METU EE447
HW1
Due: Nov. 19th, 2018 12:00

1.

a) Write the basic components of a microprocessor and a microcontroller. State the differences clearly.
b) What is the difference between von Neumann (Princeton) architecture and Harvard architecture? Explain clearly.
c) If the content of register R1 is 0x00112233 and R2 is 0x20000000, show the memory locations that are changed and their contents after the instruction

```
STR R1, [R2].
```

Address	Memory Byte Content

d) List the instruction execution stages.
e) What is the specific function of PC register (R15)?
f) Explain the operation performed with the execution of
"`ADD R4, R4, R4, LSL #4`" instruction.
g) Show the contents of the memory locations given on the table below, after the execution of the following code. You may add addresses if you need.

```
LDR R0, =0x20000040
LDR R1, =0x00000000
LDRH R1, [R0]
STRH R1, [R0, #0x10]
```

Address	Content (Before)	Content (After)
0x00000000 - 0x00000003	0x00000000	
0x20000040 – 0x20000043	0x00010203	

h) If the initial values of R1, R2 and R3 are 0x09, 0x2000000 and 0x4000000 respectively, what will be their final values after the execution of the following code?

```
Loop    LDR R4, [R2], #4
        STR R4, [R3, #4]
        SUBS R1, #1
        BNE Loop
```

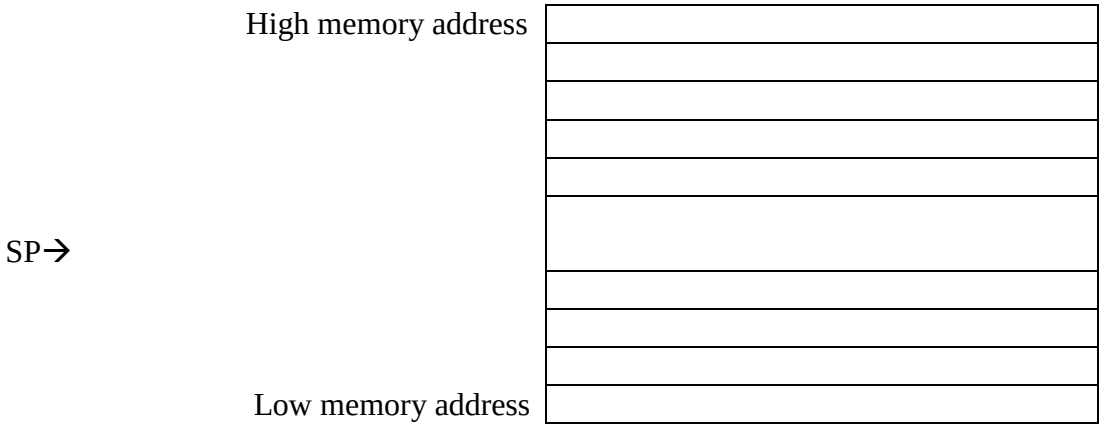
i) Suppose
r0 = 0xFFFF.FFFF,
r1 = 0x0000.0001,
r2 = 0x0000.0000,

and initially N, Z, C, V flags are zero.

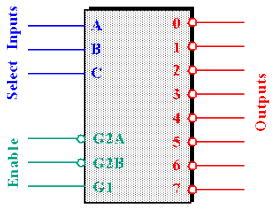
Find out the value of the NZCV flags of the following instructions. (Assume each instruction runs individually, i.e., these instructions are not part of a program.)

```
ADD r3, r0, r2
LSRS r3, r1, #1
ANDS r3, r0, r2
LSL r3, r0, #1
SUBS r3, r0, r0
ADDS r3, r0, r2
```

j) If R1, R2 and R7 have 11, 22 and 77 values respectively, show the content of the memory given below after the execution of PUSH {R2, R7, R1} instruction, where SP is the stack pointer. Show the final position of the stack pointer.

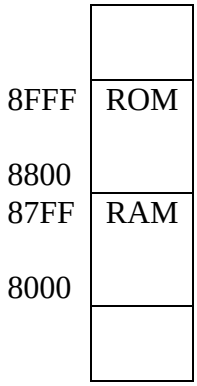


2. Use the following 3-to-8 decoder for the address decoding questions.

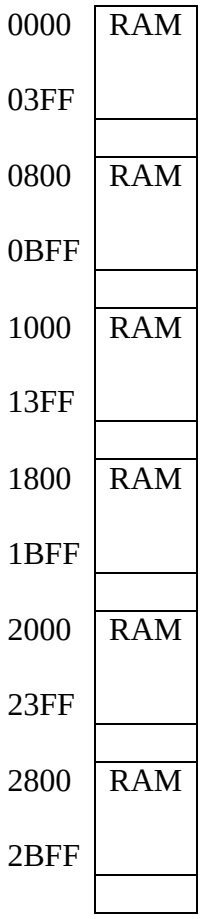


Inputs						Output							
Enable			Select										
G2A	G2B	G1	C	B	A	0	1	2	3	4	5	6	7
1	X	X	X	X	X	1	1	1	1	1	1	1	1
X	1	X	X	X	X	1	1	1	1	1	1	1	1
X	X	0	X	X	X	1	1	1	1	1	1	1	1
0	0	1	0	0	0	0	1	1	1	1	1	1	1
0	0	1	0	0	1	1	0	1	1	1	1	1	1
0	0	1	0	1	0	1	1	0	1	1	1	1	1
0	0	1	0	1	1	1	1	1	0	1	1	1	1
0	0	1	1	0	0	1	1	1	1	0	1	1	1
0	0	1	1	0	1	1	1	1	1	1	0	1	1
0	0	1	1	1	0	1	1	1	1	1	1	0	1
0	0	1	1	1	1	1	1	1	1	1	1	1	0

a) The memory map of a microprocessor with 16 bit addressing is given below. Two 1 KByte RAM chips and two 1 KByte ROM chips are to be connected. Each has one active low enable. Design the address decoding circuit. Show address bits clearly, both on the memory chips and the decoder. Logic levels 0 and 1 are available. Complements are not available.



b) The memory map of a microprocessor with 16 bit addressing is given below. Three 2 KByte RAM chips are to be connected. Each has one active low enable. Design the address decoding circuit. Show address bits clearly, both on the memory chips and the decoder. Logic levels 0 and 1 are available. Complements are not available.



3.Write an assembly program using Thumb2 instruction set that calculates the sum as given below. Variable *n* is saved in register r0 and the *sum (to be less than 2^{32})* is saved in register r1. Your code should occupy a memory region of at most 40 bytes.

$$sum = \sum_{i=1}^{n} i^2 = 1^2 + 2^2 + \cdots + n^2$$

4.

(a) Suppose the stack pointer SP is initialized to 0x20000600. Trace the following program, i.e. show how, R0,R4,PC, SP, LR, PSR and stack content changes.

A recursive assembly code

```
                AREA main, CODE,
READONLY
                EXPORT  __main



                ENTRY
0x08000124
0x08000128  __main    PROC
0x0800012C              MOV   r1, #0x04
0x08000130              MOV   r0, #0x02
0x08000134              ADDS   r1,r1,r0
                        BL    factorial
                stop    B     stop
                        ENDP
0x08000136
0x08000138  factorial
0x0800013A              PUSH  {r1, lr}
0x0800013C              MOV   r1, r0
0x0800013E              CMP   r1, #0x01
0x08000140              BNE   NZ
0x08000142              MOVS  r0, #0x01
0x08000144  loop        POP   {r1, pc}
0x08000148  NZ          SUBS  r0, r1, #1
0x0800014C              BL    factorial
                        MUL   r0, r1, r0
                        B     loop


                        END
```

Use for stack

Inst	R0	R1	R4	PC	SP	LR	PSR	

(b) Suppose the SysTick interrupt occurs when PC = 0x0800012C.

Memory Address	Instruction
	SysTick_Handler PROC
	EXPORT
0x0800001C	SysTick_Handler
0x0800001E	ADD r0, #1
0x08000020	ADD r1, #1
0x08000024	ADD r5, #1
	BX lr
	ENDP

Show the stack content (if the value of a register to be stacked is unknown, just write its name) and the value of PC and SP immediately after entering the SysTick interrupt service routine. What are the value of register PC, r0, r1, and r5 immediately after the SysTick interrupt handler exits?

5. Write an assembly subroutine using Thumb2 instruction set that calculates the following cost. Positive variable x is saved in register r0 and the cost(x) (less than 2^{32}) is saved in register r1.

$$cost(x) = \begin{cases} 9x & if\ x \leq 10 \\ 8x & if\ x > 10\ and\ x \leq 100 \\ 7x & if\ x > 100\ and\ x \leq 1000 \\ 6x & if\ x > 1000 \end{cases}$$