University of Virginia, Department of Computer Science
CS/ECE 3330: Computer Architecture, Fall 2011

Exam 1
September 26, 2011

Name: Chuqiao Wang

Problem	Possible Points
1	20
2	20
3	8
4	20
5	20
6	12
Bonus	5
Total	105

COMP 015 005 Student Name:

Student Username: aaly01

Name: Chuqiao Wang

1. True or False (20 points)

a. T F The "multicore revolution" happened because silicon became too expensive in the early 2000s.

b. T F Energy is defined as the amount of power per unit time.

c. T F MIPS is one of the oldest ISAs.

d. T F In MIPS, single-precision arithmetic always produces a single-precision result.

e. T F The MIPS `jal` instruction stores the next instruction into the `$ra` register.

f. T F MIPS instructions can range from 4-bits to 32-bits long.

g. T F The opcode for the MIPS `sb` instruction is 28(hex).

h. T F The MIPS `$sp` (stack pointer) register is modified automatically by the MIPS hardware.

i. T F By convention, the argument registers `$a0-$a3` are preserved after function calls.

j. T F To multiply the contents of a register by two, `sll` is used with `shamt` set to 2.

k. T F The binary number `1001.101` equals `9.625` in decimal.

l. T F In IEEE 754 floating point notation, there are two values for zero.

m. T F "Denormal numbers" represent numbers that slowly overflow in floating point arithmetic.

n. T F Floating point numbers have an exponent bias in order to make number comparisons easier.

o. T F The *decimal* number 0.1 can be represented exactly in IEEE floating point notation.

p. T F The *binary* number 0.1 can be represented exactly in IEEE floating point notation.

q. T F Intel lost millions of dollars in 1994 because of a multiplication bug in the Pentium processor.

r. T F Java programs are compiled to "byte code" which runs natively on all computers.

s. T F The "linker" produces an executable file that can be run on a computer.

t. T F A 16-bit division produces a 32-bit quotient.

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2. Performance Analysis (20 pts)

a. (5 points) Using the table below, calculate the average CPI for the machine described.

Instruction Class	Cycles/Instruction Class	Frequency
A	2	60%
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C	4	10%

$2 \times 60\% + 3 \times 30\% + 4 \times 10\% = 2.5$ cycles / instruction

Average CPI is 2.5 cycles per instruction

b. (8 points) Computer A has an overall CPI of 1.2 and can be run at a clock rate of 550MHz. Computer B has a CPI of 2.1 and can be run at a clock rate of 680 MHz. We have a particular program we wish to run. When compiled for computer A, this program has exactly 120,000 instructions. How many instructions would the program need to have when compiled for Computer B, in order for the two computers to have exactly the same execution time for this program?

execution $time_A$ = 120,000 instruction * 1.2 cycles/instruction ÷ 550 MHz $\approx 2.6182 \times 10^{-4}$ s.

execution $time_B$ = Execution $time_A$ = Instructions * CPI / clock rate

2.6182×10^{-4} = I * 2.1 cycles/instruction / 680 MHz

$I \approx 84779$ instructions

c. (7 points) Suppose that we can improve the floating point instruction performance of a machine by a factor of 9 (the same floating point instructions run 9 times faster on this new machine). What percent of the instructions must be floating point to achieve a Speedup of at least 5?

Suppose there're total I instructions, x% FP instructions

$$\frac{I}{5} = \frac{I \cdot x\%}{9} + (1 - x\%) I$$

$$\frac{1}{5} = \frac{x}{900} + 1 - \frac{x}{100}$$

$$x = 90$$

Therefore, 90% of the instructions must be FP.

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3. ISA: MIPS to/from C (8 pts)

a. (4 points) The following C code has been partially translated into MIPS assembly. Fill in the blanks. Assume a, b, c are in $s1, $s2, $s3.

```
if (a > b) c++
                        slt  $t0 , $S2 , $S1      a>b  t0=1
                        beq  $t0 , $zero ,L
                        addi $S3 , $S3 , 1
                   L:
```

b. (4 points) The following C code has been partially translated into MIPS assembly. Fill in the blanks. Assume h is in $s2, and the base address of A is in $s3.

```
A[15] = h + A[9]
                        lw $t0, 36 ( $S3 )
                        add $t0, $S2 , $t0
                        sw $t0, 60 ( $S3 )
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4. ISA: MIPS to/from Binary (20 pts)

a. (9 points) Consider the hex value `0x8d28fff4`.

(1) What binary number does it represent?

0x 8d28fff4 = 1000 1101 0010 1000 1111 1111 1111 0100$_2$

(2) What MIPS instruction does it represent? (A copy of the tear-out card is shown on the last page of the exam.) Show the entire instruction, with all fields.

lw $t0, 65524($t1)

(3) What type (R-type, I-type, J-type) does it represent?

I-type

b. (5 points) Encode the following instruction. Show your answer as a word in hex.

```
and $t1, $s0, $t3
```

op	rs	rt	rd	shamt	funct
000000	10000	01011,	01001	00000	100100,

0x020B4824

c. (6 points) Encode the branch/jump instructions below by filling in the TWO missing fields.

(All values in table are in *hexadecimal*)

Loop:	**sll $t1, $s3, 2**	**40000**	**0**	**0**	**13**	**9**	**4**	**0**
	add $t1, $t1, $s6	**40004**	**0**	**9**	**16**	**9**	**0**	**20**
	bne $t0, $s5, Exit	**40008**	**5**	**8**	**15**	3		
	sw $t0, 2($t1)	**4000c**	**2B**	**9**	**8**	**2**		
	addi $s3, $s3, 1	**40010**	**8**	**13**	**13**	**1**		
	j Loop	**40014**	**2**	10000				
Exit:	...	**40018**	**...**					

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5. Integer Arithmetic (20 pts)

a. **(8 points)** Perform the following operations by converting the operands to 2's complement binary numbers and then doing the addition or subtraction shown. Please show all work in binary, operating on 8-bit numbers.

(1) 7 + 19

00000111_2
$+\ 00010011_2$
$00011010_2 = 26$

Overflow? Circle one: Y N

(2) 14 – 8

$8_{10} = 00001000_2$
$-8_{10} = 11110111 + 1 = 11111000_2$

00001110_2
$+\ 11111000_2$
$*\ 00000110_2 = 6$

Overflow? Circle one: Y N

b. **(12 points)** Perform the following operations using sign magnitude form. Please show all work in binary, operating on 8-bit numbers.

(1) (-12) + (-5)

$1000\ 1100_2$ (-12)
$+\ 1000\ 0101_2$ (-15)
$1001\ 0001_2 = -17_{10}$

Overflow? Circle one: Y N

(2)` 1 – 24

$1001\ 1000_2$ (-24)
$-\ 0000\ 0001_2$ (1)
$1001\ 0111_2 = -23_{10}$

Overflow? Circle one: Y N

(3) (-28) – (-9)
$= -28+9$

$1001\ 1100_2$ (-28)
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$1001\ 0011_2 = -19_{10}$

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6. Floating-Point (12 pts)

a. (6 points) Assuming single-precision IEEE 754 format, what decimal is represented by this word? (Hint: remember to use the biased form of the exponent)

`1 10000111 11100000000000000000000`

Sign: $(-1)^1 = -1$

exponent: $135 - 127 = 8$

fraction: $\frac{1}{2^1} + \frac{1}{2^2} + \frac{1}{2^3} = 0.875$

$(-1)^1 * (1+0.875) \times 2^8 = -1.875 \times 2^8$

b. (6 points) Perform rounding on the following fractional binary numbers, use the bit positions in italics to determine rounding (use the rightmost 3 bits). Your result should have six bits to the right of the decimal point.

(1) Round toward positive infinity: `+0.101101`*`101`* binary

$+0.101110_2$

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7. Bonus Points for Coming to Class and Reading the Book (5 pts)

a. (1 points) What branch of the service is Chris Gregg in?

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d. (1 point) What power of 10 does the size prefix "zepto-" stand for? (as in, 1.2 zeptometers)

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A[15] = h + A[9]        lw $t0, 36 ( $S3 )
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lw \$t0, 65524(\$t1)

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	bne	**\$t0, \$s5, Exit**	**40008**	**5**	**8**	**15**	3		
	sw	**\$t0, 2(\$t1)**	**4000c**	**2B**	**9**	**8**	**2**		
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7. Bonus Points for Coming to Class and Reading the Book (5 pts)

a. (1 points) What branch of the service is Chris Gregg in?

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-21

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Do you believe your performance on this exam will fairly and adequately reflect your understanding of the course material? If not, explain why.

University of Virginia, Department of Computer Science
CS/ECE 3330: Computer Architecture, Fall 2011

Exam 1
September 26, 2011

Name: Chuqiao Wang

Problem	Possible Points
1	20
2	20
3	8
4	20
5	20
6	12
Bonus	5
Total	105

COMP 015 005 Student Name:

Student Username: akim14

a b c d e f g h i j k l m n o p q r s t u v w x y z 0 1 2 3 4 5 6 7 8 9
a b c d e f g h i j k l m n o p q r s t u v w x y z 0 1 2 3 4 5 6 7 8 9
a b c d e f g h i j k l m n o p q r s t u v w x y z 0 1 2 3 4 5 6 7 8 9
a b c d e f g h i j k l m n o p q r s t u v w x y z 0 1 2 3 4 5 6 7 8 9
a b c d e f g h i j k l m n o p q r s t u v w x y z 0 1 2 3 4 5 6 7 8 9
a b c d e f g h i j k l m n o p q r s t u v w x y z 0 1 2 3 4 5 6 7 8 9
a b c d e f g h i j k l m n o p q r s t u v w x y z 0 1 2 3 4 5 6 7 8 9
a b c d e f g h i j k l m n o p q r s t u v w x y z 0 1 2 3 4 5 6 7 8 9

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1. True or False (20 points)

a. T F The "multicore revolution" happened because silicon became too expensive in the early 2000s.

b. T F Energy is defined as the amount of power per unit time.

c. T F MIPS is one of the oldest ISAs.

d. T F In MIPS, single-precision arithmetic always produces a single-precision result.

e. T F The MIPS `jal` instruction stores the next instruction into the `$ra` register.

f. T F MIPS instructions can range from 4-bits to 32-bits long.

g. T F The opcode for the MIPS `sb` instruction is 28(hex).

h. T F The MIPS `$sp` (stack pointer) register is modified automatically by the MIPS hardware.

i. T F By convention, the argument registers `$a0-$a3` are preserved after function calls.

j. T F To multiply the contents of a register by two, `sll` is used with `shamt` set to 2.

k. T F The binary number `1001.101` equals `9.625` in decimal.

l. T F In IEEE 754 floating point notation, there are two values for zero.

m. T F "Denormal numbers" represent numbers that slowly overflow in floating point arithmetic.

n. T F Floating point numbers have an exponent bias in order to make number comparisons easier.

o. T F The *decimal* number 0.1 can be represented exactly in IEEE floating point notation.

p. T F The *binary* number 0.1 can be represented exactly in IEEE floating point notation.

q. T F Intel lost millions of dollars in 1994 because of a multiplication bug in the Pentium processor.

r. T F Java programs are compiled to "byte code" which runs natively on all computers.

s. T F The "linker" produces an executable file that can be run on a computer.

t. T F A 16-bit division produces a 32-bit quotient.

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2. Performance Analysis (20 pts)

a. (5 points) Using the table below, calculate the average CPI for the machine described.

Instruction Class	Cycles/Instruction Class	Frequency
A	2	60%
B	3	30%
C	4	10%

$2 \times 60\% + 3 \times 30\% + 4 \times 10\% = 2.5$ cycles / instruction

Average CPI is 2.5 cycles per instruction

b. (8 points) Computer A has an overall CPI of 1.2 and can be run at a clock rate of 550MHz. Computer B has a CPI of 2.1 and can be run at a clock rate of 680 MHz. We have a particular program we wish to run. When compiled for computer A, this program has exactly 120,000 instructions. How many instructions would the program need to have when compiled for Computer B, in order for the two computers to have exactly the same execution time for this program?

execution $time_A$ = 120,000 instruction * 1.2 cycles/instruction ÷ 550 MHz $\approx 2.6182 \times 10^{-4}$ s.

execution $time_B$ = Execution $time_A$ = Instructions * CPI / clock rate

2.6182×10^{-4} = I * 2.1 cycles/ instruction / 680 MHz

$I \approx 84779$ instructions

c. (7 points) Suppose that we can improve the floating point instruction performance of a machine by a factor of 9 (the same floating point instructions run 9 times faster on this new machine). What percent of the instructions must be floating point to achieve a Speedup of at least 5?

Suppose there're total I instructions, x% FP instructions

$$\frac{I}{5} = \frac{I \cdot x\%}{9} + (1 - x\%) I$$

$$\frac{1}{5} = \frac{x}{900} + 1 - \frac{x}{100}$$

$$x = 90$$

Therefore, 90% of the instructions must be FP.

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3. ISA: MIPS to/from C (8 pts)

a. (4 points) The following C code has been partially translated into MIPS assembly. Fill in the blanks. Assume a, b, c are in $s1, $s2, $s3.

```
if (a > b) c++                slt  $t0 , $s2 , $s1      a>b  t0=1
                              beq  $t0 , $zero ,L
                              addi $s3 , $s3 , 1
                         L:
```

b. (4 points) The following C code has been partially translated into MIPS assembly. Fill in the blanks. Assume h is in $s2, and the base address of A is in $s3.

```
A[15] = h + A[9]              lw $t0, 36 ( $s3 )
                              add $t0, $s2 , $t0
                              sw $t0, 60 ( $s3 )
```

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4. ISA: MIPS to/from Binary (20 pts)

a. (9 points) Consider the hex value `0x8d28fff4`.

(1) What binary number does it represent?

0x 8d28fff4 = 1000 1101 0010 1000 1111 1111 1111 0100 ₂

(2) What MIPS instruction does it represent? (A copy of the tear-out card is shown on the last page of the exam.) Show the entire instruction, with all fields.

lw $t0, 65524($t1)

(3) What type (R-type, I-type, J-type) does it represent?

I-type

b. (5 points) Encode the following instruction. Show your answer as a word in hex.

`and $t1, $s0, $t3`

op	rs	rt	rd	shamt	funct
000000	10000	01011	01001	00000	100100

0x020B4824

c. (6 points) Encode the branch/jump instructions below by filling in the TWO missing fields.

(All values in table are in *hexadecimal*)

Loop:	`sll $t1, $s3, 2`	40000	0	0	13	9	4	0
	`add $t1, $t1, $s6`	40004	0	9	16	9	0	20
	`bne $t0, $s5, Exit`	40008	5	8	15	3		
	`sw $t0, 2($t1)`	4000c	2B	9	8	2		
	`addi $s3, $s3, 1`	40010	8	13	13	1		
	`j Loop`	40014	2	10000				
Exit:	...	40018	...					

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5. Integer Arithmetic (20 pts)

a. **(8 points)** Perform the following operations by converting the operands to 2's complement binary numbers and then doing the addition or subtraction shown. Please show all work in binary, operating on 8-bit numbers.

(1) 7 + 19

$$\begin{array}{r} 00000111_2 \\ +\ 00010011_2 \\ \hline 00011010_2 = 26 \end{array}$$

Overflow? Circle one: Y N

(2) 14 – 8

$8_{10} = 00001000_2$

$-8_{10} = 11110111 + 1 = 11111000_2$

$$\begin{array}{r} 00001110_2 \\ +\ 11111000_2 \\ \hline *\ 00000110_2 = 6 \end{array}$$

Overflow? Circle one: Y N

b. **(12 points)** Perform the following operations using sign magnitude form. Please show all work in binary, operating on 8-bit numbers.

(1) (-12) + (-5)

$$\begin{array}{rl} 1000\ 1100_2 & (-12) \\ +\ 1000\ 0101_2 & (-15) \\ \hline 1001\ 0001_2 = -17_{10} & \end{array}$$

Overflow? Circle one: Y N

(2)` 1 – 24

$$\begin{array}{rl} 1001\ 1000_2 & (-24) \\ -\ 0000\ 0001_2 & (1) \\ \hline 1001\ 0111_2 = -23_{10} & \end{array}$$

Overflow? Circle one: Y N

(3) (-28) – (-9)

$= -28 + 9$

$$\begin{array}{rl} 1001\ 1100_2 & (-28) \\ -\ 0000\ 1001_2 & (9) \\ \hline 1001\ 0011_2 = -19_{10} & \end{array}$$

Overflow? Circle one: Y N

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6. Floating-Point (12 pts)

a. (6 points) Assuming single-precision IEEE 754 format, what decimal is represented by this word? (Hint: remember to use the biased form of the exponent)

`1 10000111 11100000000000000000000`

sign: $(-1)^1 = -1$

exponent: $135 - 127 = 8$

fraction: $\frac{1}{2^1} + \frac{1}{2^2} + \frac{1}{2^3} = 0.875$

$(-1)^1 * (1 + 0.875) \times 2^8 = -1.875 \times 2^8$

b. (6 points) Perform rounding on the following fractional binary numbers, use the bit positions in italics to determine rounding (use the rightmost 3 bits). Your result should have six bits to the right of the decimal point.

(1) Round toward positive infinity: `+0.101101`*`101`* $_{binary}$

$+0.101110_2$

(2) Round toward negative infinity: `-0.001011`*`001`* $_{binary}$

-0.001100_2

(3) Round toward zero: `+0.110101`*`000`* $_{binary}$

$+0.110101_2$

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