Questions:

2.1 What is a stored program computer?

- **Stored-program computer** is a computer that stores program instructions in electronically or optically accessible memory. Programs are represented in a form suitable for storing in memory alongside the data. The computer gets its instructions by reading them from memory, and a program can be set or altered by setting the values of a portion of memory.

2.2 What are the four main components of any general-purpose computer?

- **Central processing unit (CPU):** Controls the operation of the computer and performs its data processing functions.
- **Main memory:** Stores data.
- **I/O:** Moves data between the computer and its external environment.
- **System interconnection**: Some mechanism that provides for communication among CPU, main memory, and I/O (Busses)

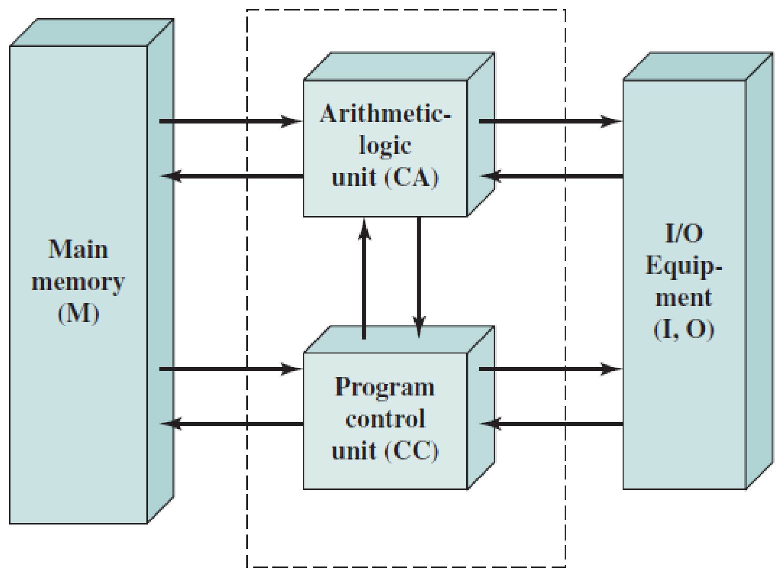

Figure 2.1 Structure of the IAS Computer

2.4 Explain Moore's law

The number of transistors per silicon chip doubles every year.

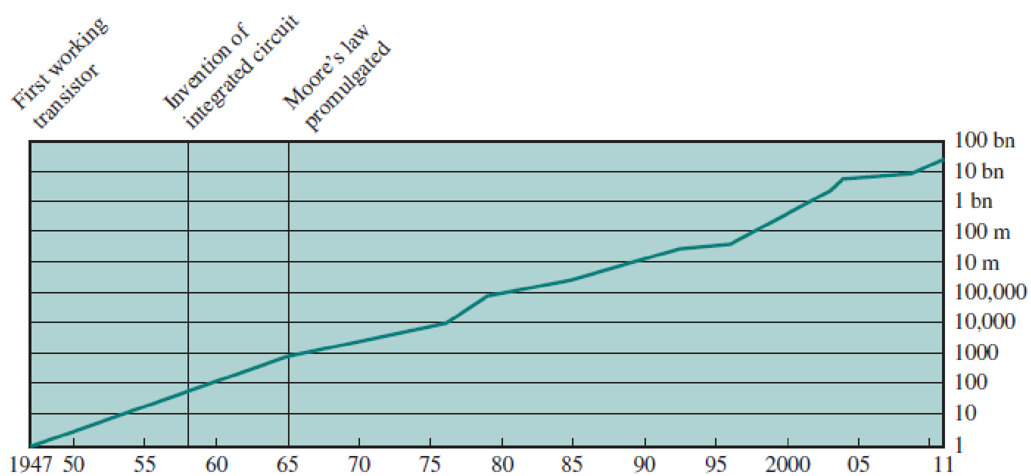

Figure 2.8 Growth in Transistor Count on Integrated Circuits

Problems:

2.10 A benchmark program is run on a **40 MHz** processor. The executed program consists of 100,000 instruction executions, with the following instruction mix and clock cycle count:

Instruction Type	Instruction Count	Cycles per Instruction
Integer arithmetic	45,000	1
Data transfer	32,000	2
Floating point	15,000	2
Control transfer	8000	2

Determine the effective **CPI**, **MIPS rate**, and **execution time** for this program.

Answer:

- $CPI = \frac{\sum_{i=1}^{n} CPI_i * I_i}{I_C}$

  Where : CPI = average Cycles per instruction for program
  CPI_i = Cycles per instruction for instruction type i
  I_i = Instruction Count for instruction type i
  I_c = Instruction Count for program (total instruction count)

  $I_c = \sum_{i=1}^{n} I_i$ = 45000+32000+15000+8000 = 100000 instructions

  $CPI = \frac{\sum_{i=1}^{n} CPI_i * I_i}{I_C} = \frac{(45000*1)+(32000*2)+(15000*2)+(8000*2)}{100000}$ = 1.55

- $MIPS = \frac{f}{CPI*10^6}$

  Where : CPI = average Cycles per instruction for program
  f = Frequency (clock rate)

  $MIPS = \frac{f}{CPI*10^6} = \frac{40*10^6}{1.55*10^6}$ = 25.8

- $T = \frac{I_c*CPI}{f}$

  Where : T = Execution time for program (cpu time)

  $T = \frac{I_c*CPI}{f} = \frac{100000*1.55}{40*10^6}$ = 3.875 msec

2.11 Consider two different machines, with two different instruction sets, both of which have a clock rate of **200 MHz**. The following measurements are recorded on the two machines running a given set of benchmark programs:

Machine	Instruction Type	Instruction Count	Cycles Per Instruction
A	Arithmetic and logic	$\mathbf{8*10^6}$	1
	Load and store	$\mathbf{4*10^6}$	3
	Branch	$\mathbf{2*10^6}$	4
	Others	$\mathbf{4*10^6}$	3
B	Arithmetic and logic	$\mathbf{10*10^6}$	1
	Load and store	$\mathbf{8*10^6}$	2
	Branch	$\mathbf{2*10^6}$	4
	Others	$\mathbf{4*10^6}$	3

Determine the effective **CPI**, **MIPS rate**, and **execution time** for each machine.

Answer:

For Machine A:

- $CPI = \frac{\sum_{i=1}^{n} CPI_i * I_i}{I_C} = \frac{(\mathbf{8*10^6}*1)+(4*\mathbf{10^6}*3)+(2*\mathbf{10^6}*4)+(4*\mathbf{10^6}*3)}{(\mathbf{8*10^6})+(4*\mathbf{10^6})+(2*\mathbf{10^6})+(4*\mathbf{10^6})}$ = 2.222
- $MIPS = \frac{f}{CPI*10^6} = \frac{200*\mathbf{10^6}}{2.222*\mathbf{10^6}}$ = 90
- $T = \frac{I_c*CPI}{f} = \frac{[(\mathbf{8*10^6})+(4*\mathbf{10^6})+(2*\mathbf{10^6})+(4*\mathbf{10^6})]*2.222}{200*\mathbf{10^6}}$ = 0.2 sec

For Machine B:

- $CPI = \frac{\sum_{i=1}^{n} CPI_i * I_i}{I_C} = \frac{(10*\mathbf{10^6}*1)+(8*\mathbf{10^6}*2)+(2*\mathbf{10^6}*4)+(4*\mathbf{10^6}*3)}{(10*\mathbf{10^6})+(8*\mathbf{10^6})+(2*\mathbf{10^6})+(4*\mathbf{10^6})}$ = 1.9167
- $MIPS = \frac{f}{CPI*10^6} = \frac{200*\mathbf{10^6}}{2.222*\mathbf{10^6}}$ = 104.35
- $T = \frac{I_c*CPI}{f} = \frac{[(10*\mathbf{10^6})+(8*\mathbf{10^6})+(2*\mathbf{10^6})+(4*\mathbf{10^6})]*1.9167}{200*\mathbf{10^6}}$ = 0.23 sec

2.13 Four benchmark programs are executed on three computers with the following results:

	Computer A	Computer B	Computer C
Program 1	1	10	20
Program 1	1000	100	20
Program 1	500	1000	50
Program 1	100	80	100

The table shows the execution time in seconds, with 100,000,000 instructions executed in each of the four programs. Calculate the MIPS values for each computer for each program. Then calculate the arithmetic and harmonic means assuming equal weights for the four programs, and rank the computers based on arithmetic mean and harmonic mean.

Answer:

$MIPS = \frac{I_C}{T*10^6} = \frac{100000000}{T*10^6} = \frac{100}{T}$

Computer A:	Computer B:	Computer C:
$MIPS_{Program\ 1} = \frac{100}{T_1} = \frac{100}{1} = 100$	$MIPS_{Program\ 1} = \frac{100}{T_1} = \frac{100}{10} = 10$	$MIPS_{Program\ 1} = \frac{100}{T_1} = \frac{100}{20} = 5$
$MIPS_{Program\ 2} = \frac{100}{T_2} = \frac{100}{1000} = 0.1$	$MIPS_{Program\ 2} = \frac{100}{T_2} = \frac{100}{100} = 1$	$MIPS_{Program\ 2} = \frac{100}{T_2} = \frac{100}{20} = 5$
$MIPS_{Program\ 3} = \frac{100}{T_3} = \frac{100}{500} = 0.2$	$MIPS_{Program\ 3} = \frac{100}{T_3} = \frac{100}{1000} = 0.1$	$MIPS_{Program\ 3} = \frac{100}{T_3} = \frac{100}{50} = 2$
$MIPS_{Program\ 4} = \frac{100}{T_4} = \frac{100}{100} = 1$	$MIPS_{Program\ 4} = \frac{100}{T_4} = \frac{100}{800} = 0.125$	$MIPS_{Program\ 4} = \frac{100}{T_4} = \frac{100}{100} = 1$

$R_A = \frac{1}{m}\sum_{i=1}^{m} R_i$

Where : R_A = Arithmetic mean of execution rate
R_i = Execution rate for benchmark i
m = number of benchmarks

$R_H = \frac{m}{\sum_{i=1}^{m}\frac{1}{R_i}}$

Where : R_H = Harmonic mean of execution rate
R_i = Execution rate for benchmark i
m = number of benchmarks

For Machine A:

a) $R_A = \frac{1}{m}\sum_{i=1}^{m} R_i = \frac{1}{4} * (100 + 0.1 + 0.2 + 1) = 25.325$

b) $R_H = \frac{m}{\sum_{i=1}^{m}\frac{1}{R_i}} = \frac{4}{\frac{1}{100}+\frac{1}{0.1}+\frac{1}{0.2}+\frac{1}{1}} = 0.25$

For Machine B:

a) $R_A = \frac{1}{m}\sum_{i=1}^{m} R_i = \frac{1}{4} * (10 + 1 + 0.1 + 0.125) = 2.80625$

b) $R_H = \frac{m}{\sum_{i=1}^{m}\frac{1}{R_i}} = \frac{4}{\frac{1}{10}+\frac{1}{1}+\frac{1}{0.1}+\frac{1}{0.125}} = 0.209$

For Machine C:

a) $R_A = \frac{1}{m}\sum_{i=1}^{m} R_i = \frac{1}{4} * (5 + 5 + 2 + 1) = 3.25$

b) $R_H = \frac{m}{\sum_{i=1}^{m}\frac{1}{R_i}} = \frac{4}{\frac{1}{5}+\frac{1}{5}+\frac{1}{2}+\frac{1}{1}} = 2.1$

Ranking according to Arithmetic mean: (A – C – B)
Ranking according to Harmonic mean: (C – A – B)