Computer Systems

- Computer System Components
- Key Concepts
- Performance

Types of Computing Device

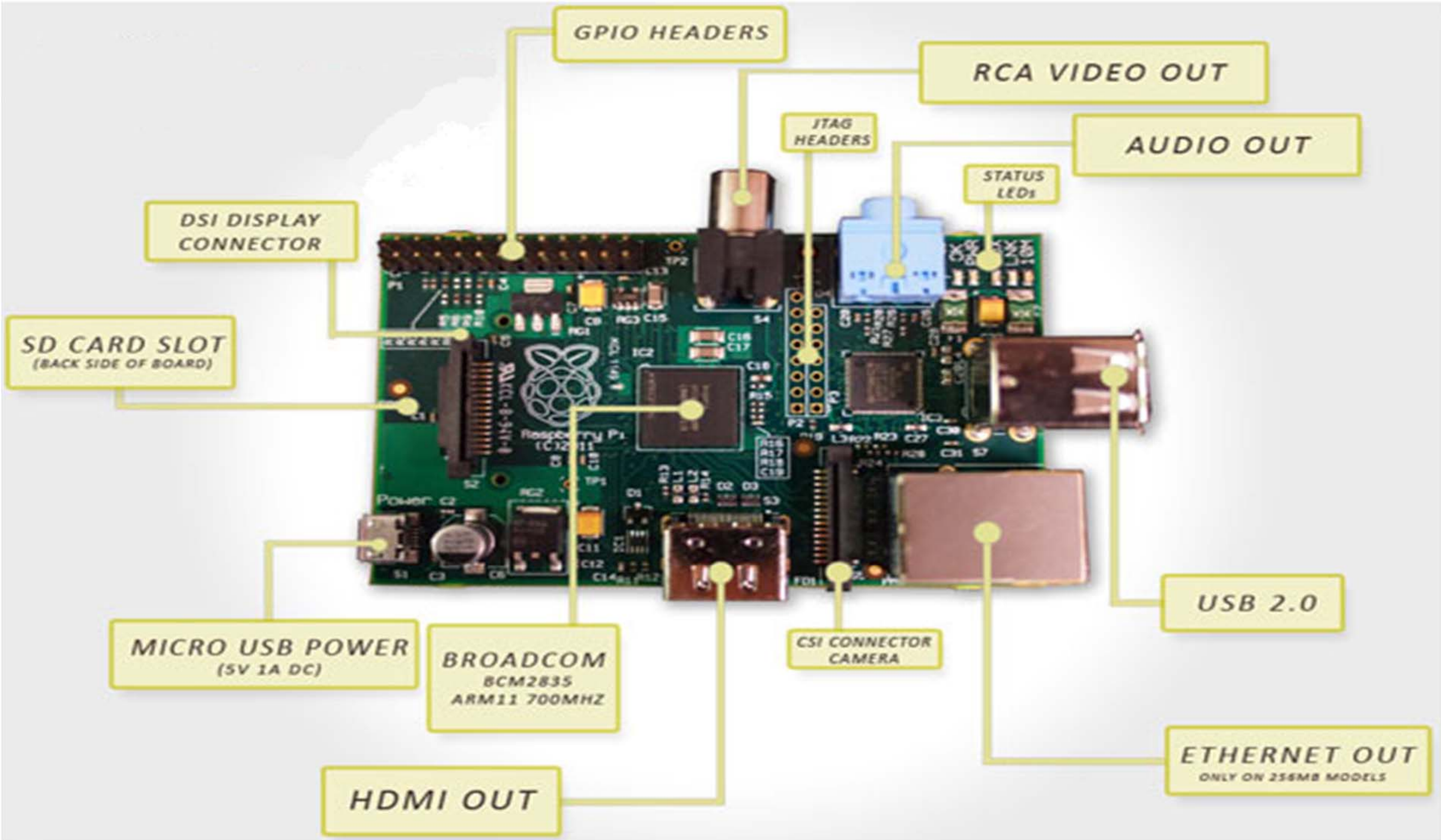
Microprocessor : General purpose processor, mainly used in desktop computers and servers.

Microcontroller : Lots of peripheral support, includes functional parts to reduce the external parts count, real-time applications.

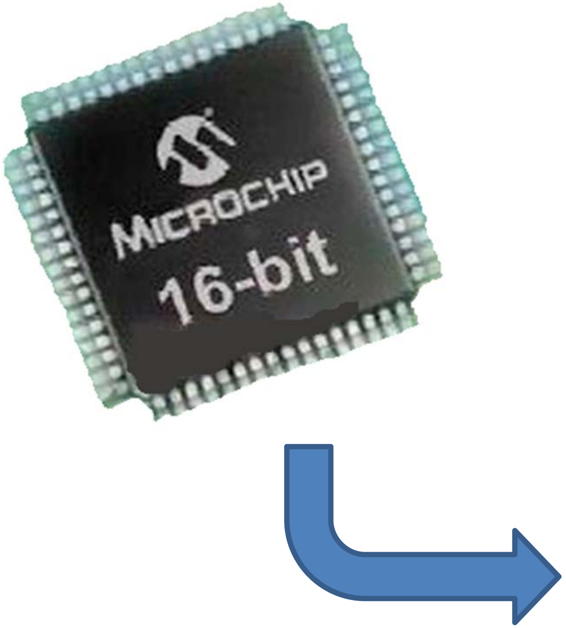
Digital Signal Processor (DSP): Processor optimized for Multiply Accumulate (MAC) operations. Processes data in real time.

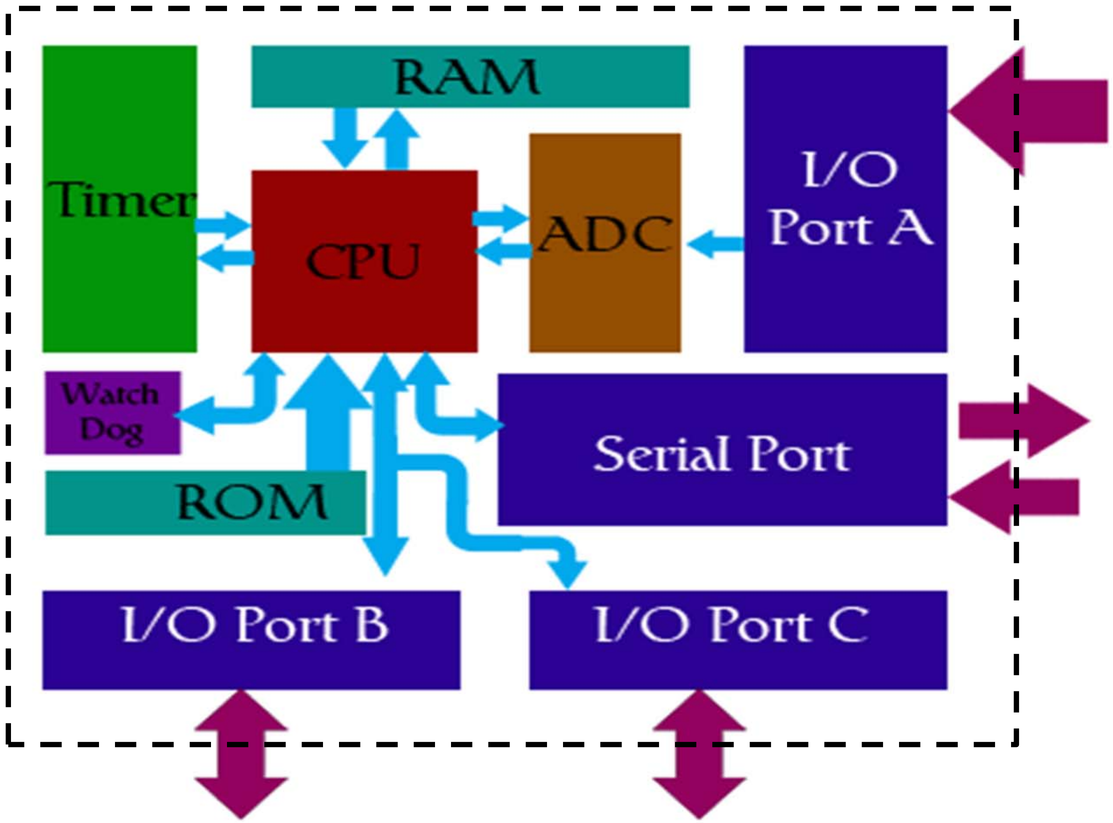
ARM 11 – 32 bit RISC microprocessor

Raspberry Pi - an ARM GNU/Linux box for £29

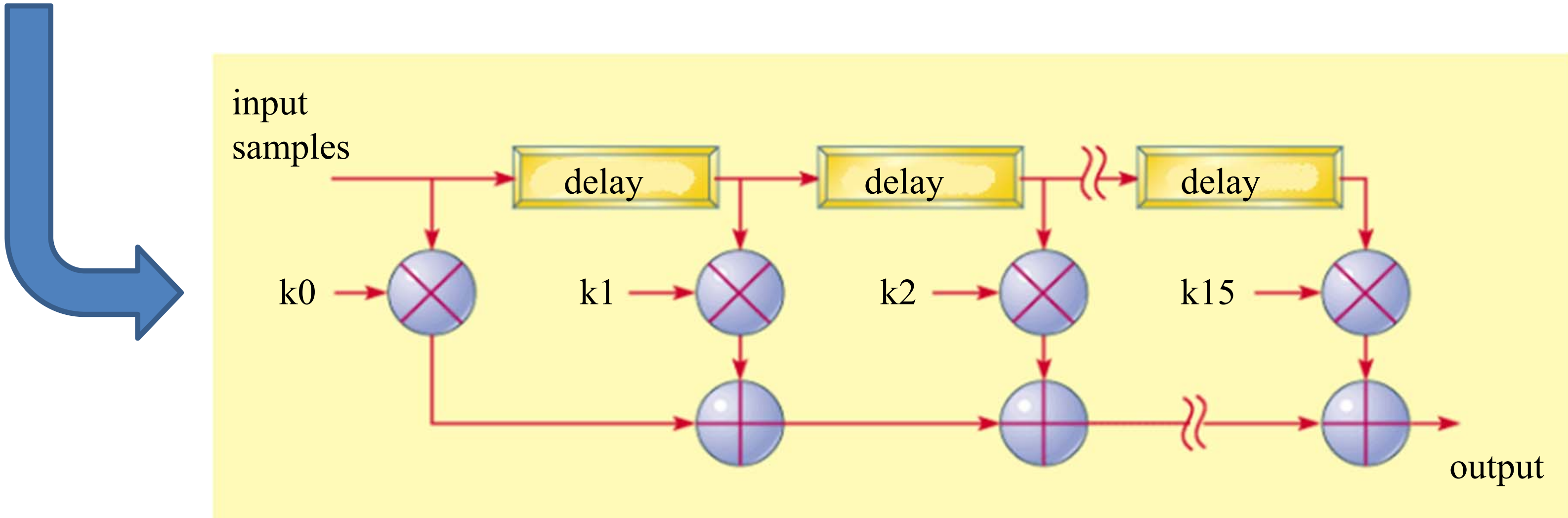


PIC Microcontrollers

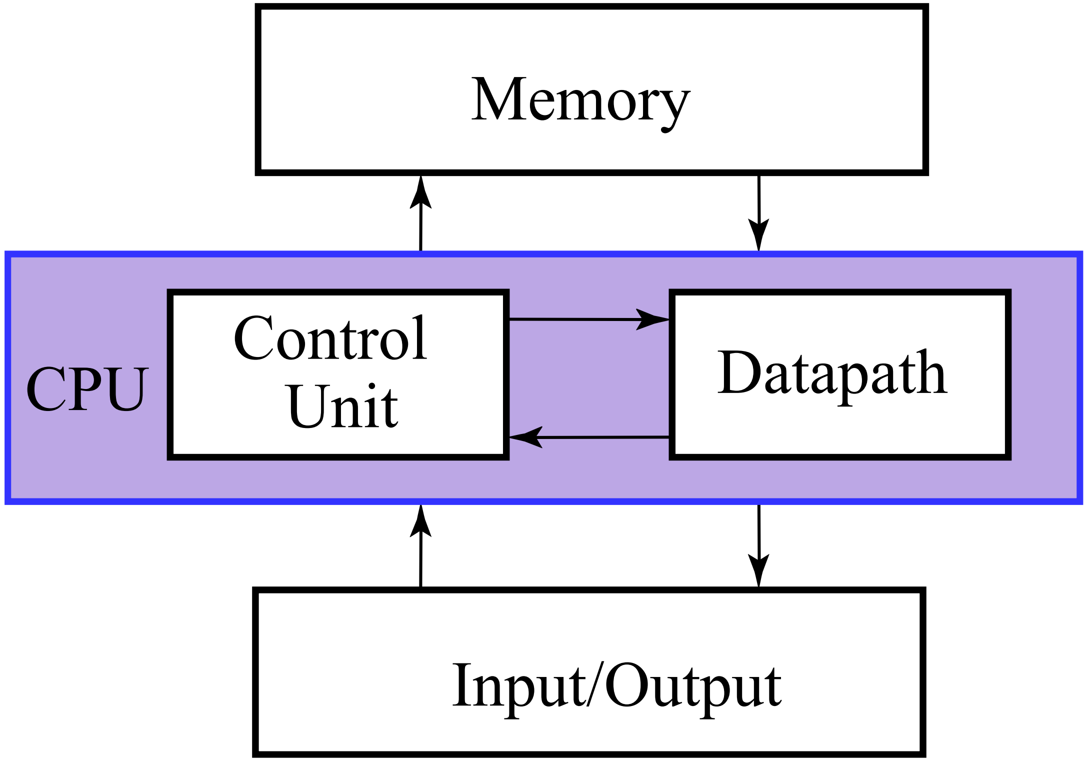




DSP – Texas Instruments TMS320



Simple Model

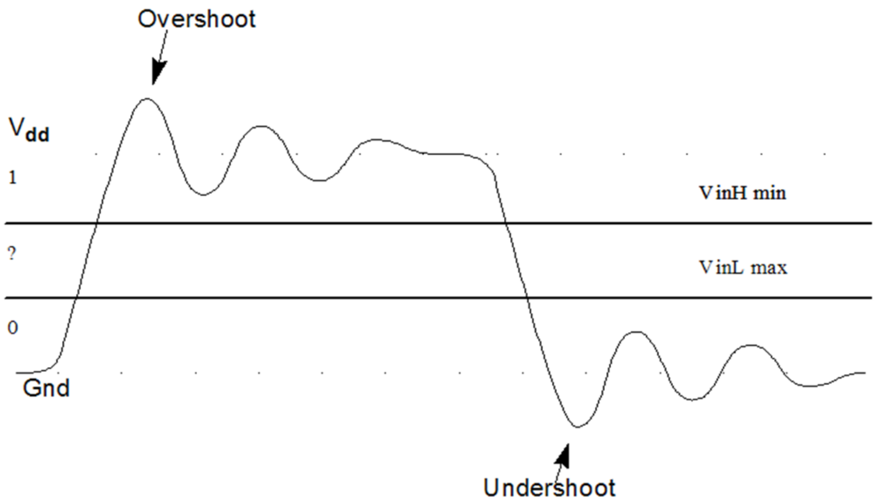


- A computer takes input and acts on it according to stored instructions (program)
- To store instructions, we need some memory
- To process instructions, we need a processor (Central Processing Unit or CPU)
- To transact with the computer we need input and output

Representation of information

- Binary signal (two states)
- Achieved using transistors switches
- Low voltage = 0, High voltage = 1
- Voltage level, V_{DD} , depends upon the chosen technology

ON	OFF
HIGH	LOW
1	0



Combinations of bits

A binary digit is called a ‘bit’ and can take the values **0** or **1**

1 bit - 2 alternatives **0**,**1**
2 bits - 4 alternatives **00**, **01**, **10**, **11**
3 bits - 8 alternatives
4 bits - 16 alternatives
8 bits - 2^8 = 256 alternatives
n bits - 2^n alternatives

Information words are built up from binary digits to form a word of any desired length. The length depends on the application. A group of 8 bits is called a byte.

e.g. 4 bit word ABCD = 0000, 0001, 0010, 0011, ..., 1111

Binary Numbers

The position of the bit in a binary number indicates its weight which is a power of two. A binary number can be converted to decimal by adding the weights of all bits that are **1**.

$$1101_2 = (1 \times 2^3) + (1 \times 2^2) + (0 \times 2^1) + (1 \times 2^0)$$
$$= (1 \times 8) + (1 \times 4) + (0 \times 2) + (1 \times 1) = 8 + 4 + 1 = 13_{10}$$

The left-most bit is known as the most significant bit or MSB.
The right-most bit is known as the least significant bit or LSB.

Binary to Hexadecimal Conversion

Hex : there are 16 digits

0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F

each digit corresponds to four binary digits as $2^4 = 16$

0000	0001	0010	0011
0100	0101	0110	0111
1000	1001	1010	1011
1100	1101	1110	1111

Binary to Hexadecimal Conversion

To convert from binary to hex, group the binary number in fours and assign the corresponding hex digit to each group.

$$(110\ \ 1010\ \ 0101\ \ 1111)_2 = (6A5F)_{16}$$

6 A 5 F

convert from binary to hex:

a. 10010111001101

b. 101001111101001

convert from hex to binary:

a. B42C

b. EFC

convert from binary to hex:

a. 0010_0101_1100_1101

2 5 C D

b. 0101_0011_1110_1001

5 3 E 9

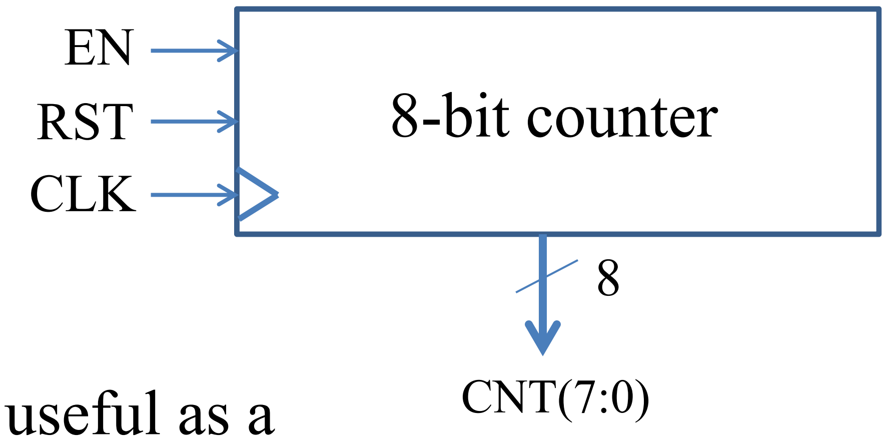
a. B42C

1011010000101100

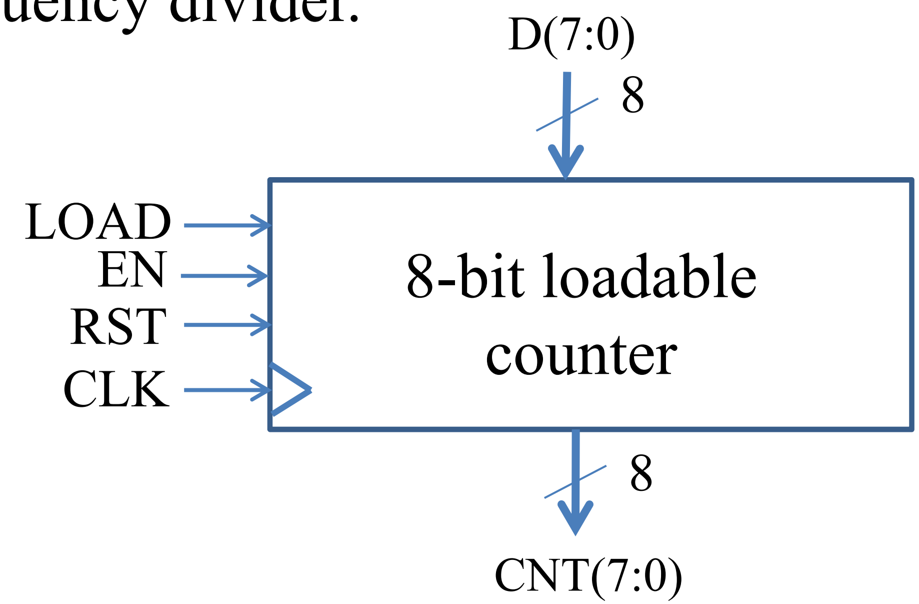
b. EFC

111011111100

Counters



Also useful as a frequency divider.



decimal	binary	hex
0	0 0 0 0 0	0
1	0 0 0 0 1	1
2	0 0 0 1 0	2
3	0 0 0 1 1	3
4	0 0 1 0 0	4
5	0 0 1 0 1	5
6	0 0 1 1 0	6
7	0 0 1 1 1	7
8	0 1 0 0 0	8
9	0 1 0 0 1	9
10	0 1 0 1 0	A
11	0 1 0 1 1	B
12	0 1 1 0 0	C
13	0 1 1 0 1	D
14	0 1 1 1 0	E
15	0 1 1 1 1	F
16	1 0 0 0 0	10
17	1 0 0 0 1	11
18	1 0 0 1 0	12

Non-Numeric Information

Instructions and non-numeric data are a problem. So we represent both of these by numbers.

An instruction is a number which the processor interprets as a particular, unique instruction.

LD A,3	=	49	Instruction Code
		03	Associated Operand

Non-numeric data such as text is handled similarly. For example ASCII (American Standard for Character Information Interchange) codes represent each character by a number:

'0'	=	48
'A'	=	65
' '	=	32


747
BOEING


DC-8-50


BOEING 777


BRITISH AIRWAYS

Some approximate figures for aircraft performance:

Aircraft	Passengers	Range (miles)	Speed (mph)	Passenger throughput (passengers x mph)
Boeing 777	375	4630	610	228,750
Boeing 747	470	4150	610	286,700
Concorde	132	4000	1350	178,200
DC-8-50	146	8720	544	79,424

Response Time : the response time or execution time is the total time for the computer to complete a task.

Throughput : the throughput or bandwidth is the number of tasks completed per unit time.

Performance in relation to Execution Time

For a computer X, simplifying execution time to CPU execution time:

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

For two computers X and Y, if the performance of X is greater than the performance of Y

$$\text{Performance}_X > \text{Performance}_Y$$
$$\text{Execution time}_Y > \text{Execution time}_X$$

So if we say that X is ***n*** times faster than Y

$$\frac{\text{Performance}_X}{\text{Performance}_Y} = \frac{\text{Execution time}_Y}{\text{Execution time}_X} = \boldsymbol{n}$$

Relative Performance Example

If computer X runs a program in 10 seconds and computer Y runs the same program in 15 seconds, how much faster is X than Y?

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Relative Performance Example

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$$\frac{\text{Performance}_X}{\text{Performance}_Y} = \frac{\text{Execution time}_Y}{\text{Execution time}_X} = \frac{15}{10} = 1.5$$

Computer X is 1.5 times faster than computer Y.

To improve performance we need to decrease execution time.

How can we improve performance ?

Find the bottleneck.

CPU limited task

Input ⟶ Processing ⟶ Output

I/O limited task

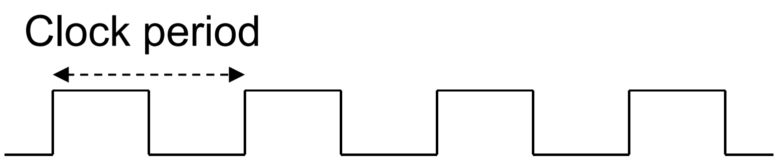
CPU Performance

If we limit ourselves to CPU performance, we obtain the expression for CPU execution time.

$$\text{CPU execution time for a program} = \text{CPU clock cycles for a program} \times \text{Clock cycle time}$$

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

Clock rate: 1 GHz = 10^9 cycles / s (cycle time 10^{-9} s = 1 ns)
200 MHz = 200×10^6 cycles / s (cycle time = 5 ns)



Instruction Performance

The previous analysis did not take into consideration the number of instructions in the program..

$$\text{CPU clock cycles} = \text{Instructions for a program} \times \text{Average clock cycles per instruction}$$

Average clock cycles per instruction is often abbreviated to CPI

$$\boxed{\text{CPU time} = \text{Instructions count} \times \text{CPI} \times \text{Clock cycle time}}$$

Example

Suppose we have two computers which have the same instruction set architecture.
Computer A has a clock cycle time of 250ps and a CPI of 2.0 for a certain program. Computer B has a clock cycle time of 500ps and a CPI of 1.2 for the same program. Which computer is faster for this program and by how much?

Each computer will execute the same number of instructions for the program, say I.

First find the number of processor clock cycles for each computer.

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$$\text{CPU clock cycles}_B = I \times 1.2$$

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$$\text{CPU clock cycles}_A = I \times 2.0$$

$$\text{CPU clock cycles}_B = I \times 1.2$$

Now we can compute the CPU time for each computer.

$$\text{CPU time}_A = I \times 2.0 \times 250\text{ps} = 500 \times I \text{ ps}$$

$$\text{CPU time}_B = I \times 1.2 \times 500\text{ps} = 600 \times I \text{ ps}$$

We see that computer A is faster. How much faster ?

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$$\text{CPU time}_B = I \times 1.2 \times 500\text{ps} = 600 \times I \text{ ps}$$

We see that computer A is faster. How much faster ?

$$\frac{\text{Performance}_A}{\text{Performance}_B} = \frac{\text{Execution time}_B}{\text{Execution time}_A} = \frac{600 \times I \text{ ps}}{500 \times I \text{ ps}} = 1.2$$

Computer A is 1.2 times faster than computer B for this program.