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Washington University in St. Louis

McKelvey School of Engineering

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CSE467M: Embedded Computing Systems

Homework #1

Chapter 1 problems (textbook pages 52 and 53):

1) **Q1-1 (10 points)**
    a. The requirement is the user's explanation of what the finished product should do. But the specification is more precise and it serves as contract between the customer and the architects.
2) **Q1-7 (10 points)**
    a. Describing how the system implements those functions is the purpose of the architecture. The specification does not say how the system does things, only what the system does.
3) **Q1-8 (10 points)**
    a. Architecture design step.
4) **Q1-9 (10 points)**
    a. Architecture design step.
5) **Q1-11 (10 points)**
    a. Both ‘Components’ phase and ‘System integration’ phase.
6) **Q1-12 (10 points)**
    a. Both of approaches are to design an embedded system. Top down approach begins with most abstract description of the system while bottom-up approach start with components to build a system.
7) **Q1-13 (10 points)**
    a. Defining a large and complex embedded system is the example of design problem that is best solved using top-down techniques.
8) **Q1-14 (10 points)**
    a. System’s performance and memory capacity is the example of design problem that is best solved using bottom-up techniques.

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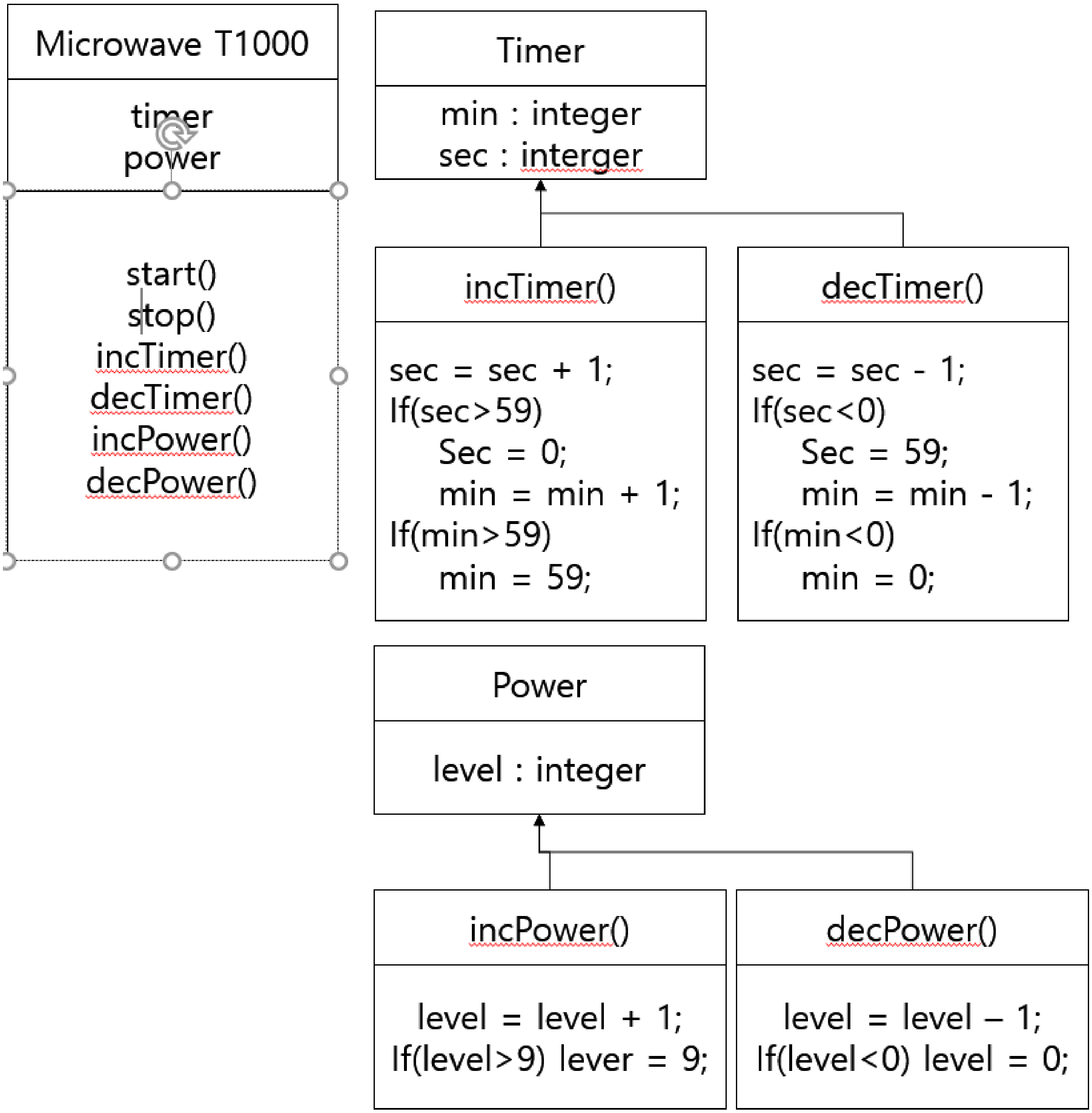
9) Q1-23 (10 points)



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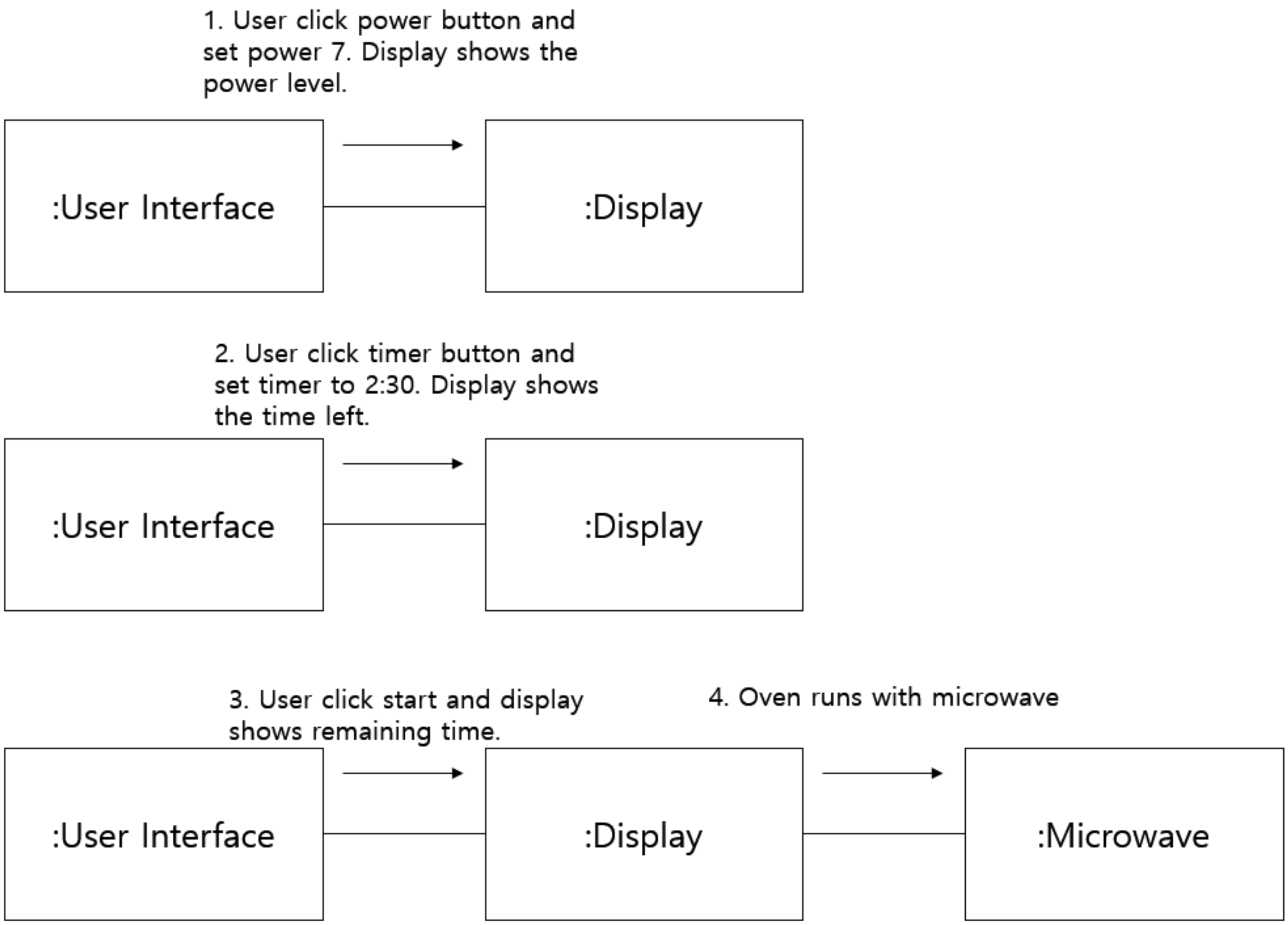
10) Q1- 24 (10 points)



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Chapter 2 problems:

1) **Q2-1 (10 points)**
    a. Little-endian : the lowest-order byte residing in the low-order bits of the word
    b. Big-endian : the lowest-order byte stored in the highest bits of the word
2) **Q2-2 (10 points)**
    a. Von Neumann architectures: A computer whose memory holds both data and instructions
    b. Harvard architectures: It has separate memories for data and program.
3) **Q2-10 (10 points)**
    a. Yes
4) **Q2-11 (10 points)**
    a. 8 levels
5) **Q2-14 (10 points)**
    a. The C55x has four 40-bit accumulators AC0,AC1,AC2 and AC3.
6) **Q2-25 (10 points)**
    a. Fetch packets are instructions that are fetched in groups whereas Execute packet is a set of instructions that execute together.
7) **Implement C statement x = a + b – c*(d + e); using ARM instruction set. Please comment all instructions in your assembly code. (40 points)**

    **** I will use a frame pointer to hold the variables: a is at -24, b at -28, c at -32, d at -36, e at -40 and x at -44**

```
LDR r0, [fp, #-24]   ; load value a into r0
LDR r1, [fp, #-28]   ; load value b into r1
ADD r0, r0, r1       ; a + b, add two value and store it in r0

LDR r1, [fp, #-36]   ; load value d into r1
LDR r2, [fp, #-40]   ; load value e into r2
ADD r1, r1, r2       ; d + e, add two value and store it in r1
LDR r2, [fp, #-32]   ; load value c into r2
MUL r1, r1, r2       ; c*(d + e), multiply two value and store it in r1

SUB r0, r0, r1       ; a+b – c*(d+e) and then store it r0
STR r0, [fp, #-44]   ; save result value into x
```

8) Implement the following C if statement using ARM instruction set.

```
if (a<b) {
            x = c – d;
            y = 10*(e + f);
          }
else      {
            x = 5*c + d;
            y = e – f;
          }
```

Please comment all instructions in your assembly code. (40 points)

**** I will use a frame pointer to hold the variables: a is at -24, b at -28, c at -32, d at -36, e at -40, f at -44, x at -48 and y at -52**

```
        LDR r0, [fp, #-24]   ; load value a into r0
        LDR r1, [fp, #-28]   ; load value b into r1
        CMP r0, r1           ; compare a, b
        BLT .L2

.L2 :   LDR r0, [fp, #-32]   ; load value c into r0
        LDR r1, [fp, #-36]   ; load value d into r1
        SUB r0, r0, r1       ; subtract c – d
        STR r0, [fp, #-48]   ; save result value into x

        LDR r1, [fp, #-40]   ; load value e into r1
        LDR r2, [fp, #-44]   ; load value f into r2
        ADD r1, r1, r2       ; e+f, add two value and store it in r1
        MOV r2, #10          ; load 10 into register r2
        MUL r1, r2, r1       ; 10*(e + f), multiply two value and store it in r1
        STR r1, [fp, #-52]   ; save result value into y
        B .L3

        MOV r0, #5           ; load 5 into register r0
        LDR r1, [fp, #-32]   ; load value c into r1
        MUL r0, r0, r1       ; 5*c, multiply two value and store it in r0
        LDR r1, [fp, #-36]   ; load value d into r0
        ADD r0, r0, r1       ;(5*c) + d, add two value and store it in r0
        STR r0, [fp, #-48]   ; save result value into x
```

```
        LDR r0, [fp, #-40]   ; load value e into r0
        LDR r1, [fp, #-44]   ; load value f into r1
        SUB r0, r0, r1       ; subtract e – f
        STR r0, [fp, #-52]   ; save result value into y
    .L3 :
```

9) **Implement the following C for statement using ARM instruction set.**

for (i=0, f=0; i<5; i++)
f = f + (a[i] + b[i])*x[i] – y[i];

Please comment all instructions in your assembly code. (80 points)

**** I will use a frame pointer to hold the variables:**
i is at -24, f at -28, a at -40, b at -60, x at -80 and y at -100

```
.INIT:
        mov   r3, #0             ; set r3 to 0
        str   r3, [fp, # -24]    ; store 0 into i
        mov   r3, #0             ; set r3 to 0
        str   r3, [fp, # -28]    ; store 0 into f

.COMPARE:
        ldr   r3, [fp, # -24]    ; set r3 to value of i
        cmp   r3, #5             ; compare i with number 5
        blt   .LOOP              ; jump to :LOOP if r3 is less than number 5
        b     .OUT               ; jump to :OUT

.LOOP:
        ldr   r3, [fp, # -24]    ; set r3 to value of i
        mov   r3, r3, asl #2     ; set r3 to value of i * 4
        sub   r3, fp, r3         ; set r3 to i-th element offset from frame pointer
        sub   r0, r3, #40        ; set r0 to an address of a array’s i-th element
```

```
        ldr     r3, [fp, # -24]         ; set r3 to value of i
        mov     r3, r3, asl #2          ; set r3 to value of i * 4
        sub     r3, fp, r3              ; set r3 to i-th element offset from frame pointer
        sub     r1, r3, #60             ; set r1 to an address of b array's i-th element

        ldr     r2, [r0, #0]            ; set r2 to value of a[i]
        ldr     r3, [r1, #0]            ; set r3 to value of b[i]
        add     r0, r2, r3              ; set r0 to value of a[i] + b[i]

        ldr     r3, [fp, # -24]         ; set r3 to value of i
        mov     r3, r3, asl #2          ; set r3 to value of i * 4
        sub     r3, fp, r3              ; set r3 to i-th element offset from frame pointer
        sub     r2, r3, #80             ; set r2 to an address of x array's i-th element

        ldr     r1, [r2, #0]            ; set r1 to value of x[i]
        mul     r0, r0, r1              ; set r0 to value of (a[i] + b[i])*x[i]

        ldr     r3, [fp, # -24]         ; set r3 to value of i
        mov     r3, r3, asl #2          ; set r3 to value of i * 4
        sub     r3, fp, r3              ; set r3 to i-th element offset from frame pointer
        sub     r2, r3, #100            ; set r2 to an address of y array's i-th element

        ldr     r1, [r2, #0]            ; set r1 to value of y[i]
        sub     r0, r0, r1              ; set r0 to value of (a[i] + b[i])*x[i] – y[i]

        ldr     r3, [fp, # -28]         ; set r3 to value of f
        add     r0, r0, r3              ; set r0 to value of f + (a[i] + b[i])*x[i] – y[i]
        str     r0, [fp, # -28]         ; f = f + (a[i] + b[i])*x[i] – y[i]

        ldr     r3, [fp, # -24]         ; set r3 to value of i
        add     r3, r3, #1              ; i + 1
        str     r3, [fp, # -24]         ; i = i+1
        b       .COMPARE
.OUT:
```

10) Implement the following C for statement using Microchip PIC32 FIR Filter example.

```
for (i=0, f=0; i<10; i++)
f = f + (a[i]*b[i] - c[i])*x[i] + y[i];
```

Please comment all instructions in your assembly code. (80 points)

**** I assume that**

i variable : 0 byte offset from fp
f variable : 4 bytes offset from fp
a array : 8 bytes offset from fp
b array : 48 bytes offset from fp
c array : 88 bytes offset from fp
x array : 128 bytes offset from fp
y array : 168 bytes offset from fp

```
.L2 :
        lw      $2, 0($fp)          ;  load i value into $2
        slt     $2, $2, 10          ; compare i and number 10
        beq     $2, $0, .L3         ; i equals 10 then jump to L3
        nop

        lw      $2, 0($fp)          ; load i value into $2
        sll     $2, $2, 2           ; shift 2 bits to get the offset of next element
        addu    $2, $2, $fp         ; add offset with fp
        lw      $3, 8($2)           ; load a[i] into $3

        lw      $2, 0($fp)          ; load i value into $2
        sll     $2, $2, 2           ; shift 2 bits to get the offset of next element
        addu    $2, $2, $fp         ; add offset with fp
        lw      $2, 48($2)          ; load b[i] into $2
        mul     $3, $3, $2          ; a[i] * b[i]

        lw      $2, 0($fp)          ; load i value into $2
        sll     $2, $2, 2           ; shift 2 bits to get the offset of next element
        addu    $2, $2, $fp         ; add offset with fp
        lw      $2, 88($2)          ; load c[i] into $2
        sub     $3, $3, $2          ; a[i] * b[i] - c[i]
```

```
        lw     $2, 0($fp)          ; load i value into $2
        sll    $2, $2, 2           ; shift 2 bits to get the offset of next element
        addu   $2, $2, $fp         ; add offset with fp
        lw     $2, 128($2)         ; load x[i] into $2
        mul    $3, $3, $2          ; (a[i] * b[i] - c[i])*x[i]

        lw     $2, 0($fp)          ; load i value into $2
        sll    $2, $2, 2           ; shift 2 bits to get the offset of next element
        addu   $2, $2, $fp         ; add offset with fp
        lw     $2, 168($2)         ; load y[i] into $2
        add    $3, $3, $2          ; (a[i] * b[i] - c[i])*x[i] + y[i]

        lw     $2, 4($fp)          ; load f into $2
        add    $3, $3, $2          ; f + (a[i] * b[i] - c[i])*x[i] + y[i]
        sw     $3, 4($fp)          ; store result
        lw     $2, 0($fp)          ; load value i
        addiu  $2, $2, 1           ; increment loop count
        sw     $2, 0($fp)          ; store loop count
        b      .L2                 ; jump to L2
        nop
.L3:
```