CIS 600

Advanced Computer Architecture

HW# 1

Due: 2/8 (Thursday)

Turn in the answer to Blackboard.

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Question 1 (13pts)

1. (2pts) What three steps occur to execute MIPS instructions?
   [Fetch], [**Decode**], [**Execute**]

2. (2pts) The C compiler is actually two separate programs: the [**preprocessor**] and the [**translator**].

3. "True"or "False" to the following statements. (All numbers are **decimal** numbers.)

True	(a) "sw $1, $3(100)"	is a legal MIPS instruction.
False	(b) "sw $1, 100($3)"	is a legal MIPS instruction.
False	(c) "add $4, $5, 100($3)"	is a legal MIPS instruction.
False	(d) "add $4, 200($4), 100($3)"	is a legal MIPS instruction.
True	(e) "lw $1, 102($3)"	is a legal MIPS instruction.

3. The following diagram is to explain two multiplexor control signals: "RegDst" and "MemtoReg". They are used to select destination register number and write data to the destination register. Answer with TRUE or FALSE on the following five statements.

add $8, $17, $18

000000	10001	10010	01000	00000	100000
op	rs	rt	rd	shamt	funct

lw $1,

100011	00010	00001	0000 0000 0110 0100
op	rs	rt	16 bit offset

True (i) "RegDst" control signal selects "rt" field ($18) when executing the "add" instruction.
True (ii) "RegDst" selects "rt" field ($1) when executing the "lw" instruction.
False (iii) "MemtoReg" selects ALU output ($17+$18) when executing the "add" instruction.
False (iv) "MemtoReg" selects ALU output ($2+100) when executing the "lw" instruction.

Question 2 (17pts)

The following variables are allocated in the memory beginning at address 2000 on a **64-bit** operating system. Note that the allocation goes towards the **upper end** of the address space.

1. (3 pts): How many bytes does the following data type occupy?

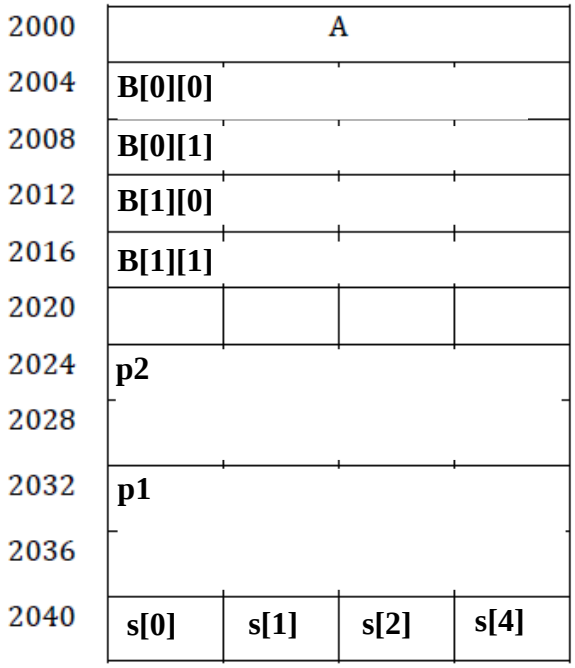
1. char – 1 byte
2. int – 4 bytes
3. float – 4 bytes
4. char* - **8 bytes**
5. int* - **8 bytes**
6. float* **- 8 bytes**

2. (6pts): Complete the memory map below with the variable names at each word or byte in memory. Do not include the variable's value. For B[2][2], you need to specify the mapping for each of the 3 elements in array B.

```
Int A = 200;
float B[2][2] = {{1.0,2.0},
{3.0,4.0}};
float *p2 = &(B[1][1]);
int *p1 = &A;
char s[  ] = "foo";
```

p2 is 8 bytes long, need allocated at an address that is a multiple of 8

s[4] is '\0'



The variables are allocated in the order that they are defined. The allocation scheme tries not to leave gaps in the memory unless necessary (e.g no gaps between char data types).
Hint: **Watch for alignment**: a data type of 4 bytes is always allocated at an address that is a multiple of 4. A data type of 8 bytes is always allocated at an address that is a multiple of 8.

3. (8 pts): using the values in part B, give the value of each expression. Answers may be characters

p1 **2000** *p1 **200** &p1 **2032** p2 **2016**

*p2 **4.0** &p2 **2024** &(f[1]) **2041** *(f+3) **'\0'**

here f should be s

Question 3 (30pts)

1. (8 pts) Write a MIPS code fragment that adds the value 0x4FA2C3 to register $1 and puts the result in $2. Modify only registers $1 and $2. (You may use hexadecimal immediate values.) *For maximum credit, include comments.*

   An integer is 4 bytes long, that is double-word length. Because MIPS can only load up to one word length in one instruction, 0x4FA2C3 need to load into $2 separately, first load to upper 16bits (one word length), then load the rest to lower 16bits, the second load need to use OR operation to avoid upper bit overwritten by 0.

Label	Instruction	Comment
1	lui $2, 0x4F	$2 = 0x4F * 2^{16}
2	ori $2, $2, 0xA2C3	$2 = $2 | 0xA2C3
3	add $2, $2, $1	$2 = $2 + $1

2. (10pts) Write a C code fragment that loops through an array of integers A until it its one that is zero. It should compute and store in the variable p the running product of the nonzero integers that occur in the array before the zero. Assume that A contains at least one zero and it contains at least one nonzero integer before the first zero. *For maximum credit, choose the most appropriate loop construct and declare and initialize variables as needed.*

```
int A[ ] = {..., 0, ...};     // Array A
int p = 1;                    // product initialize as 1
int i = 0;
do {                          // in loop body, iterate
     p = p*A[i];              // through array A, until
     i++;                     // A[i] == 0, store running
} while(A[i]);                // product in p
return p;
```

3. (12pts) Suppose A is stored in memory location 1020 and B is stored in memory location 1024. Write a MIPS program fragment that computes "$256 \cdot (A + B/16)$" and stores the result at memory location 1028. Use a minimum number of instructions and registers.

Instruction	Comment
lw $1, 1020($0)	$1 = mem[$0+1020], load A into $1
lw $2, 1024($0)	$2 = mem[$0+1024], load B into $2
sra $2, $2, 4	$2 = $2 >> 4 (arithmetic), now B = $B/2^4$
add $2, $2, $1	$2 = $2 +$1, now $2 = A + B/16
sll $2, $2, 8	$2 = $2 << 8 (logical), now $2 = $2 * 256
sw $2, 1028($0)	Mem[$0+1028] = $2, store $2 to memory location 1024

Question 4. (20pts)

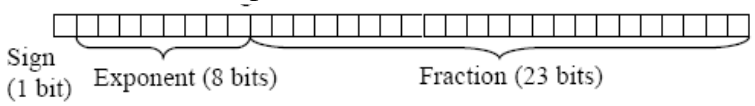
1. (20pts) Write a MIPS code fragment that corresponds to this C fragment. Assume `$1` holds `N`, and `$2` holds `Sum`. Feel free to use additional registers, but use a minimum number of instructions and registers.

```
Sum = 0;
while (N!=0){
     Sum += N&1;
     N = N >> 1;
}
```

Label	Instruction	Comment
	addi $2, $0, 0	$2 = $0 + 0, add immediate 0 to $2, Sum = 0
Loop:	beq $1, $0, Exit	branch if($1=$0), go to label Exit
	andi $3, $1, 1	$3 = $1 & 1, and immediate 1 with $1, store to $3
	add $2, $2, $3	$2 = $2 + $3, add $3 to $2, Sum += N&1
	srl $1, $1, 1	$1 = $1 >> 1 (logical), $1 shift right one bit, N = N>>1
	j Loop	jump back to label Loop, continue loop body
Exit:		

Question 5. (20pts)

Number conversion. IEEE 754 floating-point standard represents a 32-bit single-precision normalized decimal number into floating-point number to be the following. Please convert the given IEEE 754 FP representation (in hex). Describe the intermediates.



$$= (-1)^{sign} * (1+fraction) * 2^{Exponent-127}$$

1 **negative number, set Sign bit to 1**

2 **the integer part, 30, convert to binary, $(30)_{10} = (11110)_2$**

3 **the fraction part, 0.375, keep multiply 2, until fraction part equals zero, record result in integer part each time in binary bits as following,**

- **3.1 0.375 * 2 = 0.75 ==> $b^{-1} = 0$**
- **3.2 0.75 * 2 = 1.5 ==> $b^{-2} = 1$**
- **3.3 0.5 * 2 = 1.0 ==> $b^{-3} = 1$, since fraction part is 0, stop**
- **3.4 now we get $(0.375)_{10} = (0.011)_2$**

4 **put binary form from step 2 and step 3.4 together, we get $(11110.011)_2$**

5 **since IEEE 754 single-precision requires format as $(1.xxxxxx)_2 * 2^e$, convert the binary from step 4 as $(1.1111011)_2 * 2^4$**

6 **the fraction part (right side of the binary point) is 1111011**

7 **the exponential is 4, need to add 127 to get bias form 131, convert to binary, $(131)_{10} = (10000011)_2$**

8 **now put sign bit, exponent binary, fraction binary together, fill the following bits with 0**

1-10000011-11110110000000000000000

9 **convert binary to Hex, we get** $(-30.375)_{10} = ($ **C1FB0000** $)_{16}$

MIPS Instruction Set (core)

instruction	*example*	*meaning*
arithmetic		
add	add $1,$2,$3	$1 = $2 + $3
subtract	sub $1,$2,$3	$1 = $2 - $3
add immediate	addi $1,$2,100	$1 = $2 + 100
add unsigned	addu $1,$2,$3	$1 = $2 + $3
subtract unsigned	subu $1,$2,$3	$1 = $2 - $3
add immediate unsigned	addiu $1,$2,100	$1 = $2 + 100
set if less than	slt $1, $2, $3	if ($2 < $3), $1 = 1 else $1 = 0
set if less than immediate	slti $1, $2, 100	if ($2 < 100), $1 = 1 else $1 = 0
set if less than unsigned	sltu $1, $2, $3	if ($2 < $3), $1 = 1 else $1 = 0
set if < immediate unsigned	sltui $1, $2, 100	if ($2 < 100), $1 = 1 else $1 = 0
multiply	mult $2,$3	Hi, Lo = $2 * $3, 64-bit signed product
multiply unsigned	multu $2,$3	Hi, Lo = $2 * $3, 64-bit unsigned product
divide	div $2,$3	Lo = $2 / $3, Hi = $2 mod $3
divide unsigned	divu $2,$3	Lo = $2 / $3, Hi = $2 mod $3, unsigned
transfer		
move from Hi	mfhi $1	$1 = Hi
move from Lo	mflo $1	$1 = Lo
load upper immediate	lui $1,100	$1 = 100 x 2^{16}
logic		
and	and $1,$2,$3	$1 = $2 & $3
or	or $1,$2,$3	$1 = $2 | $3
and immediate	andi $1,$2,100	$1 = $2 & 100
or immediate	ori $1,$2,100	$1 = $2 | 100
nor	nor $1,$2,$3	$1 = not($2 | $3)
xor	xor $1, $2, $3	$1 = $2 ⊕ $3
xor immediate	xori $1, $2, 255	$1 = $2 ⊕ 255
shift		
shift left logical	sll $1,$2,5	$1 = $2 << 5 (logical)
shift left logical variable	sllv $1,$2,$3	$1 = $2 << $3 (logical), variable shift amt
shift right logical	srl $1,$2,5	$1 = $2 >> 5 (logical)
shift right logical variable	srlv $1,$2,$3	$1 = $2 >> $3 (logical), variable shift amt
shift right arithmetic	sra $1,$2,5	$1 = $2 >> 5 (arithmetic)
shift right arithmetic variable	srav $1,$2,$3	$1 = $2 >> $3 (arithmetic), variable shift amt
memory		
load word	lw $1, 1000($2)	$1 = memory [$2+1000]
store word	sw $1, 1000($2)	memory [$2+1000] = $1
load byte	lb $1, 1002($2)	$1 = memory[$2+1002] in least sig. byte
load byte unsigned	lbu $1, 1002($2)	$1 = memory[$2+1002] in least sig. byte
store byte	sb $1, 1002($2)	memory[$2+1002] = $1 (byte modified only)
branch		
branch if equal	beq $1,$2,100	if ($1 = $2), PC = PC + 4 + (100*4)
branch if not equal	bne $1,$2,100	if ($1 ≠ $2), PC = PC + 4 + (100*4)
jump		
jump	j 10000	PC = 10000*4
jump register	jr $31	PC = $31
jump and link	jal 10000	$31 = PC + 4; PC = 10000*4