COMPUTER SCIENCE

Computer Organization and Architecture

ALU & Control unit

Lecture_06

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TOPICS TO BE COVERED

01 CPU Time Calculation

Micro operation

Micro Program

& Working

Control Unit

Hardwired CU Design

Micro Programmed CU Design

1. Horizontal μprog.
2. Vertical μprog.

CPU Time Calculation

(1) Cycle (eg T_1, T_2 clock cycle)

(2) Cycle time

Working

then How to Calculate ProgET, MIPS Rate ?

3.7 GHz Processor.

64 bit Processor $\Rightarrow$ word length = 64 bit

$\Downarrow$

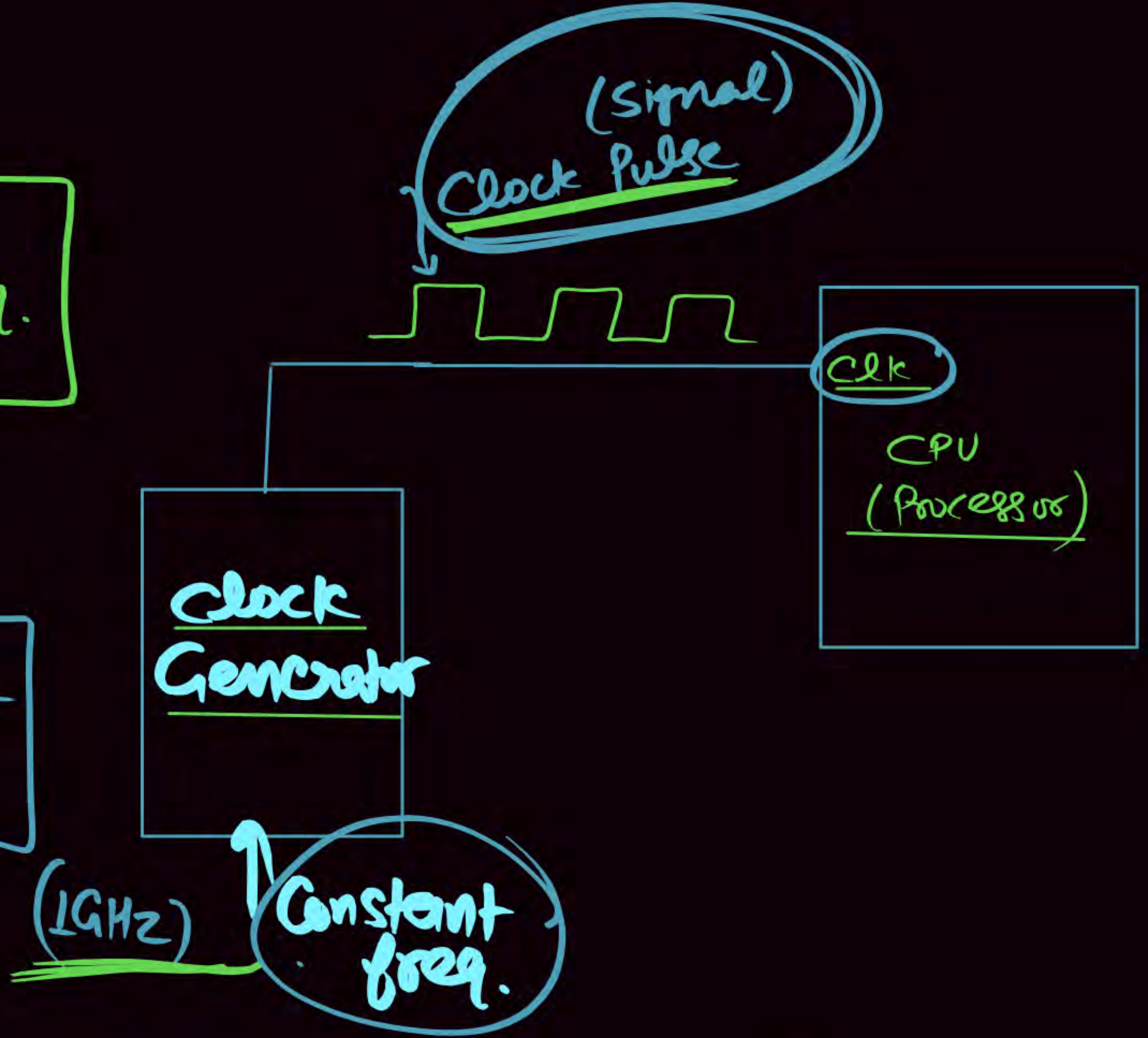
operation Performed on 64 bit Data.

8GB RAM $\Rightarrow$ $\boxed{2^{33} \times 8}$

1TB Hard disk [S.M]

$$\text{Cycle time} = \frac{1}{\text{Clock freq.}}$$

$$\text{Clock frequency} = 1\,\text{GHz}$$

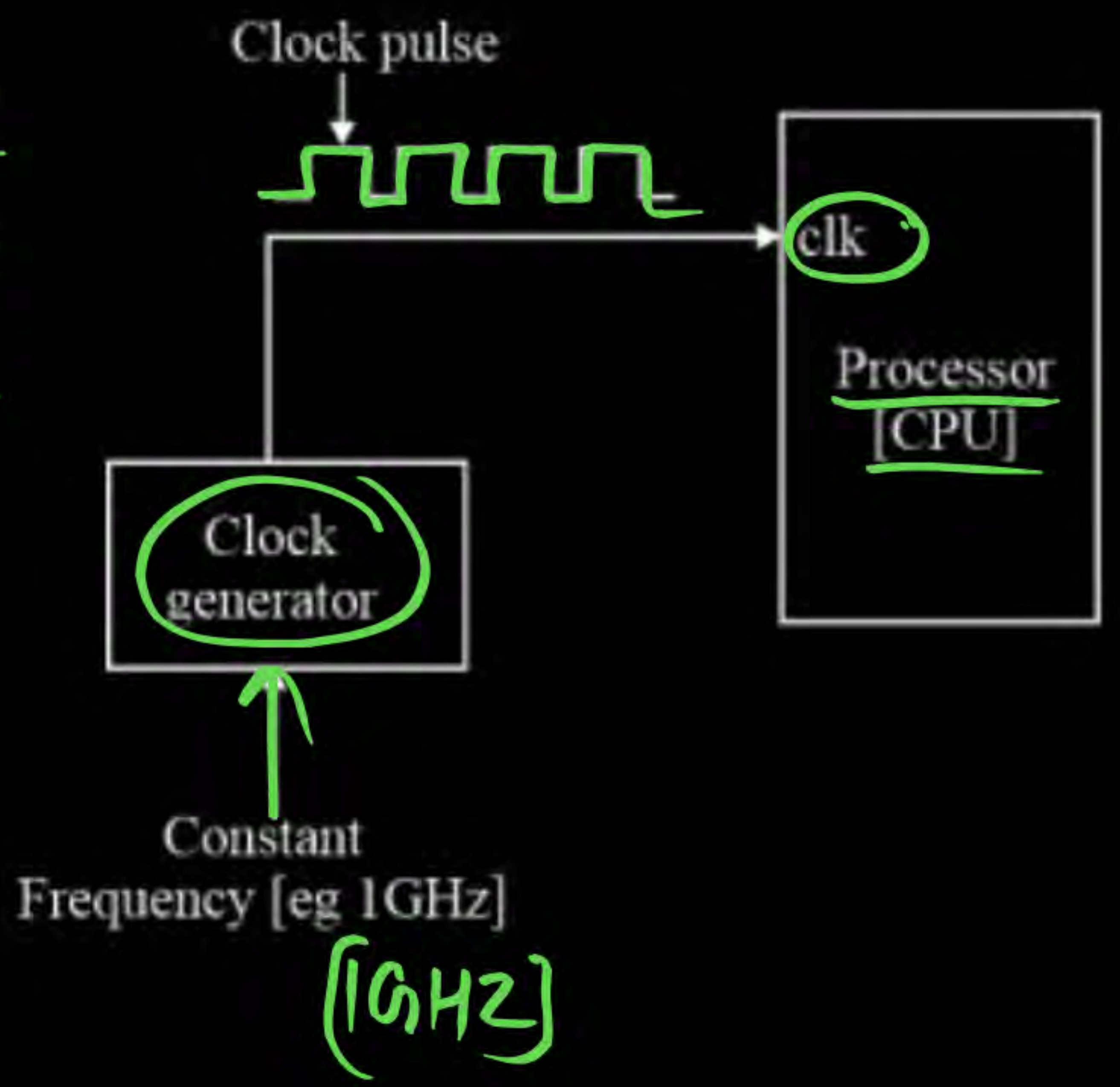


CPU Time Calculation

- CPU time calculation program execution time.
- Program execution time is calculated based on the clock.
- Processor contain clock pins and these clock pin is externally connected with the clock generator.
- So in the computer system all the operation are controlled by the clock so CPU contain pins which is externally connected with clock generator.
- Clock generator is operating with a constant frequency to generate the clock pulse [clock signal]

CPU Time Calculation

- These clock pulses are carried into the CPU through (with the help of) Clk pin. So, CPU operation are controlled by the clock signal.

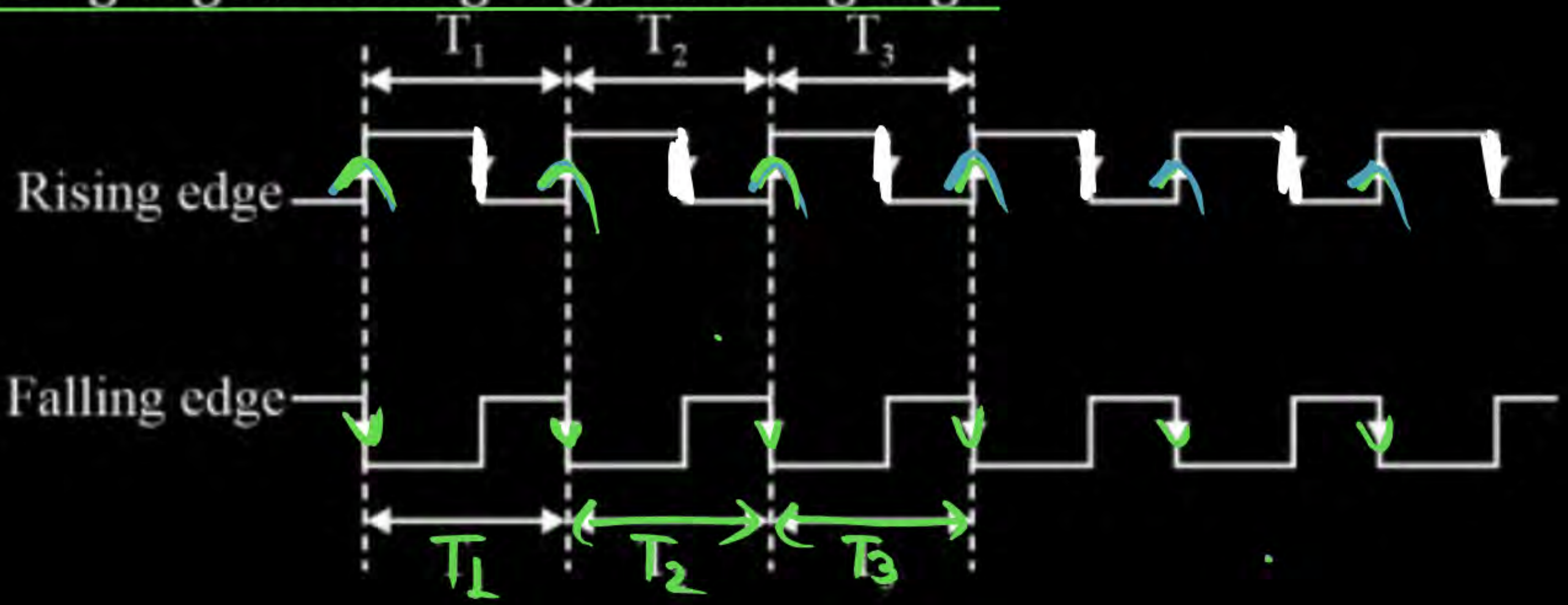


CPU Time Calculation

Program ET(execution time) is calculated based on 2 Factor.

1. Cycle
2. Cycle time

1. **Cycle:** Cycle is defined as clock pulse transition either from rising edge to rising edge or falling edge to falling edge.



CPU Time Calculation

2. **Cycle Time:** The time required to transfer the pulse either from rising edge to rising edge or falling edge to falling edge is called cycle time.

Cycle time depend on clock frequency

$$\boxed{\textit{Cycle Time} \ \alpha \ \frac{1}{\textit{Clock frequency}}}$$

Cycle time α $\frac{1}{\text{Clock Frequency (Rate)}}$

1 GHz clock is used

eg $\boxed{\text{1GHz Clock}}$

Cycle time = $\frac{1}{1\ GHz}$ sec

= $\frac{1}{10^9}$ sec

10–9sec

Cycle time = 1 nsec

Cycle time = $\frac{1}{1GHz}$ sec = $\frac{1}{10^9}$ sec = 10^{-9} sec.

$\boxed{\text{Cycle time} = 1\text{nsec}}$ (nano sec).

In Super Computer
FLOAPS (Floating Point operation Per sec)

MIPS (Million of Instn Per sec) =

$2^{10} = 1K = 10^3$

$2^{20} = 1M = 10^6$

$2^{30} = \boxed{1G = 10^9}$

$2^{40} = 1T = 10^{12}$

$2^{50} = 1$ Peta

1 Millisec (1 msec) = 10^{-3} sec.

1 Microsec (1 μsec) = 10^{-6} sec

1 Nanosec (1 ηsec) = 10^{-9} sec.

$$\boxed{\text{Cycle time} = 10^{-9}\ \text{sec}}$$

0.5×10^{-9} sec.

$$\boxed{\text{Cycle time} = 0.5\ \text{nsec.}}$$

eg If 2GHz Processor

$$\text{Cycle time} = \frac{1}{2\text{GHz}}\ \text{sec}$$

$$= \frac{1}{2\times10^{9}}\ \text{sec}$$

$$= \frac{1}{2}\times10^{-9}\ \text{sec} \Rightarrow 0.5\ \text{nsec}$$

Cycle time

$$\boxed{\text{Cycle time} \propto \frac{1}{\text{Clock Freq.}}}$$

eg 1GHz

$$\text{Cycle time} = \frac{1}{10^9} \text{ sec}$$

$$= 1 \text{ nsec.}$$

Program ET

Q. Program P_1 1GHz

100 Inst^n

each Inst^n takes 5 cycle then the Prog ET ?

Cycle time = 1nsec.

Q) CPU has 1GHz Clock Frequency & Program P_1 having 100 $Inst^n$ & each $Inst^n$ takes 5 Cycle the Prog ET in Cycle & in ns.

Sol^n Program P_1 = 100 Instruction (IC) → Number of Instruction (Instruction Count in Prog.)

Each $Inst^n$ takes 5 Cycle (CPI) → CPI [Cycle Per Instruction]

Cycle time = 1nsec → Cycle time:

Program ET = 100 × 5 Cycle = 500 Cycle. Ans

Program ET (in nsec) = 500 Cycle ⇒ 500 × 1ns = 500nsec. Ans

How Much time taken to execute a Program.

$$\boxed{\text{Program ET} \Rightarrow \frac{\#\,\text{Seconds}}{\text{Program}} \longleftarrow \text{'Per'}}$$

In the Program we have Different type of Instr

& Each Instn take Different Cycle.
(Consume)

then Prog ET = . . .

CPU Time Calculation

CPU time calculation/program ET:

CPU time means program execution time.

Program execution time = #seconds/program

#*Instruction/program* × #*Cycle/instruction* × # *Second/C ycle*

⇓ *Instruction count* (*IC*)

⇓ *Cycle per instructoin* (*CPI*)

⇓ *Cycle Time* (*Cycle time*)

Program ET { CPU Time} = IC × CPI × Cycle time

Freq

CPU Time Calculation

Program is a combination of data transfer, data manipulation and transfer of control (TOC) instruction. Different instruction takes [consume] different cycle to complete the execution. So,

$$\boxed{\text{Program ET \{CPU Time\}} = [\Sigma(Ic_i \times CP_i)] \text{ Cycle time}}$$

Prog ET. $= \left[\Sigma(I_{c_i} \times CPI_i)\right] \times$ Cycle time.

i : Type of instructions

100 Instⁿ

Previous eg.

IC × CPI

100 × 5

= 500 cycle

100 Instⁿ

① IC 40 × CPI 10

② IC 40 × CPI 5

③ IC 20 × CPI 10

400 + 200 + 200

= 800 cycle

Q.

Consider a 1.5 GHz clock frequency processor used to execute the following program segment

Instruction type	Instruction count [IC]	CPI
Load	300	11
Store	200	9
Arithmetic	250	7
Shift	150	6
Branch	50	4
Total	950	

Q.1 What is Average Instn ET ?

Q.2 What is the MIPS Rate ?

Q.3 What is Total Prog ET ?

CPU time Calculation

(i). What is average instruction execution of the program?

$$\frac{\#\text{Cycle}}{\#\text{Instr}^n \text{ in Prog}}$$

$$\left[\sum (IC_i \times CPI_i)\right] \times c\text{---}$$

$$\text{Avg Inst}^n\text{ ET} = \frac{(300\times 11) + (200\times 9) + (250\times 7) + (150\times 6) + (50\times 4)}{950}$$

$$= \frac{3300 + 1800 + 1750 + 900 + 200}{950} = 8.36 \text{ cycle.}$$

$$\text{Cycle time} = \frac{1}{1.5\,\text{GHz}} \text{ sec}$$

$$= \frac{1}{1.5} \times 10^{-9}$$

$$\boxed{\text{Cycle time} = 0.66 \text{ nsec}}$$

$$\text{Program ET} = 8.36 \text{ cycle}$$

$$= 8.36 \times 0.66 \text{ nsec.}$$

$$\boxed{\text{Avg Inst}^n\text{ ET} = 5.51 \text{ nsec}}$$

Avg

CPU time Calculation

(ii). What is the MIPS rate of a program?

1 Inst^n ET = 5.51×10^{-9} sec.

In 1 Sec → # Instruction

in 1 sec = $\frac{1}{5.51 \times 10^{-9}}$ Inst^n/sec

$\Rightarrow \frac{1}{5.51} \times 10^{+9}$ Inst^n/sec

$= 0.1814 \times 10^{9}$ Inst^n/sec

$\Rightarrow \underline{0.1814} \times 10^{9}$ Inst^n/sec

$\Rightarrow \underline{181.4} \times 10^{6}$ Inst^n/sec

$\boxed{181.4 \text{ MIPS}}$ Ans

CPU time Calculation

(iii). What is the total program ET?

Program ET = No. of Instn in Prog × Avg Instn ET

$(\#\text{Instn}/\text{Prog}) \times \text{Avg Instn ET}$

$= 950 \times 5.51 \text{ nsec}$

$= 5234.5 \times 10^{-9} \text{ sec} = 5234.5 \text{ nsec}$ Ans

OR

$5.2345 \times 10^{-6} \text{ Sec}$ 5.2345 µsec Ans

Q. 1 nsec clock cycle processor consume 4 cycle for load and store operation and 6 cycle for ALU operation and 2 cycle for branch operation. The relative frequency of these operation are 40%, 40% and 20% respectively.

(i) What is the average instruction ET?

(ii). What is the performance in term of MIPS?

(iii). If program contain 10^6 instruction them what is total program ET?

(i) What is the average instruction ET?

$$\text{Avg Instr}^n \text{ ET} = [.40 \times 4 + .40 \times 6 + .20 \times 2] \text{ Cycles}$$

$$= 1.6 + 2.4 + 0.4$$

$\boxed{\text{Cycle time} = 1 \text{ nsec}}$

$$= 4.4 \text{ Cycle} \Rightarrow 4.4 \times 1 \text{ nsec}$$

$$\boxed{\text{Avg Instr}^n \text{ ET} = 4.4 \text{ nsec.}} \quad \underline{\text{Ans}}$$

(ii). What is the performance in term of MIPS?

1 Instn takes $= 4.4 \times 10^{-9}$ sec.

In 1 sec $= \dfrac{1}{4.4 \times 10^{-9}}$ Instn/sec

$\Rightarrow \dfrac{1}{4.4} \times 10^{9}$ Instn/sec

$= \dfrac{1000}{4.4} \times 10^{6}$ Instn/sec

$= 227.2 \times 10^{6}$ Instn/sec

$\boxed{227.2 \text{ MIPS}}$

Ans

(iii). If program contain 10^6 instruction them what is total program ET?

Total Prog ET = #Instⁿ/Prog × Avg Instⁿ ET

$= 10^6 \times 4.4 \times 10^{-9}$ sec

$= 4.4 \times 10^{-3}$ sec.

$\boxed{\text{Prog ET} = 4.4 \text{ msec.}}$ Ans

Performance GAIN [Speedup Factor] $= \frac{\text{Performance of New}}{\text{Performance of OLD}}$

$= \frac{1/ET_{New}}{1/ET_{OLD}} \Rightarrow \frac{ET_{OLD}}{ET_{New}}$

$$\boxed{\text{Performance GAIN [Speed up Factor]} = \frac{ET_{OLD}}{ET_{New}}}$$

Same work

Ram — 10 hours

SHYAM — 5 Hours

∴ So SHYAM Performance Fast

$$\boxed{\text{Performance} \propto \frac{1}{\text{Execution Time [E.T]}}}$$

Q.

Consider a 2.3ns clock cycle processor which consume 9 cycle for load and store instruction and 7 cycle for ALU instruction and 3 cycle for branch instruction. Relative frequency of their instruction are 40% , 40% and 20% respectively. Processor is enhanced with an average CPI of 1. During the enhancement, cycle time is increased by 40%, them what is performance GAIN [speed up factor] of new and OLD Design? (2.3 + 40% of 2.3)

$\boxed{\text{Ans (5)}}$

Avg ET = [.40 × 9 + .40 × 7 × .20 × 3] × 2.3 nsec

[3.6 + 2.8 + 0.6] × 2.3

$\boxed{\text{Avg ET}_{OLD} = 16.1 \text{ nsec}}$

New Design:

Avg CPI = 1

Cycle time increased by 40%

$2.3 + .40 \times 2.3$

Avg Inst^n ET_{New} = $(.40\times1 + .40\times1 + .20\times1) \times 3.22\,nsec \Rightarrow 2.3 + 0.92$

$= 3.22\,nsec$

$\boxed{\text{Avg Inst}^n\ ET_{New} = 3.22\,nsec}$

Performance GAIN = $\dfrac{\text{Perf. of New}}{\text{Perf. of OLD}} \Rightarrow \dfrac{ET_{OLD}}{ET_{New}} = \dfrac{16.1}{3.22} = 5$ Ans

THANK YOU!