Homework #1

Assigned: 14/03/2023
Due: 21/03/2023
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1. (**25 pts**) Consider three different processors P1, P2 and P3 executing the same instruction set. Clock rates and CPIs of the processors are given below.

Processor	Clock Rate	CPI
P1	2.0 GHz	1.0
P2	2.5 GHz	1.25
P3	3.0 GHz	2.5

a. (**5 pts**) Compute MIPS rates of the processors.

Solution:
MIPS of P1 = 2*10^9/(1*10^6) = 2000 MIPS
MIPS of P2 = 2.5*10^9/(1.25*10^6) = 2000 MIPS
MIPS of P3 = 3*10^9/(2.5*10^6) = 1200 MIPS

b. (**5 pts**) The programs C1, C2 and C3 are executed in P1, P2 and P3, respectively. All executions take 5 seconds. Find the number of instructions for each program.

Solution:
Number of instructions = MIPS * 10^6 * passed time in seconds

Number of Instructions of P1 = 2000*10^6*5 = 10^{10} Instructions

Number of Instructions of P2 = 2000*10^6*5 = 10^{10} Instructions

Number of Instructions of P3 = 1200*10^6*5 = 6 * 10^9 Instructions

c. (**15 pts**) The modification to reduce the execution time by 20%, leads to an increase of 20% in the CPI. What should be the new clock rates of the processors to achieve the targeted performance.

Solution:
$t = (IC * CPI) / f_1$
$(0.8 * t) = (IC * 1.2 * CPI) / f_2$
F2/F1 = 3/2

P1: f_1=2 => f_2 = 2*3/2 = 3 GHz

P2: f_1=2.5 => f_2 = 2.5*3/2 = 3.75 GHz

P3: f_1=3 => f_2 = 3*3/2 = 4.5 GHz

2. (**30 pts**) Consider two processors (P1 and P2) are the different implementations of the same ISA. The clock rates of the processors are 2.5 GHz and 3 GHz, respectively. The instructions are divided into three classes according to their CPIs, which are given below.

	P1	P2
Class A	1	2
Class B	1.5	2
Class C	3	2

Given a program with a dynamic instruction count of 10^6 instructions divided into classes as follows: 40% class A, 35% class B and 25% class D.

a. (**10 pts**) What is the global CPI for each implementation?

Solution:
IC of A : 400000
IC of B : 350000
IC of C: 250000

P1:
CC = (4*10^5 + 3.5*10^5*1.5 + 2.5*10^5*3) = 1675000 Cycles
Global CPI = 1675000/10^6=1.675

P2:
CC = (4*10^5*2+3.5*10^5*2+2.5*10^5*2) = 2000000 Cycles
Global CPI = (2* 10^6) /10^6=2

b. (**10 pts**) Find the clock cycles required in both cases.

Solution:
CC = IC x CPI
Processor P1:
Clock cycles = 10^6 * 1.675 = 1675000 Cycles

Processor P2:
Clock cycles = 10^6 x 2.0 = 2000000 Cycles.

c. (**10 pts**) Find the execution time in both cases.

Solution:

CPU execution time = (IC x CPI)/f = CC / f

Processor P1:
Execution time = 1675000 Cycles / (2.5 * 10^9) Hz = 0.00067 seconds

Processor P2:
Execution time = 2000000 Cycles / (3 * 10^9) Hz = 0.000666 seconds

3. (**30 pts**) Consider a given benchmark has an instruction count of 2.1 x 10^{12} and a reference time of 8000s. The execution of the benchmark takes 900 s on a processor with the cycle time of 0.25 ns.

a. (**10 pts**) Find the CPI of the processor.

Solution:

CPI = Clock Count / Instruction Count
Instruction Count = 2.1 * 10^{12}
Frequency = 1/period = 1/(2.5 * 10^(-10)) = 4 * 10^9 Hz
Clock Count = 900 s * 4 * 10^9 Hz = 3.6 * 10^{12}
CPI = (3.6 * 10^{12}) / (2.1 * 10^{12}) = 1.714

b. (**5 pts**) Find the SPECratio of the processor.

Solution:
SPECratio = (reference machine time) / (target machine time)
SPECratio = 8000 s / 900 s = 8.889

c. (**15 pts**) Suppose that a new version of the processor with the clock rate of 4.5 GHz is developed. A couple of new instructions have been added to new design and the number of instructions has been reduced by 15%. The SPECratio for the new version is 12. Find the execution time and CPI of the new processor.

Solution:
New Execution Time = Reference Time / SPECratio = 8000 / 12 = 666.67 seconds

CPI = CC / IC (Clock Count / Instruction Count)

New Instruction Count = 2.1*10^{12} * 0.85 = 1.785*10^12

New Clock Count = 666.67 s * 4.5 * 10^9 Hz = 3.000015 *10^12

New CPI = (3.000015 *10^12) / (1.785 x 10^12) = 1.680