

Computer Architecture I Mid-Term I

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| Question | Points | Score |
|----------|--------|-------|
| 1 | 1 | |
| 2 | 11 | |
| 3 | 10 | |
| 4 | 9 | |
| 5 | 14 | |
| 6 | 29 | |
| 7 | 14 | |
| 8 | 12 | |
| Total: | 100 | |

- This test contains 14 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 out of reach.

- You have 120 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 handwritten notes in addition to the provided green sheet (one of those can be printed).
- The total estimated time is 120 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 exam.

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 14 times).

2. Various Questions

- 3 (a) Name 6 Great Ideas in Computer Architecture.
- 1 (b) Which registers will not be preserved over a function call? (Only Considering $\$t$, $\$a$, $\$s$, $\$v$, $\$at$ and $\$sp$, same range of registers for the two following problems.)
- 1 (c) Which registers will be preserved in the stack while we do function call?
- 6 (d) Let's play with CALL!
Connect the definition with the name of the process that describes it. (Please fill in the blanks before 1) to 9))
a) Compiler b) Assembler c) Linker d) Loader
- ___ 1) Outputs code that may still contain pseudoinstructions.
- ___ 2) Takes binaries stored on disk and places them in memory to run.
- ___ 3) Makes two passes over the code to solve the "forward reference" problem.
- ___ 4) Creates a symbol table.
- ___ 5) Combines multiple text and data segments.
- ___ 6) Generates assembly language code.
- ___ 7) Generates machine language code.
- ___ 8) Only allows generation of TAL.
- ___ 9) Only allows generation of binary machine code.
- ___ 10) Resolves relative addressing.
- ___ 11) Resolves absolute addressing
- ___ 12) Which may make use of at register?

3. Number Representation

Fill in the blanks below

- 4 (a) Given a 10-bit binary number, what is the range of the integer it can represent?

If unsigned smallest: _____ largest: _____

If one's complement smallest: _____ largest: _____

If two's complement smallest: _____ largest: _____

- 4 (b) Convert 2018_{ten}

To Binary _____

To Hexadecimal _____

To a base-15 number [A(10), B(11), C(12), D(13), E(14)]

- 2 (c) Concisely describe how to identify **overflow**

4. Memory With C

Note: The following code is compiled with `"-m32 -std=c89"`

- 2 (a) Suppose we have defined the C structure:

```
1  struct student {
2      int id;
3      int score;
4      char name[8];
5  };
```

Also, we declare:

```
1  struct student students[3];
2  struct student *studentTwo = students + 2;
```

Suppose that students starts at $0x10000000$. What is the value of studentTwo?

(a) _____

We are creating songs in preparation of the graduation party. Consider the following program:

```
1  #include <stdio.h>
2  #include <stdlib.h>
3  #include <string.h>
4
5  typedef struct Song {
6      char *title;
7      char *artist;
8  } Song;
9
10 Song * createSong() {
11     Song* song = (Song*) malloc(sizeof(Song));
12     song->title = "this old dog";
13     char artist[100] = "mac demarco";
14     song->artist = artist;
15     return song;
16 }
17
18 int main(int argc, char **argv) {
19     Song *song1 = createSong();
20     printf("%s\n", "Song written:");
21     printf("%s\n", song1->title); // print statement #1
22     printf("%s\n", song1->artist); // print statement #2
23     Song song2;
24     song2.title = malloc(sizeof(char)*100);
25     strcpy(song2.title, song1->title);
26     song2.artist = "MAC DEMARCO";
27     printf("%s\n", "Song written:");
28     printf("%s\n", song2.title); // print statement #3
29     printf("%s\n", song2.artist); // print statement #4
30     return 0;
31 }
```

- 5 (b) In the following code is listed that prints a certain address. In which part of the memory will this address be located? (Circle it)

1. `printf("%p", song1);`
 - (a) Stack
 - (b) Heap
 - (c) Static
 - (d) Code
2. `printf("%p", song1->title);`
 - (a) Stack
 - (b) Heap
 - (c) Static
 - (d) Code
3. `printf("%p", song1->artist);`
 - (a) Stack
 - (b) Heap
 - (c) Static
 - (d) Code
4. `printf("%p", &song2);`
 - (a) Stack
 - (b) Heap
 - (c) Static
 - (d) Code
5. `printf("%p", song2.title);`
 - (a) Stack
 - (b) Heap
 - (c) Static
 - (d) Code

- 2 (c) Will all print statements execute as expected? Circle: YES NO

If you answered yes, leave this blank. If you answered no, write the number(s) of the print statement(s) which will not execute as expected.

(c) _____

5. C Programming (Variables & pointers)

All questions in this section are based on the following code.
Assume the code is natively compiled on a 64-bit system.

```
1     #include <stdio.h>
2     #include <stdlib.h>
3     #include <stdint.h>
4
5     long int exam_foo(const uint32_t * array_foo){
6         return sizeof(array_foo);
7     }
8
9     int main(){
10        uint32_t a = 0;
11        uint32_t * b = &a;
12        uint32_t ** c = &b;
13
14        uint32_t arr[5] = {0x2018, 0x4, 0x1, 0x110, 0x2019};
15        uint32_t * p = arr;
16    }
```

7 (a) What's the size of the following variables? (Your answer should be in bytes.)

a:

b:

c:

arr:

arr[0]:

p:

array_foo:

2 (b) What type does **sizeof(array_foo)** return? What is the value of **sizeof(sizeof(array_foo))**?

(b) _____

- 5 (c) What's the expected value of the following expression. If an expression might cause an error, write "ERROR". For all numbers, write them down in their hexadecimal form. (0x)

*(p+3):

p[2]:

*(p+2) + p[1]:

*(uint16_t *)p[0]:

(uint8_t)(p+4):

6. MIPS

Notice. In this part (especially parts (d) and (e)), you can write at most **ONE** line of code in each space when we ask you to write down codes, but you do not have to use all of the spaces. **If you write more than one line of code in one space, that answer will be voided.** ("one line of code" means one semicolon in C or one instruction in MIPS)

- 5 (a) This subquestion involves T / F questions. Circle the correct answer.

T / F: *li* is a pseudo instruction.

T / F: There are at most 15 trailing bits with value zero in *\$t0* after the execution of the following instruction:

```
1      lui    $t0,  $t0,  0x8000
```

T / F: The value in *\$t0* and *\$t1* are the same after the execution of the following instruction:

```
1      addi  $a0,  $zero, 10
2      sra   $t0,  $a0,  1
3      srl   $t1,  $a0,  1
```

T / F: You can jump to any instruction you like using a J type instruction as long as the label is provided.

T / F: Instruction *addi* can cause overflow exception.

- 6 (b) Please translate the following instruction from MIPS to hex value and vice versa. Besides, specify which type of instructions are these.

```

1      addu  $t0, $t9, $s1
2      jr   $ra
3      0x8fb00020
4      0x014b4826

```

Translation of Line 1: _____, instruction type: _____

Translation of Line 2: _____, instruction type: _____

Translation of Line 3: _____, instruction type: _____

Translation of Line 4: _____, instruction type: _____

- 3 (c) Creative Instructions.

Write a MIPS instruction which will cause an infinite loop if ever executed, anywhere, in any MIPS program.

(Both instruction and Hex value along with it's type)

Instruction: _____

Hex value: _____

- 7 (d) Let's talk about branches.

1.) You may have used *ble* in your projects. But it is known as a pseudo instruction. For example the following instruction. Please write down the complete RTL for it.

```

1 ble  $t0, $t1, Label

```

2.) Pseudo instructions can not be compiled into machine code directly, it has to be translated to some real instructions beforehand. Please come up with **two TAL instructions** that can be used to **translate the pseudo instruction above**.

The instructions you write should be able to **substitute** any *ble* pseudo instruction anywhere in a MIPS program.

Hint: If you can't think of a way to explain that pseudo instruction in 2 instructions, you can write a solution with 3 instructions. We will deduct some pts but not all of them.

```

1
2      _____
3
4      _____
5
6      # Think harder before you write anything below.
7
8      - - - - -

```


3.) In 2.), why don't we use $\$t2$ or $\$t3$ as a temporary register? Which register did we use instead? What is the purpose of using this one?

8

(e) StarCraft is a famous RTS(Real Time Strategy) game. The first edition was issued in 1998 and it has been played by *zealots* all over the world for 20 years. In this game, you will be commanding an army to fight your enemy until he/she has no buildings left (or, unfortunately, you have nothing left).

To build such a game, you need a combat system. In the simplest case, when two units meet, they attack each other until one dies, thus both of them must have health points (hp) and damage. When one side has 0 or negative hp, we consider it dead. Notice the possibility that two units may die at the same time (both of them throw a critical strike to each other at the same time).

Let's assume two units (call them unit0 and unit1) meet, they attack each until one or both die. You should report which one died (0 or 1). If both of them died, report -1.

In this part, you will be filling unfinished C and MIPS code.

```
1  const bool bothAlive(  
2      const int hp0, const int hp1){  
3      return (hp0>0 && hp1>0);  
4  }  
5  const int attack(  
6      int hp0, int hp1,  
7      const int damage0, const int damage1){  
8      while (bothAlive(hp0, hp1)){  
9          hp0 -= damage1;  
10         hp1 -= damage0;  
11     }  
12     if (hp0 <= 0 && hp1 <= 0){  
13         return -1;  
14     } else {  
15  
16         _____  
17     }  
18 }
```

```
1 bothAlive:
2     slt  $t0, $zero, $a0
3     slt  $t1, $zero, $a1
4
5     _____
6     jr   $ra
7
8 attack:
9     sw   $ra, 0($sp)
10    addi $sp, $sp, -4
11    LoopChecker:
12        jal bothAlive
13
14    _____
15    Loop: subu $a0, $a0, $a3
16        subu $a1, $a1, $a2
17        j   LoopChecker
18    EndLoop:
19
20    _____
21
22    _____
23
24    and  $t3, $t0, $t1
25    if: bne $t3, 1, else
26        addiu $v0, $zero, -1
27        j   endIf
28    else:
29
30    _____
31    endIf:
32    addi $sp, $sp, 4
33    lw   $ra, 0($sp)
34
35    _____
```

- a) Please fill in the C code.
- b) Please fill in the (half-translated) MIPS code.
- c) Your peer thinks that function *bothAlive* is wrong as *\$ra* is not saved beforehand. Please write the instructions to make it right or argue with your peer about why he is wrong.

7. C Programming

- 8 (a) This subquestion involves T / F questions. Incorrect answers on T / F questions are penalized with negative credit. Circle the correct answer.

T / F: Every C Program must have the statement `#include <stdio.h>`.

T / F: A memory leak can always be detected because the program crashes whenever one is present.

T / F: The ASCII values for the standard characters go from 1 to 128.

T / F: Static memory means that it exists throughout the execution of a program.

T / F: Given the array `char letters[26]`, `letters` is the address of `letters[0]`

T / F: If `ptr2` is set to `ptr` (a pointer given by the declaration "`char ptr[10]`") then `ptr2++` points to the cell `ptr[1]`

T / F: The following is a legal macro:

```
1 #define Love printf("I love Computer Architecture!\n")
```

T / F: If `Yang` is a pointer to a structure that has an `int*` variable `age` with `*age = 21`, then to access the value of `age` we can write:

```
1 Yang -> (*age);
```

T / F: If we are given `char str[] = "Rua!"` then the command `printf("%s", str+2)` will print out "a!"

T / F: If we are given `char str[] = "Rua!"` then the command `printf("%s", ++str)` will print out "ua!"

- 6 (b) You are asked to allocate and free a 2 dimensional array dynamically. You do not need to check memory validity when you are using `malloc`. The 2 dimensional array `a` should be accessed as `a[Row][Col]` (index of row starts from 0, ends with `nRow-1`; index of column starts from 0, ends with `nCol-1`).

There is a way to program this such that during execution the `free` function will be called only 2 times, regardless (independent) of the size of `nCol` and `nRow`. If you implement this version you can get full points, otherwise you can only get 4 points for this question.

```
1  int **a;
2  int i, iRow, iCol;
3  /* Allocate a 2 dimensional array with nRow rows and nCol
   columns using malloc */
4
5  _____
6
7  _____
8
9  _____
10
11 _____
12
13 _____
14
15 _____
16
17 for (iRow = 0; iRow < nRow; iRow++) {
18     for (iCol = 0; iCol < nCol; iCol++) {
19         a[iRow][iCol] = iRow + iCol;
20     }
21 }
22
23 /* Free the 2 dimensional array */
24
25 _____
26
27 _____
28
29 _____
30
31 _____
32
33 _____
```

8. C Programming

2

(a) Fill in the declaration of a single linked list below.

```
1  /* definition of single linked list */
2  typedef struct node{
3      int value;
4      /* a pointer to the next node */
5
6
7      _____ next;
8  } node;
```

5

- (b) You are asked to convert an int array to a single linked list. All variables you are allowed to use have been defined in the beginning of the function.

```
1  /* turn an array to linked list */
2  /* if the array is empty, just return NULL */
3  node * int_arr_to_list(const int * arr, int len){
4      /* declare all variables you might use */
5      node * header;
6      node * curr;
7      int i;
8
9      /* student should fill in everything here */
10     if (len == 0) return NULL;
11
12     /* deal with the header */
13
14
15     header = _____
16
17
18     header->value = _____
19
20
21     header->next = _____
22
23     /* fill in the rest */
24     curr = header;
25
26
27     _____
28
29
30     _____
31
32
33     _____
34
35
36     _____
37
38
39     _____
40
41     return header;
42 }
```

5

(c) Below is code to append a new node after the end of a linked-list. Part of the code is wrong, read the code and answer the following questions.

Note: Suppose main() and other supporting functions are bug-free. Header files have been included properly.

```
1  /* append an element to end of the list */
2  void append_node(node * list_head, int val){
3      node * curr = list_head;
4      node new_node;
5      while(curr->next != NULL){
6          curr = curr->next;
7      }
8
9      new_node.value = val;
10     new_node.next = NULL;
11     curr->next = &new_node;
12 }
```

1. Can the program successfully compile (produce executable file), if the above function is not called but presented in the source code?

2. Can the above program successfully compile (produce executable file) if the above function is called?

3. Point out the error and correct it in the following format.

Example: Line: 3 | Correction: node * new_curr = list_header;

