Lab 3 – Practice for Performance – Jacob Whitlow

Friday, February 12, 2021 10:07 AM

1. Consider the following data:

    machine M1: clock rate = 900 MHz
    machine M2: clock rate = 800 MHz
    running program-1 on M1 takes 20 sec, on M2 takes 15 sec
    running program-2 on M1 takes 8 sec, on M2 takes 10 sec

   For program-1, assume that the number of instructions executed on M1 and M2 are 500 million and 400 million, respectively.
   Find the clock cycles per instruction (CPI) for program-1 on both machines.

M1 = 900 MHz M2 = 800 MHz

MHz = CLOCK CYCLES / SEC

M1: 500 MILLION INSTRUCTIONS / 20 SEC
M2: 400 MILLION INSTRUCTIONS / 15 SEC

$$CPI_{M1} = \frac{900{,}000{,}000 \text{ CLOCK CYCLES}}{1 \cancel{\text{SEC}}} \cdot \frac{20 \cancel{\text{SEC}}}{500{,}000{,}000 \text{ INSTRUCTIONS}} = 36 \frac{\text{CLOCK CYCLES}}{\text{INSTRUCTION}}$$

$$CPI_{M2} = \frac{800{,}000{,}000 \text{ CLOCK CYCLES}}{1 \cancel{\text{SEC}}} \cdot \frac{15 \cancel{\text{SEC}}}{400{,}000{,}000 \text{ INSTRUCTIONS}} = 30 \frac{\text{CLOCK CYCLES}}{\text{INSTRUCTION}}$$

2. Assume that the CPI for program-2 on each machine described in #1 is the same as the CPI for program-1 on each machine found in #1.
   Find the instruction count (IC) for program-2 running on each machine using the execution times shown in #1.

$CPI_{M1} = 36$ M1 = 900 MHz $T(P_{2_{M1}}) = 8$ SEC
$CPI_{M2} = 30$ M2 = 800 MHz $T(P_{2_{M2}}) = 10$ SEC

$$IC_{M1} = \frac{\text{INSTRUCTION}}{36 \cancel{\text{CLOCKS}}} \cdot \frac{900{,}000{,}000 \cancel{\text{CLOCKS}}}{\cancel{\text{SEC}}} \cdot 8 \cancel{\text{SEC}} = 200{,}000{,}000 \text{ INSTRUCTIONS}$$

$$IC_{M2} = \frac{\text{INSTRUCTION}}{30 \text{ CLOCKS}} \cdot \frac{800{,}000{,}000 \cancel{\text{CLOCKS}}}{\cancel{\text{SEC}}} \cdot 10 \cancel{\text{SEC}} = 266{,}666{,}667 \text{ INSTRUCTIONS}$$

3. Consider two different implementations, machine M1 and machine M2, of the same instruction set architecture as described below.
   Note that there are four types of instructions (A, B, C and D) in the instruction set.

    M1: clock rate = 800 MHz,
    CPI_A = 1, CPI_B = 2, CPI_C = 3, CPI_D = 4
    M2: clock rate = 900 MHz,
    CPI_A = 3, CPI_B = 2, CPI_C = 4, CPI_D = 2

   Assume that the 'peak performance' is defined as the fastest rate that a machine can execute an instruction sequence chosen to maximize that rate. What are the peak performances of M1 and M2 expressed as instructions per second? Answer with MIPS.

$$M1 = \frac{800{,}000{,}000 \cancel{\text{CYCLES}}}{\text{SEC}} \cdot \frac{\text{INSTRUCTION}}{\cancel{\text{CYCLE}}} = 800 \text{ MIPS AT PEAK PERFORMANCE}$$

$$M2 = \frac{900{,}000{,}000 \cancel{\text{CYCLES}}}{\text{SEC}} \cdot \frac{\text{INSTRUCTION}}{2 \cancel{\text{CYCLES}}} = 450 \text{ MIPS AT PEAK PERFORMANCE}$$

4. If the number of instructions executed in a certain program is divided equally among the four types of instructions shown in #3, which machine is faster? Please show how much times faster than the other machine.

M1 AVG $CPI = \frac{1+2+3+4}{4} = 2.5$ CPI AVG IF EVENLY DISTRIBUTED

M2 AVG $CPI = \frac{3+2+4+2}{4} = 2.75$ CPI AVG IF EVENLY DISTRIBUTED

$$\text{M1 EXECUTION TIME} = \frac{\text{SEC}}{800{,}000{,}000 \cancel{\text{CLOCKS}}} \cdot \frac{2.5 \cancel{\text{CLOCKS}}}{\cancel{\text{INSTRUCTION}}} \cdot 500{,}000{,}000 \cancel{\text{INSTRUCTIONS}} = 1.5625 \text{ SECONDS}$$

$$\text{M2 EXECUTION TIME} = \frac{\text{SEC}}{900{,}000{,}000 \cancel{\text{CLOCKS}}} \cdot \frac{2.75 \cancel{\text{CLOCKS}}}{\cancel{\text{INSTRUCTION}}} \cdot 500{,}000{,}000 \cancel{\text{INSTRUCTIONS}} = 1.5\overline{27} \text{ SECONDS}$$

$$M2 = \frac{1.5625}{1.5\overline{27}} = 1.023 \text{ TIMES FASTER THAN M1}$$

5. Consider the CPI values from #3 and the instruction type distribution from #4.
   At what clock rate would M1 have the same performance as the 900 MHz version of M2?

M1 CPI = 2.5 800 MHz
M2 CPI = 2.75 900 MHz

$$1.5\overline{27} = \underbrace{500{,}000{,}000}_{\text{INSTRUCTIONS PER PROGRAM}} \cdot \underbrace{\frac{2.5}{1}}_{\text{CPI}} \cdot \underbrace{\frac{1}{x}}_{\text{SEC/CLOCK CYCLE}}$$

$$x = \frac{500{,}000{,}000 \cdot 2.5}{1.5\overline{27}}$$

$$= 818 \text{ MHz} \quad (818{,}181{,}818.\overline{18} \text{ Hz})$$

6. Consider the following data for computer C1:

    C1: clock rate = 2.5 GHz, running a benchmark program on C1 takes 15 sec.

   A design team is developing a new computer C2 aiming the double performance by increasing the clock rate with the cost of increased clock cycles with the factor of 1.5.
   What would be the clock rate of computer C2?

C1 2.5 GHz 15 SECONDS
C2 ? 7.5 SECONDS

C1	2.5 GHz	15 seconds
C2	?	7.5 seconds

1.5 TIMES CLOCK CYCLES MEANS WE NEED 1.5 TIMES CLOCK RATE

$$1.5 \cdot 2.5 \text{ GHz} = 3.75 \text{ GHz}$$

NEEDS TO RUN IN HALF THE TIME SO DOUBLE ADJUSTED CLOCK RATE

$$2 \cdot 3.75 \text{ GHz} = \boxed{7.5 \text{ GHz}}$$