# DIGITAL INTEGRATED CIRCUITS

# Topic Outcomes

- 1. Differentiate Linear and Digital IC
- 2. Describe the different Linear and Digital IC
- 3. Analyze the operation of Linear IC
- 4. Implement the basic Digital Circuits

# Introduction to Linear and Digital Integrated Circuits (IC)

# Integrated Circuits (IC)

- An integrated circuit is one in which circuit components such as transistors, diodes, resistors, capacitors etc. are automatically part of a small semiconductor chip. An IC consists of number of circuit components interconnected into a single small package that has a complete electronic function. IC is classified based on its mode of operation.

# Advantages of Integrated Circuits (IC)

- Advantages of IC over single electronic components:

Smaller size: ICs are much smaller in size compared to individual electronic components.

Lower weight: As ICs are smaller in size, they have lower weight.

Lower power consumption: ICs consume less power than individual electronic components.

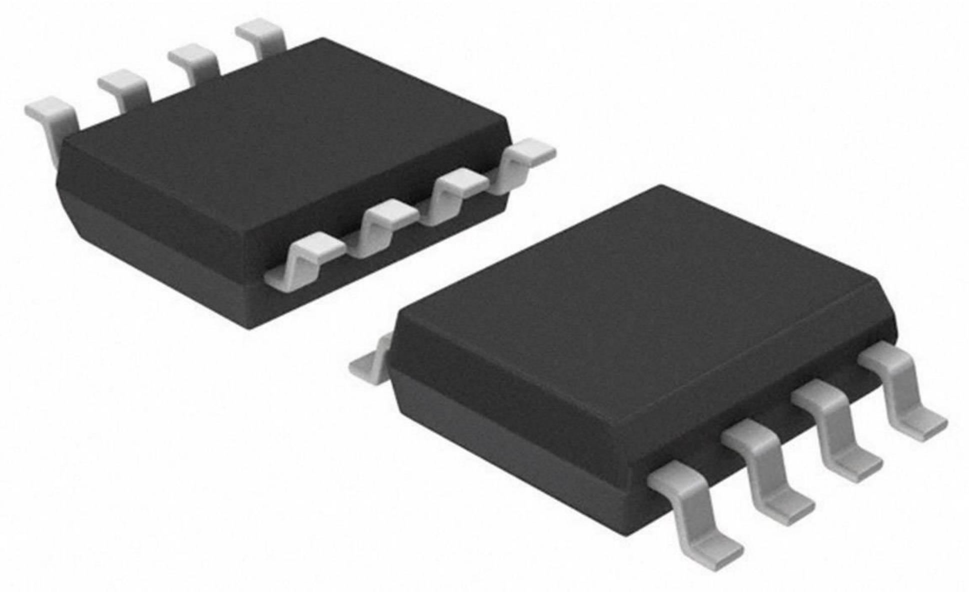
Lower cost: The manufacturing cost of ICs is much lower compared to the cost of individual electronic components.

Better performance: ICs offer better performance due to the close proximity of electronic components on the chip, resulting in faster operation and higher reliability.

# Integrated Circuits (IC)

- Linear IC

Equivalents of discrete transistor networks, such as amplifiers, filters, frequency multipliers, and modulators that often require additional external components for satisfactory operation.



- Digital IC

Complete functioning logic networks that are equivalents of basic transistor logic circuits.

# Linear IC

# Linear IC

Applications of linear ICs

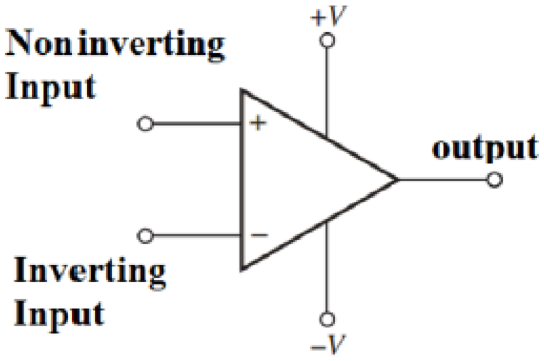
- Op-amp (Comparator(311, 399))
- Timer (555)
- Voltage-Controlled Oscillator (VCO) (556)
- Phase-Locked Loop (PLL)

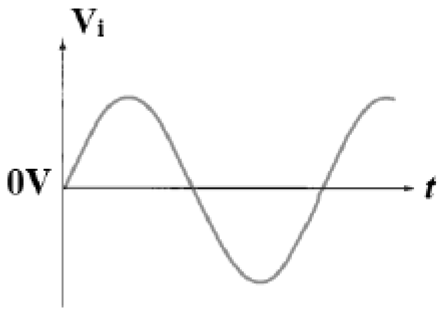
# Comparator

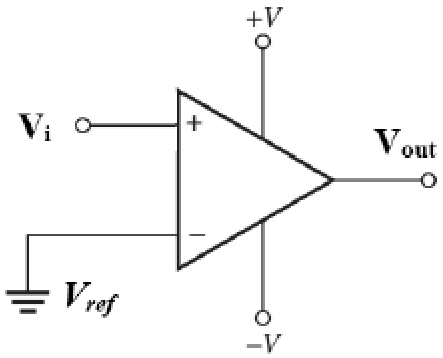
# Comparator Circuit

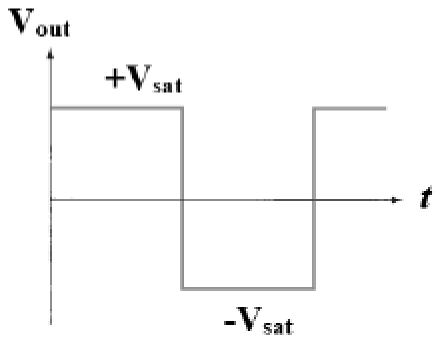
- A comparator is a circuit that compares the applied input signal to one input of an op-amp with a known reference to the other input.
- A comparator accepts input of linear voltages and provides a digital output that indicates when one input is less than or greater than the second.

- The output of the comparator circuit is a digital signal that will stays at high voltage level when the noninverting (–) input is greater than the voltage at the inverting (+) input and switches to a lower voltage level when the noninverting input voltage goes below the inverting input voltage.



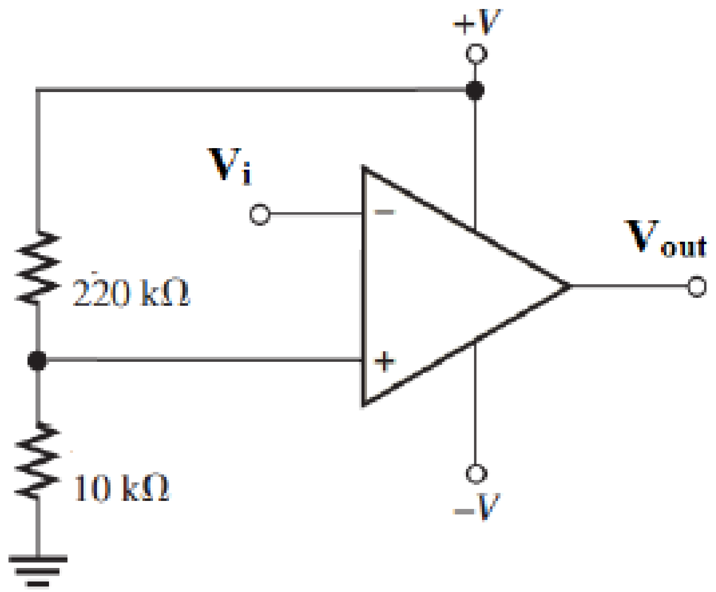



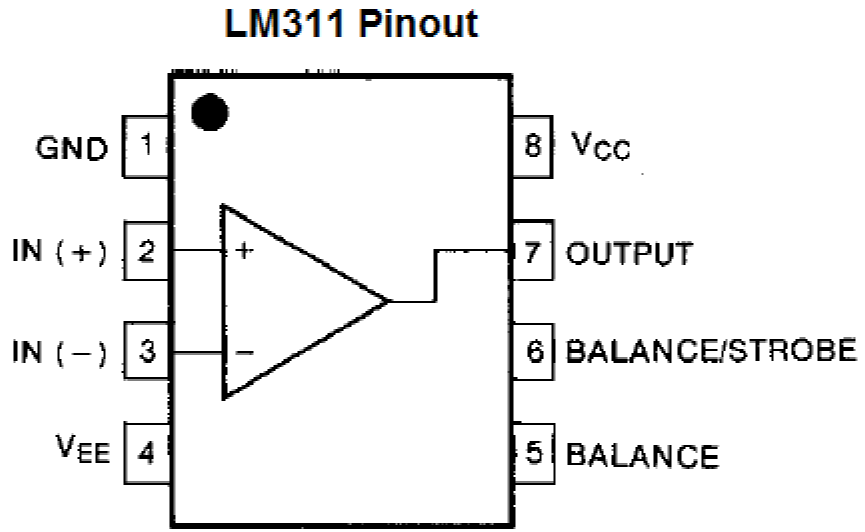
# Comparator Circuit

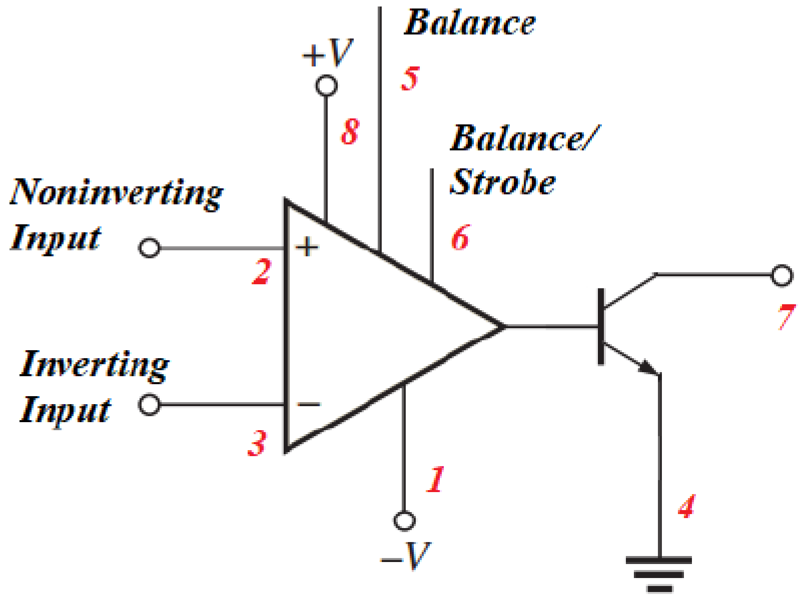
- Comparator with Positive Reference Voltage



# 311 Comparator

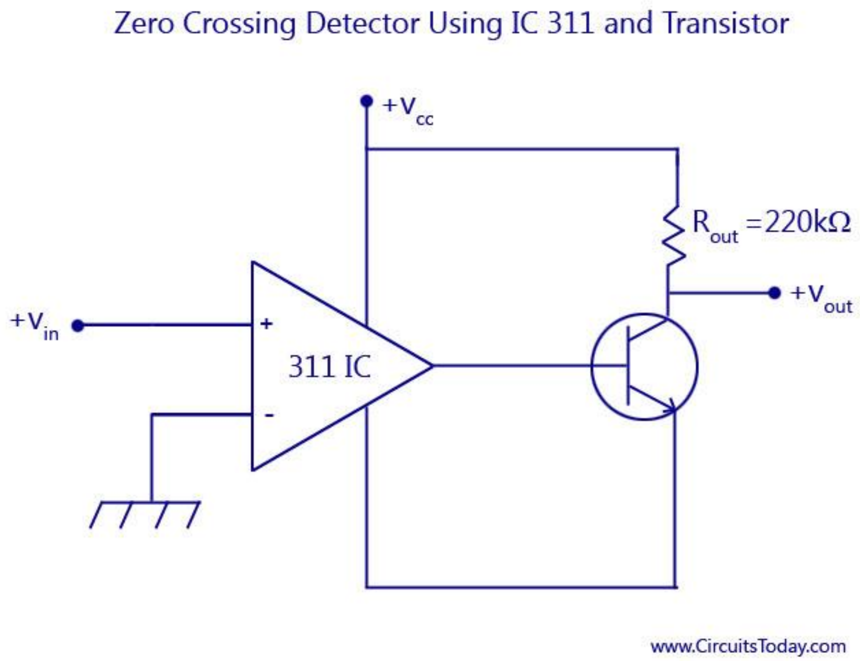
- The 311 voltage comparator is an eight pin single IC comparator that can operate from dual power supplies of $\pm 15V$ as from a single $+5V$ supply.
- This comparator can provide a voltage at one of two distinct levels (suitable for driving a lamp or a relay).
- The output is taken from a BJT to allow driving different loads. It has also a balance and strobe inputs that allows the gating of the output.



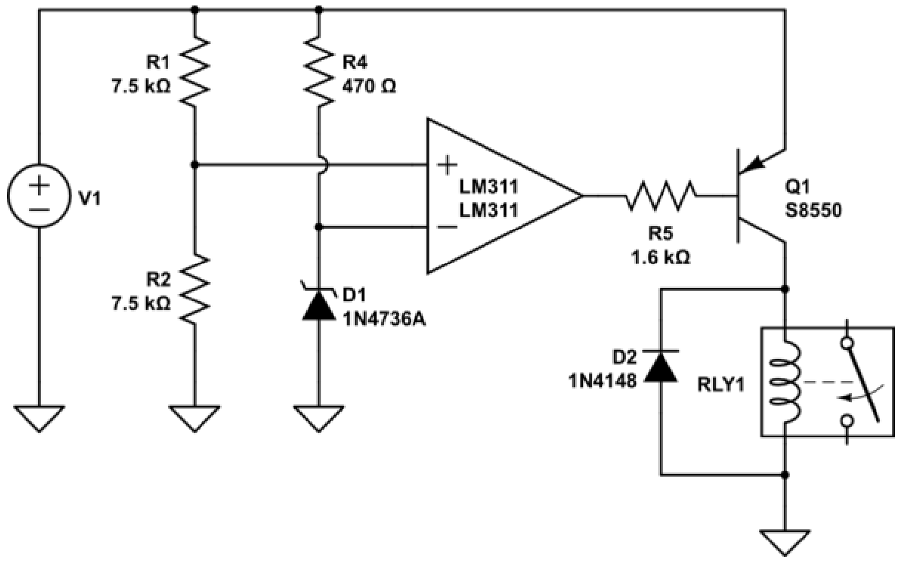



# 311 Comparator

- Application:
- - zero-crossing detector: The LM311 can be used to detect when an AC signal crosses zero volts. This is useful in applications such as phase control and power regulation.

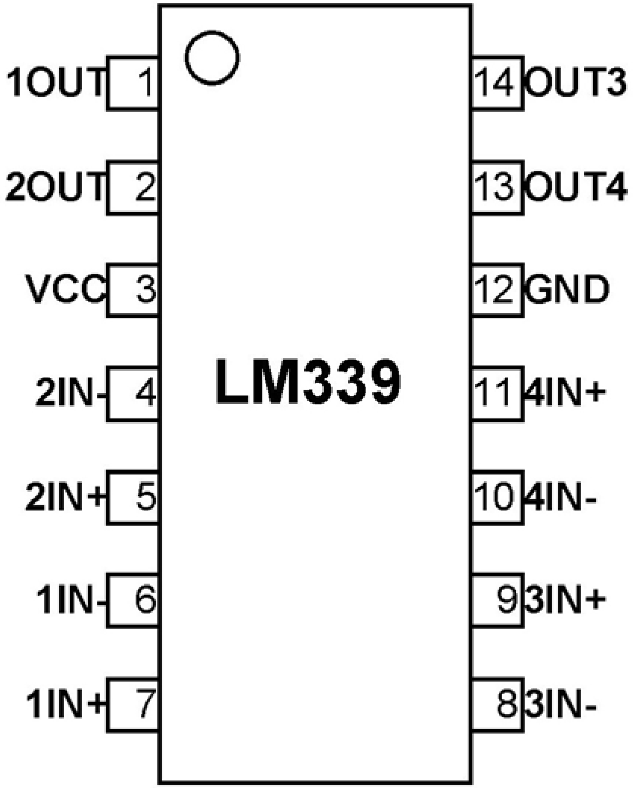



- - driving a relay: The LM311 can be used as a relay driver by using it as a voltage comparator to switch a transistor that in turn drives the relay.



# 399 Comparator

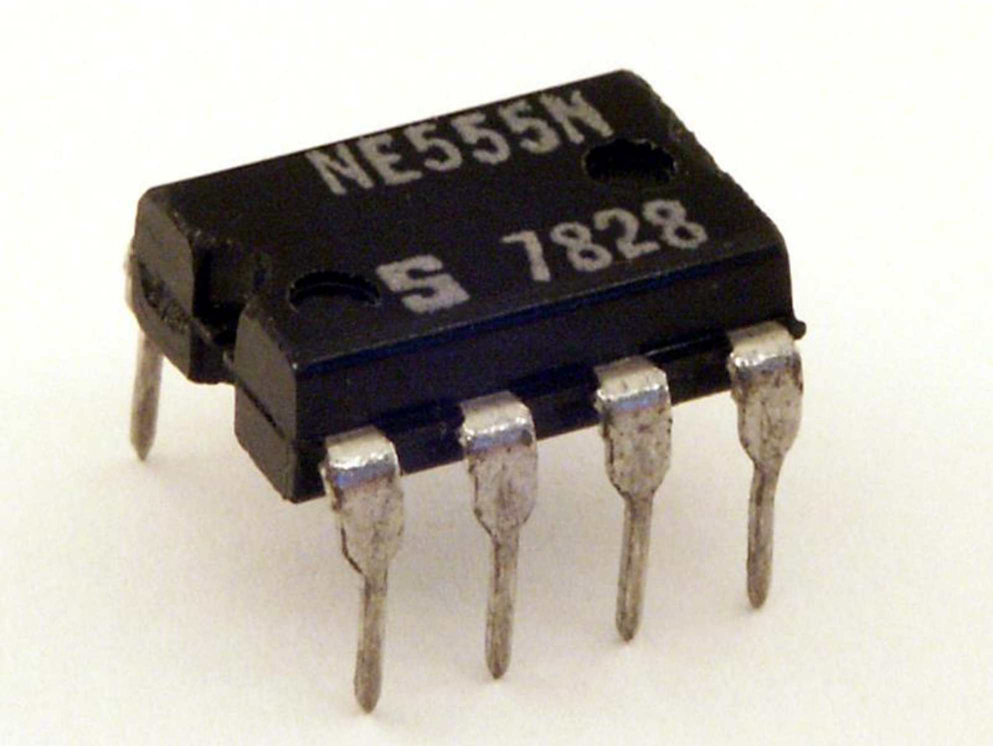
- 399 IC quad comparator containing four independent comparator circuits. Each comparator has noninverting and inverting input and a single output. All comparators inside has a supply voltage applied to a pair of pins only.



# Timers

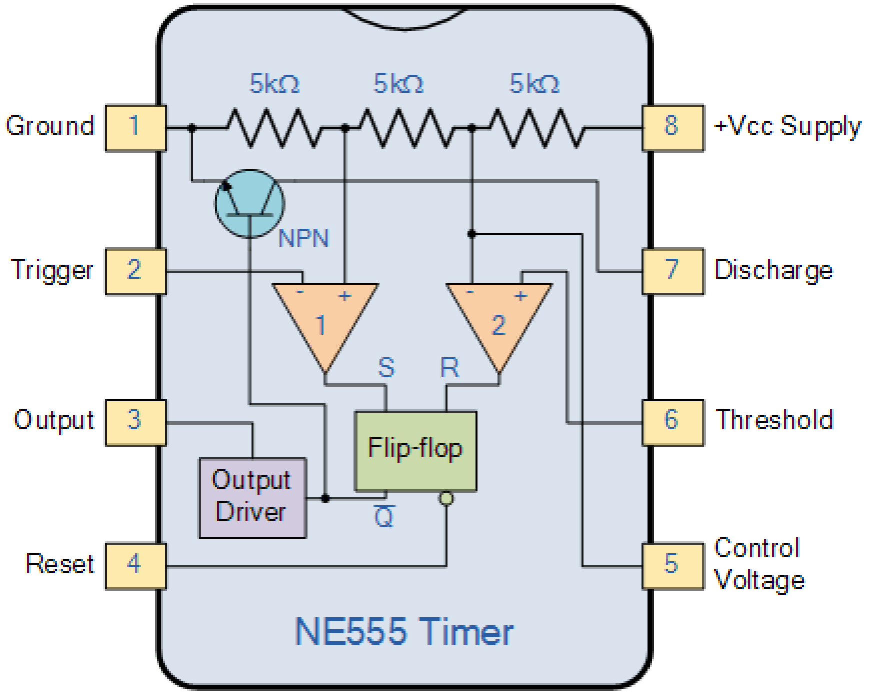
# Timers

- Timers are electronic circuits used to generate timing signals or time delays in a circuit.
- They are commonly used in electronic systems to generate clock signals, time events, or control the timing of operations.
- Timers can be implemented using different types of integrated circuits (ICs) such as 555 timer, 556 timer, or microcontrollers.



# 555 Timer

- The 555 timer IC is a popular IC that can be used to generate various timing signals.
- It can be configured as a timer, oscillator, or flip-flop.
- The timing of the 555 timer can be controlled by adjusting the values of resistors and capacitors in the circuit.
- It is usually in an eight-pin DIP packaging.



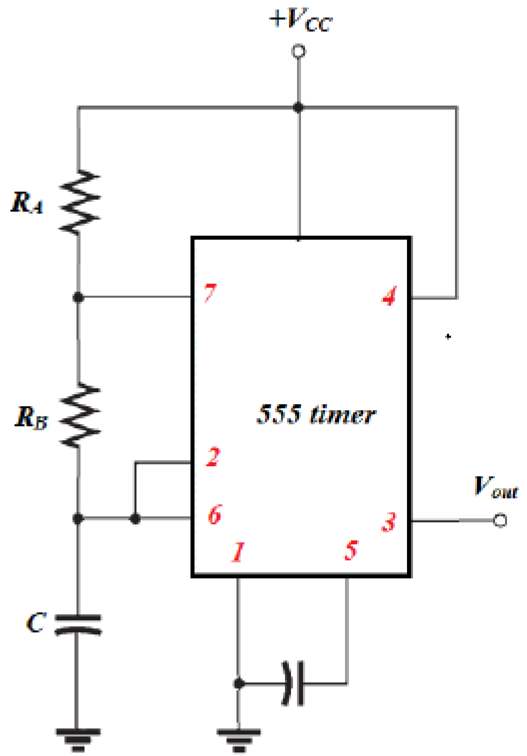
# 555 Timer

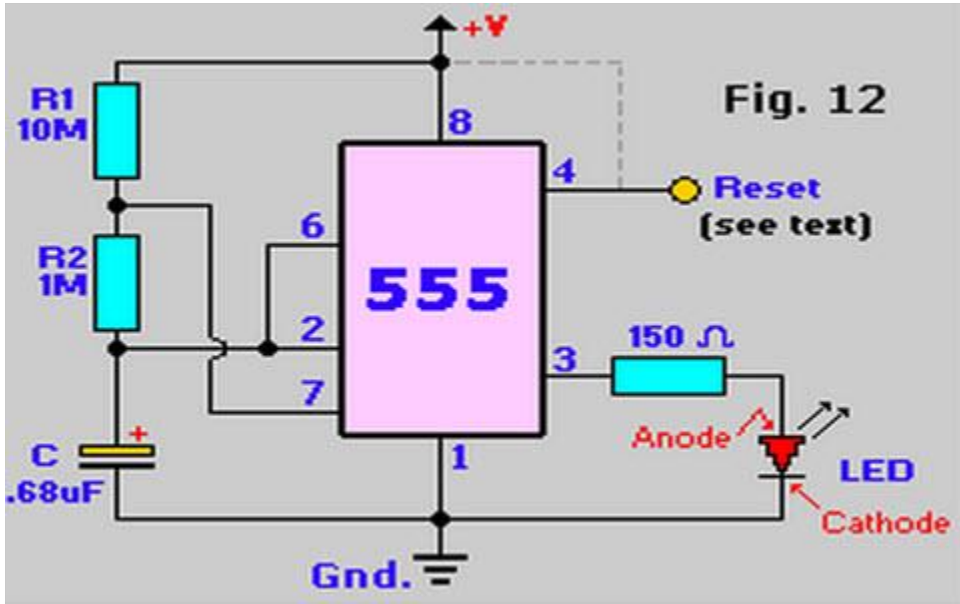
- Application
  - The astable and monostable modes can be implemented using the same 555 timer IC. The astable mode requires at least two external resistors and one capacitor, while the monostable mode requires one external resistor and one capacitor.

  - Monostable mode: In this mode, the 555 timer IC generates a single pulse of a specific duration in response to a trigger input. The output voltage remains high for a period determined by the values of resistors and capacitors in the circuit. After the time period has elapsed, the output voltage returns to its original low state.

# Astable Multivibrator

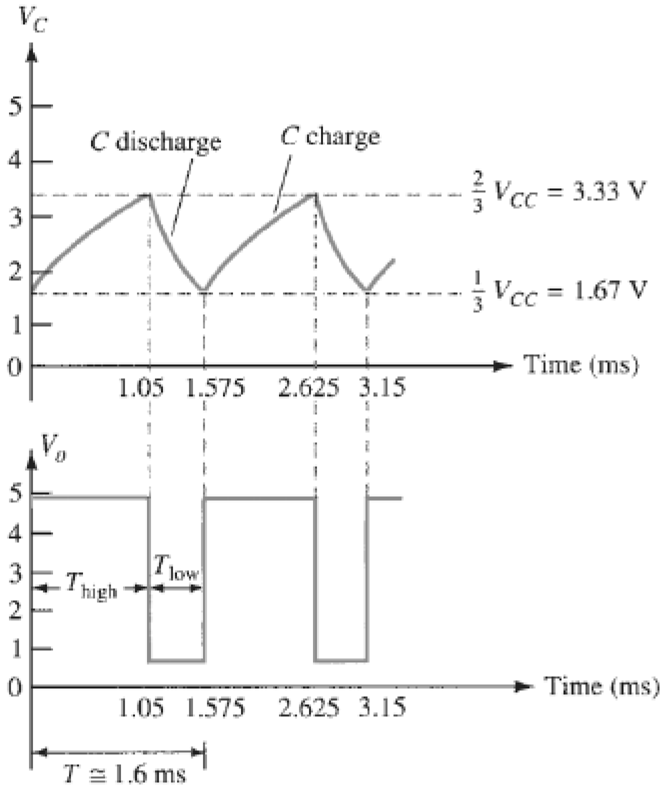
- An astable multivibrator is an electronic oscillator that generates a continuous square wave output.
- The circuit consists of a 555 timer IC, two resistors (RA and RB), and a capacitor (C).
- Initially, the capacitor is discharged, and the output of the 555 timer IC is low.
- The capacitor starts charging through resistor RA and when the voltage across the capacitor reaches 2/3 of the supply voltage, the output of the 555 timer IC goes high.
- The capacitor then starts discharging through resistor RB, and when the voltage across the capacitor drops to 1/3 of the supply voltage, the output of the 555 timer IC goes low.
- The cycle repeats, and the output of the 555 timer IC oscillates between high and low states, generating a continuous square wave output.
- The frequency and duty cycle of the output waveform can be adjusted by changing the values of resistors RA and RB and capacitor C.
- Astable multivibrators have many applications, including clock generation, signal generation, and tone generation in audio circuits.



# Astable Multivibrator

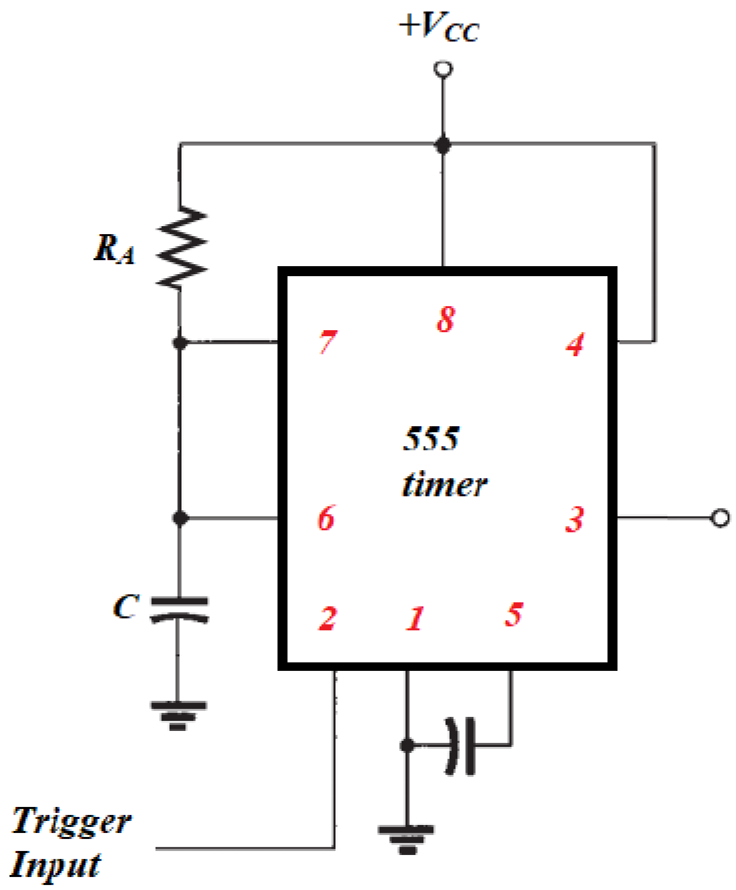
- The frequency (f) of the output waveform can be calculated using the formula: f = 1.44 / ((RA + 2*RB) * C)
- The duty cycle (D) of the output waveform can be calculated using the formula: D = (RA + RB) / (RA + 2*RB)
- High period - $Thigh \approx 0.7(RA + RB)C$
- Low period - $Tlow \approx 0.7RBC$
- The period is Thigh + T low.




Applying values of $R_A = 7.5k\Omega$, $R_B = 7.5k\Omega$, $C = 0.1\mu F$, $and\ V_{supply} = 5V$, we can compute the values of $T_{high}$, $T_{low}$, $period\ and\ frequency$, and can plot its output wave form.

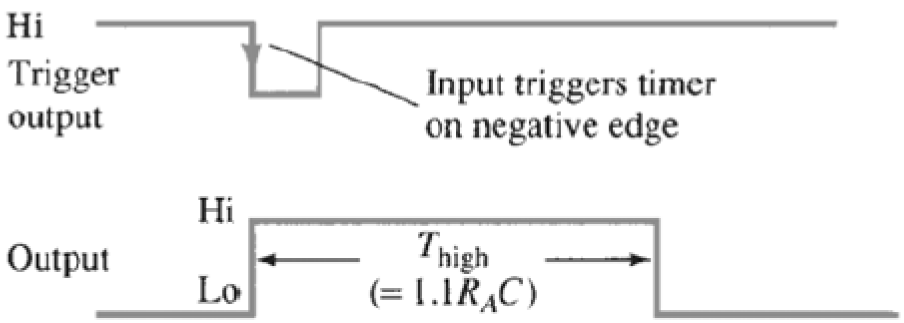
# Monostable Multivibrator

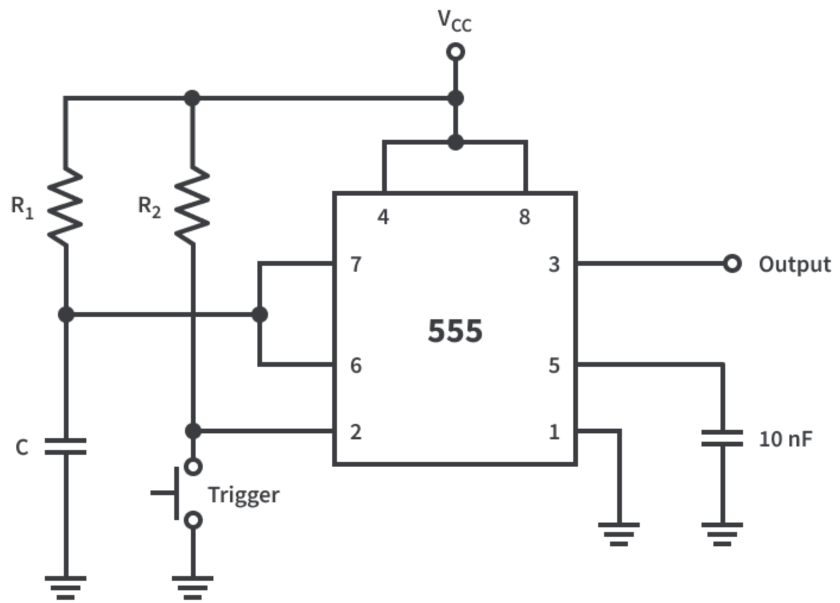
- A monostable multivibrator is a type of oscillator that generates a single pulse output.
- The circuit consists of a 555 timer IC, a resistor (R), a capacitor (C), and a trigger signal input.
- Initially, the output of the 555 timer IC is low, and the capacitor is discharged.
- When a trigger signal is applied to the trigger input, the voltage at the trigger (TR) pin of the 555 timer IC drops below 1/3 of the supply voltage (Vcc), and the output of the 555 timer IC goes high for a fixed period of time.
- During this period, the capacitor charges through resistor R towards the supply voltage (Vcc).
- When the voltage across the capacitor reaches 2/3 of the supply voltage (Vcc), the threshold (TH) pin of the 555 timer IC detects this voltage and triggers the output of the 555 timer IC to go low.
- The capacitor then discharges through resistor R towards the ground, and the circuit returns to its initial state.
- The duration of the output pulse can be adjusted by changing the values of resistor R and capacitor C.
- Monostable multivibrators have many applications, including pulse shaping, pulse stretching, and delay circuits.



# Monostable Multivibrator

- $Thigh = 1.1RAC$

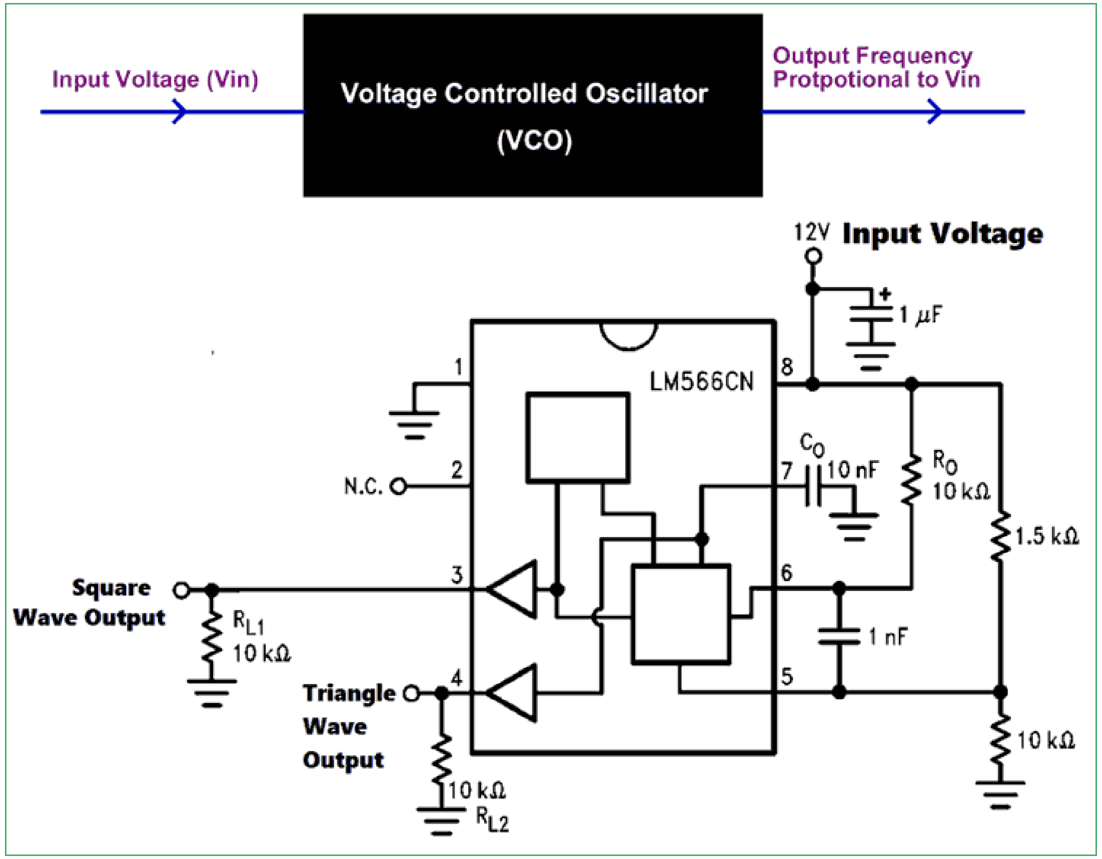


# Voltage-controlled Oscillator (VCO)

# Voltage-controlled Oscillator (VCO)

- A type of relaxation oscillator whose frequency can be varied by a dc control voltage; an oscillator for which the output frequency is dependent on a controlling input voltage.

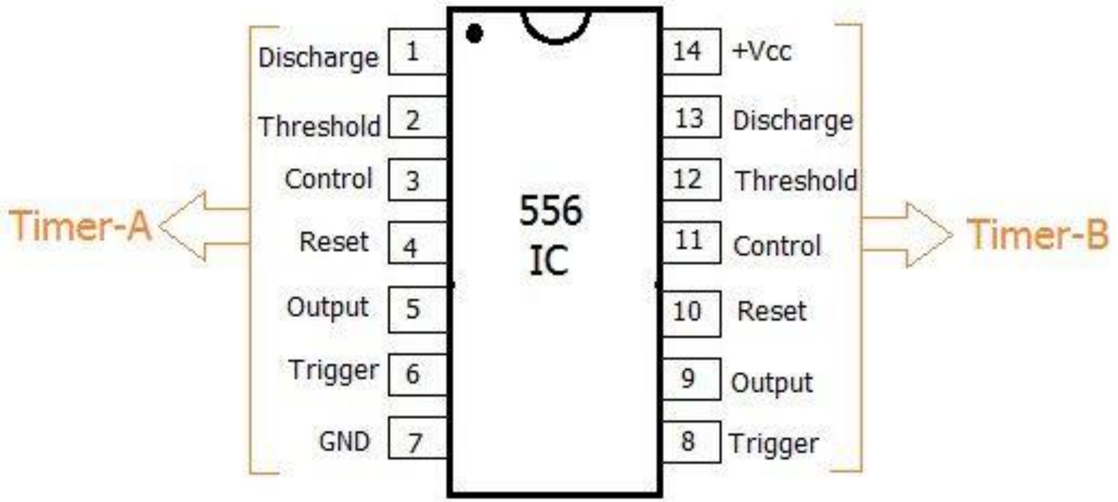


# Voltage-controlled Oscillator (VCO)

- 556 IC

556 IC is an example of VCO contains circuitry that generate both triangular and square wave shape output signal.

The frequency of the 556 is set by an external resistor and capacitor varied by an applied dc voltage.



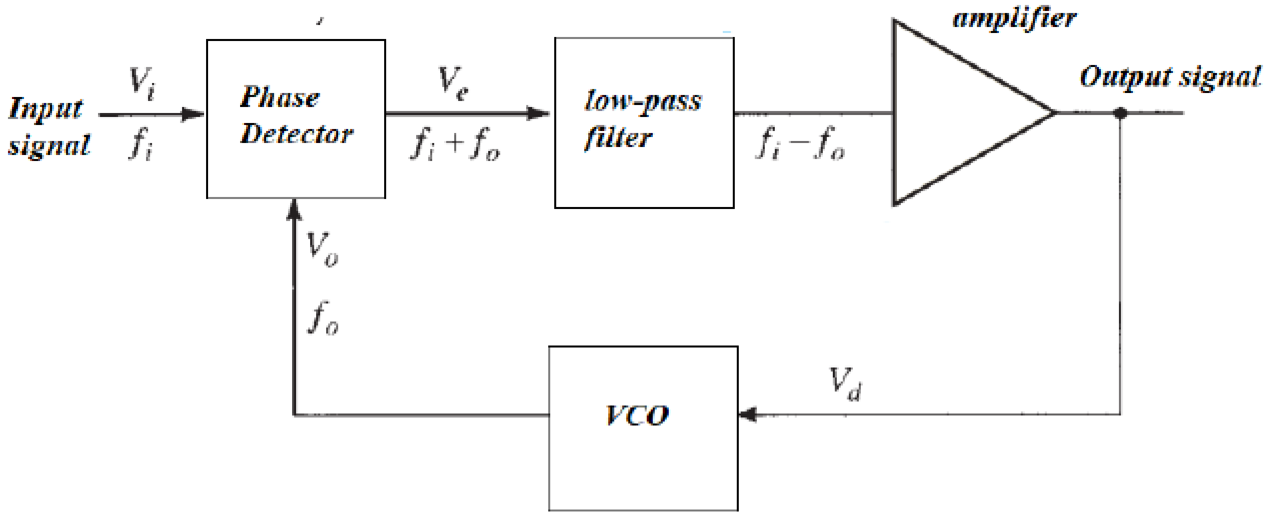
# Voltage-controlled Oscillator (VCO)

- 556 IC contains current sources, Schmitt trigger, and buffers circuit.
- Current source is the one that responsible for the charging and discharging of the external capacitance ($C$) at the rate set by the external resistor ($R$) and the modulating dc input voltage
- The Schmitt trigger circuit is act like a switch for the current sources between charging and discharging of the capacitor.
- The output triangular voltage (developed across capacitor) and square wave (produced by the Schmitt trigger) are provided through the buffer amplifiers.
- The center frequency ($f$0) can be calculate: $f_o = \frac{2}{R_C}\left(\frac{V^+ - V_C}{V^+}\right)$ given the following condition;
- 1. $R1$ should be the range $2k\Omega \le R1 \le 20k\Omega$
- 2. $V_c$ should be within the range $^3/_4 \le V_c \le V^+$
- 3. $f_o$ should be below 1 $MHz$
- 4. $V^+$ should range below 10$V$ $and$ 24$V$.

# Phase-locked Loop(PLL)

# Phase-locked Loop

- Phase-locked loop (PLL) is a circuit that consists of phase detector, low-pass filter, and VCO used primarily in signal transmission and receiving.



# Phase-locked Loop

- $Vi$ and $Vo$ compared by phase comparator that provide an $Ve$ that represents the phase difference between two signals.
- $Ve$ is now fed to a low pass filter, which provides an output voltage (amplified if necessary), that can be taken as the output of the PLL circuit and used internally as the voltage to modulate the VCO's frequency.
- The closed-loop operation of the circuit is to maintain the VCO frequency locked to that of the input signal frequency.

Applications

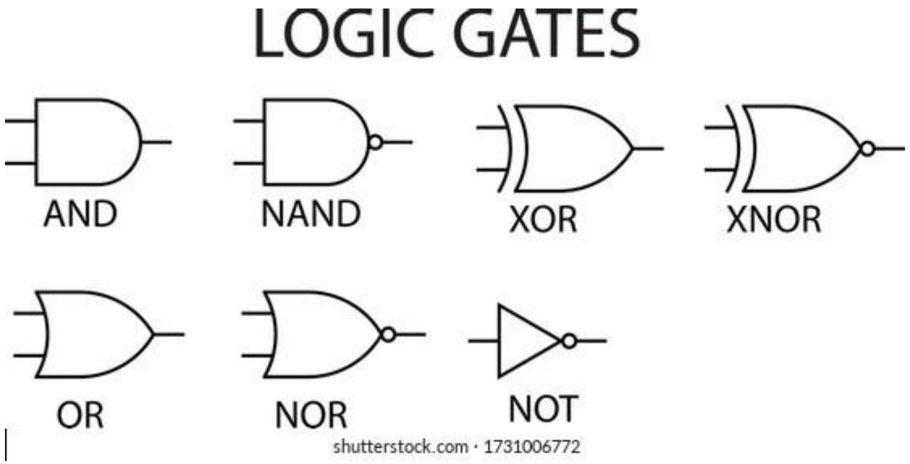
- 1. Frequency Demodulation
- 2. Frequency Synthesis
- 3. Frequency-shift keyed (FSK) Decoders

# Digital Integrated Circuit

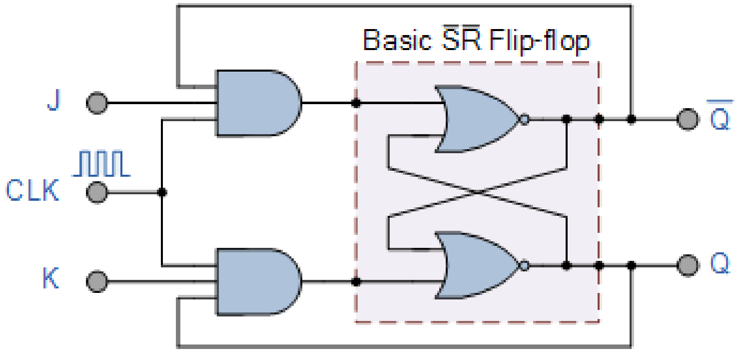
# Digital Integrated Circuit

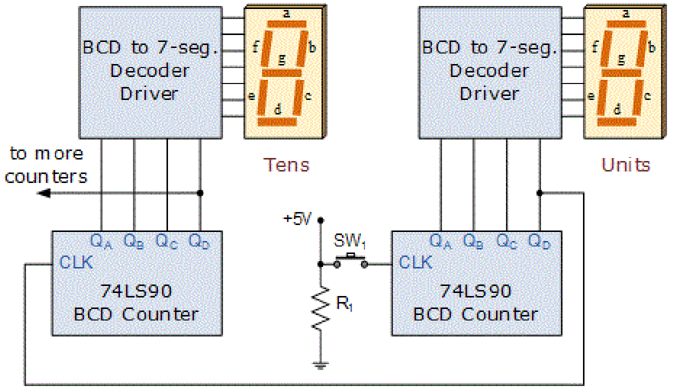
- Digital ICs deals with digital input and output that use switching action. The simplest digital ICs carry out just one type of switching action, and they can perform logic actions.
- Digital ICs are used in a wide range of applications, including computers, communication systems, control systems, and consumer electronics.

# Digital Integrated Circuit




- Some common types of digital ICs include:
  - Logic gates: basic building blocks of digital circuits that perform logical operations on input signals to produce an output signal.
  - Flip-flops: circuits that store binary values and can be used for data storage or synchronization.
  - Counters: circuits that count and sequence binary values.
  - Shift registers: circuits that shift binary values in and out in a controlled manner.
  - Microcontrollers: integrated circuits that combine a microprocessor with input/output peripherals to form a complete system on a chip.



# Logic Gates

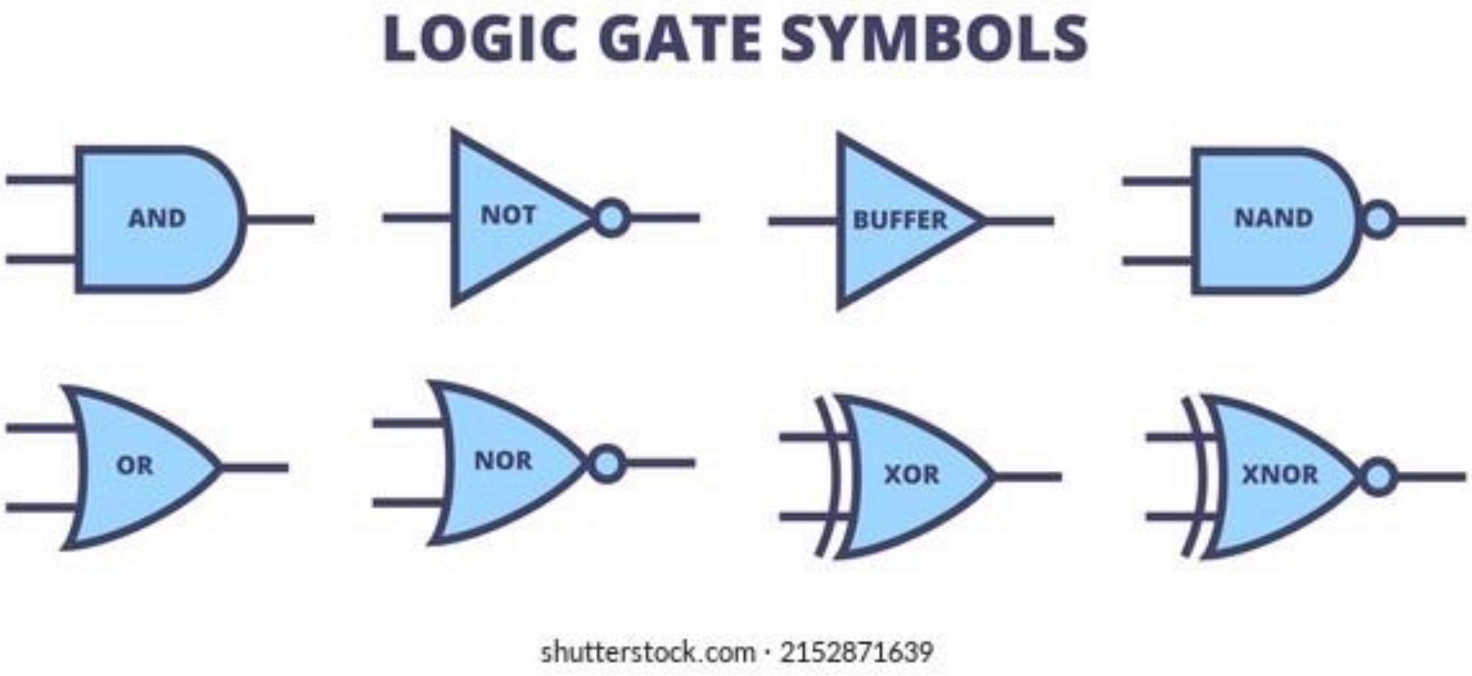
- Logic gate is an elementary building block of a digital circuit. Most logic gates have two inputs and one output.
- The input and the output signals of a gate can be in one of the two binary conditions: low (0 or “off”) or high (1 or “on”). The value of output depends on the combination of the inputs.
- Logic gates are electronic devices allows an electronic system to make decision based on the inputs.

# Boolean Algebra and Truth Table

- Logic gates use the principles of a mathematical system called Boolean algebra, a branch of mathematics that deals with the operations on logical values. Boolean expression is the input-output information of logic gates can be schemed into truth table to visualize the switching function of the system.
- Truth table shows the behavior of logic gates. A logic gate truth table shows each possible input combination to the gate or circuit with the resultant output depending upon the combination of these input(s).

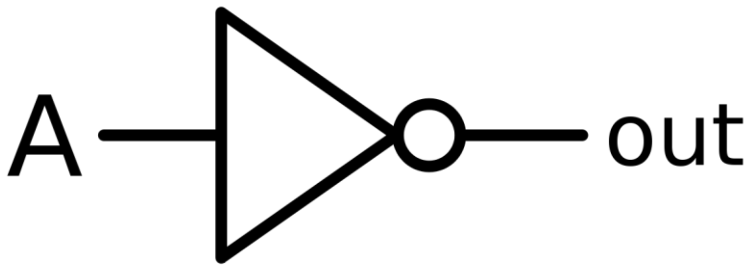
# Logic Gates

- Seven basic logic gates
  - NOT
  - AND
  - OR
  - NOR
  - NAND
  - XOR
  - XNOR



# Logic Gates

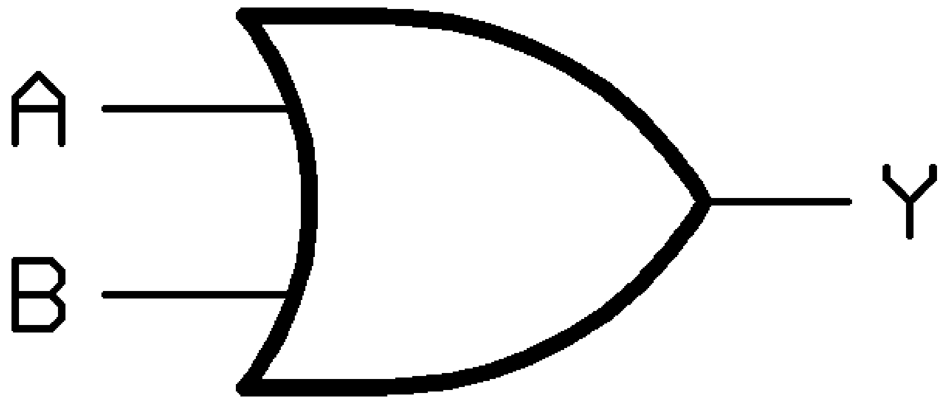
- NOT gate
  - Not gate is the simplest gate also called “inverter that consists only of a single input and single output. The input of the NOT gate is always the reverse of the output: if the input is high (1), the output is low (0) and vice versa.




| A | Y |
|---|---|
| 0 | 1 |
| 1 | 0 |

- $Y = \overline{A}$
- NOT A = $\overline{A}$

# Logic Gates



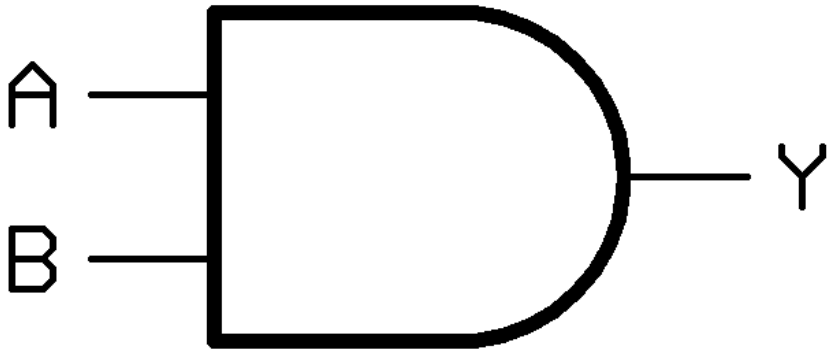

- OR gate
  - An OR gate is a multiple input single output that will give a high output if any of the inputs is high.

- Y=A+B

- A OR B = A+B

| A | B | Y |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |

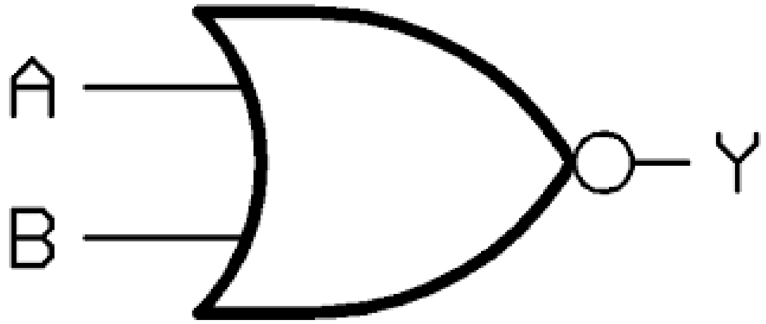
# Logic Gates




- AND gate
  - An AND gate is a multiple input single output circuit that will give a high output if all of the input is high.
- Y=AB
- A AND B = AB

| A | B | Y |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

# Logic Gates

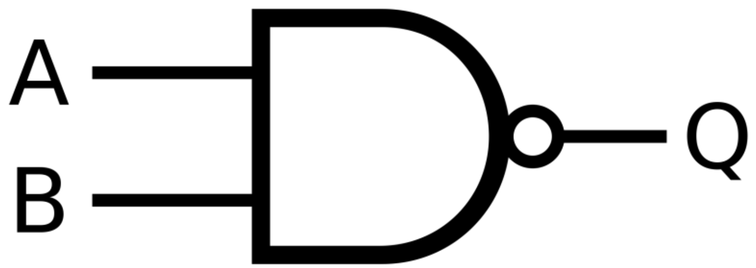



- NOR gate
  - A NOR (Not OR) gate is a multiple input single output gate that will give an output of high if all the input is low;
  - This is one of the universal gate as it can be only used to implement any Boolean function
- $Y = \overline{(A + B)}$
- A NOR B = $\overline{(A + B)}$

| A | B | Y |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

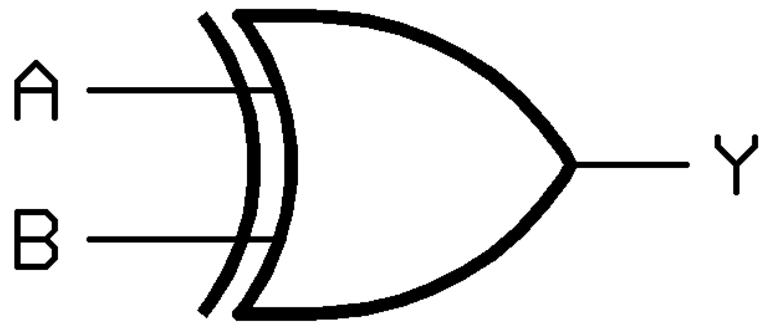
# Logic Gates

- NAND gate
  - A NAND (Not AND) gate is a multiple input single output gate that will give an output low of if all the input is high.
  - This is one of the universal gate as it can be only used to implement any Boolean function
- $Y = \overline{(AB)}$
- A NAND B = $\overline{(AB)}$




| A | B | Y |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

# Logic Gates

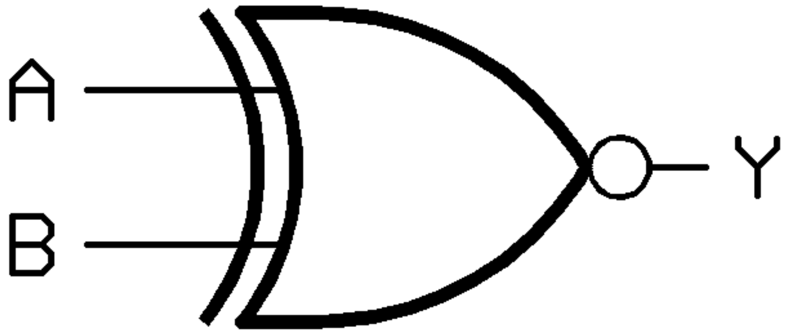



- XOR gate
  - XOR stands for Exclusive-OR is circuit with multiple input single output gate that will give an output of high if the number of “1” in the input are odd.

| A | B | Y |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

- $Y = \bar{A}B + A\bar{B}$
- A XOR B = $\bar{A}B + A\bar{B}$ = A $\oplus$ B

# Logic Gates




- XNOR gate
  - Exclusive-NOR or XNOR is circuit with multiple input single output gate that will give an output of high if the number of "1" in the input are even;

| A | B | Y |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

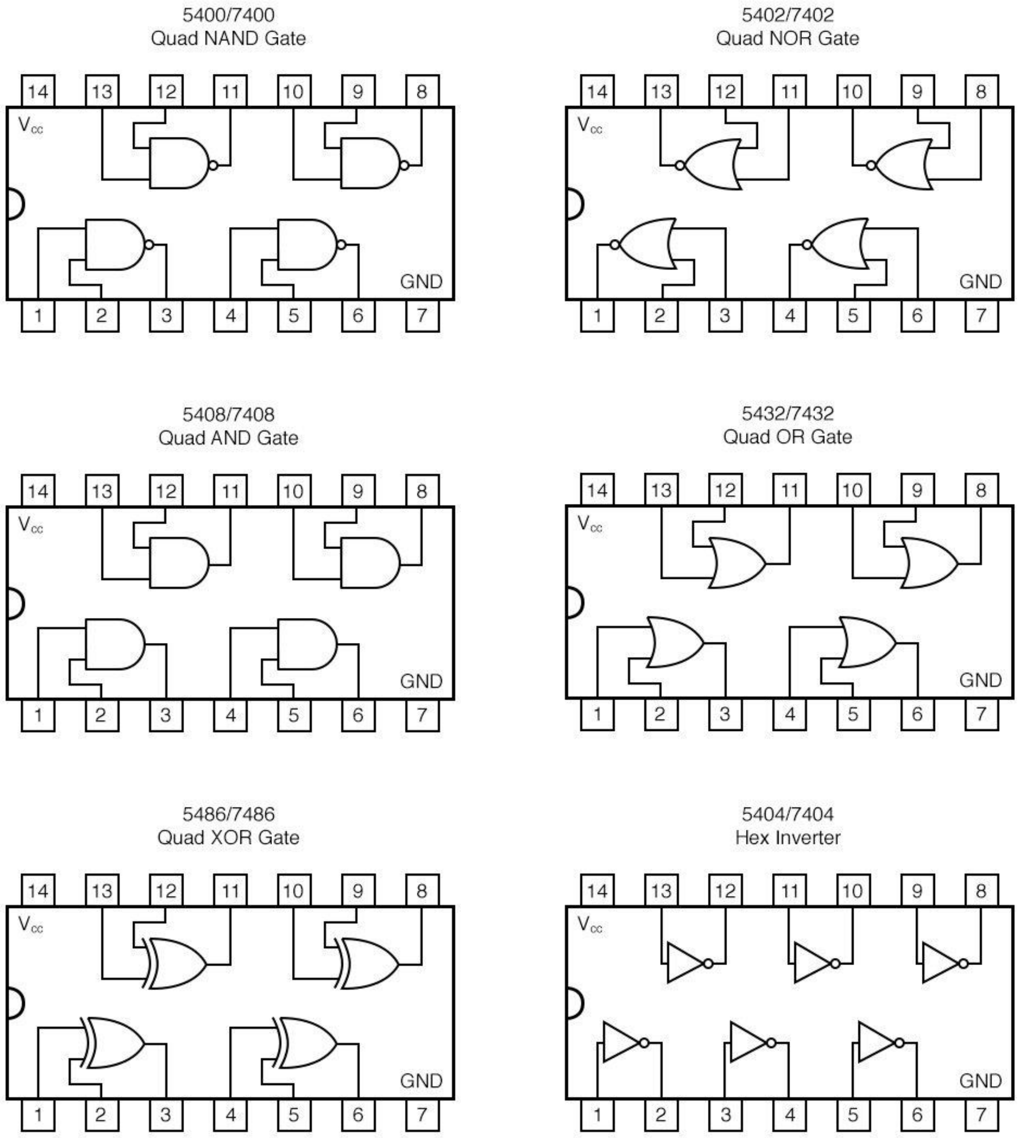
- $Y = \overline{AB} + AB$

- A XNOR B = $\overline{AB} + AB$ = $\overline{A \oplus B}$

# Logic Gates

- Lists are the equivalent IC for each logic gate:

- 7400 - Quad 2-input NAND gate
- 7402 - Quad 2-input NOR gate
- 7404 - Hex Inverter
- 7408 - Quad 2-input AND gate
- 7432 - Quad 2-input OR gate
- 7486 - Quad 2-input XOR gate
- 74266 - Quad 2-input XNOR gate



# End