sum DCD 0 ; sum declaration



1. Compare your assembly codes in part (a) and part (b) in terms of number of instructions in each code and the number of instructions executed in each code.

As one can see, using conditional instructions saves one instruction in the code size and one less instruction to be executed in every loop iteration. More importantly a conditional branch instruction is avoided which could result in flushing pipeline when this is branch misprediction.

1. Compile your C program to ARM assembly code and compare your handwritten assembly program in part (b) with the compiler-generated assembly code using LPCXpresso IDE. Explain any differences between the two assembly programs.

# The relevant code generated by the compiler is given below. As can be seen our code in (b) is more efficient that the code generated by the compiler. In addition, the way data is declared and the way address of sum is loaded are different.

mov r3, #0

ldr r2, .L6

.L4:

cmp r3, #3

ldrle r1, [r2]

addle r1, r1, r3, lsl #1

ldrgt r0, [r2]

addgt r1, r3, r3, lsl #1

addgt r1, r1, r0

str r1, [r2]

add r3, r3, #1

cmp r3, #8

bne .L4

.L6:

.word .LANCHOR0

.LFE0:

.section .bss.sum.3686,"aw",%nobits

.align 2

.set .LANCHOR0,. + 0

sum.3686:

.space 4

# Consider the C code given below:

**volatile** **static** **int** x; // assume x is a memory variable

x = x \* 217;

1. Write the given C code in ARM assembly without the use of multiplication instructions. Simulate your program using VisUAL ARM emulator and include a snapshot to show that your program produced the correct result of sum.

; 217 = 31 \* 7

 adr r0, Xvar

 ldr r1, [r0]

 rsb r1, r1, r1, lsl #5 ; X = X \* 31

 rsb r1, r1, r1, lsl #3 ; X = X \* 31 \* 7

 str r1, [r0]

Xvar DCD 1



1. Compile your C program to ARM assembly code and compare your handwritten assembly program in part (b) with the compiler-generated assembly code using LPCXpresso IDE. Explain any differences between the two assembly programs.

# The relevant code generated by the compiler is given below, which is similar to our code with the difference of the order of multiplication of 31 and 7.

ldr r2, .L2

ldr r3, [r2]

rsb r3, r3, r3, lsl #3

rsb r3, r3, r3, lsl #5

str r3, [r2]

.L2:

.word .LANCHOR0

.LFE0:

.section .bss.x.3686,"aw",%nobits

.align 2

.set .LANCHOR0,. + 0

x.3686:

.space 4