

# 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

$CC_B = 1,2 \times CC_A$

$CR_B = ?$

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

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

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

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

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

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

$$CPI_A = 2.0$$

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

$$CPI_B = 1.2$$

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

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

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

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

Processor Performance Equation

# Inst. Class

	ALU	MEM	B <sub>1</sub>
CPI	1	2	3
CS	ALU	MEM	B <sub>1</sub>
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)

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

CS<sub>2</sub> 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 <sub>time</sub> = 10	CC	IC
P <sub>1</sub>	3GHz	1.3	$2 \cdot 10^9$			
P <sub>2</sub>	3.5	1.0	$2.5 \cdot 10^9$			
P <sub>3</sub>	4.0	2.2	$1.8 \cdot 10^9$			

a) highest performance  
in IPS

b) if CPU<sub>time</sub> = 10  
CC = ? IC = ?

c) reduce

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

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

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

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

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

$$\text{IC}_1 = \frac{10 \cdot \overbrace{5 \cdot 10^9}^{\text{CPU time}}}{\underbrace{15}_{\text{CPI}}}$$

$$\text{IC}_2 = \frac{10 \cdot 2,5 \cdot 10^9}{1}$$

$$\text{IC}_3 = \frac{10 \cdot 4,0 \cdot 10^9}{2,2}$$

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

P	CR	Processor CPI	Performance
P <sub>1</sub>	3 GHz	1,5	
P <sub>2</sub>	2,5 GHz	1,0	
P <sub>3</sub>	4,0 GHz	2,2	

1.6 TB RAM, COBRA

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

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?

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

$$\text{CC}_1 = \frac{10}{3 \cdot 10^9} = 3 \cdot 10^{-10}$$

$$\text{CC}_2 = 2,5 \cdot 10^{-10}$$

$$\text{CC}_3 = 5 \cdot 10^{-10}$$

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

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

$$\text{CR}_M = \frac{12}{7} \cdot 3 \cdot 10^9 = \frac{36}{7} \cdot 10^9 \approx 5,1 \cdot 10^9$$

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

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

$$\text{IC}_1 = \frac{10 \cdot 3 \cdot 10^9}{15} = 2 \cdot 10^9$$

$$\text{IC}_2 = \frac{10 \cdot 2,5 \cdot 10^9}{1} = 2,5 \cdot 10^9$$

$$\text{IC}_3 = 1,8 \cdot 10^9$$

$$\left\{ \begin{array}{l} \text{CPU}_{\text{old}} = \frac{\text{IC} \cdot \text{CPI}_{\text{old}}}{\text{CR}_0} \\ 0,7 \text{CPU}_{\text{old}} = \frac{\text{IC} \cdot 1,2 \cdot \text{CPI}_{\text{old}}}{\text{CR}_M} \end{array} \Rightarrow \right.$$

$$\frac{10}{7} = \frac{\text{IC} \cdot \text{CPI}_{\text{old}}}{\text{CR}_0} \cdot \frac{\text{CR}_M}{\text{IC} \cdot 1,2 \cdot \text{CPI}_{\text{old}}}$$

$$\frac{210}{7} = \frac{\text{IC} \cdot \text{CPI}_{\text{old}}}{6 \cdot \text{CPI}_{\text{old}}} \Rightarrow \frac{\text{CR}_M}{\text{CR}_0} = \frac{12}{7} \Rightarrow \text{CR}_M = \frac{12}{7} \text{CR}_0$$



**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.

ISA	Clk Rate	CPI	A	B	C	D	CC	Exec
P <sub>1</sub>	2.5 GHz	1		2	3	3	$2.6 \cdot 10^6$	
P <sub>2</sub>	3 GHz	2		2	2	2	$2 \cdot 10^6$	

$$IC = 10^6$$

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

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

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

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

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

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

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

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

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

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

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

CPU<sub>2</sub> is faster than CPU<sub>1</sub>