Digital Logic

EX 502

2nd Year/1st Part

Objective

- To introduce basic principles of digital designs, its implementation and applications

Chapters

Chapters	Name	Lecturer Hours	Marks
1	Introduction	3	6
2	Digital Logic	1	8
3	Data Processing Circuits	5	10
4	Arithmetic Circuits	5	8
5	Flip flops	5	8
6	Registers	2	4
7	Counters	5	8
8	Sequential Machines	8	12
9	Digital Integrated Circuits	4	8
10	Applications	2	4
	Total	45	80

References

1. “Digital Principles and Applications”, Donald P. Leach, Albert Paul Malvino and Goutam Saha
2. “Digital Logic and State Machine Desing”, David J comer
3. “An Engineering Approach to Digital Design”, William I. Fletcher
4. “ Digital Electronics, An Introduction to Theory and Pratice”, William H. Gothamann
5. “Fundamentals of Digital Logic with VHDL Desing”, Stephen Brown and Zvonko Vranesic
6. “Foundation of Digital Electronics and Logic Design”, Subir Kumar Sarkar, Asish Kumar De and Sovik Sarkar
7. “Logic and Computer Design Fundamentals”, M. Morris Mano and Charles Kime

Methodology

- Lectures
- Notes
- Class Activities
- Tutorials
- Lab
- Exam
  - Assessment
  - Terminal
  - Viva

Marks Distribution

Total : 150 Marks (Theory: 100 + Lab: 50)

- Theory : 100
- Board: 80
- Internal: 20
  - ❖Unit Tests
  - ❖Terminals
  - ❖Attendance
  - ❖Tutorials/Assignment
- Lab: 50
  - ❖Lab Attendance
  - ❖Lab Report
  - ❖Viva
  - ❖Exam

Chapter 1: Digital Principles

- Definition of Digital signals
- Digital Waveforms
- Digital Logic
- Moving and Storing Digital Information
- Digital Operations
- Digital Computers
- Digital Integrated Circuits
- Digital IC Signals Levels
- Clock Waveform
- Coding
    - ❖ASCII Code
    - ❖BCD
    - ❖The Excess-3 Code
    - ❖The Grey Code

Background

- Modern world of digital electronics → digital and computer
- Every sphere of life → banks, insurance, airlines, telecommunication
- IC – integrated circuits → used to develop smaller, faster, more economical, and more powerful digital computer

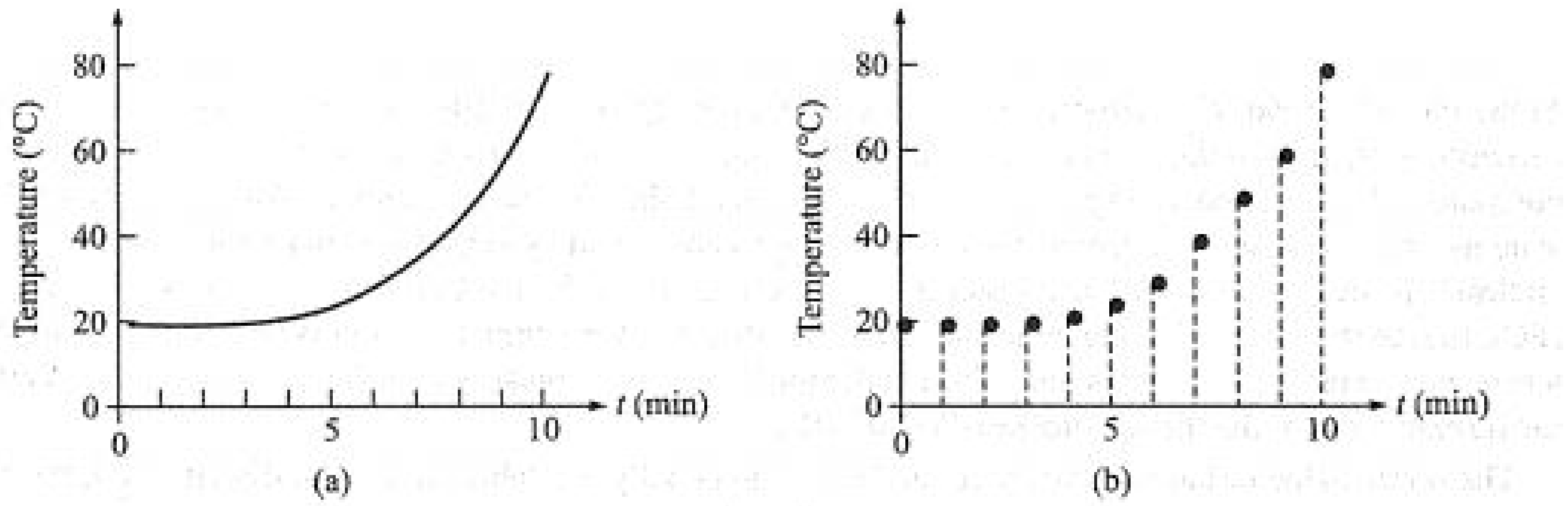
Definition of signal

- A signal is a function of one or more independent variables (like time, temperature, position, pressure, distance etc.) which contains some information is called a signal.
- In electrical sense, the signal can be voltage or current. The voltage or current is the function of time as an independent variable.
- In electronics, a signal is an electric current or electromagnetic field used to convey data from one place to another.
- In daily life, we come across several electric signals such as Radio signals, T.V. signals, computer signal etc.
- The simplest form of signal is a direct current (DC) that is switched on and off

Definition of Digital Signals

- Electronics circuits and systems broadly divided into two types: Analog and Digital.
- An analog signal is a continuous waveform (signal) that contains time varying quantities.
- Analog circuits, designed with small signals, can be made to work in linear fashion. Example: an operation amplifier (op-amp).
- A digital signal is discrete time value signal i.e. it has finite number of discrete values at each sampling point.
- Digital circuits are generally work with large signals and considered as non-linear.

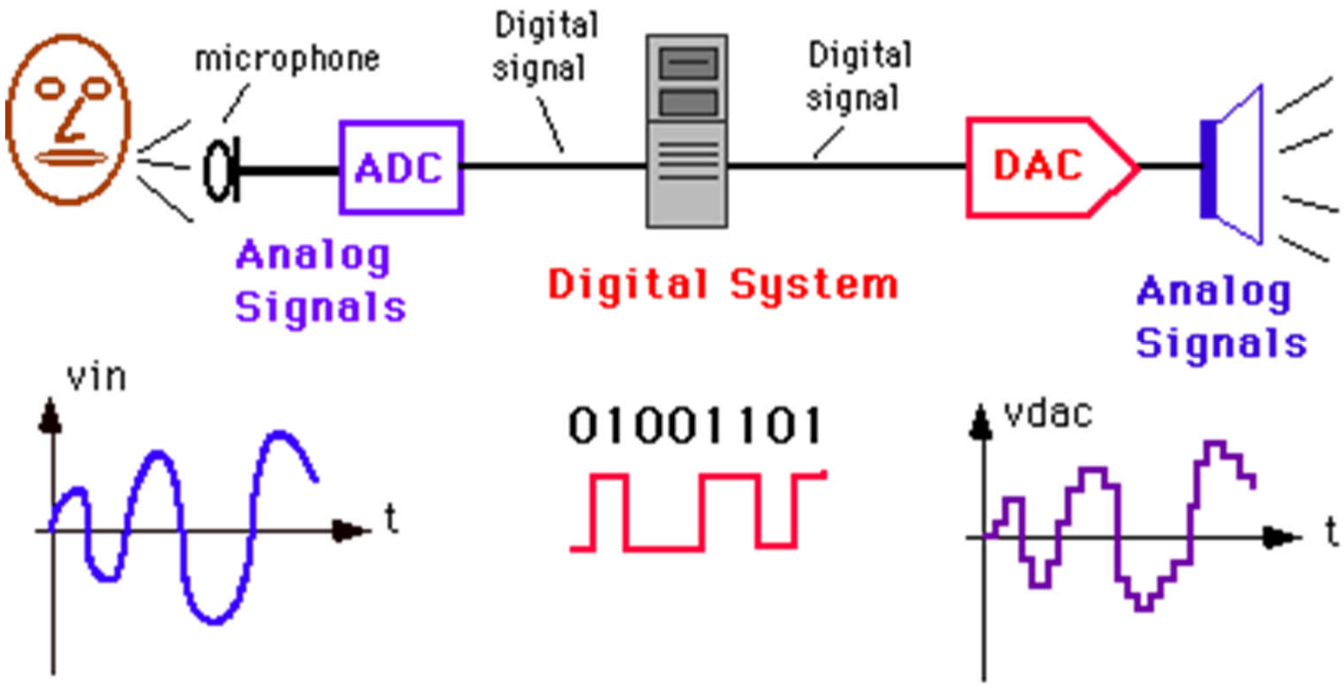
Example: measure of temperature of bucket of water place on stove



ADC-Analog to Digital Converter
DAV-Digital to Analog Converter

Figure: a) an analog signal b) a digital signal

ADC-DAC



microphone
Digital signal
Digital signal
ADC
DAC
Analog Signals
Digital System
Analog Signals
vin
t
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vdac
t

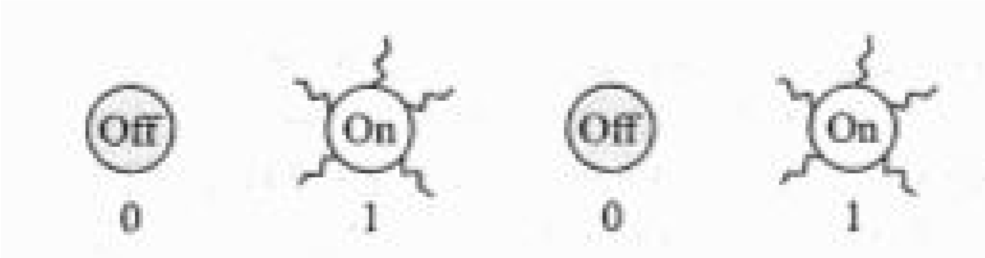
Binary System

- Digital electronics today involves circuits that have exactly two states.
- A system having only two states is said to be binary(‘bi’ means “two”).
- The binary system has exactly two symbols: 0 and 1.

- The operation of an electronic circuit can be described in terms of its voltage levels: *positive voltage level* (High level(H)) and *negative voltage level* (Low level(L)).
- Many operation performed by digital circuits are *logical operation* and thus the term true (T) and false (F) are often used.
- Generally,
  - +5 V dc = H = 1 = T → positive logic
  - 0 V dc = L = 0 = F → negative logic

Example

- A lamp or LED is frequently used to indicate digital signal.
- On (illuminated) represents 1, and off (extinguished) represents 0.
- An example, the four LED in figure, are indicating the binary number 0101.



Ideal Digital Signal

- The voltage levels in an ideal digital circuits will have values of either +5 Vdc or 0 Vdc.
- Furthermore, when the voltage change (switch) between values, they do so in zero time!

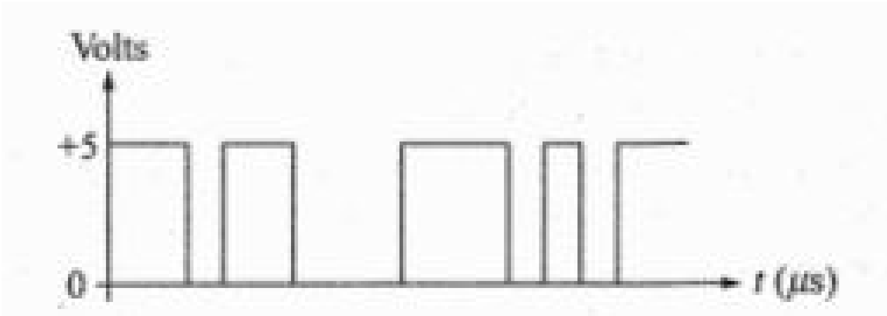
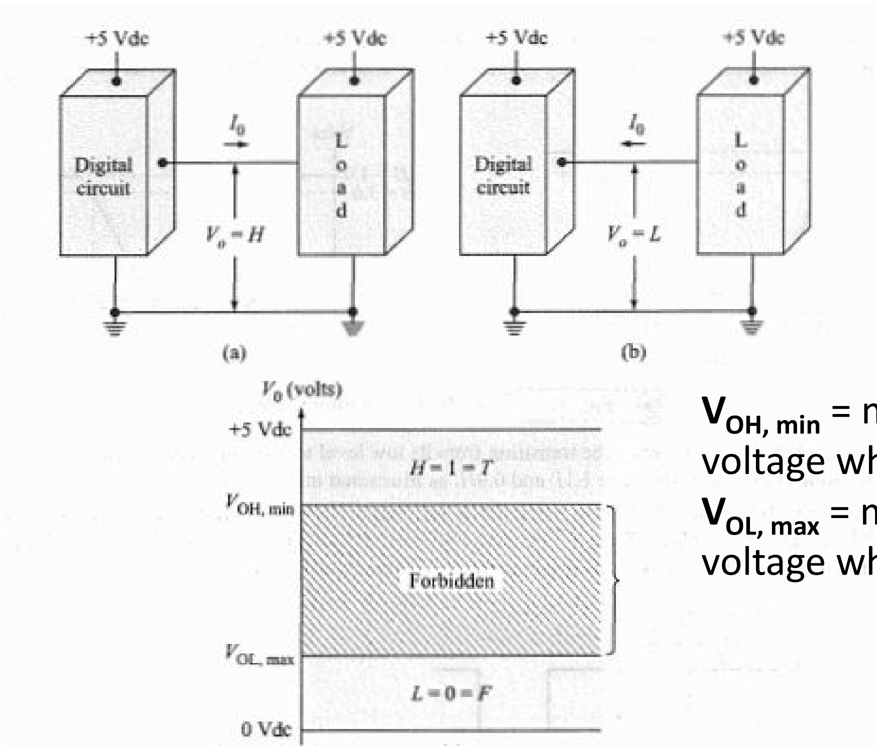


Figure: An ideal digital signal

Digital Waveform

Voltage Level

- Practically, a certain rage of voltage range is used to represent either high logic or low logic.
- Voltage level for any digital circuit depend somewhat on its load.
- For different IC technologies, its voltage levels are different with each other.
- For example: For TTL (Transistor-Transistor Logic) $\mathbf{V_{OH,\ min}}$ = +3.5 Vdc and $\mathbf{V_{OL,\ max}}$ = +0.1 Vdc
- Any voltage level in between +5 Vdc and 3.5 Vdc is considered as H=1 and any voltage level in between 0 Vdc and 0.1 Vdc is considered as L=0.



$\mathbf{V_{OH,\ min}}$ = minimum output voltage when high

$\mathbf{V_{OL,\ max}}$ = maximum output voltage when low

Figure: Loading of digital circuits

Explanation

- When $\boldsymbol{V_o}$ is high, the voltage should be +5 Vdc. In this case, a digital circuit as ***a current source*** to deliver current to the load. However, the circuit may not be capable to deliver the necessary current $\boldsymbol{I_0}$ to while maintaining + 5 Vdc. To account for this, it is agreed that may output voltage close to +5 Vdc within a certain range will be considered high.

- When $\boldsymbol{V_o}$ is low, and the digital circuit must act as a ***current sink***. That is, it must be capable of accepting a current $\boldsymbol{I_o}$ from the load and delivering it to ground. In this situation, Vo should be 0 Vdc, but the circuit may not be capable of this. So it is agreed any output voltage that is close to 0 Vdc within certain limits as the low level.

- The voltage level in between $\boldsymbol{V_{OL,\ max}}$ and $\boldsymbol{V_{OH,\ min}}$ are unacceptable and considered as Forbidden.

Switching

- In digital circuit, it always takes certain finite time to switch V_o from the logic from high to low or low to high.
- V_o does take on values in the forbidden range between the high and low band- but only for a very short time, and only while switching.
- When it not switching, V_o remains within the high or low band as required.

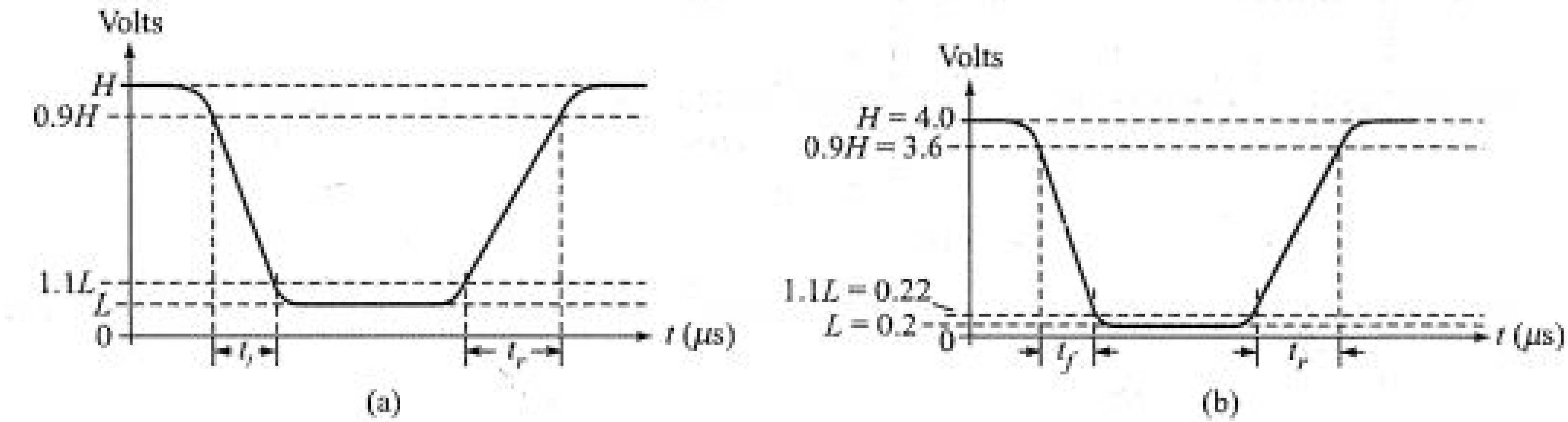


Figure: Switching in digital circuits

Terminology

Fall time

- The time required for V_0 to make the transition from the high logic to the low logic. It is measured using 0.9H and 1.1L.

Rise Time

- The time required for V_0 to make the transition from the low logic to the high logic. It is measure between 1.1L and 0.9H.

Period and Frequency

- Period (T)→ the time over which the signal repeats itself.
- Frequency (f)→ it is the number of cycles repeated per cycle.

  f=1/T. Its unit is Hertz (Hz).
- *System clock* (an electronic circuits) generates the *clock signal*, which is square symmetric waveform needed for the timing operation of digital systems.

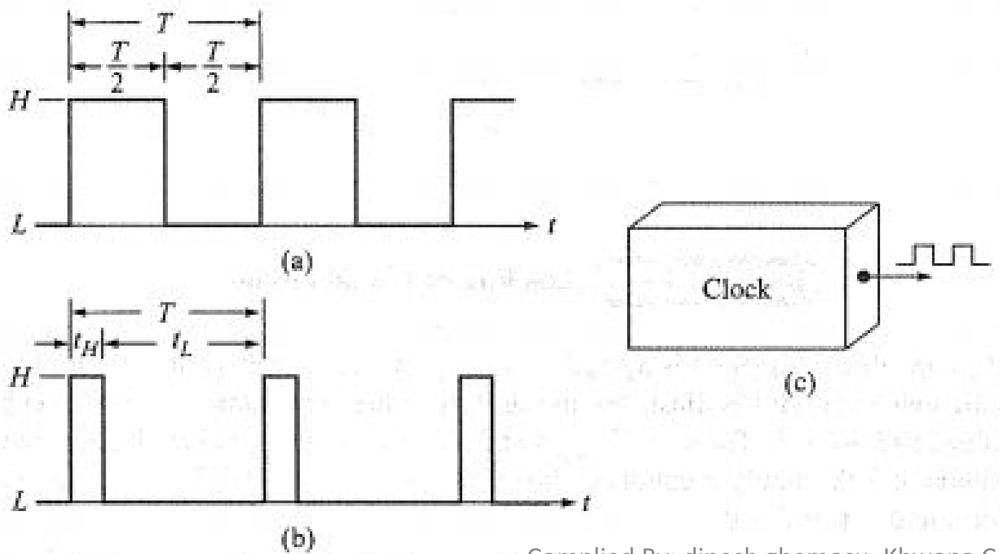


Figure: a) symmetrical signal with period T,
b) Asymmetrical signal with period T,
c) System Clock

Duty Cycle

- It is measure to test if signal is symmetrical or asymmetrical.

  Duty cycle H = t_H/T t_H=width of positive pulse

  Duty cycle L = t_L/T t_L=width of negative pulse

- For symmetrical wave form t_H=T/2 and T_L=T/2

Thus,

- Duty cycle H = $\frac{T/2}{T}$ = 0.5 or (50 %)

- **Q**. The waveform b has frequency of 5 MHz, and the width of the positive pulse is 0.05μs. What is the duty cycle?

Digital Logic

Generating Logic Levels

- Logic Levels can be generated using:
  - Switch
  - Relay
  - Transistor
  - The buffer
  - The tri-state buffer
  - The inverter
  - The tri-state Inverter
  - The AND gate
  - The OR gate

Switch

- Switches can be used to produce the digital voltage levels describes earlier. It is operated by hand.
  - When switch is down, $\mathbf{V_o}$ =L=0.
  - When switch is up, $\mathbf{V_o}$=H=1.

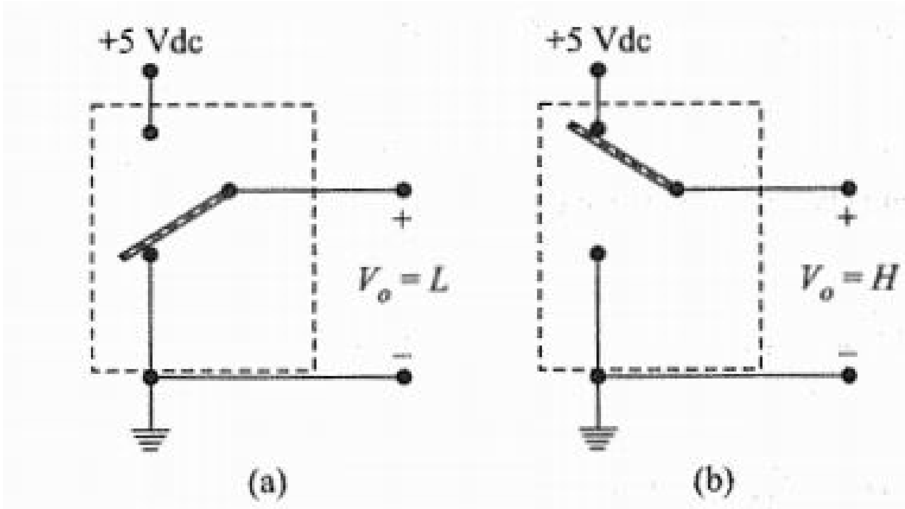


Figure: Switch

Relay

- A relay is a switch that is actuated by applying a voltage to a coil.
- The coil develops a magnetic field that moves the switch arm from one contact to other.
  - When V_i=0 Vdc, V_0=L=0
  - When V_i=V Vdc (certain finite non-zero input voltage), V_0=H=1

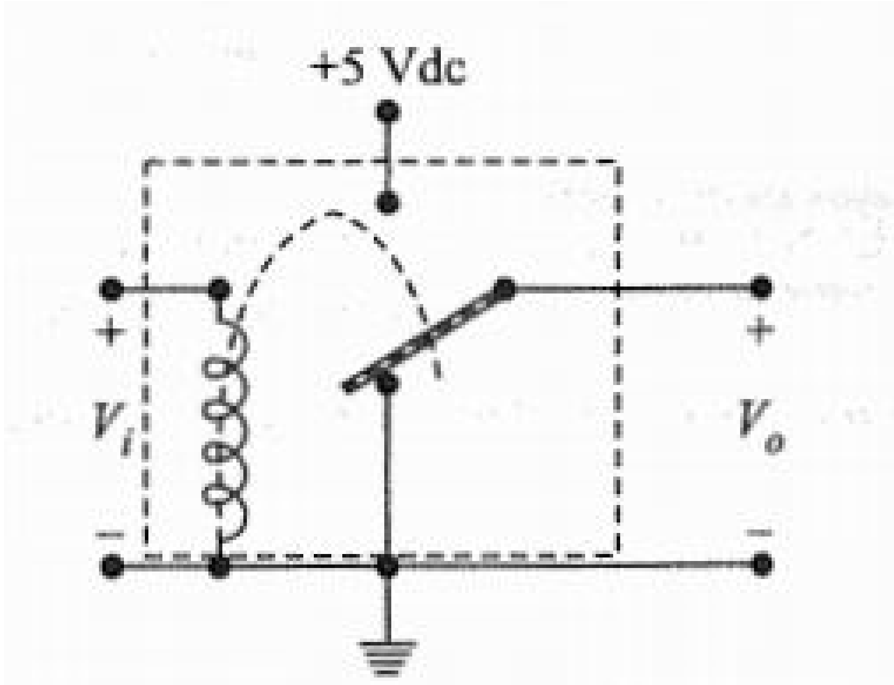


Figure: Relay

Transistor

- Modern computer are capable of performing billions of switching operation every second! Switches and relay are clearly not capable of this performance.
- So, a digital IC are constructed using transistor, which acts like an electronic switch.

Buffer

- A buffer is a switch actuated by the input voltage V_i such that it is capable of delivering additional current to load, so often called as a buffer amplifier.
  - When V_i=low, V_0 is down
  - When V_i=high, V_0 is high

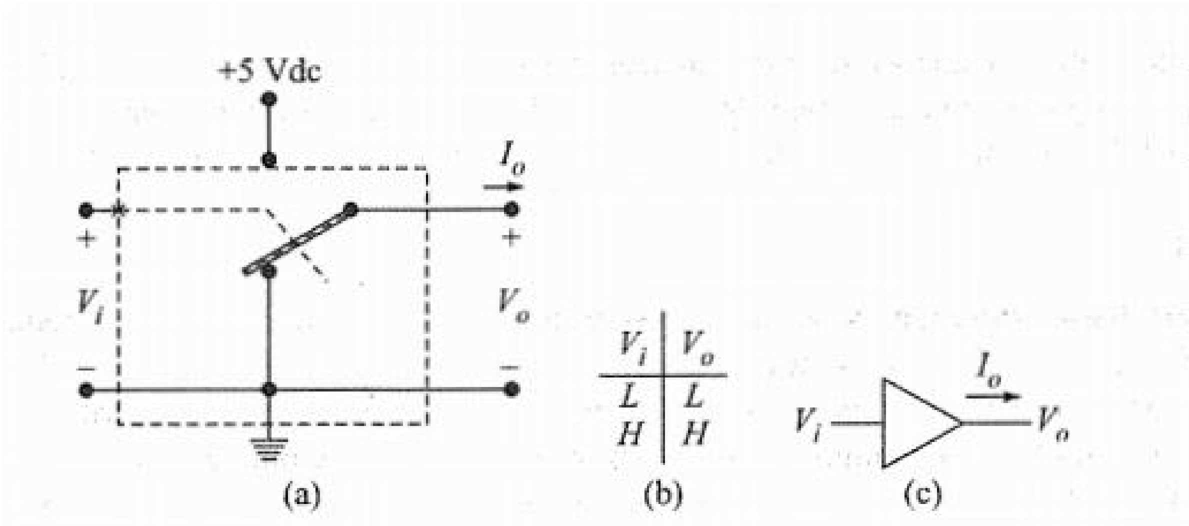
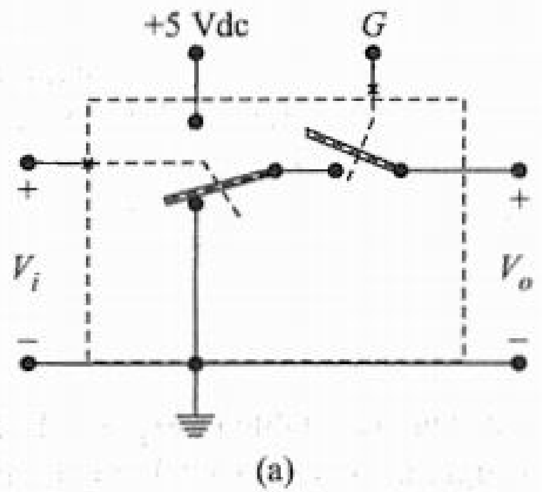


Figure: a) Buffer amplifier model b) Truth Table c) Symbol

The Tri-State Buffer (three state buffer)

- The tri-state buffer is a buffer switch with additional control input, labelled as G. It controls the operation , and referred to as the enable input.
  - When **G**=0, this switch is ***open*** and the *output is "disconnected*".
  - When **G**=1, this switch is ***close*** and the *output follows the input*.



V_i	G	V_o
L	L	Open
H	L	Open
L	H	L
H	H	H

(b)

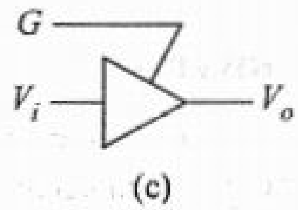


Figure: (a) A tri-state buffer model (b) Truth Table (c) Symbol

The Inverter

- The inverter is a circuit that *inverts the a digital level*, and this operation is referred as *inversion*, or *negation.*
- It is also called *NOT circuit*.
- When V_i=low, the switch remains up and V_0=high
- When V_i=high, the switch moved down and the V_0=low.

the output is the negative , or the inverse of the input.

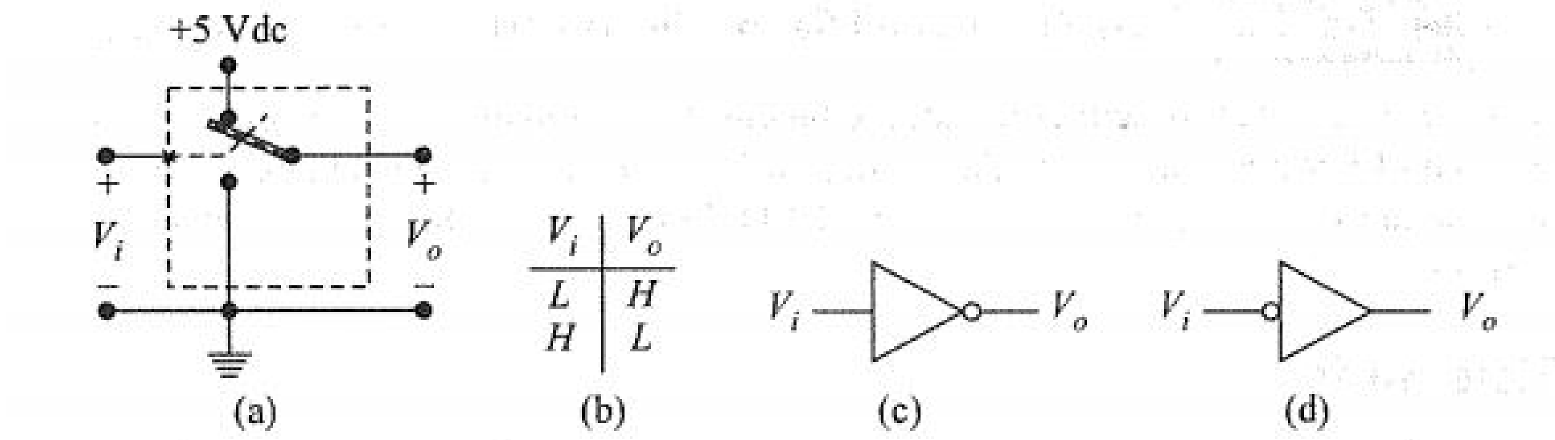
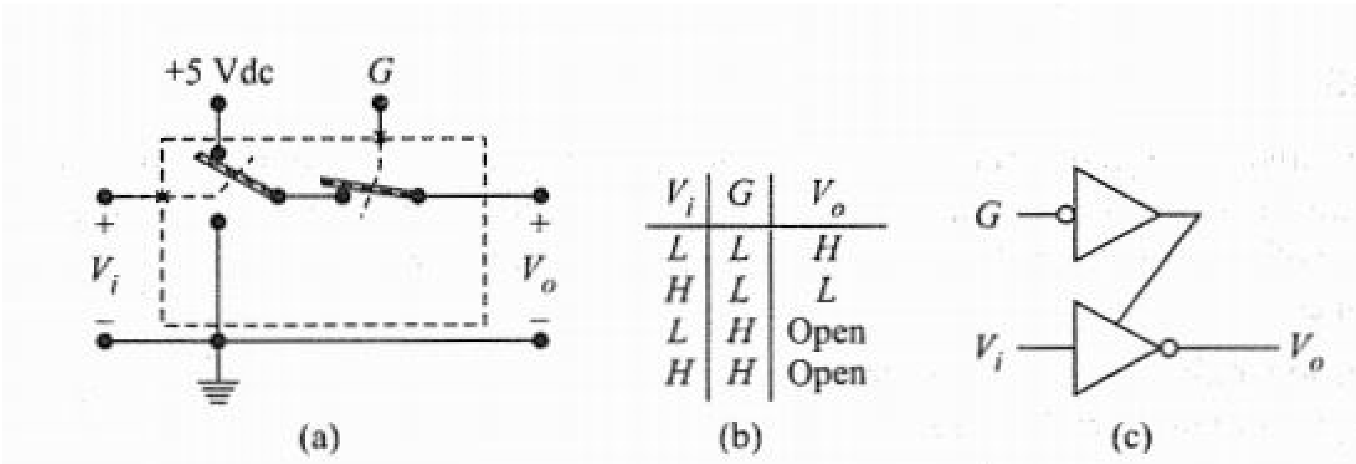


Figure: (a) NOT circuit model (b) Truth Table (c) symbol (d) Another symbol

The Tri-state Inverter

- A tri-state inverter is an inverter circuit with addition enable input control, labelled as G such that
  - ➢ When G is high, the switch is open, and the output is disconnected from the inverter.
  - ➢ When G is low, the enable switch is close, and the output is connected to the output



V_i	G	V_o
L	L	H
H	L	L
L	H	Open
H	H	Open

Figure: (a) Tri-state inverter model (b) Truth Table (c) symbol

The AND Gate

- An AND gate is a digital circuit having two or more inputs and single output as indicated in figure.
- The input to this gate are labeled ***V_1, V_2, V_3, ……. V_n*** (there are n inputs) and the output is labeled as ***V_0***.
- The operation of AND gate is:
  - If any of the input is low, ***V_o*** will be low
  - Only if all the inputs are high, ***V_o*** will be high.

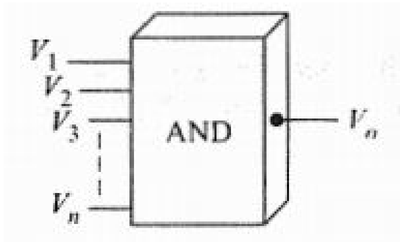
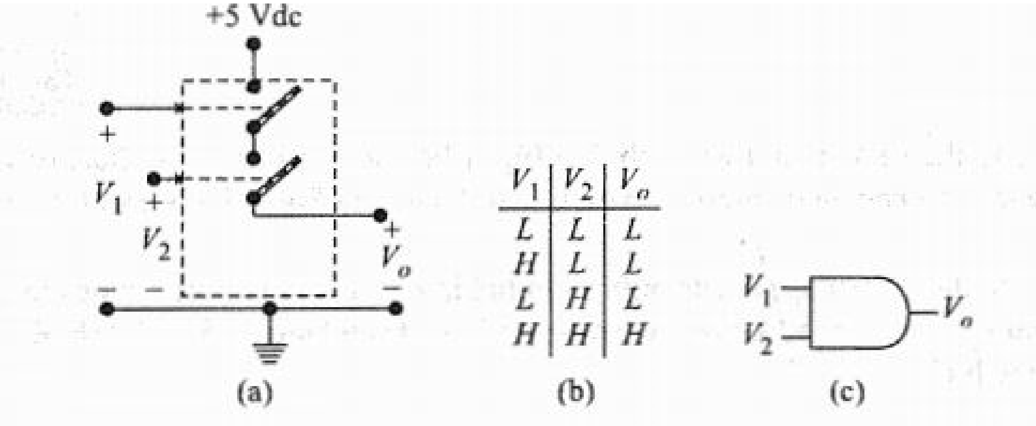


Figure: AND gate



V_1	V_2	V_o
L	L	L
H	L	L
L	H	L
H	H	H

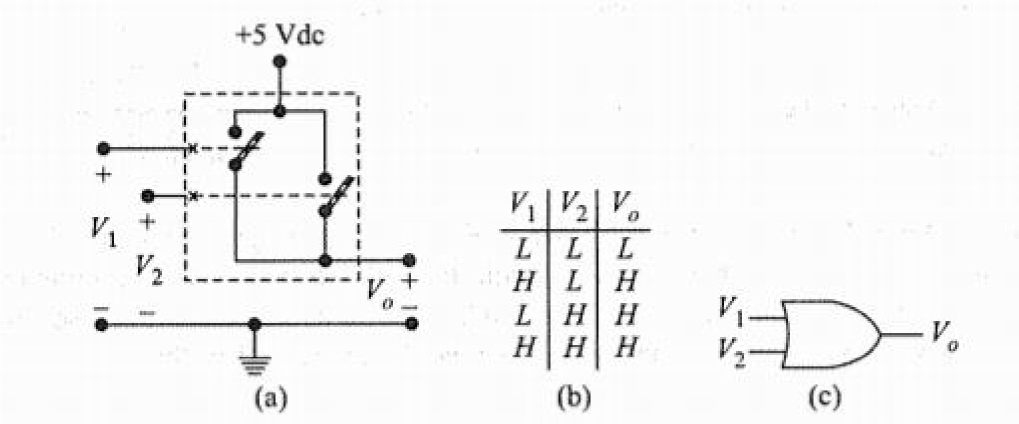
Figure: Two input AND gate (a) Model (b) Truth table (c) Symbol

<u>Logical equation of AND gate is written as:</u>

$V_0 = V_1$ **AND** V_2 **AND** ……. **AND** V_n

The OR Gate

- An OR gate is a digital circuit having two or more inputs and single output as indicated in figure.
- The input to this gate are labeled $\boldsymbol{V_1, V_2, V_3, \ldots\ldots V_n}$ (there are n inputs) and the output is labeled as $\boldsymbol{V_0}$.
- The operation of OR gate is:
  - If any of the input is high, $\boldsymbol{V_o}$ will be high
  - Only if all the inputs are low, $\boldsymbol{V_o}$ will be low.



V_1	V_2	V_o
L	L	L
H	L	H
L	H	H
H	H	H

Figure: Two input OR gate: (a) Model (b) Truth table (c) Symbol

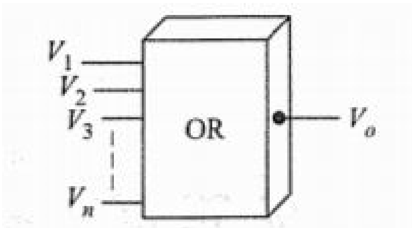


Figure: OR gate

<u>Logical equation of OR gate is written as:</u>

$V_0 = V_1$ **OR** V_2 **OR** ……. **OR** V_n

Number Systems

- Binary
- Decimal
- Octal
- Hexadecimal

Binary Codes

- Gray code
- BCD code
- Excess-3 code
- ASCII code
- 8-4-2-1 Code