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SCSR1013 DIGITAL LOGIC

MODULE 1: INTRODUCTORY CONCEPTS

FACULTY OF COMPUTING



CONTENTS

MODULE 1: DIGITAL LOGIC OVERVIEW

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Fixed-Function IC

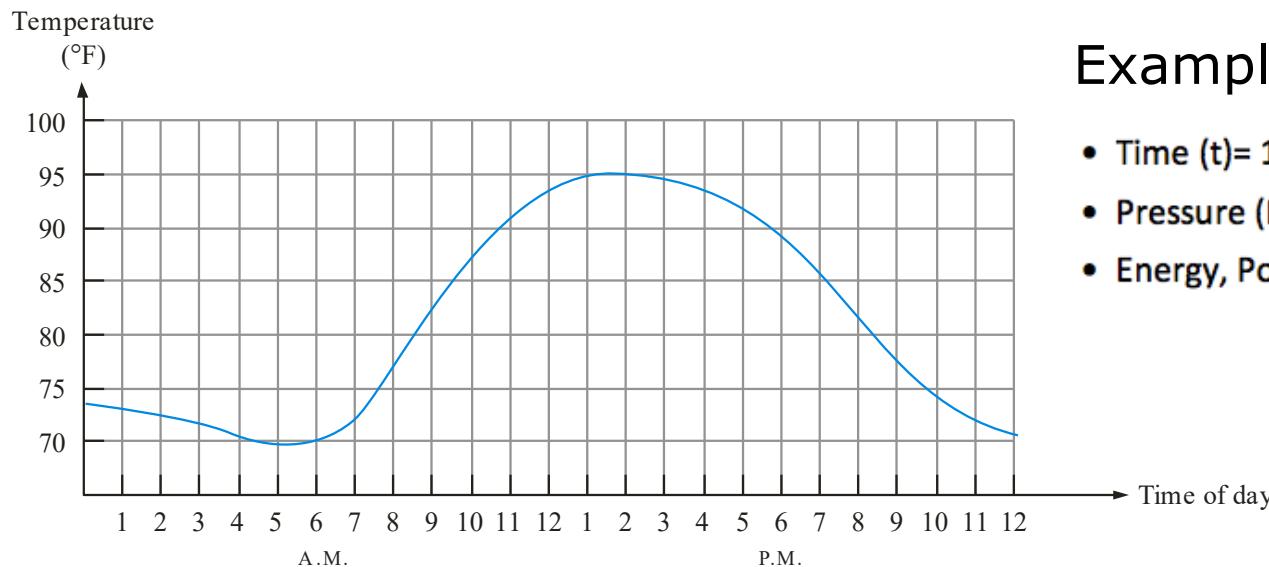
Programmable Logic Devices (PLD)



Digital and Analog Quantities

Analog quantities

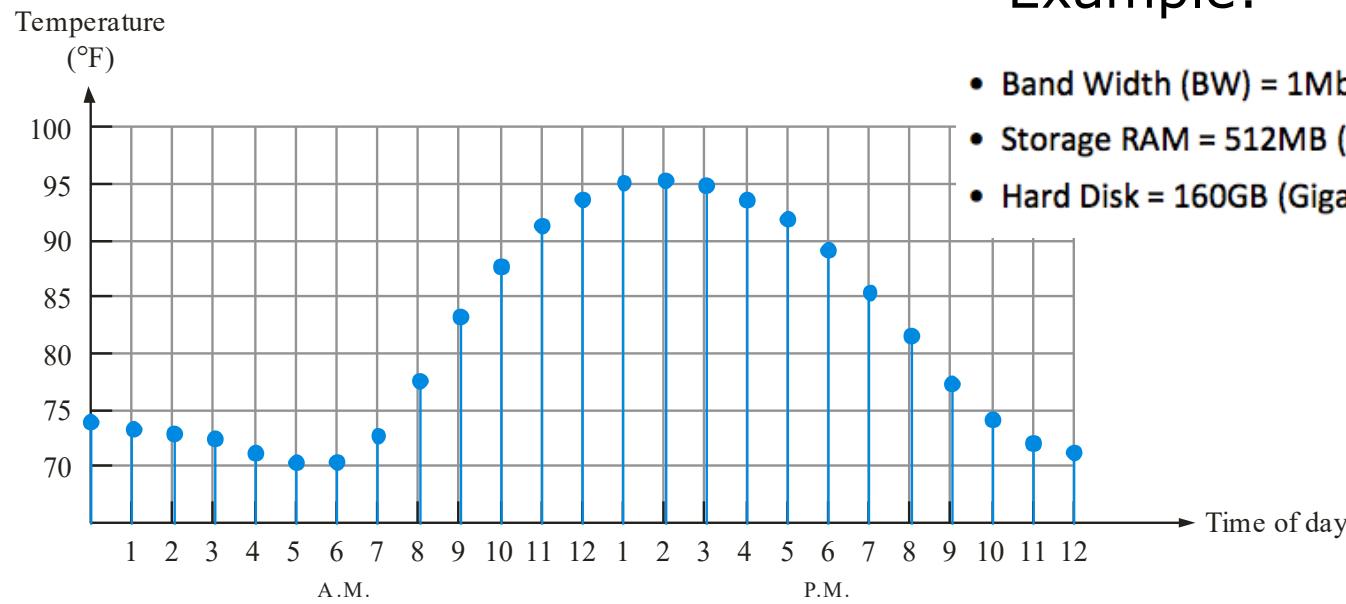
- Most natural quantities that we see are **analog** and vary continuously.
- Analog systems can generally handle higher power than digital systems.



Example:

- Time (t)= 10.16s (second)
- Pressure (P)=220.10KPa (Kilo Pascal)
- Energy, Power = 100.5KW (Kilo Watts)

Digital quantities

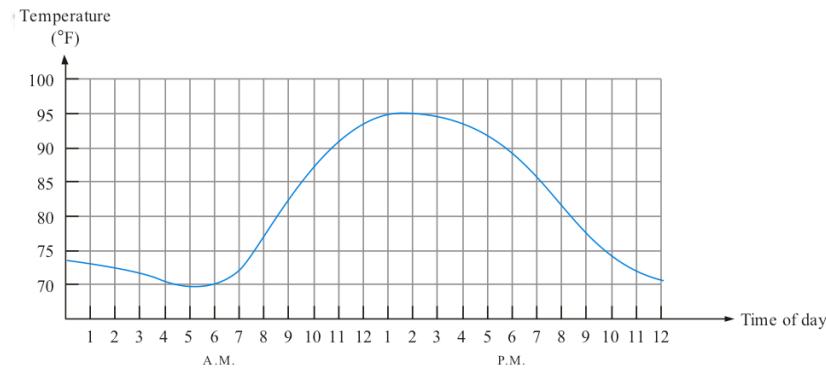


- Digital systems can **process, store, and transmit** data more efficiently but can only assign discrete values (**discontinuous**) to each point.

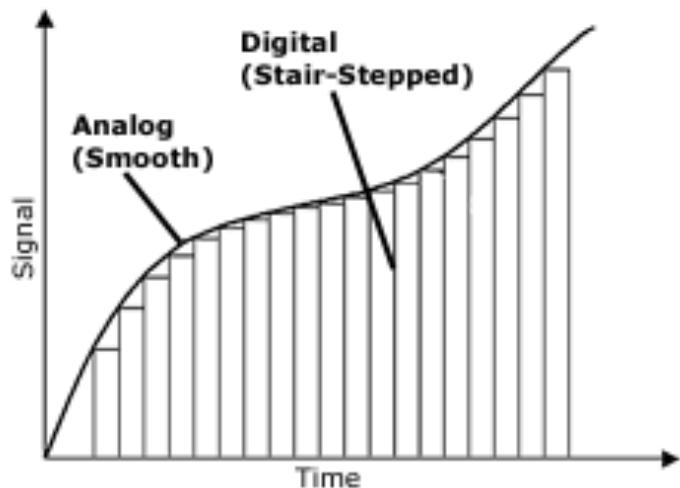
Analog vs Digital

Analog

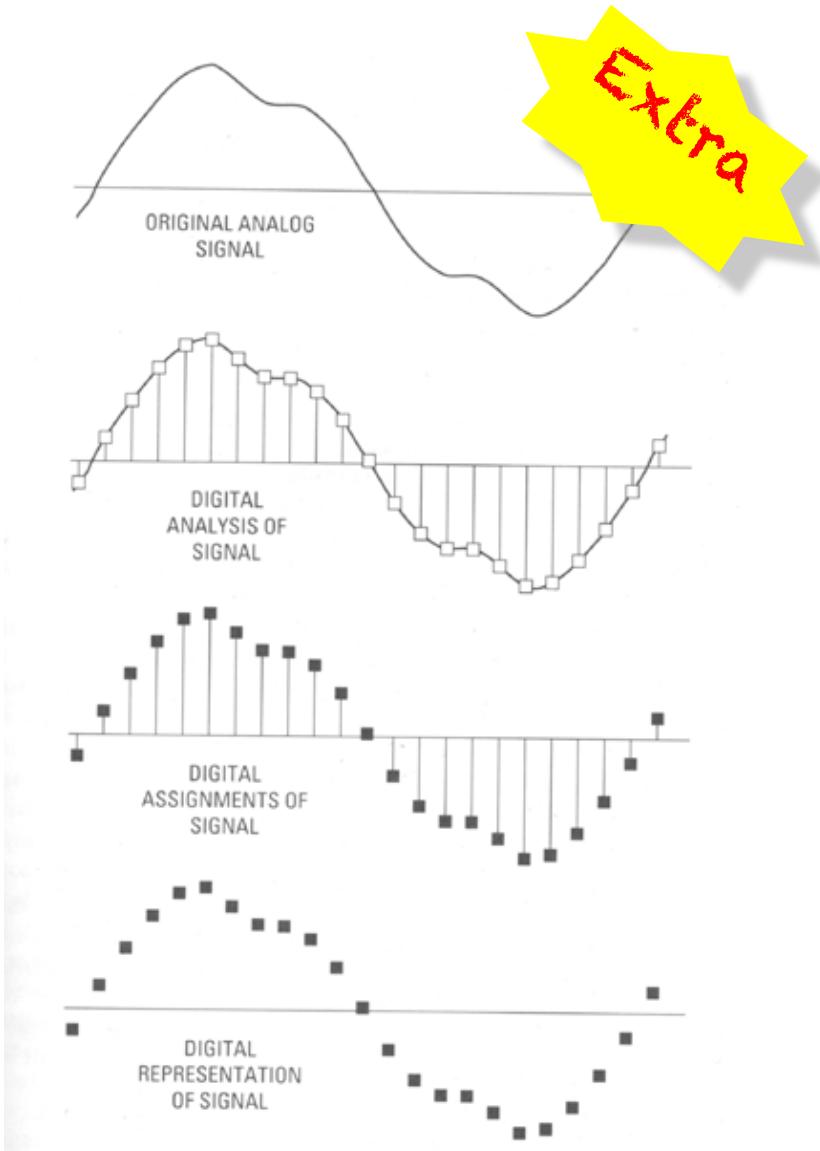
- Use base 10 (decimal)
- Represented by 10 different level:
0, 1, 2, 3, 4, 5, 6, 7, 8, and 9.
- Analog system: A combination of devices that manipulate values represented in analog form



Example of sampling analog-to-digital (frequency at least 2 times higher than analog)

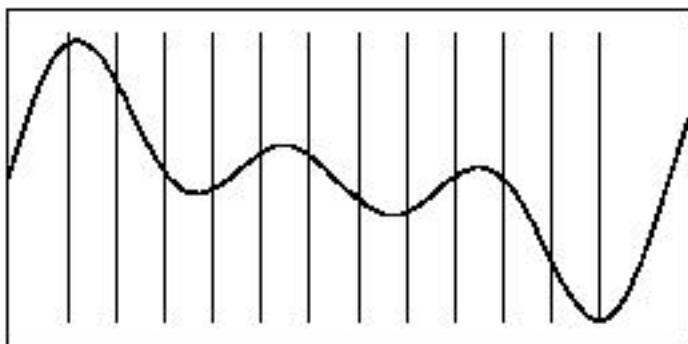


<http://www.blazeaudio.com/howto/bg-digital.html>

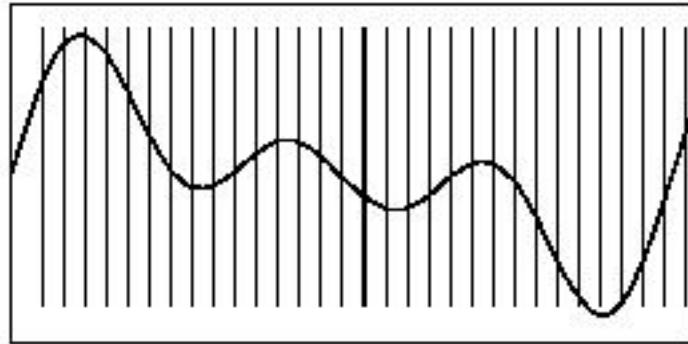


http://www.geardiary.com/2011/04/01/music-diary-notes-the-brave-new-world-of-digital-music/digital_sampling/

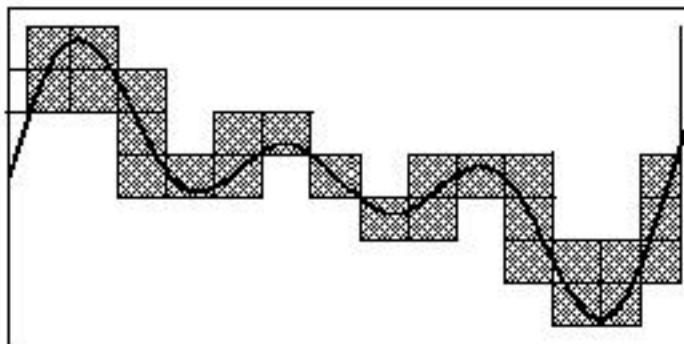
Extra



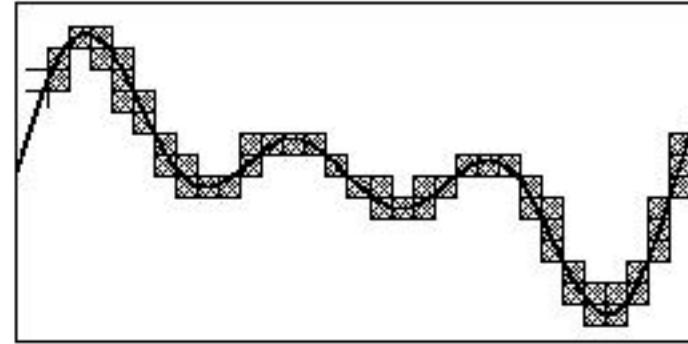
lower sample rates take fewer snapshots
of the waveform



faster sample rates take more
snapshots....



resulting in a rough recreation of the
waveform.



resulting in a smoother and more detailed
recreation of the waveform.

Extra

Self-Test: Which of the following belong to analog system?



(a)



(b)



(c)



(d)



(e)



(f)

Extra

Answer



(a)



(c)



(e)

Extra

Example: Analog systems



Extra

Example: Digital systems



- Digital technology is relatively new compared to analog technology, but a lot of analog systems has been changed to a digital systems, Examples:
 - Computers
 - Manufacturing systems
 - Medical Science
 - Transportation
 - Entertainment
 - Telecommunications



*DSL-2320B (ADSL Modem)



(b)



(e)



(a)

Exercise: Match the picture to which digital application system it belongs to.

- (a) Computers
- (b) Manufacturing systems
- (c) Medical Science
- (d) Transportation
- (e) Entertainment
- (f) Telecommunications



(d)



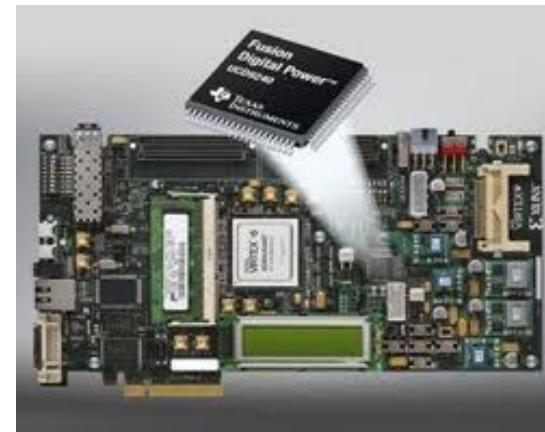
(f)



(c)

The Digital Advantages

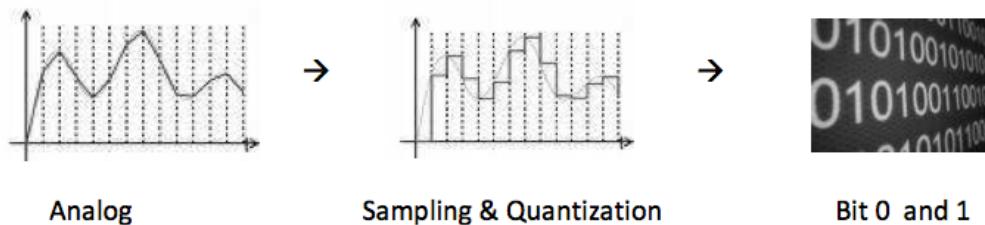
- Ease of design
 - Ease of storage
 - Accuracy and precision are easier to maintain
 - Programmable operation
 - Less affected by noise
 - Ease of fabrication on IC chips
- Thus, the digital systems is more efficient and reliable for:
- Data Processing
 - Data Transmission
 - Data Storage



Digital Disadvantages

- Greater bandwidth
- Sampling error

Sampling Error (Quantization Error): is derived from Analog to Digital Conversion Process:



- Compatibility with existing analog systems
- Short product half life

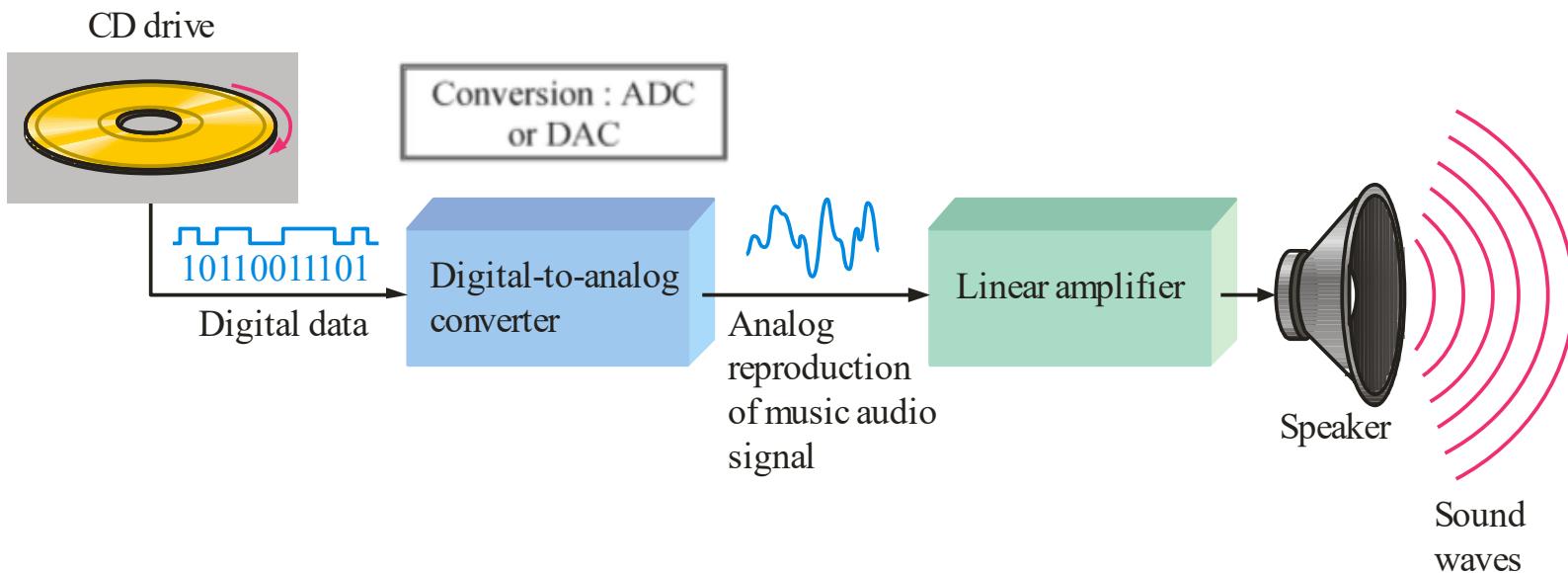


Analog and Digital Systems

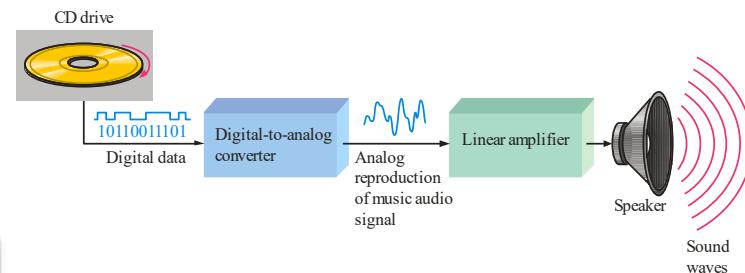
- Many systems use a **mix** of analog and digital electronics to take advantage of each technology.
- A typical CD player accepts digital data from the CD drive and converts it to an analog signal for amplification.



<http://www.it-echo.com/2009/11/14/bose-wave-music-system-and-multi-cd-changer-bundle.html>
<http://cdn-static.zdnet.com/i/story/61/18/006128/31929466-2-440-overview-1.gif>



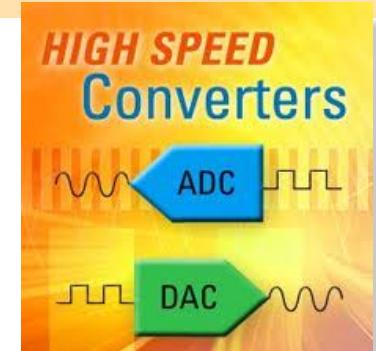
1. Convert digital sound (CD) to analog
2. Process (amplify) the analog information
3. Convert the analog signal to sound



Hybrid System

- The audio CD is a typical hybrid (Analog & Digital) system.
 - Analog sound is converted into analog voltage using a microphone.
 - Analog voltage is changed into digital through an ADC in the recorder.
 - Digital information is stored on the CD .
 - At playback the digital information is changed into analog by a DAC in the CD player.
 - The analog voltage is amplified and used to drive a speaker that produces the original analog sound.

Conversion:



<http://www.idt.com/products/data-converters>

Analog to Digital Converter (ADC):

- Convert analog signal into digital signal using process such as sampling, quantization process and digital conversion.
- Error will occur during the sampling and quantization, hence loss of information can happen.

Digital to Analog Converter (DAC):

- Needed if the speaker is using analog system.
- Need to convert the digital data to analog signal in order for the speaker works properly and the sound can be heard by human.



<http://thesoundviewstudio.com/audio-rentals.html>



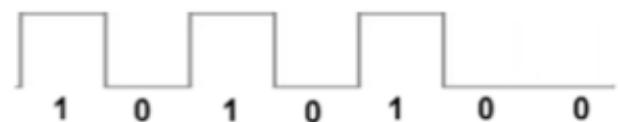
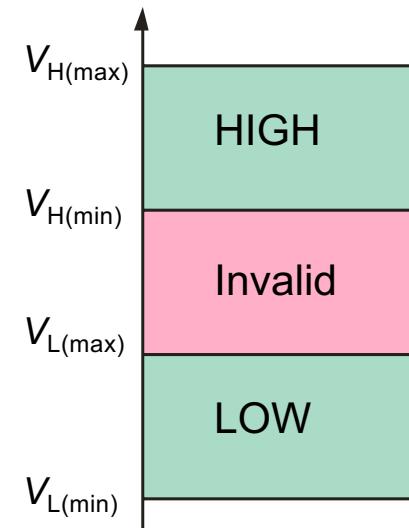
Digits, Logic Levels and Digital Waveform

Binary digits and logic levels

Digital electronics uses circuits that have two states, which are represented by two different voltage levels:

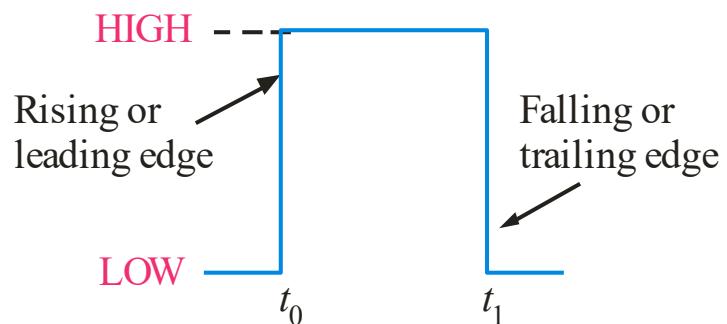
- HIGH (bit 1)
- LOW (bit 0)

A bit can have the value of either a 0 or a 1, depending on if the voltage is **HIGH** or **LOW**.



1010100 represented as electrical signal

- **Digital waveforms** change between the **LOW** and **HIGH** levels.
- A positive going pulse is one that goes from a normally **LOW** logic level to a **HIGH** level and then back again.
- **Digital waveforms** are made up of a series of pulses.



(a) Positive-going pulse

Positive Logic (active high)

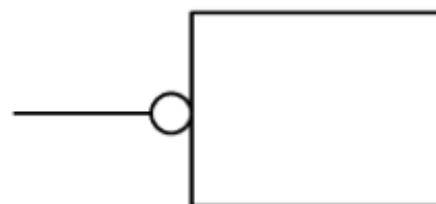
High = 1 (Bit 1)

Low = 0 (Bit 0)

Symbols to show the input state of “active high” and “active low”:



“active high”

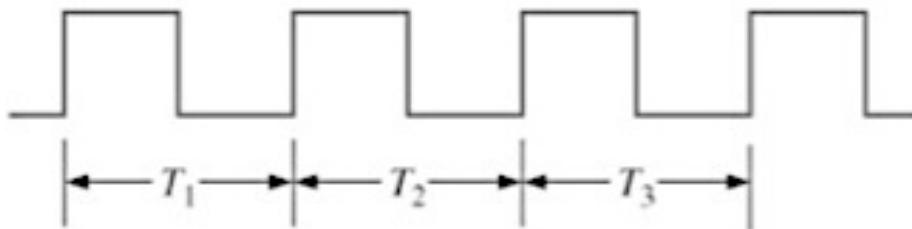


“active low”

- Two type of squarewave

- Periodic

- The signal keep on repeating after a period of time



$$\text{Period} = T_1 = T_2 = T_3 = \dots = T_n$$

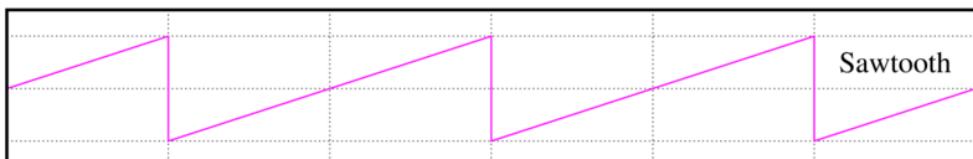
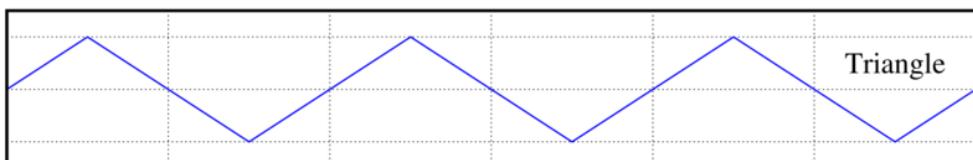
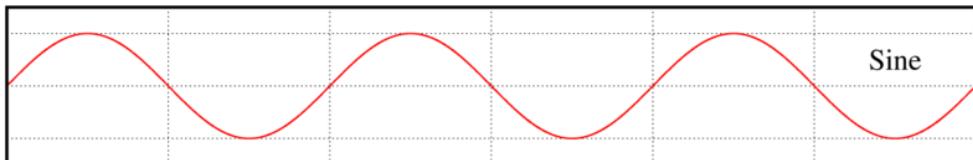
$$\text{Frequency} = \frac{1}{T}$$

- Non-Periodic / Aperiodic

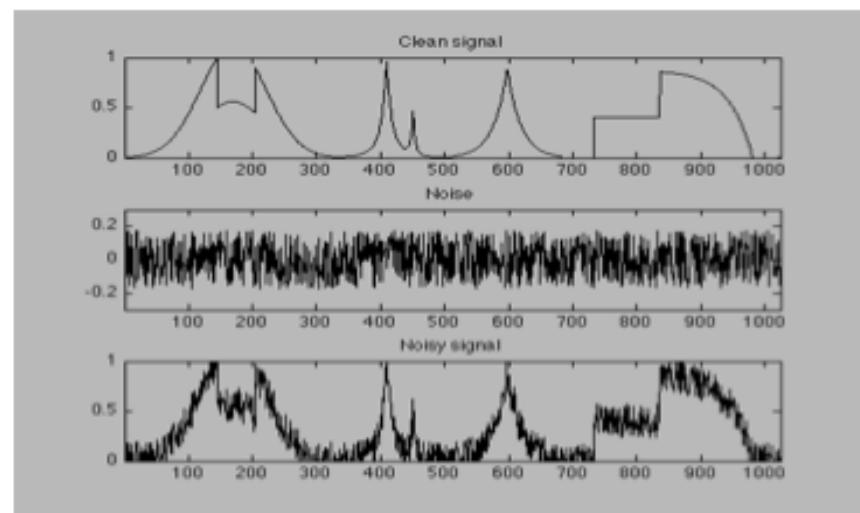
- Doesn't have a period



Periodic signal



Aperiodic signal



<http://commons.wikimedia.org/wiki/File:Waveforms.png>

Periodic Signal Parameter

- Frequency (f) is the rate at which the signal repeat itself at a fixed interval. Is measured in cycles per second or Hertz (Hz)

$$f = \frac{1}{T} \text{ Hz}$$

- Period (T) is the time from the edge of one pulse to the corresponding edge of the next pulse. Is measured in second

$$T = \frac{1}{f} \text{ seconds}$$

■ Example:

- clock frequency : $f = 100\text{Hz}$,
so, period : $T = 1/100\text{Hz} = \underline{0.01\text{s}} = 10 \times 10^{-3} = \underline{10\text{ ms}}$

$$\begin{aligned}s &\rightarrow \text{ms } (\times 10^3) \\ \text{ms} &\rightarrow s \quad (\times 10^{-3})\end{aligned}$$

Some examples of periodic signal display on the oscilloscope:

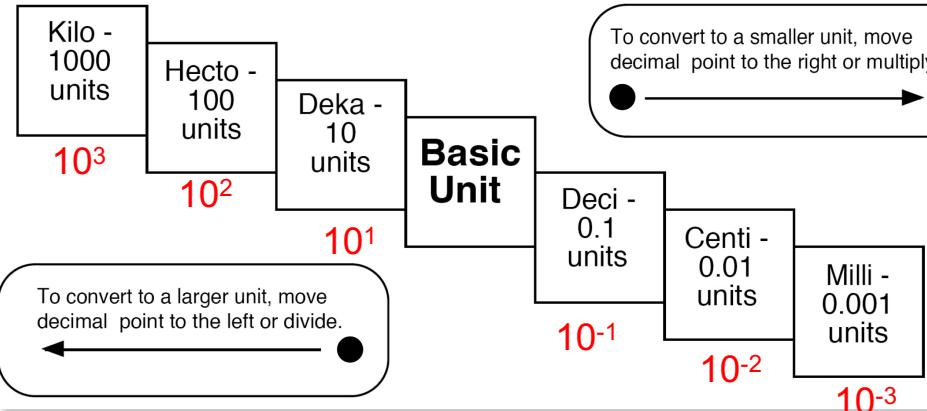


(a) Square waveform



(b) Sinusoid waveform

Metric Conversion Chart



http://ruthpawson.rbe.sk.ca/johnson_math0910

Unit Conversion

-
- ◆ Kilo (K)= 10^3
 - ◆ Mega (M)= 10^6
 - ◆ Giga (G)= 10^9
 - ◆ Tera (T)= 10^{12}
 - ◆ Mili (m)= 10^{-3}
 - ◆ Micro (μ) = 10^{-6}
 - ◆ Nano (n)= 10^{-9}
 - ◆ Piko (p)= 10^{-12}

- Mili (m) = 10^{-3}
- Micro (μ) = 10^{-6}
- Nano (n) = 10^{-9}
- Piko (p) = 10^{-12}

Example : $f = 100\text{KHz}$, So

$$T = 1/f$$

$$= 1/(100 * 10^3 \text{Hz})$$

$$= 0.01 * 10^{-3} \text{s}$$

$$= 0.01 \text{ms}$$

$$= 10 \mu\text{s}$$

$$\begin{aligned} &= (0.01 * 10^{-3}) \text{s} \times 10^3 \\ &= (0.01 * 10^{-3+3}) \text{ms} \\ &= (0.01 * 10^0) \text{ms} \\ &= 0.01 \text{ms} \end{aligned}$$

$$\begin{aligned} &= (0.01 * 10^{-3}) \text{s} \times 10^6 \\ &= (0.01 * 10^{-3+6}) \mu\text{s} \\ &= (0.01 * 10^3) \mu\text{s} \\ &= 10 \mu\text{s} \end{aligned}$$

Exercise 1.1 : Calculate the frequency of signals if time period are given as the following:

a) $10ms = \underline{\hspace{2cm}} Hz$

b) $100\mu s = \underline{\hspace{2cm}} KHz$

c) $100ns = \underline{\hspace{2cm}} MHz$

d) $1000ps = \underline{\hspace{2cm}} GHz$



Extra

Solution 1.1 :

(Convert to second)

a) $10ms$

$$= \left(\frac{10}{10^3}\right)s = \left(\frac{1}{10^2}\right)s = 0.01s$$

b) $100\mu s$

$$= \left(\frac{100}{10^6}\right)s = \left(\frac{1}{10^4}\right)s = 0.0001s$$

c) $100ns$

$$= \left(\frac{100}{10^9}\right)s = \left(\frac{1}{10^7}\right)s = 10^{-7}s$$

d) $1000ps$

$$= \left(\frac{1000}{10^{12}}\right)s = \left(\frac{1}{10^9}\right)s = 10^{-9}s$$

$$f = \frac{1}{0.01} = 100Hz$$

$$f = \frac{1}{0.0001} = 1 \times 10^4 Hz = \frac{1 \times 10^4}{10^3} = 10 KHz$$

$$f = \frac{1}{10^{-7}} = 1 \times 10^7 Hz = \frac{1 \times 10^7}{10^6} = 10 MHz$$

$$f = \frac{1}{10^{-9}} = 1 \times 10^9 Hz = \frac{1 \times 10^9}{10^9} = 1 GHz$$

Exercise 1.2 : Calculate the time period of signals if the frequencies are given as the following:

a) $1000\text{KHz} = \underline{\hspace{2cm}} \mu\text{s}$

b) $100\text{MHz} = \underline{\hspace{2cm}} \text{ns}$

c) $1000\text{GHz} = \underline{\hspace{2cm}} \text{ps}$

d) $100\text{THz} = \underline{\hspace{2cm}} \text{ps}$



Extra

Solution 1.2 :

(Convert to Hz)

a) $1000 \text{ KHz} = 1000 \times 10^3 \text{ Hz} = 10^6 \text{ Hz}$

b) $100 \text{ MHz} = 100 \times 10^6 \text{ Hz} = 10^8 \text{ Hz}$

c) $1000 \text{ GHz} = 1000 \times 10^9 \text{ Hz} = 10^{12} \text{ Hz}$

d) $100 \text{ THz} = 100 \times 10^{12} \text{ Hz} = 10^{14} \text{ Hz}$

$$T = \frac{1}{10^6} = 10^{-6} \text{ s} = 10^{-6} \times 10^6 = 1 \mu\text{s}$$

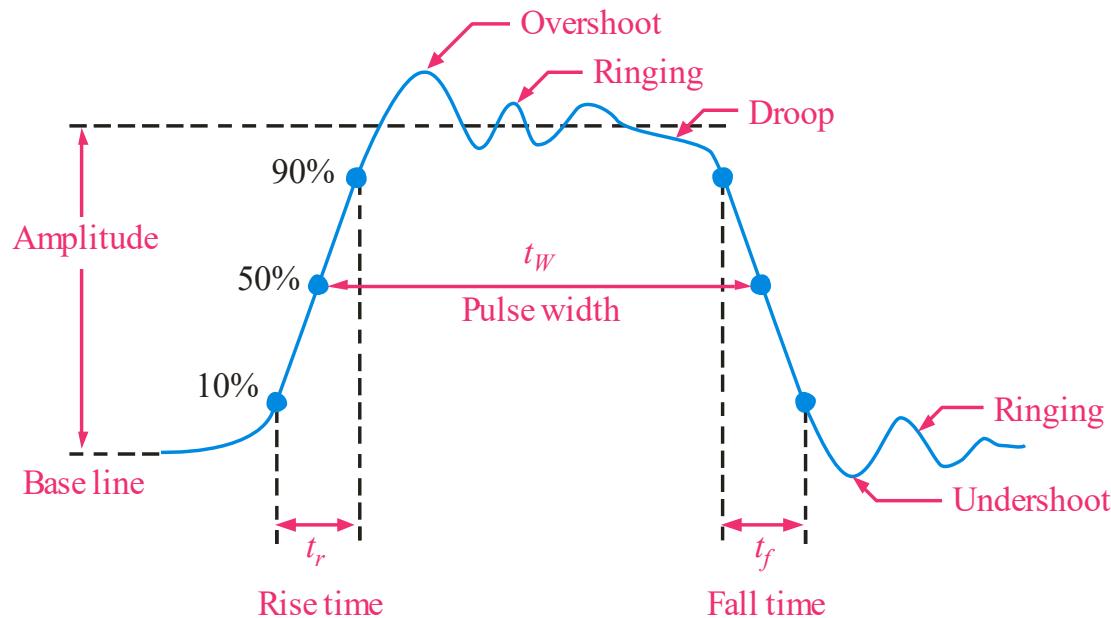
$$T = \frac{1}{10^8} = 10^{-8} \text{ s} = 10^{-8} \times 10^9 = 10 \text{ ns}$$

$$T = \frac{1}{10^{12}} = 10^{-12} \text{ s} = 10^{-12} \times 10^{12} = 1 \text{ ps}$$

$$T = \frac{1}{10^{14}} = 10^{-14} \text{ s} = 10^{-14} \times 10^{12} = 0.01 \text{ ps}$$

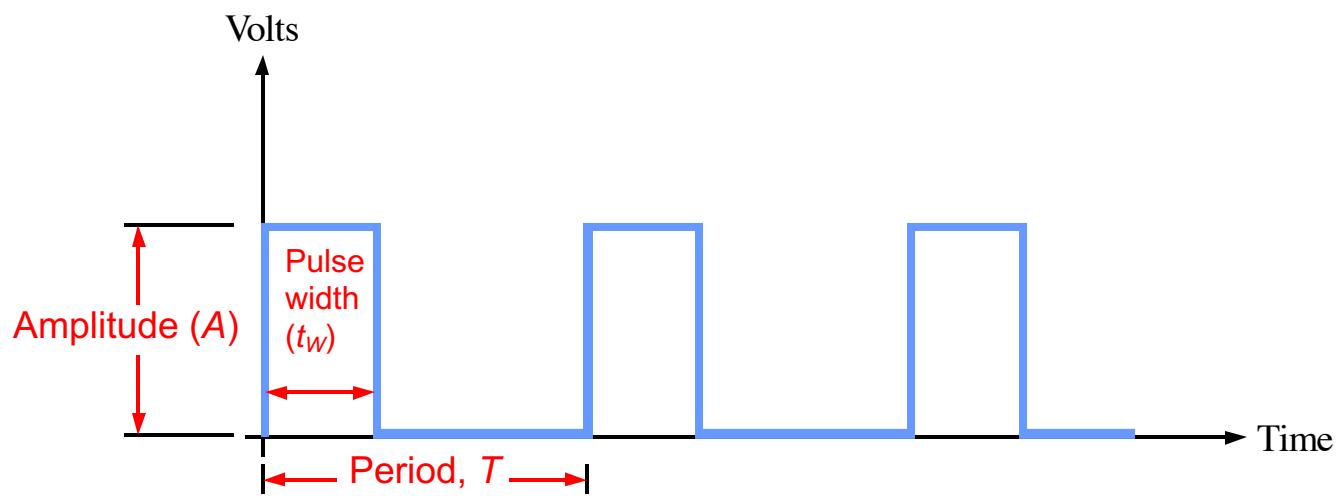
Pulse Definition

- Pulse is a rapid, transient change in the amplitude of a signal from a baseline value to a higher or lower value, followed by a rapid return to the baseline value.
- Pulse width (t_W): A measure of the duration of the pulse.
- Rise time and fall time is a measure of how fast the pulse change.



Repetitive Pulse Waveform

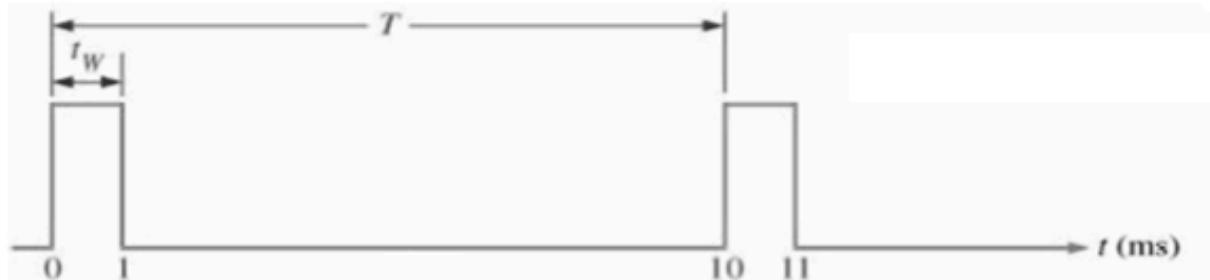
- In addition to frequency and period, repetitive pulse waveforms are described by the **amplitude (A)**, **pulse width (t_w)** and **duty cycle**.
- Duty cycle is the ratio of t_w to T .



Duty Cycle

- Duty cycle is the fraction of time that a system is in an "active" state (operated), defined as

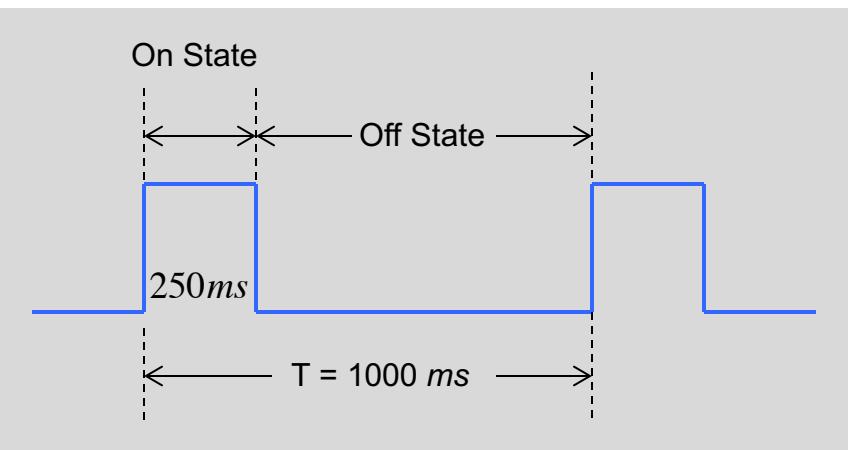
$$\text{Duty cycle} = (t_w/T)100\%$$



Example : a periodic digital waveform has a pulse width (t_w) 1ms and period time (T) 10ms, calculate duty cycle?

$$\text{Duty cycle} = 1\text{ms}/10\text{ms} * 100\% = 10\%$$

Exercise 1.3: Given the duration or period of a system is 1000ms, determine the *on state* and *off state* of the system that operate with the ratio of duty cycle is 25%. Show your works.



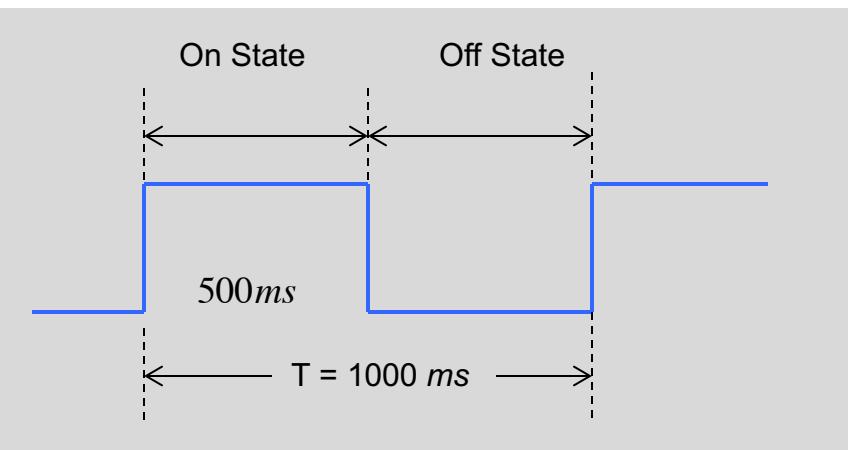
Solution 1.3:

Duty cycle → on state

$$= 25\% \times 1000\text{ ms} = \frac{25}{100} \times 1000\text{ ms} = \frac{1}{4} \times 1000\text{ ms} = 250\text{ ms}$$

$$\text{Off state : } = 1000\text{ ms} - 250\text{ ms} = 750\text{ ms}$$

Exercise 1.4: Given the duration or period of a system is 1000ms, determine the *on state* and *off state* of the system that operate with the ratio of duty cycle is 50%. Show your works.



Solution 1.4:

Duty cycle → on state

$$= 50\% \times 1000 \text{ ms} = \frac{50}{100} \times 1000 \text{ ms} = \frac{1}{2} \times 1000 \text{ ms} = 500 \text{ ms}$$

$$\text{Off state : } = 1000 \text{ ms} - 500 \text{ ms} = 500 \text{ ms}$$

Exercise 1.5: Given the *duty cycles* of a system is 40% for a duration of a system is 500ms.

- Calculate the pulse width of the system.
- Determine the *off state* of the system that operate with the ratio of duty cycle.
Show your works.

Solution 1.5:

$$a) \text{ DutyCycle} = \left(\frac{t_w}{T} \right) 100$$

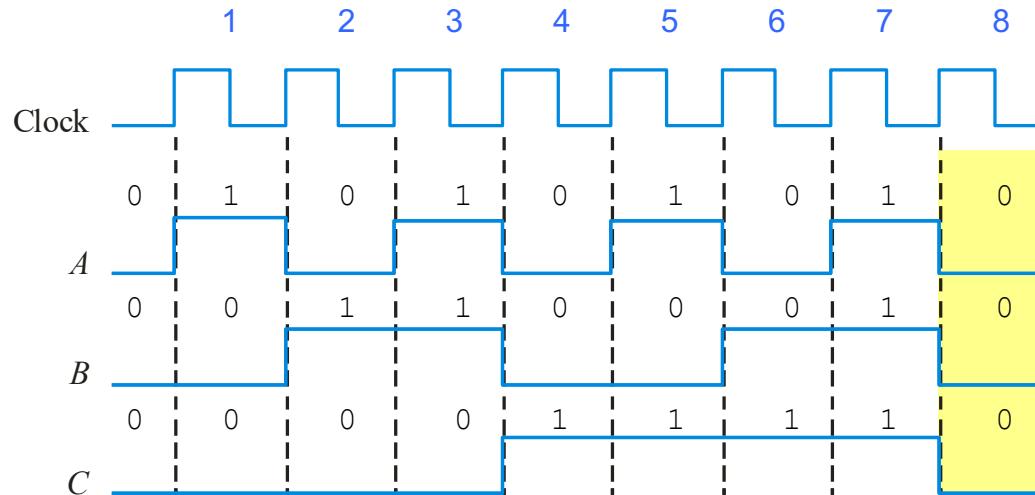
$$40 = \left(\frac{t_w}{500} \right) 100$$

$$t_w = \frac{40(500)}{100} = 200s$$

$$b) \text{ Period} = 500ms$$
$$\text{OnState} = t_w = 200ms$$
$$\therefore 500 - 200 = 300ms$$

Timing diagram

A timing diagram is used to show the relationship between two or more digital waveforms,

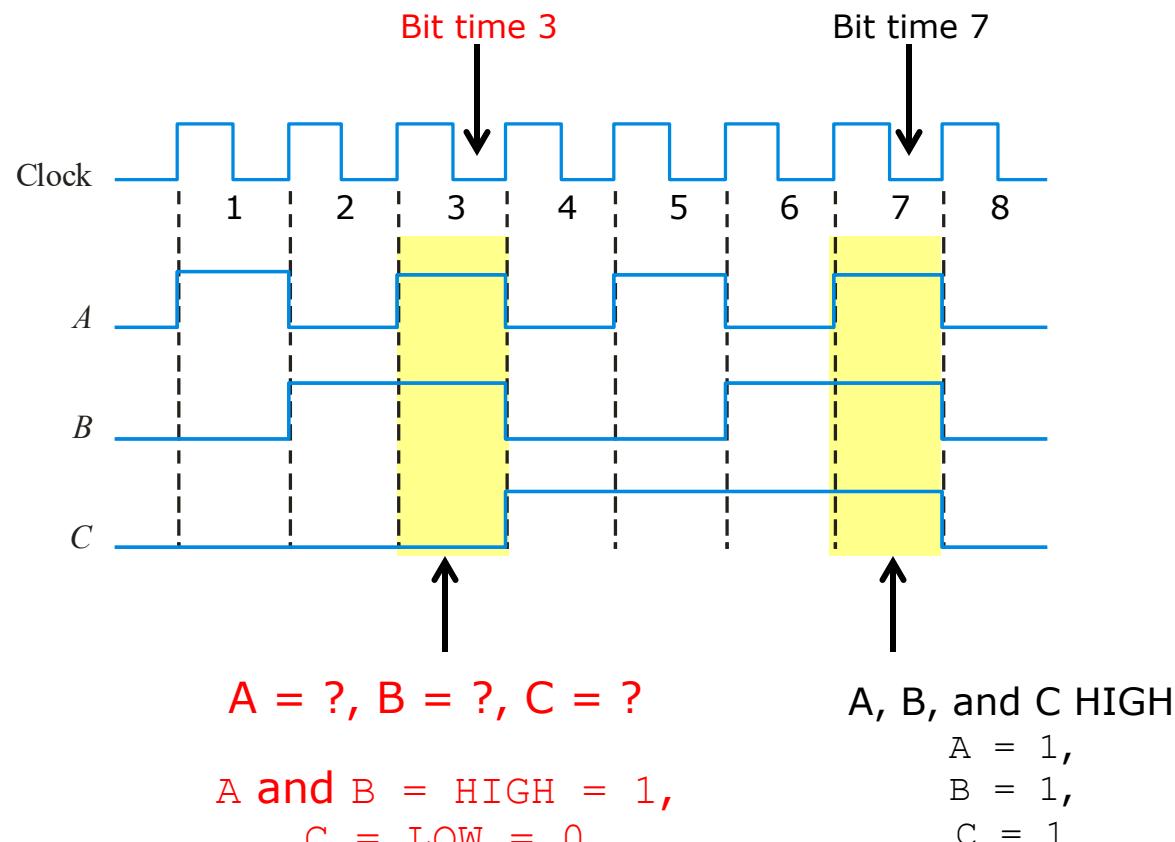


At time 8, all
A, B, and C **LOW**

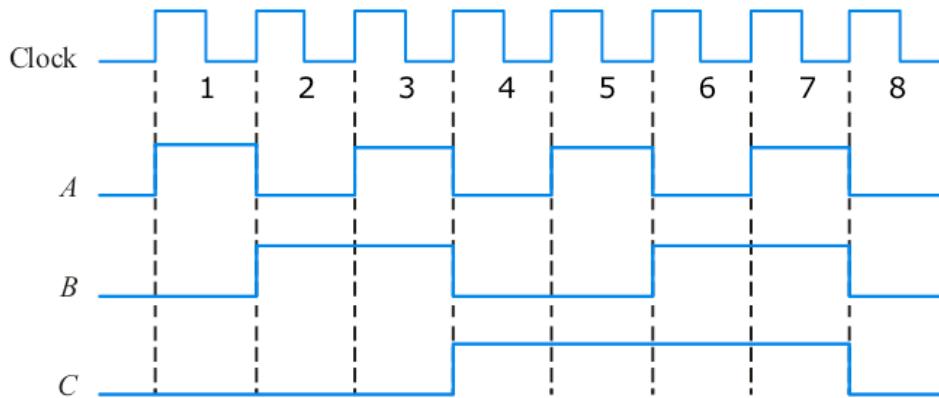


A diagram like this can be observed directly on a logic analyzer.

Example: Timing Diagram



Example: Timing Diagram

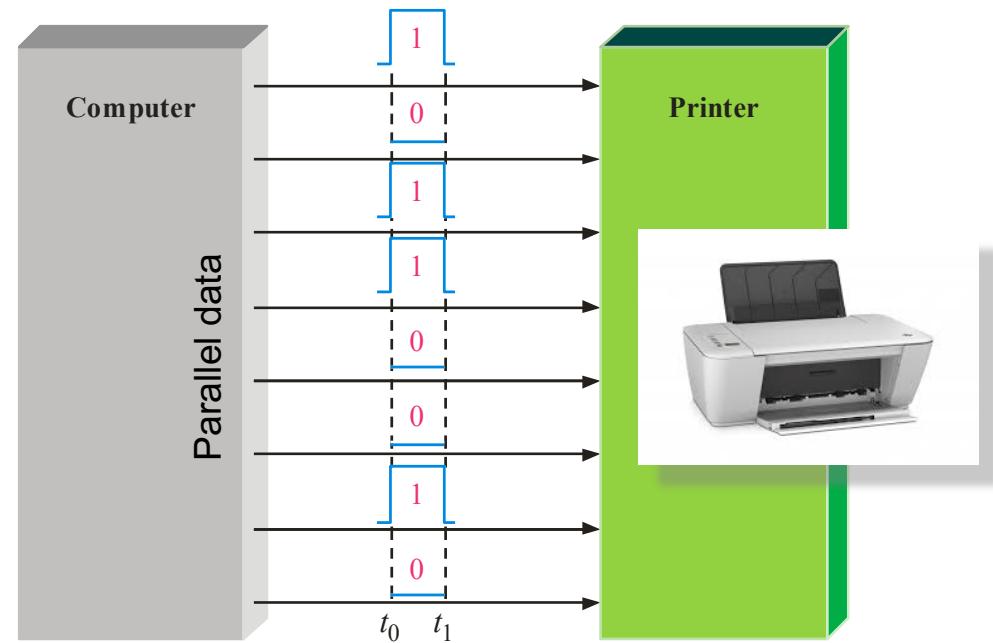
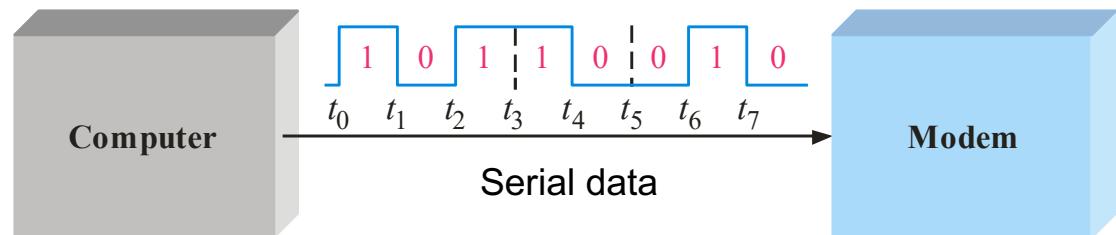


Exercise: Complete the truth table.

Clock (↑)	Input		Output
	A	B	
1	1	0	0
2	0	1	0
3	1	1	0
4	0	0	1
5	1	0	1
6	0	1	1
7	1	1	1
8	0	0	0

Data Transfer

Data can be transmitted by either **serial** transfer or **parallel** transfer.





Introduction to Logic Operations

AND

True only if **all** input conditions are true.



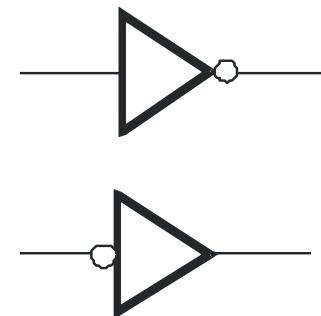
OR

True only if **one or more** input conditions are true.

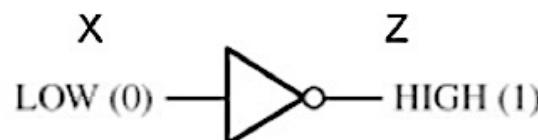
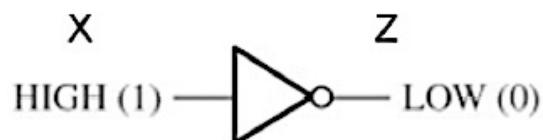


NOT

Indicates the **opposite** condition (inverter).



Logic Gates: NOT

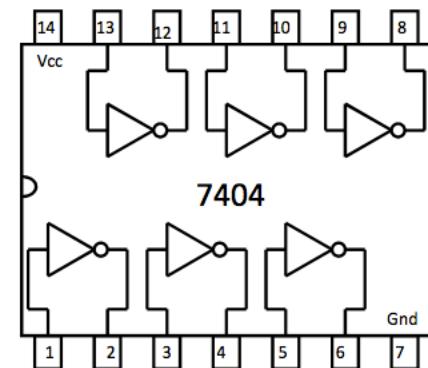


NOT operation

Truth table shows the relationship between output and the input.

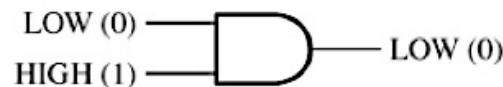
Truth Table for NOT

X	Z
0	1
1	0



7404 IC six inverters

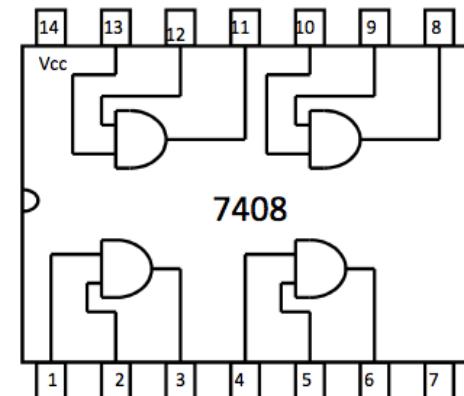
Logic Gates: AND



AND operation

Truth Table AND

X	Y	Z
0	0	0
0	1	0
1	0	0
1	1	1



7408 IC four (Quad) AND gates

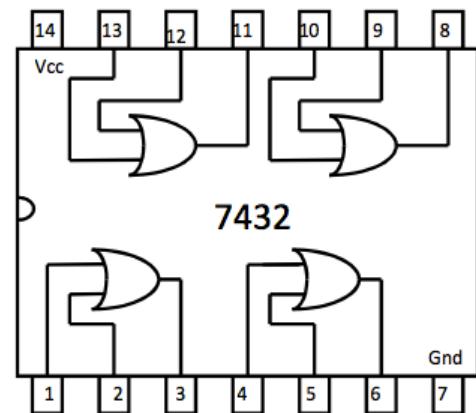
Logic Gates: OR



OR operation

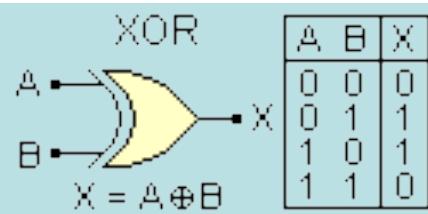
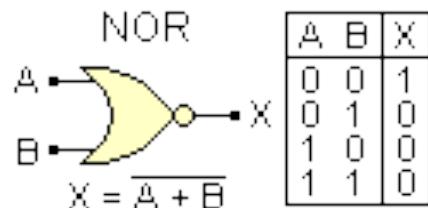
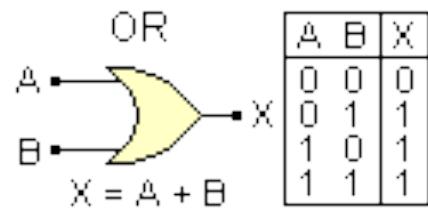
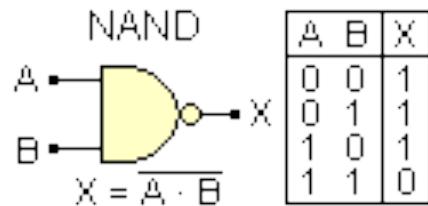
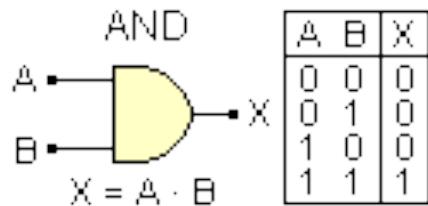
Truth Table OR

X	Y	Z
0	0	0
0	1	1
1	0	1
1	1	1



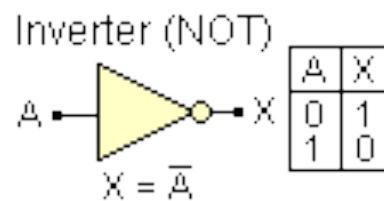
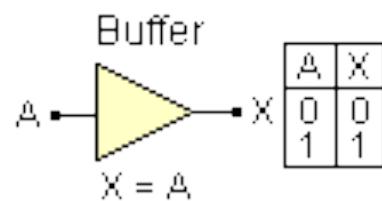
7432 integrated circuit provides four (Quad) two-inputs OR gates

Logic Gates: Summary



→ **XNOR**

$$X = \overline{A \oplus B}$$

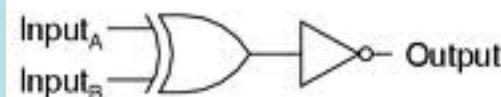


Exclusive-NOR gate



A	B	Output
0	0	1
0	1	0
1	0	0
1	1	1

Equivalent gate circuit



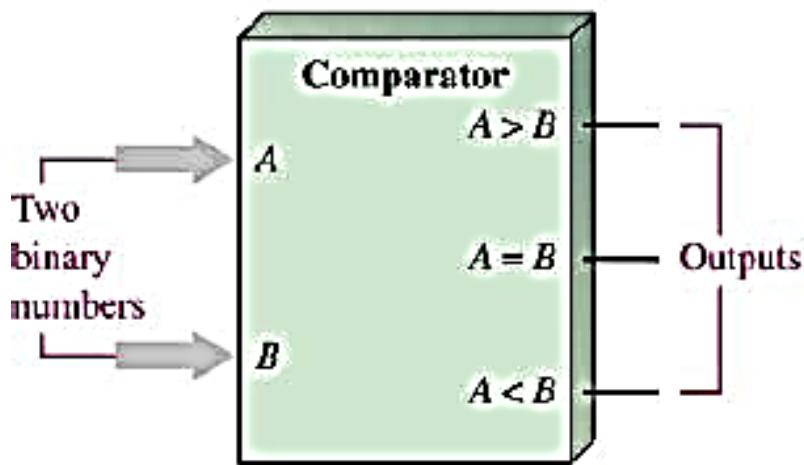


Overview of Logic Functions

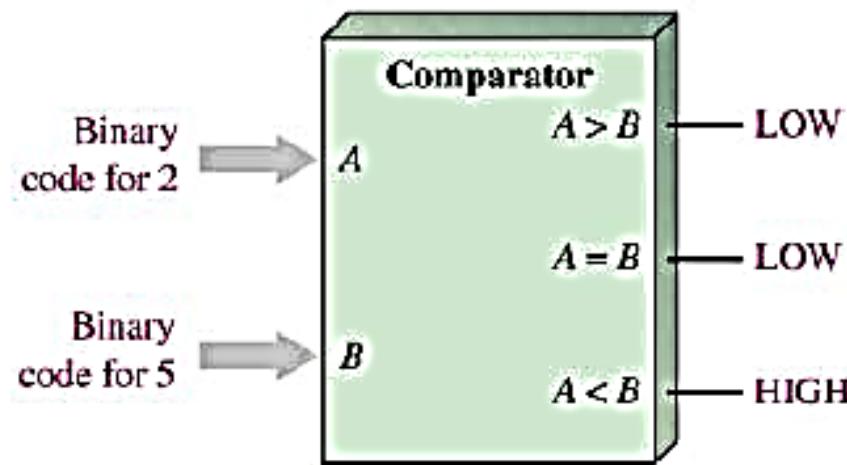
Basic Logic Functions

- Any digital systems has one or more of the following function.
 - This functions are built from the basic gates.
 - Comparison Function
 - Arithmetic Functions
 - Code conversion function
 - Encoding function
 - Decoding function
 - Data selection function
 - Data storage function
 - Counting function

Comparison Function



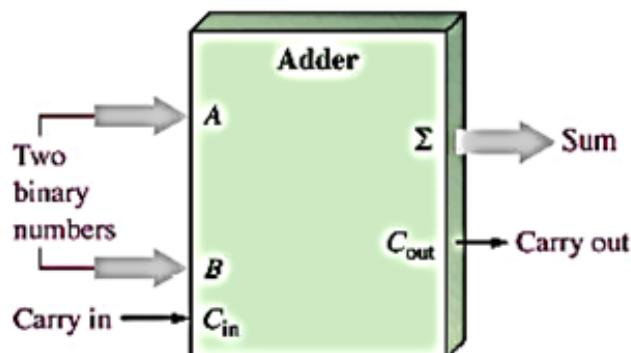
(a) Basic magnitude comparator



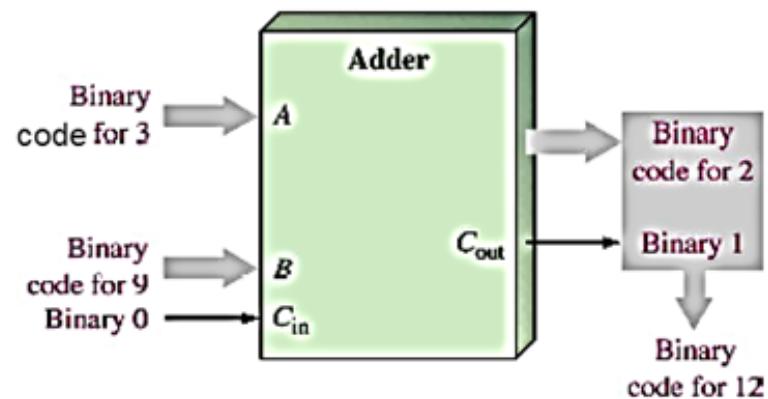
(b) Example: A is less than B ($2 < 5$) as indicated by the HIGH output ($A < B$)

Arithmetic Functions

- Adder



(a) Basic adder



(b) Example: A plus B ($3 + 9 = 12$)

- Subtractor
- Multiplier
- Division

All the other arithmetic operations can be derived from adder:

- Subtraction is and addition of negative number such as $A-B = A+(-B)$
- Multiplication is a repeated addition such as $A*3=A+A+A$
- Division is a repeated subtraction which is a repeated addition such as
 $6/3=6-3-3=6+(-3)+(-3)$
 - subtract until the remainder = 0
 - total number of subtraction = 2 which is the answer

Code Conversion Function

- A code is a set of bits arranged in a unique pattern and used to represent specified information.
 - Examples : BCD, ASCII
- The usage of codes allow a faster and more efficient data processing.



http://www.ehow.com/how_7162480_

只要去挑
只 - 听不在

Extra

symbols.com



<http://facebooksmileysinfo.com/wp-content/uploads/2012/04/Smiley-Facebook-emoticons.jpg>

و ذ خ ه ت
ج ص م ظ
ث ح و ئ ك
ي ع ل ا ئ
ا ي س ل ب ش

<http://depositphotos.com/2746252/stock-illustration-Arabic-alphabet.html>



<http://allenmathblog.files.wordpress.com/2012/01/integers.jpg>

Ctrl	Dec	Hex	Char	Code	Dec	Hex	Char	Dec	Hex	Char	Dec	Hex	Char
^@	0	00		NUL	32	20	!	64	40	@	128	80	`
^A	1	01		SOH	33	21	"	65	41	À	129	81	à
^B	2	02		STX	34	22	#	66	42	À	130	82	à
^C	3	03		ETX	35	23	\$	67	43	È	131	83	è
^D	4	04		FOT	36	24	€	68	44	È	132	84	è

Extra**To send this:**

- Smile :-(or :)
- Surprised :-o or :o
- Wink ;-) or ;)
- Confused :-s or :s
- Crying :'(
- Hot (H) or (h)
- Angel (A) or (a)
- Don't tell anyone :-#
- Nerd 8-|
- Secret telling :-*
- I don't know :^)
- Party <:o>

Type this:

- Open-mouthed :-D or :d
- Tongue out :-P or :p
- Sad :-{ or :(
- Disappointed :-| or :|
- Embarrassed :-\$ or :\$
- Angry :-@ or :@
- Devil (6)
- Baring teeth 8o|
- Sarcastic ^o)
- Sick +o(
- Thinking *-)
- Eye-rolling 8-)

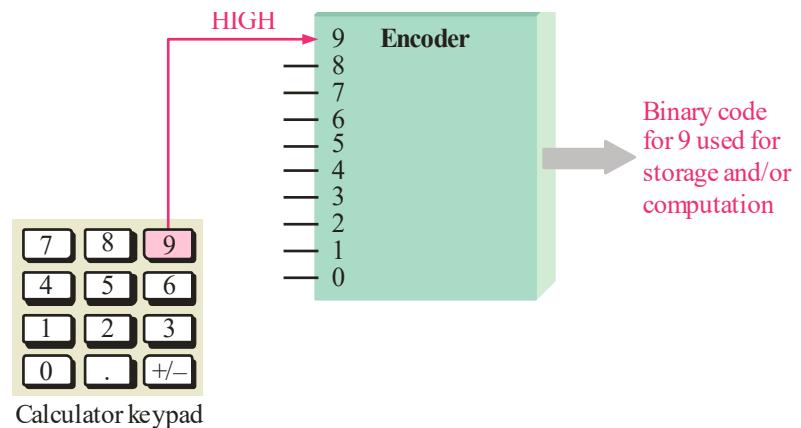
http://www.cool-smileys.com/wp-content/uploads/2009/06/regular-msn-emoticons.jpg

↑↑	30	1E	▲	RS	62	3E	>	94	5E	^	126	7E	~
^-	31	1F	▼	US	63	3F	?	95	5F	-	127	7F	Ø

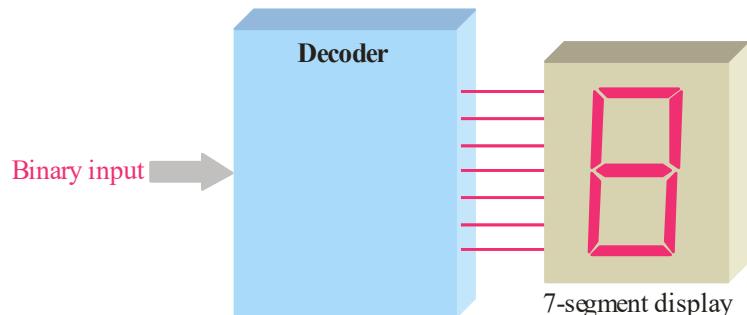
* ASCII code 127 has the code DEL. Under MS-DOS, this code has the same effect as ASCII 8 (BS). The DEL code can be generated by the CTRL + BKSP key.

Encoding & Decoding Function

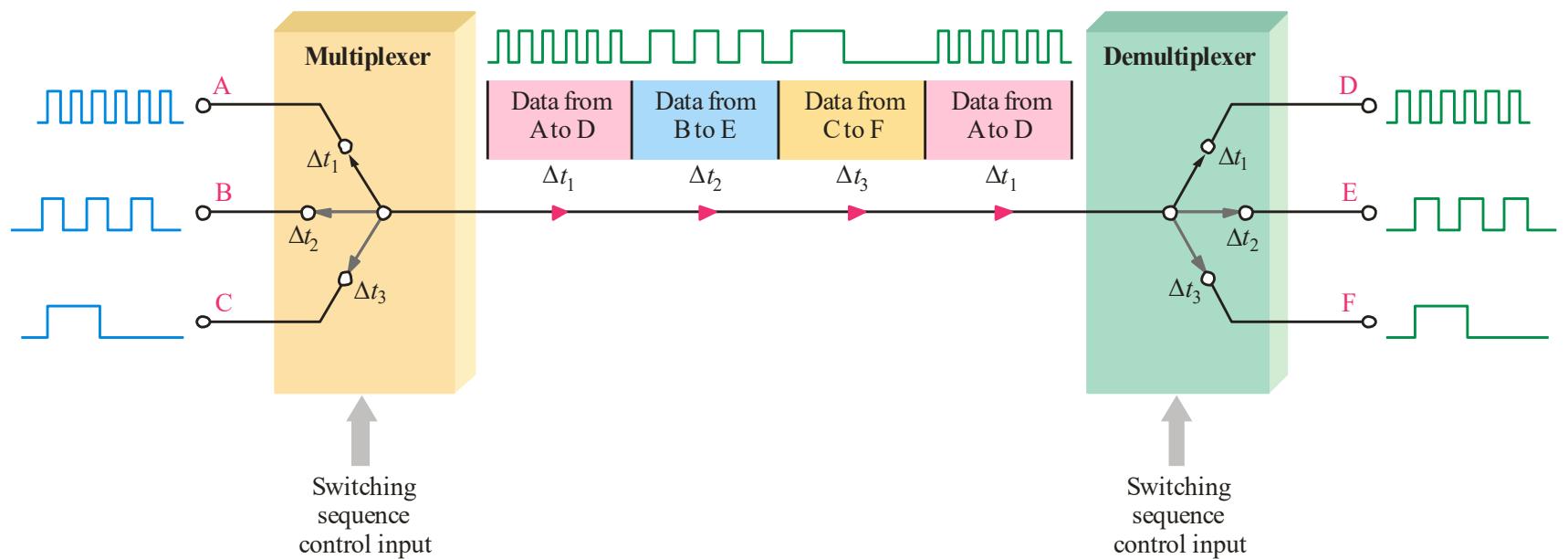
The encoding function



The decoding function



Data Selection Function: MUX & DeMUX



Problem:

Many inputs (e.g. A, B and C) wanted to use a single transmission line for their data transmission. How to make sure the data is transferred in a proper manner (issue of cost, synchronization, conflict , crash, loss?)

Source (A, B, C) and Destination (D, E, F)

$A \rightarrow D, B \rightarrow E, C \rightarrow F$

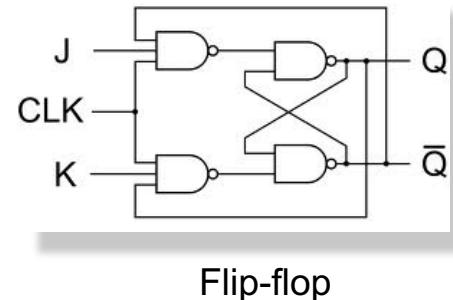
Solution:

MUX : select and permit only one device can use the line and transfer its data at one time.

Data in the transmission line would be arranged as A, B, C

DEMUX : select and route the data to their originate destination

$A \rightarrow D, B \rightarrow E, C \rightarrow F$



Data Storage Function

- Flip-flop stores a 1 or 0 only
- Registers
 - Formed by combining several flip-flops
 - 8-bit register → from 8 flip-flops
- Semiconductor Memories
 - e.g. RAM, ROM, Flash
- Magnetic/Optical Memories
 - For mass storage → e.g. hard disk, tape, DVD, Blu-Ray



Semiconductor
Memories



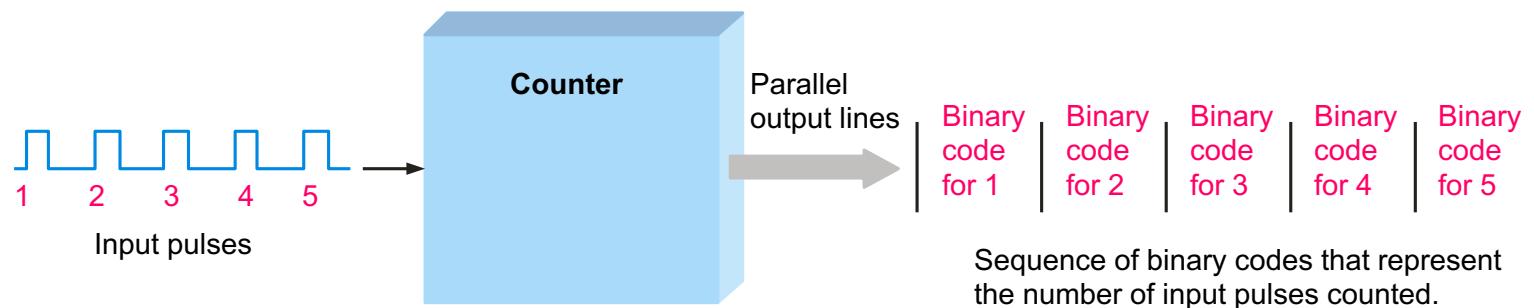
Optical Memories

Counting Function

Examples:

- Traffic light
- Washing machine
- Vending machine
- Xerox machine
- ATM machine
- etc.

- Counter
 - To count the occurrence at the input.
 - to initiate a controller after a certain count (period).

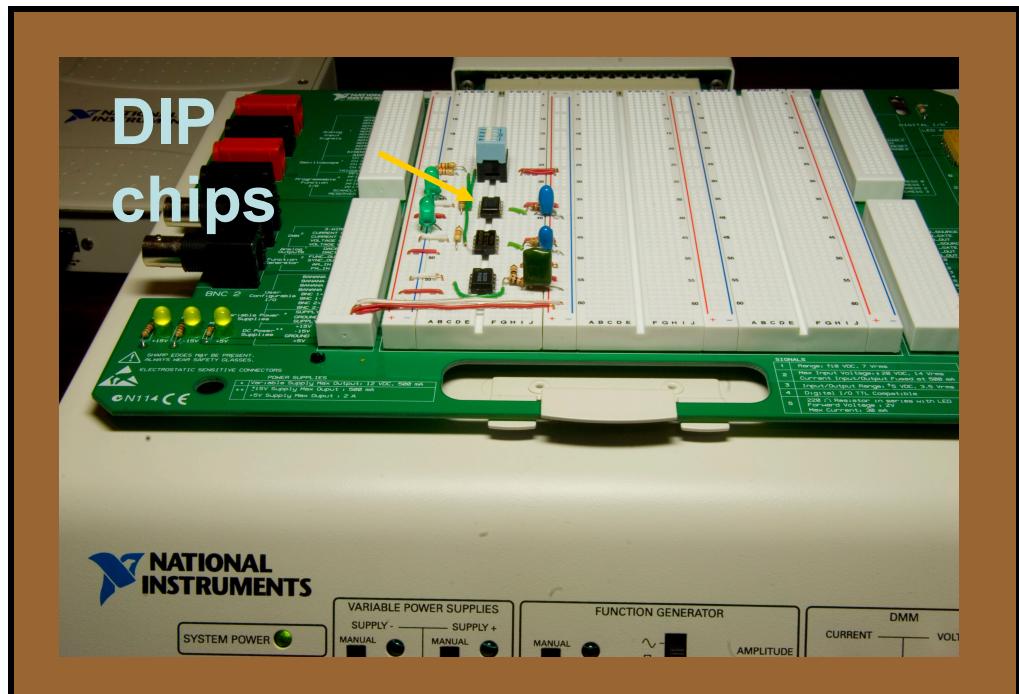




Fixed-Function Integrated Circuit (IC)

An example of laboratory prototyping is shown. The circuit is wired using DIP chips and tested.

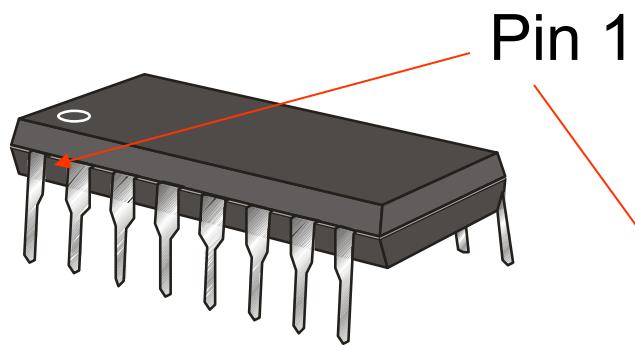
In this case, testing can be done by a computer connected to the system.



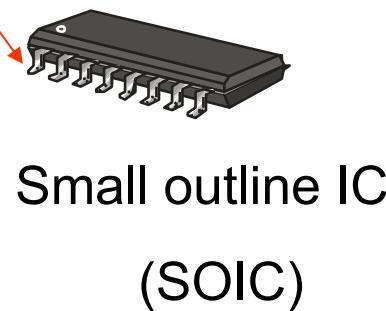
(Dual In-line Package)

IC Packages

DIP chips and surface mount chips

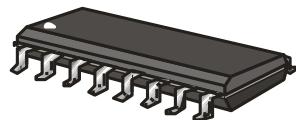


Dual in-line package
(DIP)

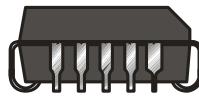
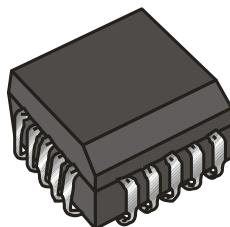


Small outline IC
(SOIC)

Other surface mount technology (SMT) packages:



SOIC
(Small-outline IC)

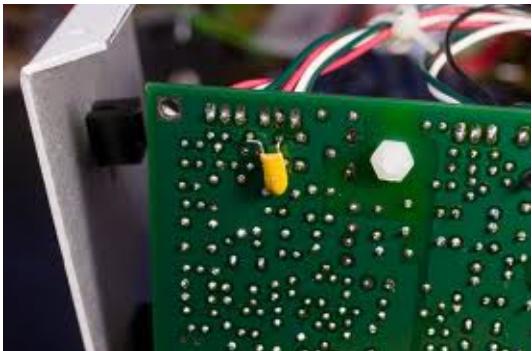


PLCC
(Plastic Leaded
Chip Carrier)

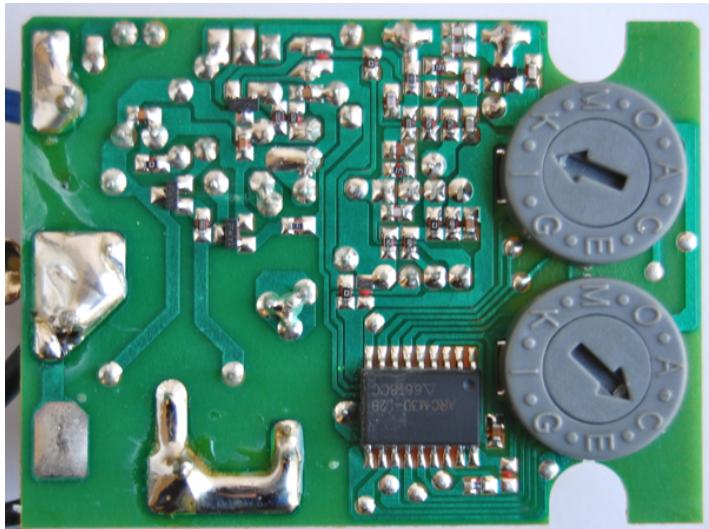


LCCC
(Leadless Ceramic
Chip Carrier)

IC and conventional through-hole technology



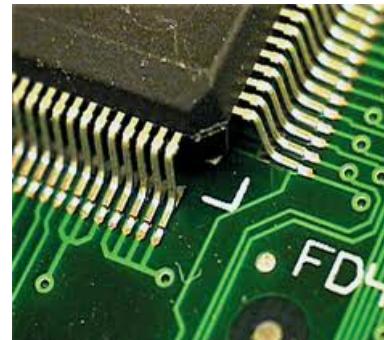
<http://aa7ee.wordpress.com/page/4/>



<http://jeelabs.org/tag/teardown/>

Printed Circuit Board (PCB)

Surface Mount PCB

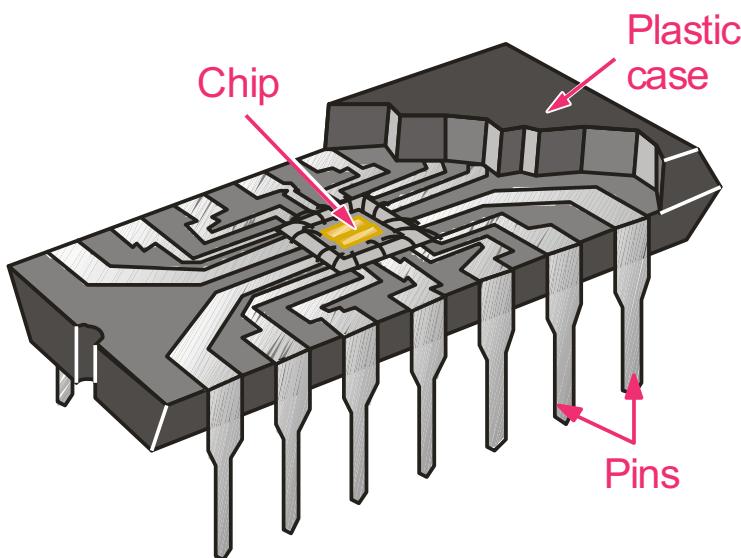


<https://neuromorphs.net/ws2007/wiki/smd>



<http://wwwpcb-manufacturers.co.uk/pcb-production-examples-c.html>

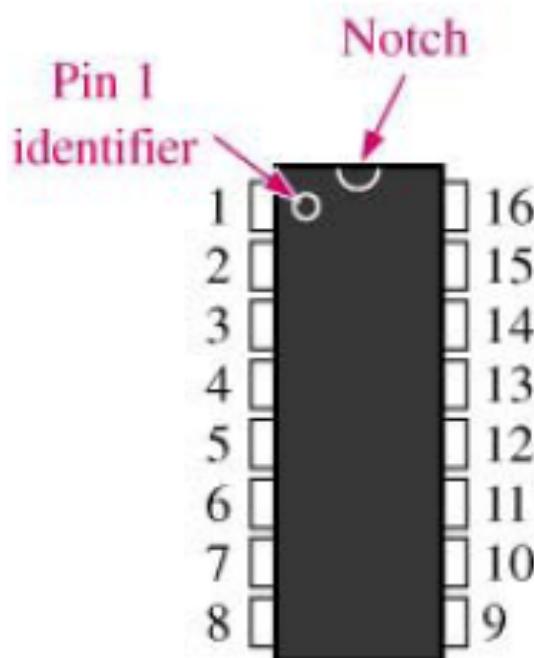
Cutaway view of DIP (Dual-In-line Pins) chip:



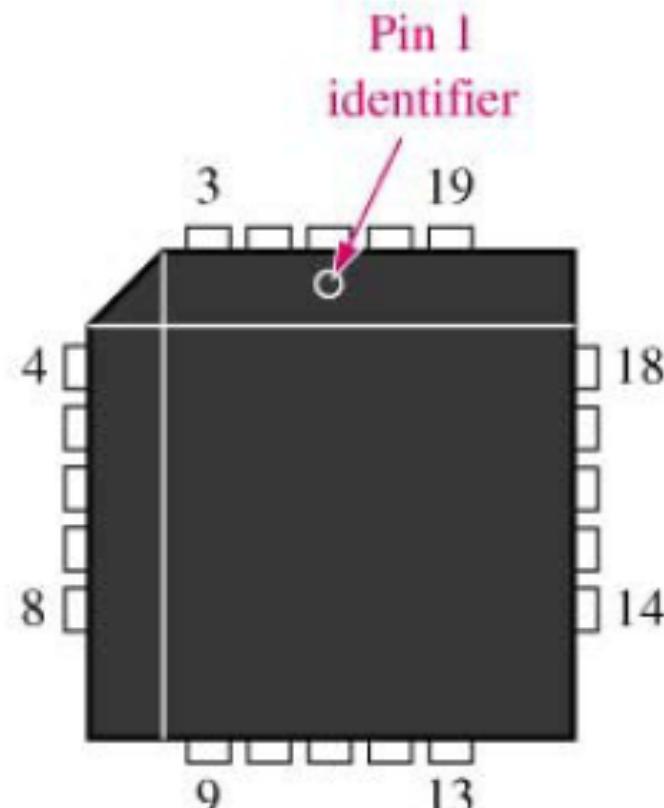
IC Packaging: Why we need packaging?

- To protect the IC (circuit)
- Have a pin system so that can connect to other circuit

Pin Numbering



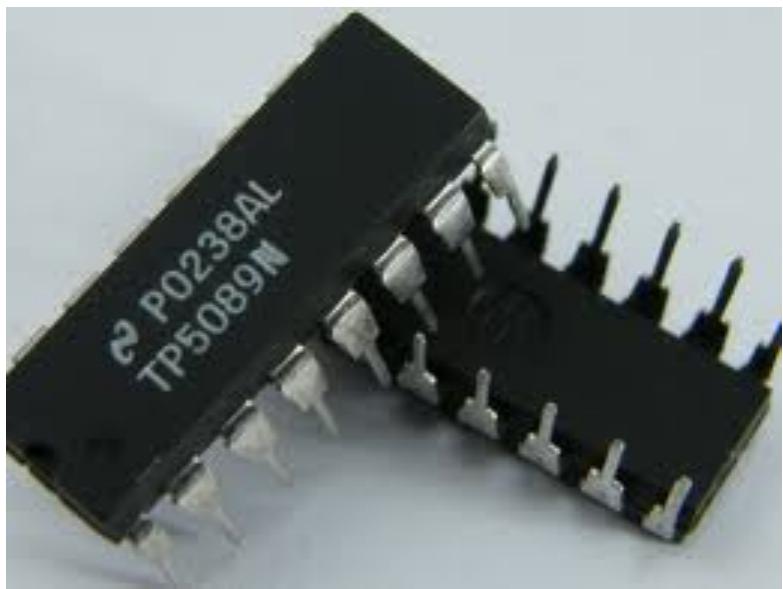
(a) DIP or SOIC



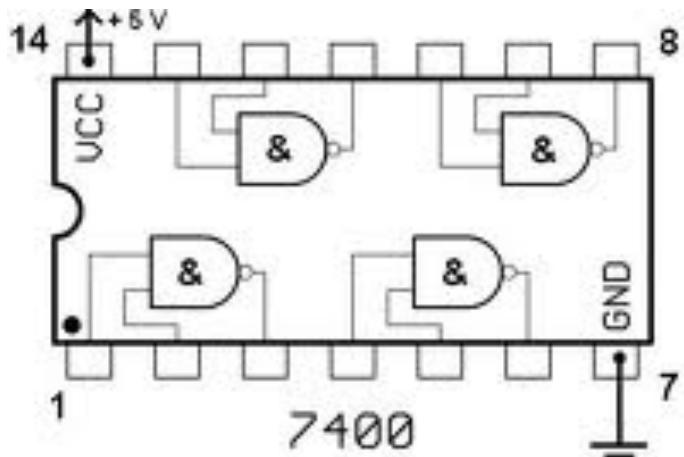
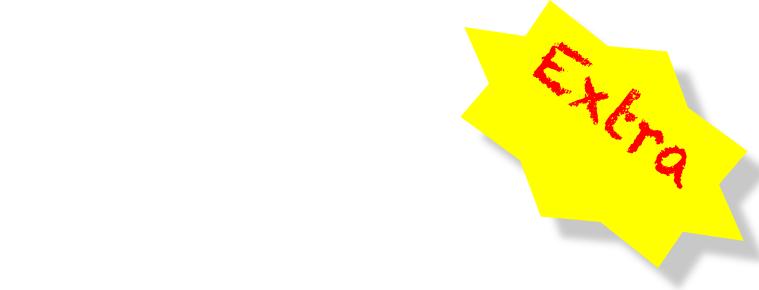
(b) PLCC or LCCC



<http://www.rkonlinestore.co.uk/556-dual-timer-ic-16-pin-dip-pack-of-4-391-p.asp>



<http://www.ebay.com/itm/10pcs-IC-TP5089N-DIP-16-PIN-TP5089-/310306081949>



<http://electroschematics.com/6529/7400-datasheet/>

Complexity Classifications for Fixed-Function ICs

- Small-scale integration (SSI)
have up to 12 gates on a single chip
- Medium-scale integration (MSI)
have from 12-99 gates on a single chip
- Large-scale integration (LSI)
have from 100-9999 gates on a single chip
- Very large-scale integration (VLSI)
have from 10,000-99,999 gates on a single chip
- Ultra large-scale integration (ULSI)
have from 100,000 and greater equivalent gates on a single chip



http://www.visual6502.org/images/263P_SI_263P_8404_chip1_package_top.jpg



<http://www.nysemagazine.com/lscicorp>

Integrated Circuit Technologies

Some examples of IC technologies:

- TTL (*Transistor-transistor Logic*)
- ECL (*Emitter-Coupled Logic*)
- CMOS (*Complementary Metal–Oxide–Semiconductor*)
- NMOS (*N-Type Metal–Oxide–Semiconductor*)
- BiCMOS (*Bipolar and Metal–Oxide–Semiconductor*)



CMOS –

<http://www.creativeplanetnetwork.com/dcp/news/cmos-technology-primer/40995>



Programmable Logic Devices (PLD)

Overview of PLD

Fixed function

- A specific logic function is contained in the IC (hardwired) and can never be changed.

PLD

- Logic function programmed by the user.
 - Some, can be reprogrammed many times.

Advantage

- More logic circuit can be ‘stuffed’ into much smaller area.
- Certain PLD, design can be changed without rewiring or replacing components.
- Can be implemented faster once the required programming language is mastered.

Types of PLD

3 major types (SPLD, CPLD, FPGA)

1. Simple Programmable Logic Devices (SPLD)

- Can replace several fixed-function SSI or MSI
- First type available
- A few categories
 - PAL (programmable Array Logic)
 - GAL (Generic Array Logic)
 - PLA (Programmable Logic Array)
 - PROM (Programmable Read-Only memory)

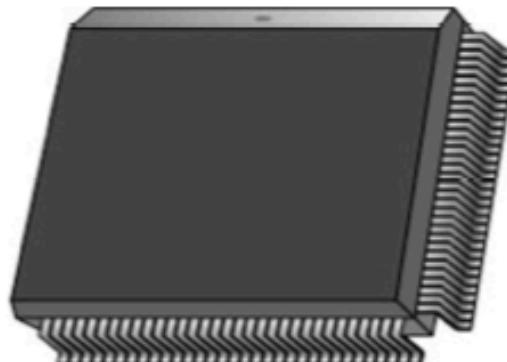
Types of PLD: CPLD

2. Complex Programmable Logic Devices (CPLD)

- Much higher capacity than SPLD (2-64 SPLD)
 - More complex logic circuits can be programmed
 - Typically in 44 – 160 pin package



(a) 84-pin PLCC package



(b) 128-pin PQFP package



Resource: http://upload.wikimedia.org/wikipedia/commons/thumb/a/a3/Altera_MAX_7128_2500_gate_CPLD.jpg/300px-Altera_MAX_7128_2500_gate_CPLD.jpg

Types of PLD: FPGA

- 3. Field-Programmable Gate Arrays (FPGA)
 - Different internal organization than SPLD and CPLD
 - Greatest logic capacity
 - Consist of 64-thousands logic block (logic gate groups)
 - Classes
 - Fine grain (smaller logic block)
 - Coarse grain (large logic block)

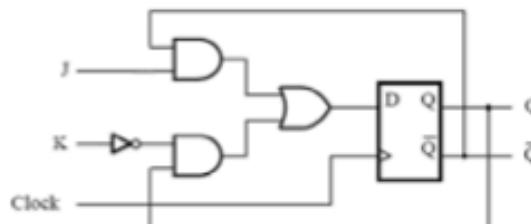


Resource: http://upload.wikimedia.org/wikipedia/commons/thumb/f/fa/Altera_StratixIVGX_FPGA.jpg/300px-Altera_StratixIVGX_FPGA.jpg

PLD Programming

- Logic circuit entered using 2 basic method

- Graphical entry
 - schematic diagram



- Text-based entry (language based entry)
 - Using Hardware Description Language (HDL)
 - Eg . ABEL, CUPL, WinCUPL
 - Becoming widely used especially for CPLD and FPGA
 - VHDL
 - Verilog

```
MODULE decoder
TITLE 'decoder'
A,B,C,D      pin    1,2,3,4;
W,X,Y,Z      pin    14,15,16,17;
equations
W=!B & C # !B & D # C & D # A;
X=!A & D # B # C;
Y=!A & !B & D # C;
Z=IB & C # D;
```