requires decreasing execution time.

2) Computer A runs a Program in 10 Sec. and Comp. B runs the Same Program in 15 Sec. which Computer's Performance is better ?

$\Rightarrow$ Performance $= \frac{1}{\text{execution time}}$

$Perf_A = \frac{1}{10} = 0.1$

$Perf_B = \frac{1}{15} = 0.06$ $0.1 > 0.06$, So A is better.

How much faster is A than B?

$\Rightarrow \frac{Perf_A}{Perf_B} = \frac{Exec_B}{Exec_A} = \frac{15}{10} = 1.5$

Perf of A = 1.5 times than Perf. B.

Execution time :- measured in seconds per program.

CPU time :- actual time the CPU spends computing for a specific task.

user CPU time (spent in user program) ^ system CPU time (spent in OS)

Clock cycle => discrete time intervals

length of CC as nanoseconds, picoseconds (0.25 ns or 250 ps etc.)

clock rate as gigahertz. (inverse of clock period)

Total execution time = total no. of CC × time taken for each CC

$$\text{clock cycle Rate (CCR)} = \frac{1}{\text{length of CC}} \longrightarrow \text{CCT (clock cycle time)}$$

$$CCR = \frac{1}{CCT}\ hz \Rightarrow \text{cycles/sec.}$$

CCR is no. of CC/sec.

~~CPU exec. Time => No. of CC / CCR~~

CPU exec. time for a program = CPU CCs for a program * (single) clock cycle time

$$\text{CPU time} = \frac{\text{CPU clock cycles for a program}}{\text{clock rate}}$$

eg :- A Program runs in 10 Secs. on Computer A, which has a 4 GHZ clock. we want to design a Computer B, that will run the Same Program in 6 Secs. To do So, Comp. B require 1.2 times as many clock cycles as Comp. A for this Program.
what clock rate is required for Comp. B.

$\Rightarrow$ find the no. of CCS required for Program on Comp. A.

$$\text{CPU time}_A = \frac{\text{CPU CCs}_A}{\text{clockrate}_A}$$

$$10 \text{ secs.} = \frac{\text{CPU CCs}_A}{4 * 10^9 \text{ cycles/sec}}$$

$$\text{CPU CCs}_A = 10 \text{ seconds} \times 4 * 10^9 \text{ cycles/sec.}$$

$$= 40 \times 10^9 \text{ cycles}$$

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CPU time for B using Comp. A is

$$\text{CPU time}_B = \frac{1.2 \times \text{CPU CCs}_A}{\text{Clock rate}_B}$$

$$6 \text{ secs} = \frac{1.2 \times 40 \times 10^9 \text{ cycles}}{\text{Clock rate}_B}$$

$$\text{Clock rate}_B = \frac{1.2 \times 40 \times 10^9 \text{ cycles}}{6 \text{ seconds}}$$

$$= \frac{8 \times 10^9 \text{ cycles}}{\text{seconds}} = 8 \text{ GHz}.$$

So, Comp. B must therefore have twice the clock rate of A to run the program in 6 seconds.

Kilo $= 10^3$
Mega $= 10^6$
Giga $= 10^9$
Peta $= 10^{12}$
Tera $= 10^{15}$

seconds.

---

eg:- A Program runs in 10s in Comp X, with a CR of 2 GHz (clock rate). If you have to design a new Comp. Y to run the same Program in 6 Sec. what is the CR required for Y. Given Y require 10% more CC than X to execute a Program.

$\Rightarrow$ Comp. X $\Rightarrow$ CPU time $= \dfrac{\text{CPU CC}}{\text{CR}}$

$$10s = \frac{\text{CPU CC}}{2 \times 10^9}$$

$$\text{CPU CC} = 20 \times 10^9 \text{ cycles}$$

Comp. Y $\Rightarrow$ CPU time $= \dfrac{10\% + \text{CPU CC}}{CR_Y}$

$$6s = \frac{10\% + 20 \times 10^9 \text{ cycles}}{CR_Y}$$

$$CR_Y = \frac{22 \times 10^9 \text{ cycles}}{6 \text{ sec}} = \frac{3.67 \times 10^9 \text{ cycles}}{\text{Sec}} = 3.67 \text{ GHz}$$

---

another measure => CPI. => clock cycles per instruction.
(i.e. avg. no. of CCs each instr. takes to execute)

Total no. of CC for a Program = Total no. of instructions * CPI

Execution time / CPU Time = Instruction Count * CPI * Clock Cycle Time

(or)

$$\text{CPU Time} = \frac{\text{Instr. Count} * \text{CPI}}{\text{clock rate}}$$

eg:- Comp. A has a clock cycle Time (CCT) of 250 ps (→ Pico seconds) and CPI of 2 for a Program. Comp. B has CCT of 500ps and a CPI of 1.2 for the Same Program. which Computer is faster for this Program and by how much?

⇒ ~~Let I be the no. of instructions of a Program.~~

~~So, CPU CCs$_A$ = I × 2~~

~~CPU CCs$_B$ = I × 1.2~~

$$\frac{Perf_A}{Perf_B} = \frac{Exe\ Time_B}{Exe\ Time_A}$$

$$= \frac{Instr.\ Count_B \times CPI_B \times CCT_B}{Inst.\ Count_A \times CPI_A \times CCT_A}$$

Since A & B have the same no. of instructions.

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

$$= 1.2$$

$Perf_A$ = 1.2 times of $Perf_B$

A is 1.2 times faster than B.

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Q: Consider 3 Processors P_1, P_2, P_3 executing same Program with CCR of 2, 1.5, 3 GHz respectively & CPI as 1.5, 1, 2.5 resp.

a) which Processor has highest Performance?

b) If each Processor executes in 10s, find the no. of CC in each.

$$\frac{IC \times CPI}{CCR} \Rightarrow \frac{1}{\frac{IC \times CPI}{CCR}} \Rightarrow \frac{CCR}{IC \times CPI}$$

$\Rightarrow$ a) $$Perf_{P_1} = \frac{1}{exe.\ time\ P_1} = \frac{CR_{P_1}}{IC_{P_1} \times CPI_{P_1}} = \frac{2}{1.5} = 1.3$$

(Since, it is Comparison, we can ignore Instr. Count $IC_{P_1} = IC_{P_2} = IC_{P_3}$)

$$Perf_{P_2} = \frac{1.5}{1} = 1.5$$

$$Perf_{P_3} = \frac{3}{2.5} = 1.2$$

So, P_2's Performance is high

3) No. of CC ?

$$\text{Exetime} = \frac{\text{no. of CC}}{\text{CCR}}$$

no. of CC = Exetime × CCR

no. of CC_{P1} = 10 × 2 = 20

P_2 = 10 × 1.5 = 15

P_3 = 10 × 3 = 30

no. of CC P1 = 10 x 2 = 20

P2 = 10 x 1.5 = 15

P3 = 10 x 3 = 30

———— x ————

Q:- we are trying to reduce exec. time of a s/w by 30% which causes the CPI to increase by 20%. what CCR should we have to achieve this if the existing CCR is 2 GHz.

$\Rightarrow$ New Exec. Time = old Exec Time $- \frac{30}{100} \times$ old Exec Time

= 0.7 old Exe. time.

New CPI = old CPI + $\frac{20}{100}$ x old CPI = 1.20 old CPI

$$\text{Exe. Time} = \frac{IC \times CPI}{CCR}$$

$$CCR = \frac{IC \times CPI}{\text{Exe. Time}}$$

we have

New Exe. Time = 0.7 old Exe. Time.

$$\frac{\cancel{\text{New}}\ IC \times \text{New CPI}}{\text{New CCR}} = 0.7 \times \frac{\cancel{\text{old}}\ IC \times \text{old CPI}}{\text{old CCR}}$$

$$\frac{1.2 \times CPI(\text{New})}{\text{New CCR}} = \frac{0.7 \times \text{old CPI}}{\text{old CCR}}$$

$$\text{New CCR} = \frac{1.2}{0.7} \times CCR\ (2\,GHz)$$

$= 1.7 \times 2 = 3.4$ GHz //

———— x ————

the Previous equations of CC

No. of CC = CPI x IC

= CCs Per Instr. x Instr. Count.

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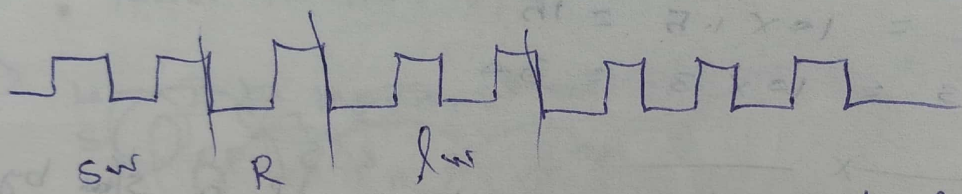
If there are different classes of Instructions each with different CPIs,

for eg:-



The no. of cc for each Instr. type / class is different.

So, Total no. of CPU clock cycles $= \sum_{i=1}^{n} (CPI_i \times C_i)$

where

C_i = Count of the no. of instructions of class i executed

CPI_i = average no. of clock cycles per instruction for that instruction class

and n = no. of instruction classes.

——— x ———

—— x ——

eg:- A Compiler designer is trying to decide between 2 code sequences for a particular m/c. The H/w designers have supplied the foll. facts.

Instr. class	CPI for this instr. class
A	1
B	2
C	3

For a particular high-level-lang. statement, the compiler writer is considering 2 code sequences that require the foll. instruction counts.

Code Sequence	Instr. count for instr. class		
	A	B	C
1	2	1	2
2	4	1	1

Which code sequence executes the most instructions? Which will be faster? What is the CPI for each sequence?

I) A) Seq. 1 executes $2+1+2 = 5$ instructions.
" 2 " $4+1+1 = 6$ " .

So, Seq. 1 executes fewer instructions &
" 2 " most " .

B) $\text{CPU CC}_1 = \sum_{i=1}^{n} (CPI_i \times C_i)$ $n = 3$ classes

$= (2\times1) + (1\times2) + (2\times3) = 10$ cycles

$\text{CPU CC}_2 = (4\times1) + (1\times2) + (1\times3) = 9$ cycles

So, code seq. 2 require less no. of clock cycles &
is faster $\Rightarrow$ total no. of CCs = CPI × IC

c) $\Rightarrow CPI_1 = \dfrac{\text{CPU CCs}}{\text{Instr. Count}} = \dfrac{10}{5} = 2$ //

$CPI_2 = \dfrac{9}{6} = 1.5$ //

eg:- Consider the 2 c/s that are executing the same appln. The IC for various classes of instructions & CPI are given as

	CPI for each class		
	lw/sw	ALU	branch
1	1.2	0.9	0.8
2	1.5	0.7	0.9

	IC for each class		
	lw/sw	ALU	branch
1	20	15	15
2	18	20	12

which of the 2 c/seq. are faster assuming both run at same CCR. what happens if S1 runs 2GHZ & S2 at 2.2GHZ?

$\Rightarrow$ No. of CC_1 = $(20 \times 1.2) + (15 \times 0.9) + (15 \times 0.8) = 49.5$

A) " CC_2 = $(18 \times 1.5) + (20 \times 0.7) + (12 \times 0.9) = 51.8$

So, Code Seq. 1 is faster since both are executed in same CCR.

B) C/Seq. 1 with 2GHZ.

$$\text{Exe. Time}_1 = \frac{\text{Total no. of } CC_1}{CCR} = \frac{49.5}{2 \times 10^9} = 25 \times 10^{-9} \text{ Sec.}$$

C/Seq. 2 with 2.2 GHZ.

$$\text{Exe. Time}_2 = \frac{52}{2.2 \times 10^9} = 23.6 \times 10^{-9} \text{ Sec.}$$

Code Seq. 1 is faster ~~[illegible]~~ ||

eg:- Code Seq 1

Instr. class	CPI	frequency
A	2	40%
B	3	25%
C	3	25%
D	5	10%

Code Seq. 2

Instr. class	CPI	freq.
A	2	40%
B	2	25%
C	3	25%
D	4	10%

Code Seq1 is executed in m/c with CCR 500 MHZ.
Is it Possible to improve the Performance of m/c with CCR of 600 MHZ?
Compute CPI for each m/c?
which Code seq. is faster?

$\Rightarrow$ $$CPI = \frac{\text{no. of CC}}{\text{Instr. Count}} = \frac{\sum IC_i \times CPI_i}{IC}$$

$$= \sum \frac{IC_i}{IC} \times CPI_i \qquad \sum \frac{IC_i}{IC} = \text{freq. of instr. class } i$$

$$CPI_1 = \frac{40}{100} \times 2 + \frac{25}{100} \times 3 + \frac{25}{100} \times 3 + \frac{10}{100} \times 5$$

$$= 0.8 + 0.75 + 0.75 + 0.5$$

$$= 2.8$$

$$CPI_2 = \frac{40}{100} \times 2 + \frac{25}{100} \times 2 + \frac{25}{100} \times 3 + \frac{10}{100} \times 4$$

$$= 0.8 + 0.5 + 0.75 + 0.4$$

$$=$$