

Processor Performance

→ Execution time \rightarrow User CPU time

→ Throughput \rightarrow Program CPU time

$$\text{Execution time} = \frac{1}{\text{Performance}}$$

$$\text{Exec. time} = \text{clock cycle time (cct)} \times \text{clk cycles}$$

$$\left(\frac{1}{\text{clk Rate}} \right)$$

A: CPU time = 20 s

CR: 2 GHz

B CPU time = 6 s

$CC_B = 1,2 \times CC_A$

$CR_B = ?$

$$20s = CC_A \times \frac{1}{2 \cdot 10^9}$$

$$CC_A = 40 \cdot 10^9 \text{ clk cycles}$$

$$6 = 1,2 CC_A \times \frac{1}{CR_B}$$

$$CR_B = \frac{1,2 CC_A}{6} \sim 8 \text{ GHz}$$

$$CC = \text{Inst. Count (IC)} \times \text{Avg. clk per inst} \quad (\text{CPI})$$

$$A : CCT_A = 250 \text{ ps}$$

$$CPI_A = 2.0$$

$$B : CCT_B = 500 \text{ ps}$$

$$CPI_B = 1.2$$

a) which is faster?
 b) by how much?

$$\frac{CPU_{time B}}{CPU_{time A}} = \frac{CCT_B \times \cancel{IC} \times CPI_B}{CCT_A \times \cancel{IC} \times CPI_A}$$

$$= \frac{500 \times 1.2}{250 \times 2} = 1.2$$

$$CPU_{time} = IC \times CPI \times CCT = \frac{IC \times CPI}{CF}$$

Processor Performance Equation

Inst. Class

| | ALU | MEM | B ₁ |
|-----|-----|-----|----------------|
| CPI | 1 | 2 | 3 |
| CS | ALU | MEM | B ₁ |
| 1 | 2 | 1 | 2 |
| 2 | 4 | 1 | 1 |

CS. exec. more instr. (2)

which is faster

$$2 \times 1 + 2 + 6 = 10$$

$$4 + 2 + 3 = 9$$

(2)

$$b) \frac{\text{CPU time } CS_1}{\text{CPU time } CS_2} = \frac{2 \times 1 + 1 \times 2 + 2 \times 3}{4 \times 1 + 2 \times 2 + 1 \times 3} = \frac{10}{9}$$

CS₂ faster

$$c) CPI_{CS_1} = \frac{10}{5} = 2 \text{ cc}$$

$$CPI_{CS_2} = \frac{CC_{CS_2}}{IC_{CS_2}} = \frac{9}{6} = 1.5 \text{ cc}$$

| | CR | CPI | IPS | CPU _{time} = 10 | CC | IC |
|----------------|------|-----|------------------|--------------------------|----|----|
| P ₁ | 3GHz | 1.3 | $2 \cdot 10^9$ | | | |
| P ₂ | 3.5 | 1.0 | $2.5 \cdot 10^9$ | | | |
| P ₃ | 4.0 | 2.2 | $1.8 \cdot 10^9$ | | | |

a) highest performance
in IPS

b) if CPU_{time} = 10
CC = ? IC = ?

c) reduce

$$\text{CPU}_{\text{time}} = \text{IC} \times \text{CPI} \times \text{CCT} = \frac{\text{IC} \times \text{CPI}}{\text{CR}}$$

$$\text{IPS} = \frac{\text{IC}}{\text{CPU}_{\text{time}}} = \frac{\frac{\text{IC}}{\text{IC} \cdot \text{CPI}}}{\frac{\text{CR}}{\text{CPI}}} = \frac{\text{CR}}{\text{CPI}}$$

$$\text{IPS}_1 = \frac{3}{1.3} \quad \text{IPS}_2 = 2.5 \quad \text{IPS}_3 = \frac{4.0}{2.2}$$

$$b) \text{ CPU time} = \frac{IC \cdot CPI}{CR}$$

$$\frac{\text{CPU}}{\text{CCT}} = CC$$

$$IC_1 = \frac{10 \cdot \overbrace{5 \cdot 10^9}^{\text{CPU time}}}{\underbrace{15}_{\text{CPI}}}$$

$$IC_2 = \frac{10 \cdot 2,5 \cdot 10^9}{1}$$

$$IC_3 = \frac{10 \cdot 4,0 \cdot 10^9}{2,2}$$

$$CC = \text{Time} \times CR$$

| P | CR | Processor CPI | Performance |
|----------------|---------|---------------|-------------|
| P ₁ | 3 GHz | 1,5 | |
| P ₂ | 2,5 GHz | 1,0 | |
| P ₃ | 4,0 GHz | 2,2 | |

1.6 HBR CORN

$$\text{CPU} = IC \cdot CPI \cdot CCT$$

a) Which processor has highest performance in instr per second?

b) if CPU time = 10 sec, CC = ? IC = ?

c) We are trying to reduce CPU time by 30%, but this increases CPI by 20%. What CR should we target?

$$10 = \frac{IC \cdot CPI}{CR} \Rightarrow IC = \frac{10 \cdot CR}{CPI}$$

$$CC_1 = \frac{10}{3 \cdot 10^9} = 3 \cdot 10^{-10}$$

$$CC_2 = 2,5 \cdot 10^{-10}$$

$$CC_3 = 5 \cdot 10^{-10}$$

$$CPI \cdot IC \cdot CCT = \text{CPU time}$$

$$\text{CPU time} = 0,7 \cdot \text{CPU time old}$$

$$CR_{\text{new}} = \frac{12}{7} \cdot 3 \cdot 10^9 = 5,14 \cdot 10^9$$

$$\frac{\text{CPU}}{\text{CCT}} = CC$$

$$CPI = 1,2 \cdot CPI_{\text{old}}$$

$$IC_1 = \frac{10 \cdot 3 \cdot 10^9}{15} = 2 \cdot 10^9$$

$$IC_2 = \frac{10 \cdot 2,5 \cdot 10^9}{1} = 2,5 \cdot 10^9$$

$$IC_3 = 1,8 \cdot 10^9$$

$$\left\{ \begin{array}{l} \text{CPU}_{\text{old}} = \frac{IC \cdot CPI_{\text{old}}}{CR_{\text{old}}} \\ 0,7 \text{CPU}_{\text{old}} = \frac{IC \cdot 1,2 \cdot CPI_{\text{old}}}{CR_{\text{new}}} \end{array} \right. \Rightarrow \frac{10}{7} = \frac{IC \cdot CPI_{\text{old}}}{CR_{\text{old}}} \cdot \frac{CR_{\text{new}}}{IC \cdot 1,2 \cdot CPI_{\text{old}}}$$

$$\frac{10}{7} = \frac{IC \cdot CPI_{\text{old}}}{CR_{\text{old}}} \cdot \frac{CR_{\text{new}}}{IC \cdot 1,2 \cdot CPI_{\text{old}}}$$

$$\frac{210}{7} = \frac{8CR_{\text{new}}}{6CR_{\text{old}}} \Rightarrow \frac{CR_{\text{new}}}{CR_{\text{old}}} = \frac{12}{7} \Rightarrow CR_{\text{new}} = \frac{12}{7} CR_{\text{old}}$$

1.6 [20] <§1.6> Consider two different implementations of the same instruction set architecture. The instructions can be divided into four classes according to their CPI (class A, B, C, and D). P1 with a clock rate of 2.5 GHz and CPIs of 1, 2, 3, and 3, and P2 with a clock rate of 3 GHz and CPIs of 2, 2, 2, and 2.

Given a program with a dynamic instruction count of $1.0E6$ instructions divided into classes as follows: 10% class A, 20% class B, 50% class C, and 20% class D, which implementation is faster?

a. What is the global CPI for each implementation?

b. Find the clock cycles required in both cases.

$$\frac{IC \times CPI}{f_{clk}} \rightarrow \frac{IC}{CPI}$$

| ISA | Clk Rate | CPI A | B | C | D | CC | Exec |
|----------------|----------|-------|---|---|---|------------------|------|
| P ₁ | 2.5 GHz | 1 | 2 | 3 | 3 | $2.6 \cdot 10^6$ | |
| P ₂ | 3 GHz | 2 | 2 | 2 | 2 | $2 \cdot 10^6$ | |

$$IC = 10^6$$

$$10\% A \quad 20\% B \quad 50\% C \quad 20\% D$$

$$a) CPI_1 = 1 \cdot 10\% + 2 \cdot 20\% + 3 \cdot 50\% + 3 \cdot 20\%$$

$$= \frac{10 + 40 + 150 + 60}{100} = \underline{\underline{2.6}}$$

$$CPI_2 = 2 \cdot 10\% + 2 \cdot 20\% + 2 \cdot 50\% + 2 \cdot 20\% =$$

$$= \underline{\underline{2}}$$

$$b) CC = IC \times CPI$$

$$CC_1 = 10^6 \times 2.6$$

$$CC_2 = 10^6 \cdot 2$$

$$c) \text{Exec. Time} = \frac{CC}{CR}$$

$$\text{Exec}_1 = \frac{2.6 \cdot 10^6}{2.5 \cdot 10^9} = 1.04 \cdot 10^{-3}$$

$$\text{Exec}_2 = \frac{2 \cdot 10^6}{3 \cdot 10^9} = 0.66 \cdot 10^{-3}$$

CPU₂ is faster than CPU₁