CDA 3101 | **Midterm Exam #1** | **Fall 2013**

PRINT YOUR NAME: __________KEY____________ **UFID [5:8]:** ____________

RECITATION Date/Time: ________________ **Your CDA3101 Number:** ____________

I have not looked at anyone else's paper, and I have not obtained unauthorized help in completing this exam. Also, I have adhered to and upheld all standards of honesty as stated in the University Honesty Policy and in the course syllabus.

YOUR SIGNATURE: ____________________________ **DATE:** _________________

YOU ARE ALLOWED TO HAVE <u>ONLY</u> THE FOLLOWING ON YOUR DESK OR WORKTABLE:

1. **A *HANDWRITTEN* CRIB SHEET 8-1/2 x 11 inches (BOTH SIDES USABLE)**
2. **A BASIC CALCULATOR – <u>NO GRAPHING</u>, <u>NO PROGRAMMABILITY</u>**
3. **YOUR PEN OR PENCIL AND AN ERASER**

ALL OTHER OF YOUR BELONGINGS BROUGHT INTO THE CLASSROOM MUST BE ON THE FLOOR, UNLESS YOU REQUIRE EYEGLASSES OR AN OPTICAL MAGNIFYING GLASS.

PLEASE TURN ALL CELL PHONES, iPHONES, iPADS, AND OTHER ELECTRONIC DEVICES (EXCEPT CALCULATORS), <u>OFF</u> AND <u>PUT THEM AWAY</u> – RINGTONES AND CELL PHONE CONVERSATIONS NOT PERMITTED DURING EXAM.

CDA 3101 **Midterm Exam #1** **Fall 2013**

PRINT YOUR NAME: _________**KEY**____________ **CDA3101 NUMBER:** ___________

SCORES: TOTAL EXAM SCORE: ____ / 120 pts *This part for Instructor & TAs only.*

Q1: ____ Q2: ____ Q3: ____ Q4: ____ Q5: ____ EC-1: ____ EC-2: ____

This exam has six regular questions and one extra-credit question. Complete the questions that are easiest for you first, then complete what you can of the difficult questions. There is no penalty for guessing. However, *on questions involving calculation*, *you must show your work*. *If you do not show your work, you risk getting only partial credit for any answer*.

Q1. (25 pts) **Define the following terms using 1-3 sentences or a formula** (5 pts each)**:**

(a) Moore's Law

Moore's law is the observation that, over thehistory of computing hardware, the number oftransistors on integrated circuits doubles approximately every two years. The period often quoted as "18 months" is due to Intel executive David House, who predicted that period for a doubling in chip performance (being a combination of the effect of more transistors and their being faster).
[Source: http://en.wikipedia.org/wiki/Moore's_law]

(b) Datapath

Part of a computer that does the work of arithmetic and logic calculations and performs other instructions including but not limited to I/O and branching.

(c) Benchmark

In computing, a **benchmark** is the act of running a computer program, a set of programs, or other operations, in order to assess the relative **performance** of an object, normally by running a number of standard tests and trials against it. The term 'benchmark' is also mostly utilized for the purposes of elaborately-designed benchmarking programs themselves. [Source: http://en.wikipedia.org/wiki/Benchmark_(computing)]

(d) Von Neumann Bottleneck

The meaning of the term ["von Neumann architecture"] has evolved to mean a stored-program computer in which an instruction fetch and a data operation cannot occur at the same time because they share a common bus. This is referred to as the Von Neumann bottleneck and often limits the performance of the system.
[Source: http://en.wikipedia.org/wiki/Von_Neumann_architecture]

(e) Register (in a CPU chip)

In computer architecture, a **processor register** is a small amount of storage available as part of a CPU or other digital processor. Such registers are (typically) addressed by mechanisms other than main memory and can be accessed more quickly.
[Source: http://en.wikipedia.org/wiki/Processor_register]

PRINT YOUR NAME: ______KEY______________ CDA3101 NUMBER: ___________

Q2. (25 pts) **Given the following parameters, answer each of the following two questions for the program P_1 on machine M_1** (10 pts for 2.1, 15 pts for 2.2)**:**

```
Instruction Count = 26,395     Average CPI = 2.17
Clock Rate = 3.24 GHz
```

2.1) Calculate the execution time $\triangle t_{exe}$ for P_1 on M_1 (show all work)**:**

$$\begin{aligned}\triangle t_{exe} &= \text{IC} \cdot \text{CPI} \cdot \triangle t_{clock} = \text{IC} \cdot \text{CPI} \cdot (\text{clock\_rate})^{-1} \\ &= 26{,}395 \text{ instr} \cdot 2.17 \text{ cycles/instr} \cdot (3.24 \text{ Gcycles/sec})^{-1} \\ &\simeq 17{,}678 \times 10^{-9} \text{ sec} \simeq 17.7 \text{ microseconds}\end{aligned}$$

2.2) If M_1 runs program P_2 2.9 times faster than P_1 with clock rate and CPI remaining the same as in 2.1, above, then what variable in the performance equation changed, and by how much? (Answer using analysis, and show all work to get full credit)**:**

If CPI and clock rate are unchanged, then the remaining variable is IC.
For P_2 to run 2.9 times faster, the runtime must be 1 / 2.9 $\underset{\sim}{\sim}$ 0.345 that of P_1.
This means that IC of P_2 must be 0.345 times the IC of P_1, so we have

$$\text{IC}(P_2) \simeq 0.345 \cdot \text{IC}(P_1) = 0.345 \cdot 26{,}395 \simeq 9{,}102 \text{ instructions}$$

Q3. (30 pts) **Diagram and give an example of each of the following MIPS instruction formats, then tell what each format is used for:** (10 pts each)

R-format:
- ► Used for arithmetic and logic operations
- ► **Ex:** add \$t0, \$s1 \$s2 # t0 ← s1 + s2

I-format:
- ► Used for load/store, conditional branch, and arithmetic/logic operations with a constant
- ► **Ex:** addi \$t0, \$s1, 24 # t0 ← s1 + 24

J-format:
- ► Used for unconditional branch
- ► **Ex:** j Loop # transfer control to statement with label "Loop"

► Diagram for R,I, and J formats at http://www.cise.ufl.edu/~mssz/CompOrg/Figure2.7-MIPSinstrFmt.gif

PRINT YOUR NAME: _______KEY______________ CDA3101 NUMBER: ___________

Q4. (20 pts) **A computer M_2 has the following CPIs for instruction types A thru D, and a program P_3 has the following mix of instructions** (*Note*: pct = percent)**:**

M_2: Type A CPI_A = 1.7 Type B CPI_B = 2.1 Type C CPI_C = 2.7 Type D CPI_D = 2.4
P_3: Type A = 22 pct Type B = 29 pct Type C = 17 pct Type D = remaining pct

4.1 (10 pts) **Calculate the average CPI of Machine M_2:**

$$
\begin{aligned}
CPI_{ave} &= \Sigma_{i\,=\,A..D} (CPI_i \cdot fraction_i) \\
&= 1.7(0.22) + 2.1(0.29) + 2.7(0.17) + 2.4(0.32) \\
&= 0.374 \quad + 0.609 \quad + 0.459 \quad + 0.768 \\
&= \mathbf{2.21}
\end{aligned}
$$

4.2 (10 pts) **Calculate the runtime of P_3 on M_2 if IC = 22,311 and clock rate is 3.3 GHz:**

$$
\begin{aligned}
\triangle t_{exe} &= IC \cdot CPI \cdot \triangle t_{clock} = IC \cdot CPI \cdot (clock\_rate)^{-1} \\
&= 22{,}311 \text{ instr} \cdot \mathbf{2.21} \text{ cycles/instr} \cdot (3.3 \text{ Gcycles/sec})^{-1} \\
&\simeq 14{,}942 \times 10^{-9} \text{ sec} \simeq 14.9 \text{ microseconds}
\end{aligned}
$$

Q5. (20 pts) **This question has two parts: 5.1 and 5.2. Explain in detail to get full credit.**

5.1) What are the best benchmarks to use, and why? (10 pts)

The best benchmarks are the real programs you plan to run on a given computer. Measuring the runtime of these programs will measure your actual workload.

452) What are SPEC CPU benchmarks about? Why was SPEC2000 CPU benchmark suite retired? (5 pts each)

SPEC (Standard Performance Evaluation Corporation) is a non-profit organization that aims to "produce, establish, maintain and endorse a standardized set" of performance benchmarks for computers. The benchmarks aim to test "real-life" situations.
[Source: http://en.wikipedia.org/wiki/Standard_Performance_Evaluation_Corporation]

SPEC CPU2000 benchmark suite was retired because (a) it no longer was found to represent the actual workload(s) on most machines after 2006, and (b) the SPEC CPU2006 benchmark suite superseded CPU2000.

CDA 3101 # Midterm Exam #1 **Fall 2013**

PRINT YOUR NAME: ________KEY___________ CDA3101 NUMBER: ___________

Extra Credit Problems:

EC-1. (20 pts) **Given a computer M_4 with clock rate = 3.1 GHz and a hardware accelerator that can make Type A instructions go 7 times faster, answer the following:**

EC-1.1 (7 pts) **If a program P_4 has 29 pct Type A instructions and the remainder are Type B instructions, and its IC = 35,450 – will the accelerator make P_4 run at least 2 times faster on M_4 than it would without an accelerator? SHOW ALL WORK**

From givens: (1) factor of improvement $f_I = 7$;
(2) fraction of system improved or enhanced $f_E = 0.29$

What is the limiting (maximum) speedup in this case?

If runtime $\Delta t = 1$ before accelerator was used, then runtime after accelerator is used is given by

$$\Delta t_A = (1 - f_E) + (f_E / f_I) = 0.71 + (0.29 / 7) \simeq 0.751$$

So max. speedup is calculated as

$$\eta_{max} = \Delta t / \Delta t_A = 1 / 0.751 \simeq 1.33 \text{ times } < 2 \text{ times}$$

As a result, the two-fold system speedup cannot be achieved.

EC-1.2 (13 pts) **Use Amdahl's Law to determine how much faster the accelerator needs to go to make P_4 run 5.5 times faster on M_4 (with accelerator) than it did without an accelerator. SHOW ALL WORK**

Suppose the accelerator was infinitely fast (as fast as it can go!!).
Then, 0.71 of the program would not be speeded up, so the limiting speedup *in this case* would be

$$\eta_{max} = \Delta t / \Delta t_A = 1 / 0.71 \simeq 1.408 \text{ times } < 5.5 \text{ times}$$

This speedup cannot be achieved, for the same general reason as in EC-1.1.

EC-2. (10 pts) **Give two examples from MIPS ISA of the design principle "SIMPLICITY FAVORS REGULARITY" EXPLAIN IN DETAIL** (5 pts each)

Example 1: MIPS has a regular instruction format (32 bits per instruction, 6-bit opcode for all instructions, etc.) which makes decoding simpler (and faster).

Example 2: MIPS has 32-bit registers only, instead of the multiple register sizes in CISC architectures like Intel x86. This makes hardware design simpler.