

Computer Architecture I Midterm I

Chinese Name: _____

Pinyin Name: _____

E-Mail ... @shanghaitech.edu.cn: _____

Question	Points	Score
1	1	
2	12	
3	16	
4	14	
5	18	
6	17	
7	22	
Total:	100	

- This test contains 10 numbered pages, including the cover page, printed on both sides of the sheet!.
- We will use gradescope for grading, so only answers filled in at the obvious places will be used.
- Use the provided blank paper for calculations and then copy your answer here.
- Please turn **off** all cell phones, smart-watches, and other mobile devices. Remove all hats and headphones. Put everything in your backpack. Place your backpacks, laptops and jackets under your seat.

- You have 85 minutes to complete this exam. The exam is closed book; no computers, phones, or calculators are allowed. You may use one A4 page (front and back) of notes in addition to the provided green sheet.
- The estimated time needed for each of the 6 topics is given in parenthesis. The total estimated time is 80 minutes.
- There may be partial credit for incomplete answers; write as much of the solution as you can. We will deduct points if your solution is far more complicated than necessary. When we provide a blank, please fit your answer within the space provided.
- Do **NOT** start reading the questions/ open the exam until we tell you so!
- Unless otherwise stated, always assume a 32 bit machine for this midterm.

1 1. First Task (worth one point): Fill in you name

Fill in your name and email on the front page and your ShanghaiTech email on top of every page (without @shanghaitech.edu.cn) (so write your email in total 8 times).

2. Various Questions (12 pts; 10 min)

- 3 (a) Name 6 Great Ideas in Computer Architecture.

Solution: 1. Abstraction (Layers of Representation/Interpretation)
 2. Moores Law (Designing through trends)
 3. Principle of Locality (Memory Hierarchy)
 4. Parallelism
 5. Performance Measurement and Improvement
 6. Dependability via Redundancy

- 2 (b) You define a short recursive MIPS procedure `foo` that is statically linked by two executables. Can the binary for the procedure `foo` be different in the two executables? Why, or why not?

Solution: They CAN be different because the address of `foo` (which will be a part of the recursive jal call) depends on where the code is placed.

- 2 (c) What is the difference between the `add` and `addu` MIPS instructions?

(c) add may cause an overflow exception, while addu will not.

- 2 (d) Which MIPS registers are preserved over a function call (write all register names - e.g. `$m2-$m6`)?

(d) \$s0-\$s7, \$gp, \$sp, \$fp

- 1 (e) How many things can you represent with N bits?

(e) 2^N

- 2 (f) In the lecture you learned about CALL (this is the CALL regarding executing a C program on a computer). Name (each a single word) the important steps of this procedure in the right order.

Solution: Compiler Assembler Linker Loader

3. Number Representation (16 pts; 15 min)

Please convert the following 8-bit Signed Integers into decimal form.

Explicitly write '+' and '-'.

For example, suppose that the binary representation is 01000001B and it is represented in Sign-Magnitude Representation, then the solution is +65D.

- 2 (a) If represented in Sign-Magnitude Representation

Suppose the binary representation is 10000001B: _____

Suppose the binary representation is 10000000B: _____

Solution: -1D -0D

- 2 (b) If represented in 2's Complement Representation

Suppose the binary representation is 10000001B: _____

Suppose the binary representation is 11111111B: _____

Solution: -127D -1D

- 4 (c) Suppose a is an 8-bit signed integer represented as $a_{hex} = 0xCB$, then its binary

representation is $a_{two} =$ _____, its decimal representation is $a_{ten} =$ _____.

Solution: Answer: 11001011, -53

- 4 (d) For an 10-bit value, two's complement integer, what are the largest AND smallest value you can represent in decimal?

Solution: Answer: 511, -512

- 4 (e) Assume an 8-bit two's complement machine on which all operators are performed on 8-bit registers. Answer the results of the following operations in hexadecimal. Assume that subtraction is done with SUBU and addition is done with ADDU.

$$\begin{array}{r} \text{a} \quad 8C \quad (\text{hex}) \\ - \quad B5 \quad (\text{hex}) \\ \hline \end{array}$$

$$\text{b} \quad 8A \quad (\text{hex})$$

+ 3E (hex)

Solution: Answer: D7, C8

4. C programming I (14 pts; 14 min)

- 4 (a) What is the value of `s` in the following code? If possible, also provide the actual number in decimal.

```
unsigned int t[] = {0, 1, 2, 3, 4, 5};
unsigned int s = sizeof(t);
```

- (I) The length of the `t` array.
 (II) The number of bytes in the `t` array.
 (III) The number of bytes in one unsigned int.
 (IV) The number of bytes in an unsigned int pointer.
 (V) Nothing: an error will be produced.

(a) _____ **II; 24**

- 5 (b) What does the following method do?

```
char * func(char *f, char y){
    char *h = f;
    for(h = f; *h != y && *h){
        h++;
        if(*h){
            *h = 0;
            h++;
        }
    }
    return h;
}
```

- (I) It returns a pointer to the first location of `y` in `f`.
 (II) It splits `f` at the first occurrence of `y` and then returns a pointer for the remaining string.
 (III) It finds the last location of `y` in `f`, zeros out that location, and then returns a pointer to the next location.
 (IV) It zeros out `f` until it finds `y`. It then returns a pointer to the location of `y` in `f`.
 (V) Nothing; it cannot be compiled.

(b) _____ **IV or V (missing semicolon in the for loop)**

- 5 (c) The `%s` format specifier takes in a `char*` and prints until it finds a null character. What do the following two lines of code print?

```
char *s = "uncharacteristic";
printf("%s", s+s[7]-s[6]);
```

(c) _____ **"characteristic"**

5. C programming II (18 pts; 10 min)

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(a) Given the code below:

```
int a;
const char * b;
int foo(short c) {
    char d;
    static int * e = malloc(sizeof(int));
}
int main() {
    int f;
    foo(3);
}
```

Name all areas of memory that are used by the program:

(a) _____ **Static data; stack; heap** _____

At which area of the memory are the following variables stored:

a:	b:
c:	d:
e:	f:

Solution:

a: static data	b: static data
c: stack (or register)	d: stack
e: static data	f: stack

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(b) 1. When passing parameters to functions, what is the difference between **call by value** and **call by reference**?

2. What is the default function call method in (I) MIPS and (II) C?

3. How can we achieve the other call method?

Solution:

1. **call by value** Use the value of parameter, but not modify it.
- call by reference** Send address of the actual parameters instead of values. Want the parameters be modified.
2. By default the functions are called by value in both MIPS and C.
3. Passing a pointer to the value

6. Bits and Pieces (17 pts; 15min)

Read the following MIPS assembly code and answer the following questions. Your answers should be as concise as possible.

```
halo:
    #BEGIN
    addiu $v0, $0, 0
    addiu $s0, $0, 0
    addiu $s1, $0, 0
    beq $a0, $0, finish_the_fight
    addiu $s0, $a0, 0
    addiu $s1, $0, 1
    andi $t0, $s0, 1
new_mombasa:
    bne $t0, $0, finish_the_fight
    srl $s0, $s0, 1
    sll $s1, $s1, 1
    andi $t0, $s0, 1
    j new_mombasa
finish_the_fight:
    addiu $v0, $s1, 0
    #END
    jr $ra
```

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(a) Briefly explain what `halo` returns with respect to the input.

Solution: Get the lowest positive bit from the input number.

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(b) Try to implement the function in C as efficient and concise as possible. (The space given below is more than enough.)

```
Solution: int masterchief(int cortana){
    return cortana & (^cortana + 1);
}
```

- 6 (c) We've broken some assembly language calling conventions with the code above. Write the code that should be inserted at the positions of *#BEGIN* and *#END* to correct it.

At **#BEGIN**:

```
Solution: addiu $sp $sp -8
sw $s0, 0($sp)
sw $s1, 4($sp)
```

At **#END**:

```
Solution: lw $s0, 0($sp)
lw $s1, 4($sp)
addiu $sp $sp 8
```

7. MIPS & Branch-if-equal instruction (22pts; 16 min)

- 10 (a) True/False: circle the correct answer (2 pts each)

- T** **F** 1. Branch instructions in MIPS can only jump forward 32768 and backward 32767 instructions.
- T** **F** 2. A carry-out at the most significant bit after an addition of two signed numbers always indicates overflow.
- T** **F** 3. I-type instructions always cause pipeline bubbles.
- T** **F** 4. If we only have three parameters to send to a non-recursive function, then we can use registers and don't need to use the stack.
- T** **F** 5. Every location in the text segment is accessible from a single branch statement.

Solution:

1. T (a branch with an immediate of 0 jumps forward 1 instruction)
2. F (operations with a negative result will always have carry-out.)
3. F
4. T
5. F

- 6 (b) Consider a hypothetical branch-if-equal instruction that is 32 bits long:
- 6 bits are used to encode the opcode
 - 6 bits are used to encode one register number
 - 6 bits are used to encode another register number
 - 14 bits are used to encode an offset that will be added to the program counter (PC) if the branch ends up being taken, and a new instruction address is required. (The number is not in 2's complement form, and all 14 bits can encode a constant.)

Thus, the instruction syntax might be: `BEQ R12, R11, X`

- If $R12 == R11$, the PC will be set to $PC+X$ instead of $PC+4$.

Given this instruction, is the code shown in the table below valid? Why or why not? Explain in detail.

Address	Instruction
5000	...
5004	BEQ R12, R11, X
5008	Add R1, R2, R3
...	...
X: 21256	Sub R1, R2, R3

Solution: Yes, this code is valid. The 14 bit offset allows you to encode a number that is as large as 16383. Thus, even if the PC has not yet been incremented, you can reach address 21384 ($5004 + 16383$), which is beyond address 21256.

Since it was not super clear we also allow:

No, the code is not valid. The 14 bit offset allows you to encode a sign-magnitude number as large as 8191, we can reach maximum 13196, which cannot reach 21256.

- 6 (c) Instruction Format: Translate the assembly into machine code and vice versa (use named registers - not register numbers).

Instruction	Code (hex)
<code>lb \$t3, 7(\$s5)</code>	0x82ab0007
<code>sll \$s1, \$s2, 8</code>	0x00128a00