Computer Organization and Architecture

Lecture – 29

Nov 28th, 2022

Final Exam Review

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- Chapter 1:
  - Performance
    - CPU Execution time
    - CPI
  - Amdahl's Law

Chapter – 1: Performance

Variables

Variables
Cycle
cycle count
Cycle time
Period
Rate
Cycles per instruction
Instruction count
Execution Time

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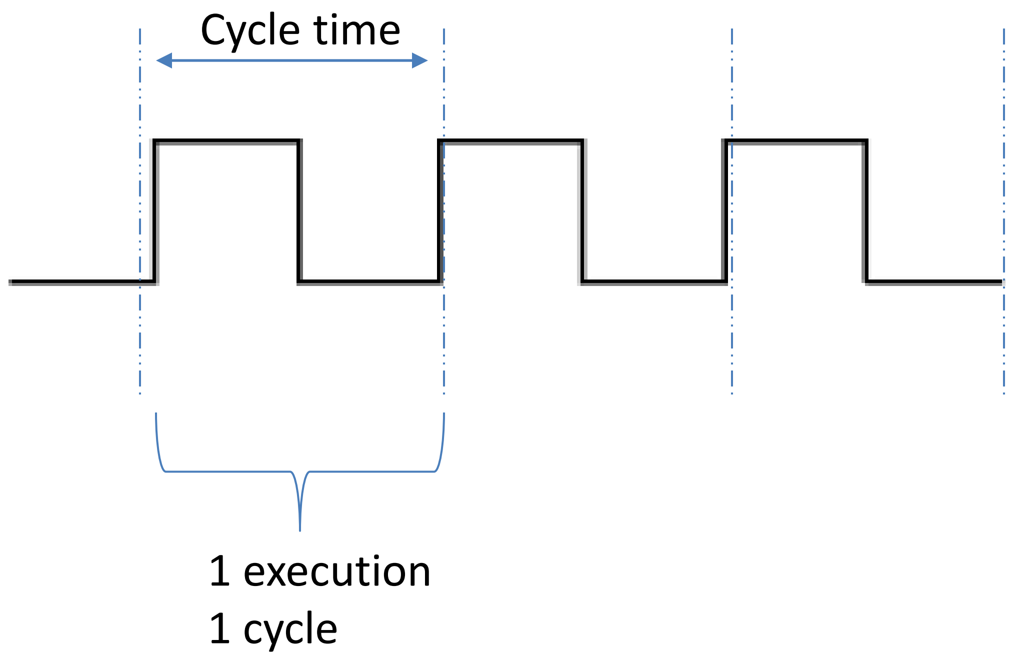
- 1 execution performed by the computer
- Cycles needed to run a program
- Time for one cycle



Performance

- To define performance of a computer A
- Run a program and compute the time to complete (execution time)
- Less the time better is the performance

$$performance_A \propto \frac{1}{\boxed{(execution\ time)}}$$

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If a program needs $5X10^9$ cycles, and the cycle time $100\ picoseconds$ on computer A.
Then the execution time ?

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If a program needs $5X10^9$ cycles, and the cycle time $100\ picoseconds$ on computer A.
Then the execution time ?

$$Execution\ time = cycle\_count\ X\ cycle\_time$$
$$= (5X10^9)X\ (100\ X\ 10^{-12}s)$$
$$= 0.5s$$

Variables

Variables	Units (usual)
Cycle	
Cycle count	cycles
Cycle time	Pico/nano seconds
Period	Pico/nano seconds
Rate	
Cycles per instruction	
Instruction count	
Execution Time	Seconds/minutes

If a program needs $5X10^9$ cycles, and the cycle time $100\ picoseconds$ on computer A.
Then the execution time ?

$$Execution\ time$$
$$= cycle\_count\ X\ cycle\_time$$
$$= (5X10^9) X\ (100\ X\ 10^{-12} s)$$
$$= .5s$$

Execution time

Variables	Units (usual)
Cycle	
Cycle count	cycles
Cycle time	Pico/nano seconds
Period	Pico/nano seconds
Rate	Hz/MHz/GHz
Cycles per instruction	
Instruction count	
Execution Time	Seconds/minutes

$$Execution\ time = cycle\_count\ X\ cycle\_time$$

Instead of cycle time, you can be given rate.

Rate = number of cycles in a second

$$Rate\ = \frac{1}{(cycle\_time)}$$

If rate (clock rate) is 4 GHz, what is the cycle time?

Execution time

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Cycle	
Cycle count	cycles
Cycle time	Pico/nano seconds
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Execution Time	Seconds/minutes

$$Execution\ time = cycle\_count\ X\ cycle\_time$$

Instead of cycle time, you can be given rate.

$$Rate = \frac{1}{(cycle\_time)}$$

If rate (clock rate) is 4 GHz, what is the cycle time?

$$cycle\_time = \frac{1}{(rate)} = \frac{1}{4 * 10^9 Hz}$$

$$= \frac{1}{4 * 10^9} s = \frac{1000}{4X10^{12}} s = \frac{1000}{4} X10^{-12} s$$

$$= 250\ picoseconds$$

Now we have cycle time, we can compute execution time

Performance Review

Our favorite program runs in 10 seconds on computer A, which has a 2 GHz clock.

How many cycles are needed to run the program (or) what is the cycle count?

Performance Review

Our favorite program runs in $\boxed{\text{10 seconds}}$ on computer A, which has a $\boxed{\text{2 GHz}}$ clock.

Execution time

Rate

How many cycles are needed to run the program?

$$Execution\ time = cycle\_count\ X\ cycle\_time$$

$$\frac{Execution\ time}{cycle\_time} = cycle\_count$$

$$cycle\_time = \frac{1}{Rate} = \frac{1}{2X10^9}s = 500X10^{-12}s = 500ps$$

$$cycle\_count = \frac{10}{500X10^{-12}} = \frac{10000}{500X10^{-9}} = 20X10^9 = 20\ billion\ cycles$$

Execution time

Variables	Units (usual)
Cycle	
Cycle count	cycles
Cycle time	Pico/nano seconds
Period	Pico/nano seconds
Rate	Hz/MHz/GHz
Cycles per instruction	cycles
Instruction count	instruction
Execution Time	Seconds/minutes

$$Execution\ time = cycle\_count\ X\ cycle\_time$$

Instead of cycle count, you can be given, instruction count and **cycles per instruction(CPI)**

CPI = cycle count for one instruction

Cycle count for 100 instructions= 100 CPI

$$cycle\_count\ = \ instruction\_count\ X\ CPI$$

- A processor has a 4 GHz clock frequency. A program requires the execution of 1.28E9 instructions, the processor has CPIs of 2. Find the total execution time for this program.

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$$cycle\_count\ =\ instruction\_count\ X\ CPI$$

$$cycle\_count = 1.28 * 10^9\ X\ 2$$

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$$Execution\ time = cycle\_count\ X\ cycle\_time$$

$$cycle\_count\ =\ instruction\_count\ X\ CPI$$

$$cycle\_count = 1.28 * 10^9\ X\ 2$$

$$cycle_{time} = \frac{1}{rate} = \frac{1}{4*10^9}\ s$$

$$Execution\ time = 1.28 * 10^9\ X\ 2\ X \frac{1}{4*10^9} = 0.64\ s$$

- A processor has a 3 GHz clock frequency. A program requires the execution of 6.0E9 instructions, the total execution time for this program is 10s. Find the CPI.

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$$Execution\ time = ins\_countX\ CPI\ X \frac{1}{rate}$$

$$10 = 6 \ * 10^9\ X\ CPI\ X \frac{1}{3 * 10^9}$$

CPI =5

Amdahl's Law

- Improved time when an aspect of the computer is improved by a certain factor

$$T_{improved} = \frac{T_{affected}}{\text{improvement factor}} + T_{unaffected}$$

Pitfall: Amdahl's Law

$$T_{\text{improved}} = \frac{T_{\text{affected}}}{\text{improvement factor}} + T_{\text{unaffected}}$$

- Example:
- Takes a total of 100s
- multiply accounts for 75s (of the 100s)
  - How much improvement in multiply performance to get 2× overall?

Pitfall: Amdahl’s Law

$$T_{\text{improved}} = \frac{T_{\text{affected}}}{\text{improvement factor}} + T_{\text{unaffected}}$$

- Example:
- Takes a total of 100s
- multiply accounts for 75s (of the 100s)
  - How much improvement in multiply performance to get 2× overall?
  - $T_{affeccted} = 75s, T_{unafected} = 100 - 75 = 25s$

Pitfall: Amdahl's Law

$$T_{\text{improved}} = \frac{T_{\text{affected}}}{\text{improvement factor}} + T_{\text{unaffected}}$$

- Example:
- Takes a total of 100s
- multiply accounts for 75s (of the 100s)
  - How much improvement in multiply performance to get 2× overall?
  - $T_{affeccted} = 75s, T_{unafected} = 100 - 75 = 25s$
  - $T_{improved} = \frac{100}{2} = 50s$

Pitfall: Amdahl's Law

$$T_{\text{improved}} = \frac{T_{\text{affected}}}{\text{improvement factor}} + T_{\text{unaffected}}$$

- Example:
- Takes a total of 100s
- multiply accounts for 75s (of the 100s)
  - How much improvement in multiply performance to get 2× overall?

$$50 = \frac{75}{n} + 25$$

$$n = 3$$

Final Exam Review

- Chapter 1:
  - Performance
    - CPU Execution time
    - CPI
  - Amdahl's Law
- Chapter 2:
  - Number System
  - Load/Store data from/in memory
  - Assembly language

Number System Conversions

1. Decimal ←→ Binary (integers/fractions)
2. Decimal ←→ Hexadecimal (integers/fractions)
3. Decimal ←→ Base n (integers/fractions)
4. Base n ←→ Base m (integers/fractions)
5. Decimal ←→ 2's complement binary
6. 2's complement
   1. Shortcut to negate
   2. Range extension

Convert to decimal

Unisgned binary 10011_{two} to decimal?

Convert to decimal

Unisgned binary 10011_{two} to decimal? **19**

$$\mathbf{1 * 2^4 + 1 * 2^1 + 1 * 2^0 = 16 + 2 + 1}$$

Convert to decimal

Unisgned binary 10011_{two} to decimal? **19**

Octal 30_{eight} to decimal?

Convert to decimal

Unisgned binary 10011_{two} to decimal? **19**

Octal 30_{eight} to decimal? **24**

$$\mathbf{3 * 8^1 = 24}$$

Convert to decimal

Unisgned binary 10011_{two} to decimal? **19**

Octal 30_{eight} to decimal? **24**

2's complement 10011_{two} to decimal?

Convert to decimal

Unisgned binary 10011_{two} to decimal? **19**

Octal 30_{eight} to decimal? **24**

2’s complement 10011_{two} to decimal? **-13**

$1 * (-2^4) + 1 * 2^1 + 1 * 2^0 = -16 + 2 + 1 = -13$

Convert to Binary

- Convert decimal 19_{ten} to binary?

Convert to Binary

- Convert decimal 19_{ten} to binary?

$$\left.\begin{aligned}
\frac{19}{2} &= 9\ remainder\ 1 \\
\frac{9}{2} &= 4\ remainder\ 1 \\
\frac{4}{2} &= 2\ remainder\ 0 \\
\frac{2}{2} &= 1\ remainder\ 0 \\
\frac{1}{2} &= 0\ remainder\ 1
\end{aligned}\right\}\ 10011$$

Convert to 2's Complement binary

- Assuming a 5-bit representation convert -13 to 2's complement binary representation

Convert to 2's Complement binary

- Assuming a 5-bit representation convert -13 to 2's complement binary representation

$$\frac{13}{2} = 6\ remainder\ 1$$
$$\frac{6}{2} = 3\ remainder\ 0$$
$$\frac{3}{2} = 1\ remainder\ 1$$
$$\frac{1}{2} = 0\ remainder\ 1$$

1101

01101 in 5-bit

Convert to 2's Complement binary

- Assuming a 5-bit representation convert -13 to 2's complement binary representation

13 in 5-bit binary is 01101

Short cut to negate → flip bits and add 1

Flip bits 01101 → 10010

Add 1 $\qquad$ 1

10011

Assembly Language

Instructions

Type	Name
Arithmetic	ADD, SUB, MUL
Data transfer	LDUR, STUR
Arithmetic Immediate	ADDI, SUBI, ORRI, ANDI, EORI
Logical Operations	LSL, LSR, AND, ORR, EOR
Branches	B, CBZ, CBNZ, B.Cond
Set Condition Flag	ADDS, ADDIS, SUBS, SUBIS, ANDS, ANDIS

Arithmetic & Immediate Instructions

Arithmetic

If f, g, and h are in registers X9, X10, and X11. What is the LEGv8 code for the c statement

1. $f = g + h$

$$ADD\ X9, X10, X11$$

2. $f = g - h$

$$SUB\ X9, \underline{X10, X11}$$

Order to compute X10 – X11

Arithmetic & Immediate Instructions

Arithmetic

If f, g, and h correspond to registers X9, X10, and X11. What is the LEGv8 code for the c statement

1. $f = g + h$

   $ADD\ X9, X10, X11$

2. $f = g - h$

   $SUB\ X9, X10, X11$

Immediate

If f and g correspond to registers X9 and X10. What is the LEGv8 code for the c statement

1. $f = g + 4$

   $ADDI\ X9, X10, \boxed{\#}4$

2. $f = g - 10$

   $SUBI\ X9, X10, \#10$

Use SUBI for subtractions, Do not give a –ve operand to ADDI

Example

If f, g, h, and i correspond to registers X9, X10, X11, and X12.
What is the LEGv8 code for the c statement

$$f = g + 4$$
$$h = f + i$$
$$h = h - 8$$

Example

- If f, g, h, and i correspond to registers X9, X10, X11, and X12. What is the LEGv8 code for the c statement

$$f = g + 4$$
$$h = f + i$$
$$h = h - 8$$

- Solution

$$ADDI\ X9, X10, \#4$$
$$ADD\ X11, X9, X12$$
$$SUBI\ X11, X11, \#8$$