G H Raisoni College of Engineering and Management, Nagpur

# Analog Integrated Circuits

## IV Semester

## Electronics and Telecommunication Engineering

by

**Dr.Swati R. Dixit**

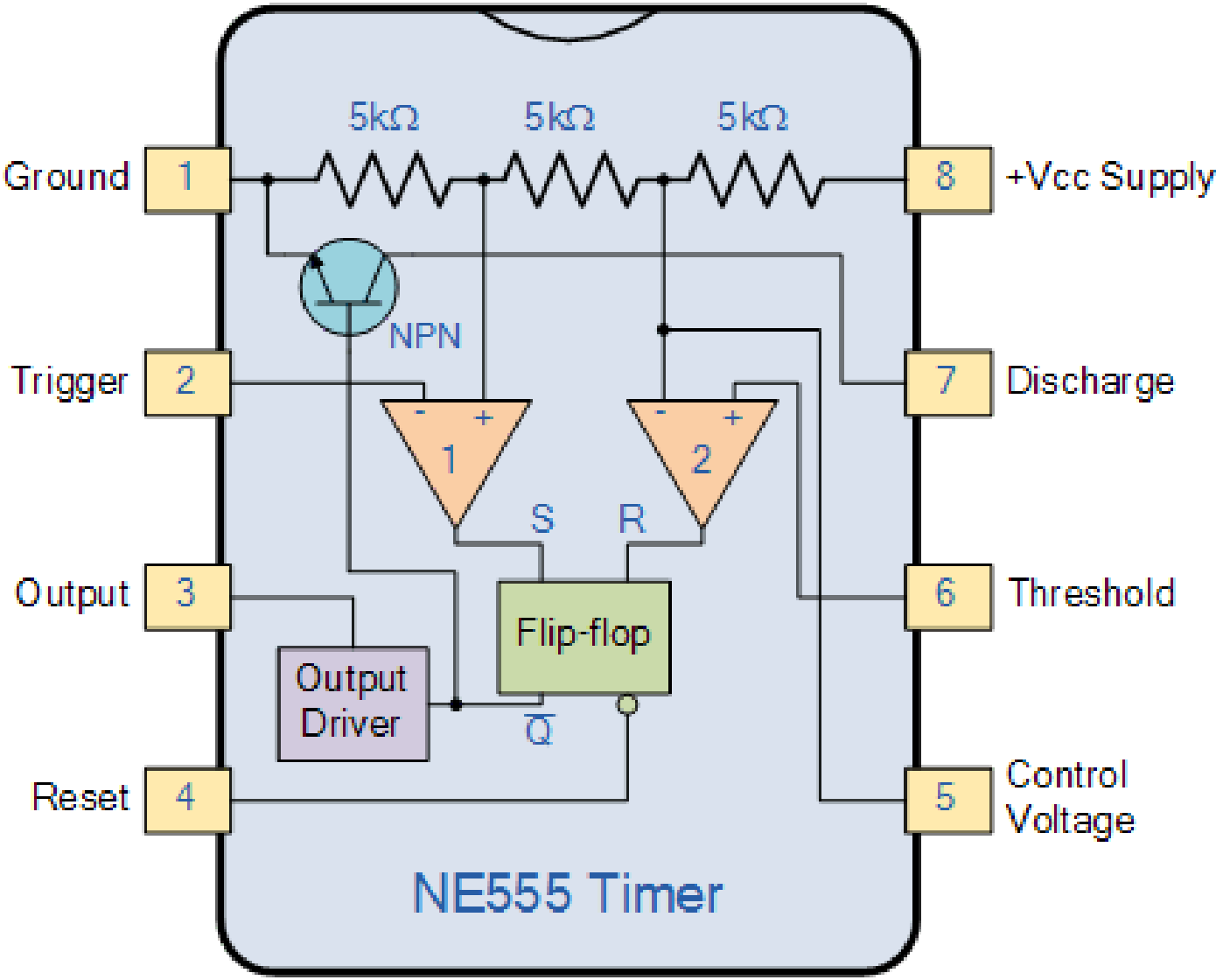
**Contents:**

- **The 555 Timer**
- **Phase Locked Loops IC565**
- **Voltage Controlled Oscillator Basic Operation**
- **IC based Voltage Regulator Circuits**

# IC 555

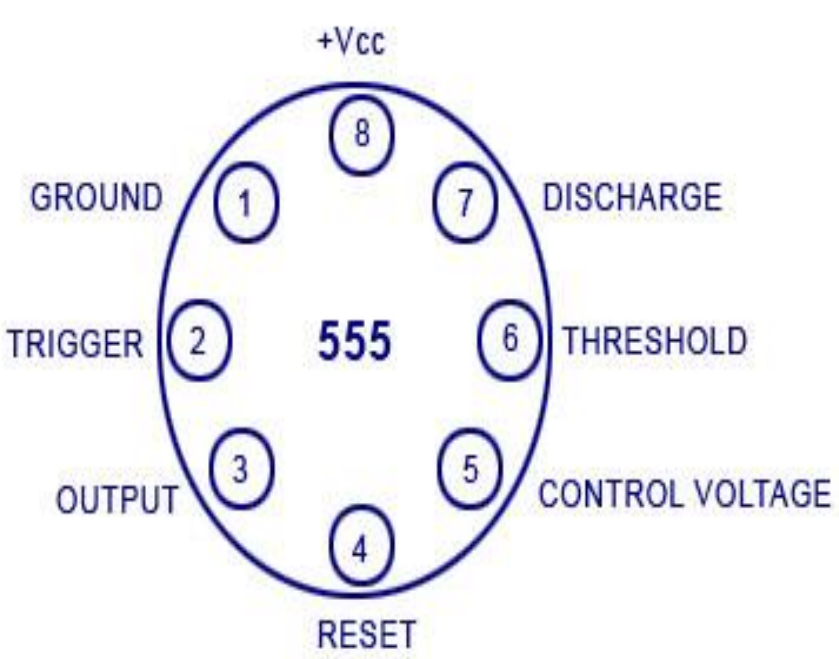
# IC 555



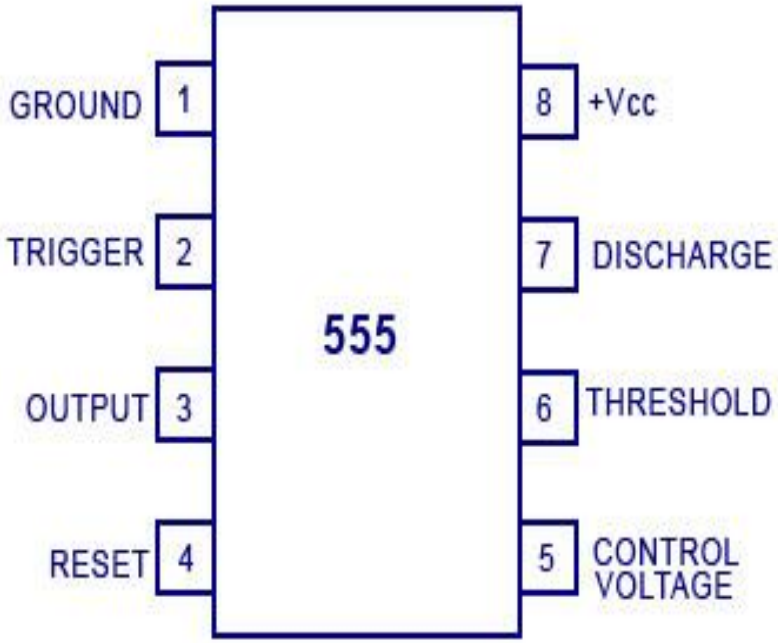

5kΩ
5kΩ
5kΩ
Ground
1
8
+Vcc Supply
NPN
Trigger
2
7
Discharge
-
+
1
-
+
2
S
R
Output
3
6
Threshold
Flip-flop
Output Driver
Q
Reset
4
5
Control Voltage
NE555 Timer

# INTRODUCTION OF NE 555

## 555 TIMER IC




Top View Of Metal Can Package

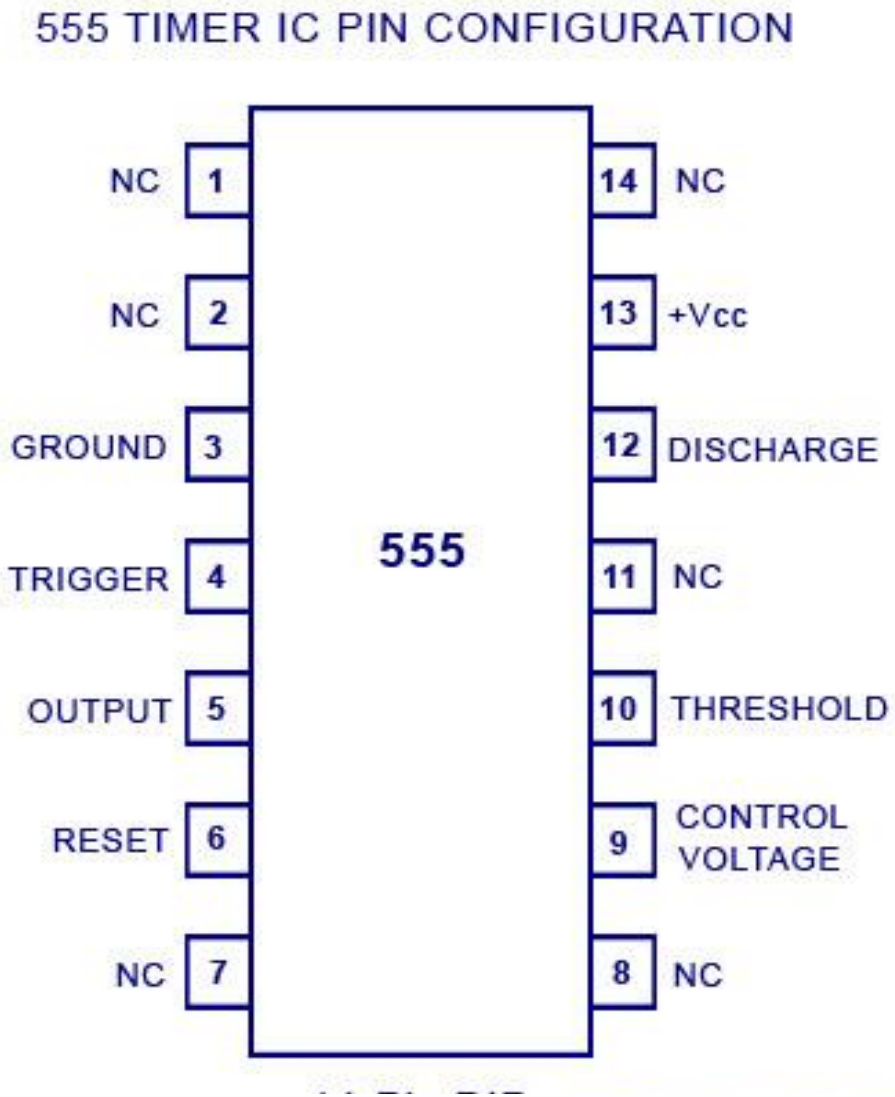



8-Pin DIP

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# PIN CONFIGURATION

- The 555 timer IC is available as an 8-pin metal can, an 8-pin mini DIP (dual-in-package) or a 14-pin DIP.
- This IC consists of 25 transistors, 2 diodes and 15 resistors.



# PIN CONFIGURATION OF IC 555

- **Pin 1**: **Grounded Terminal:** All the voltages are measured with respect to this terminal.
- **Pin 2: Trigger Terminal:** The output of the timer depends on the amplitude of the external trigger pulse applied to this pin.

  The output is low if voltage to this pin is greater than 2/3 Vcc.

  When a negative going pulse of amplitude larger than 1/3 Vcc is applied to this pin, the comparator 2 output goes low, which in turn switches the output to high. The output remains high as long as the trigger terminal is held at a low voltage.
- **Pin 3: Output Terminal:** Output of the timer is available at this pin.

- **Pin 4: Reset Terminal:** To disable or reset the timer a negative pulse is applied to this pin due to which it is referred to as reset terminal.

  When this pin is not to be used for reset purpose, it should be connected to + VCC to avoid any possibility of false triggering.
- **Pin 5: Control Voltage Terminal:** The function of this terminal is to control the threshold and trigger levels. Thus either the external voltage or a pot connected to this pin determines the pulse width of the output waveform. The external voltage applied to this pin can also be used to modulate the output waveform.

  When this pin is not used, it should be connected to ground through a 0.01 microF to avoid any noise problem.

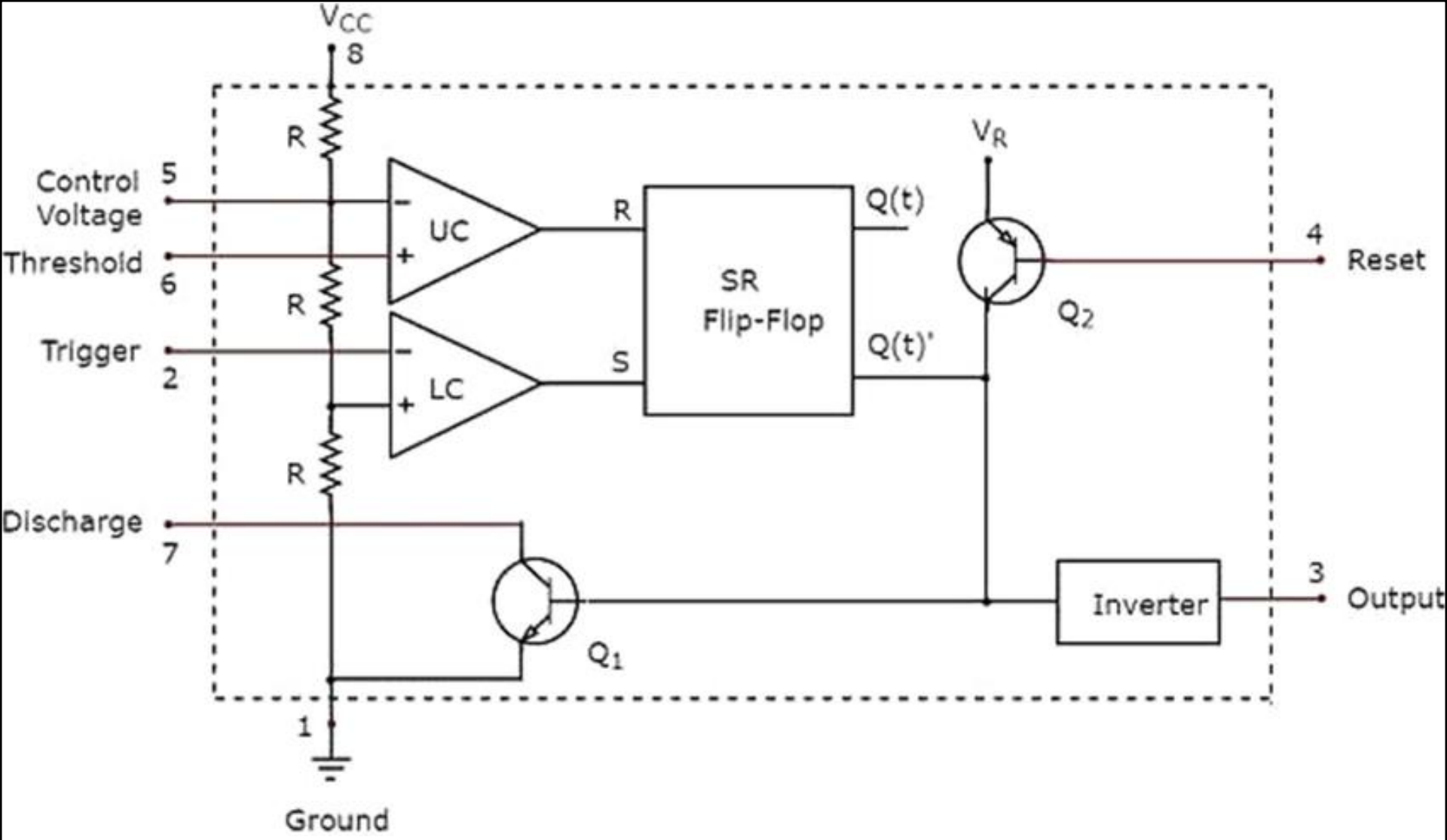
- **Pin 6**: **Threshold Terminal:** This is the non-inverting input terminal of comparator 1, which compares the voltage applied to the terminal with a reference voltage of 2/3 VCC.
- When the voltage at this pin is >=2/3Vcc, the output of the comparator 1 goes high, which in turn switches the output of the timer low.

  The amplitude of voltage applied to this terminal is responsible for the set state of flip-flop.
- **Pin 7** : **Discharge Terminal:** This pin is connected internally to the collector of transistor and mostly a capacitor is connected between this terminal and ground. It is called discharge terminal because when transistor saturates, capacitor discharges through the transistor. When the transistor is cut-off, the capacitor charges at a rate determined by the external resistor and capacitor.
- **Pin 8:** **Supply Terminal:** A supply voltage of + 5 V to + 18 V is applied to this terminal with respect to ground

## Some Applications of IC 555

- Monostable and Astable Multivibrators
- dc-dc converters
- Waveform generators
- Analog frequency meters
- Temperature measurement and control
- Burglar and toxic gas alarms
- Voltage regulators

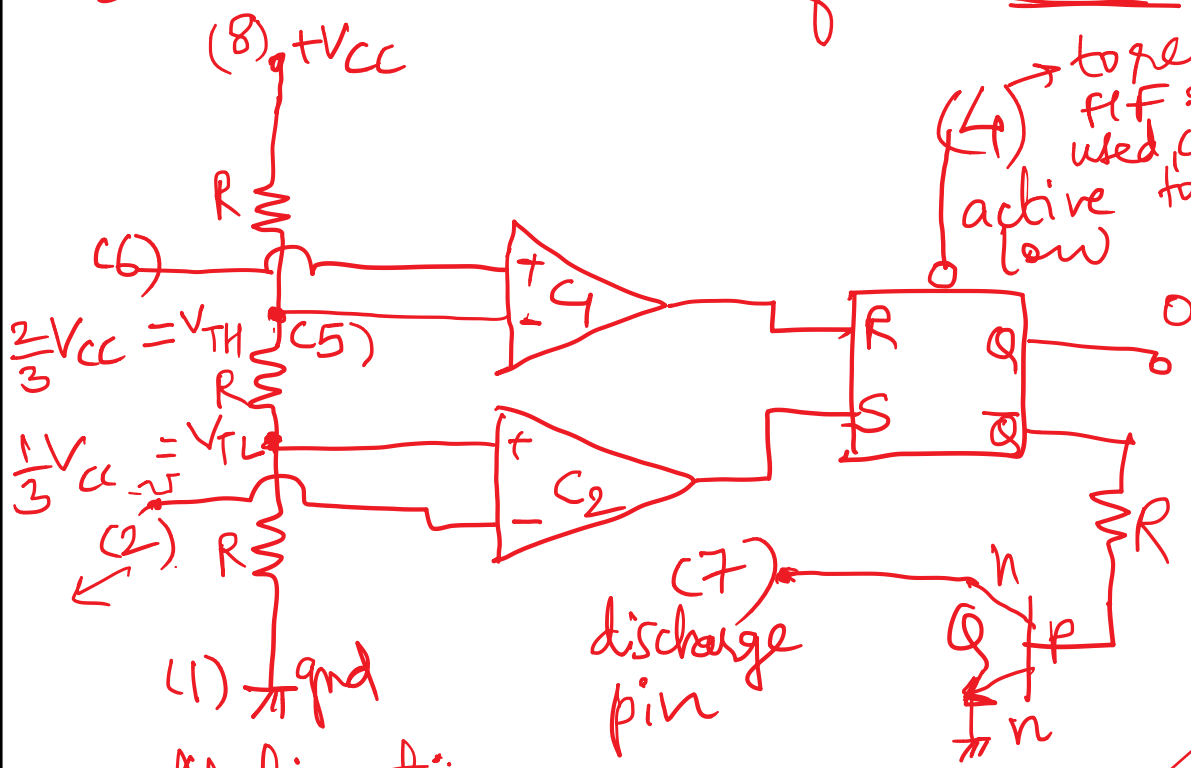
# INTERNAL DIAGRAM OF IC 555




A 555 timer has two comparators, which are basically 2 op-amps, an R-S flip-flop, two transistors and a resistive network.

Resistive network consists of three equal resistors and acts as a voltage divider.

# Internal Structure of IC 555.




$V_{TH} = \frac{2R}{(R+2R)} \times V_{CC}$

$= \frac{2}{3} V_{CC}$ ✓

$V_{TL} = \frac{R}{R+2R} \times V_{CC}$

$V_{TL} = \frac{1}{3} V_{CC}$ ✓

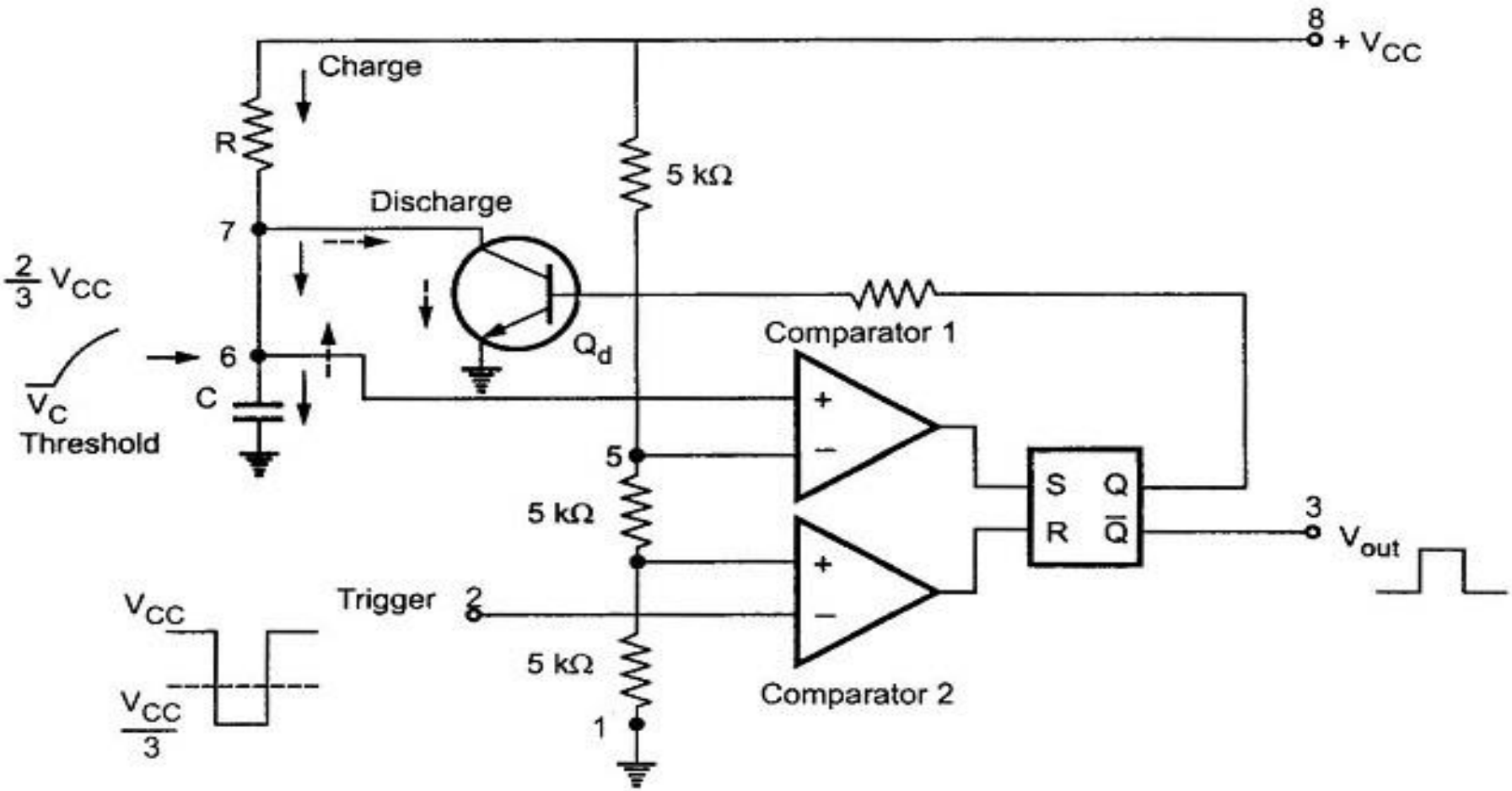
Truth Table of S-R Flipflop

| S | R | Q | $\bar{Q}$ |
|---|---|---|---|
| 0 | 0 | No change | |
| 0 | 1 | 0 | 1 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | Not possible | |

Applications -

1) Beeping & tone generation
2) PWM signal generation
3) Timing delay circuit

✓Comparator 1 compares threshold voltage with a reference voltage +2/3 VCC volts.
✓Comparator 2 compares the trigger voltage with a reference voltage +1/3VCC volts.
✓Output of both the comparators is supplied to the flip-flop. Flip-flop assumes its state according to the output of the two comparators.
✓One of the two transistors is a discharge transistor of which collector is connected to pin 7.
✓This transistor saturates or cuts-off according to the output state of the flip-flop.
✓The saturated transistor provides a discharge path to a capacitor connected externally.
✓Base of another transistor is connected to a reset terminal. A pulse applied to this terminal resets the whole timer irrespective of any input.




**Monostable operation of 555**

- Initially, when the output is low, the circuit is in stable state, transistor Q1 is on and capacitor C is shorted to ground.
- Upon application of a negative trigger pulse to pin 2, transistor Q1 is turned off,which releases the short circuit across the external capacitorC and drives the output high.
- The capacitor C now starts charging up towards Vcc through R.
- However when the voltage across the capacitor equals 2/3 Vcc, camparator 1’s output switches from low to high, which in turn frives the output to its low state via the output of the flip flop.
- At the same time, the output of the flip flop turns transistor Q1 on and hence capacitor C rapidly discharges through the transistor
- The output of the monostable remains low until a trigger pulse is again applied.
- Then the cycle repeats.
- Trigger input, Output voltage and capacitor voltage waveforms are shown.

- The pulse with of the trigger input must be smaller than the expected pulse width of the output waveform.
- The trigger pulse must be a negative going input signal with an amplitude larger than 1/3Vcc.

- The time during which the output remains high is given by
  Tp=1.1RC seconds

Where R is in ohms and C is in farads.

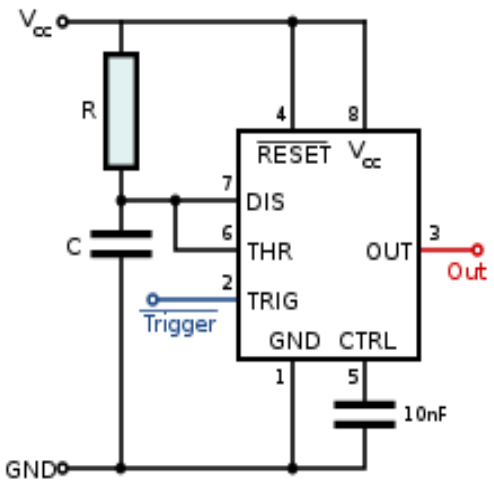
- Once triggered , the circuit's output will remain in the high state until the set time tp elapses. The output will not change its state even if an input trigger is applied again during this time interval tp. However the circuit can be reset during the timing cycle by applying a negative pulse to the reset terminal. The output will then remain in thel low stat until a trigger is again applied.

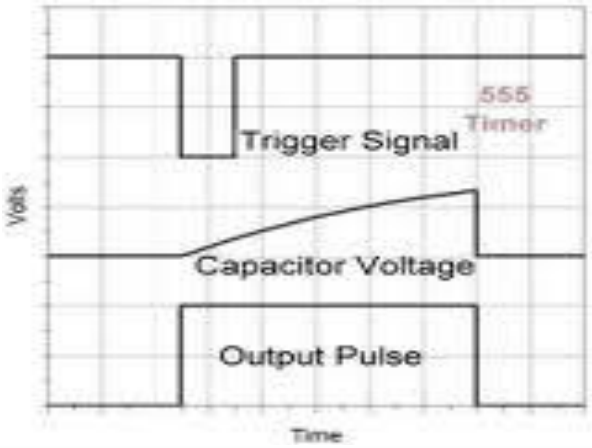
# OPERATING MODES



- NE555 HAS 3 OPERATING MODES-

## * MONOSTABLE

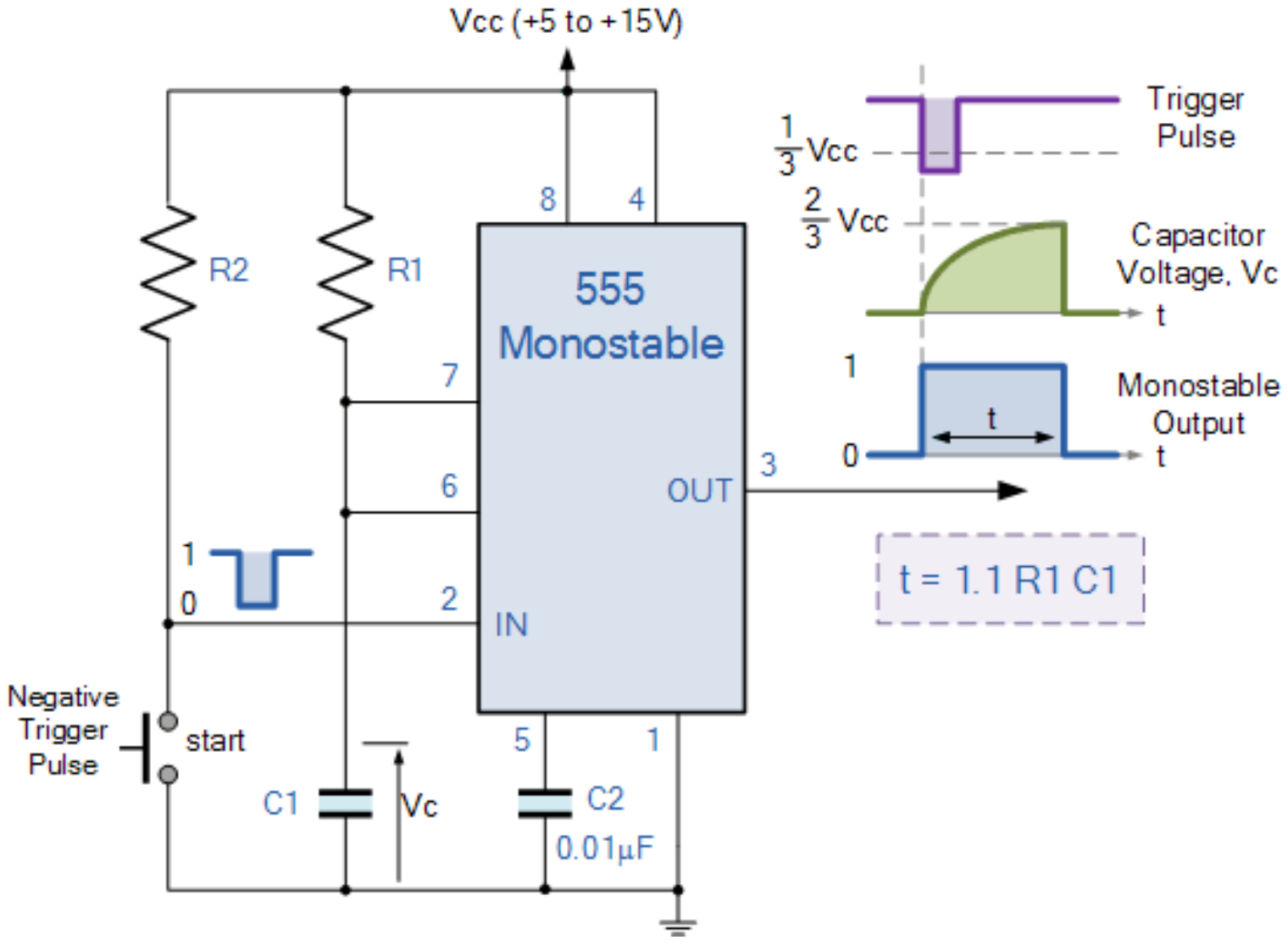



The 555 timer acts as a "one-shot" pulse generator. The pulse begins when the 555 timer receives a signal at the trigger input that falls below a third of the voltage supply. The width of the output pulse is determined by the time constant of an RC network

The output pulse ends when the voltage on the capacitor equals 2/3 of the supply voltage.

**Applications include timers, missing pulse detection, bounce free switches, touch switches, frequency divider, capacitance measurement, PWM and so on.**


Vcc (+5 to +15V)
R2
R1
8
4
555
Monostable
7
6
OUT
3
1
0
2
IN
Negative
Trigger
Pulse
start
C1
Vc
5
1
C2
0.01µF
1/3 Vcc
2/3 Vcc
Trigger
Pulse
Capacitor
Voltage, Vc
t
1
0
t
Monostable
Output
t
t = 1.1 R1 C1

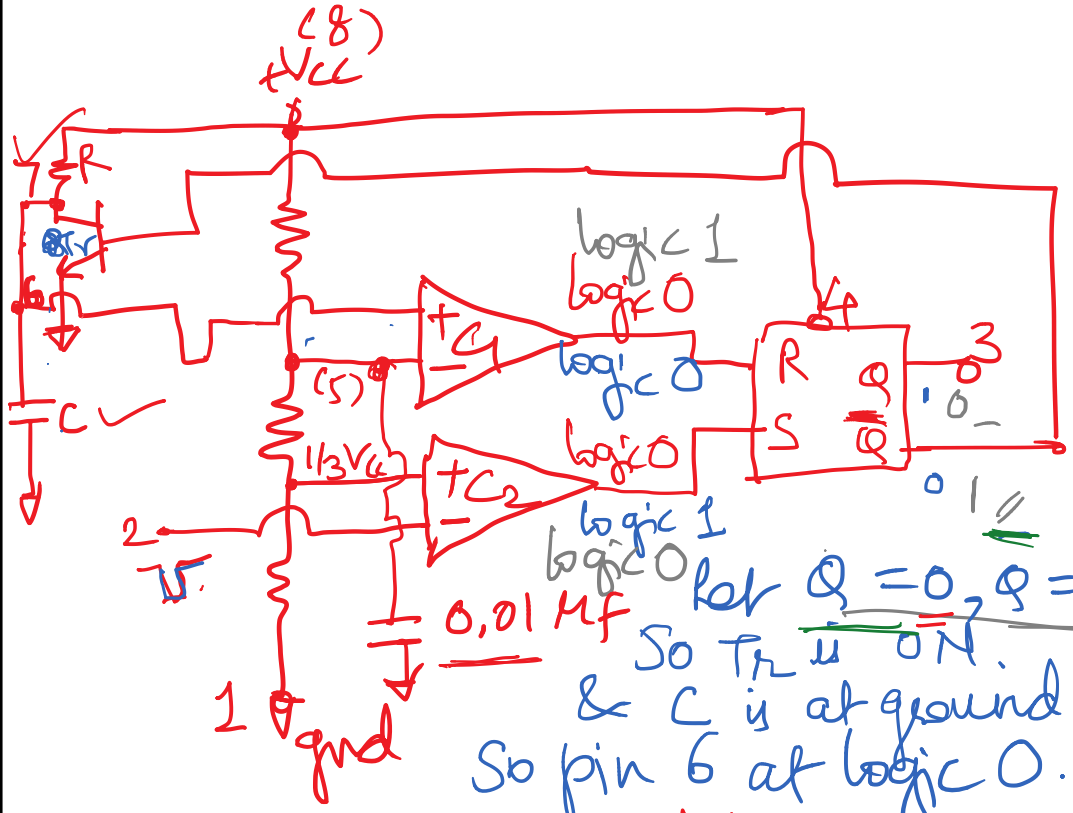
- When a negative ( 0V ) pulse is applied to the trigger input (pin 2) of the Monostable configured 555 Timer oscillator, the internal comparator, (comparator No1) detects this input and “sets” the state of the flip-flop, changing the output from a “LOW” state to a “HIGH” state. This action in turn turns “OFF” the discharge transistor connected to pin 7, thereby removing the short circuit across the external timing capacitor, C1.
- This action allows the timing capacitor to start to charge up through resistor, R1 until the voltage across the capacitor reaches the threshold (pin 6) voltage of 2/3Vcc set up by the internal voltage divider network. At this point the comparators output goes “HIGH” and “resets” the flip-flop back to its original state which in turn turns “ON” the transistor and discharges the capacitor to ground through pin 7. This causes the output to change its state back to the original stable “LOW” value awaiting another trigger pulse to start the timing process over again. Then as before, the Monostable Multivibrator has only “ONE” stable state.

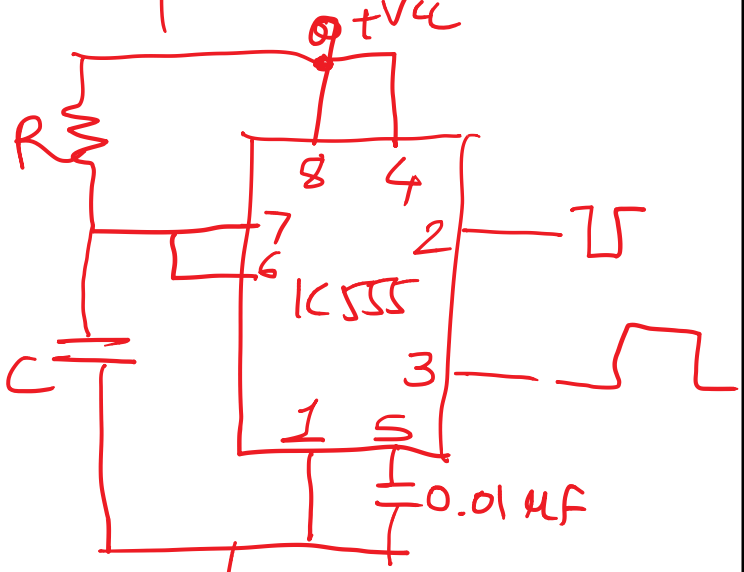
The **Monostable 555 Timer** circuit triggers on a negative-going pulse applied to pin 2 and this trigger pulse must be much shorter than the output pulse width allowing time for the timing capacitor to charge and then discharge fully. Once triggered, the 555 Monostable will remain in this "HIGH" unstable output state until the time period set up by the $R_1$ x $C_1$ network has elapsed. The amount of time that the output voltage remains "HIGH" or at a logic "1" level, is given by the following time constant equation.

$$\tau = 1.1 R_1 C_1$$

Where, t is in seconds, R is in Ω and C in Farads.

# Internal Circuit for Monostable Operation -




for Q = 0, $\bar{Q}$ = 1

So Tr is ON.

& C is at ground.

So pin 6 at logic 0 ∴ O/P of $C_1$ is at logic 0.

If no trigger signal is applied at pin 2, so pin 2 is at +Vcc.

So O/P of $C_2$ is at logic 0.

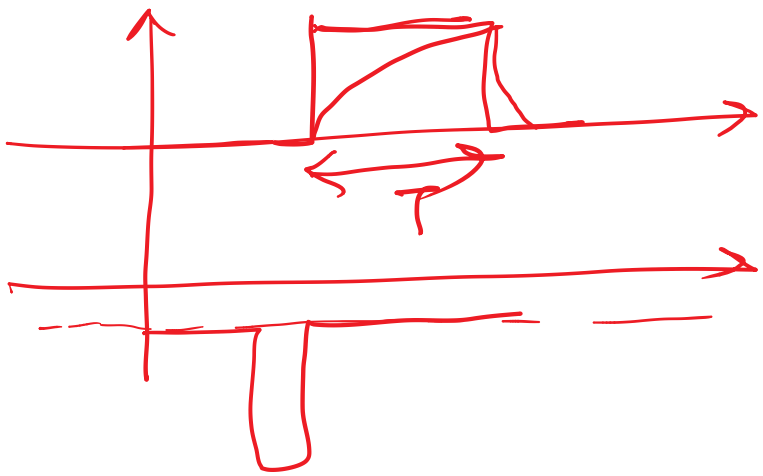
∴ S = 0, R = 0, So O/P is same as previous O/P.

In Monostable mode.

* Now if trigger signal is applied
o/p at pin 2 goes below reference voltage ($\frac{1}{3}V_{cc}$)
So o/p of $C_2$ is at logic 1.
*Since $\bar{Q} = 1$, pin 6 is at logic '0'.
∴ o/p of $C_1$ is at logic '0'.
∴ $R = 0$, $S = 1$, So $Q = 1$, $\bar{Q} = 0$
So ∵ $\bar{Q} = 0$, transistor will switch off
& capacitor C will start charging through $V_{cc}$ & $R_1$.
After triggering action, voltage at pin 2 is $+V_{cc}$
So o/p of $C_2 = 0$.
& when pin 6 becomes more positive than $\frac{2}{3}V_{cc}$,
o/p of $C_1$ is '1' ∴ $R = 1$, $S = 0$ ∴ $Q = 0$, $\bar{Q} = 1$

When O|P reaches zero, C will discharge through transistor.

Duration of pulse depends on charging of C.




$T = 1.1RC$

Depends on value of R & C as well as threshold voltage.

- An astable multivibrator , often called a free running multivibrator is a rectangular wave generating circuit.
- Unlike monostable multivibrator , this circuit does not require an external trigger to change the state of the output , hence the name free-running.
- However the time during which the output is either high or low is determined by the two resistors and a capacitor, which are externally connected to 555 timer.

- Initially, when the poutput is high, capacitor C starts charging toward Vcc through R1 and R2.
- However as soon as voltage across the capacitor equals 2/3 Vcc, camparator 1 triggers the flip flop, and the output switches low.
- Now capacitor C starts discharging through R2 and transistor Q1.
- When the voltage across C equals 1/3Vcc, comparator 2's output triggers the flip flop, and the output goes high. Then the cycle repeats.
- The capacitor is periodically charged and discharged between 2/3Vcc and 1/3Vcc, respectively. The time during which the capacitor charges from 1/3 Vcc to 2/3 Vcc is equal to the time the output is high. Similarly the time during which the capacitor discharges from 2/3Vcc to 1/3Vcc is equal to the time the output is low.
- Both are given as

$$t_1 = 0.693(R_1 + R_2).C$$

and

$$t_2 = 0.693 \times R_2 \times C$$

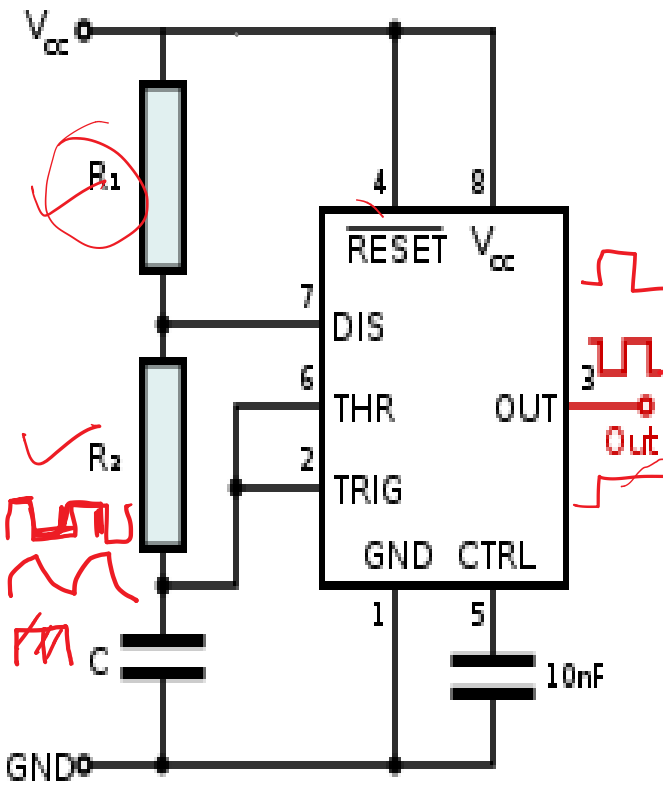
- Where R1,R2 are in ohms, C is in farads.
- The total period of the output waveform is

$$\mathbf{T = t1 + t2 = 0.693\ (R_1 + 2R_2)\ C}$$

- Frequency of oscillation is

$$\mathbf{f = 1/T = 1.44/\ (R_1 + 2R_2)C}$$

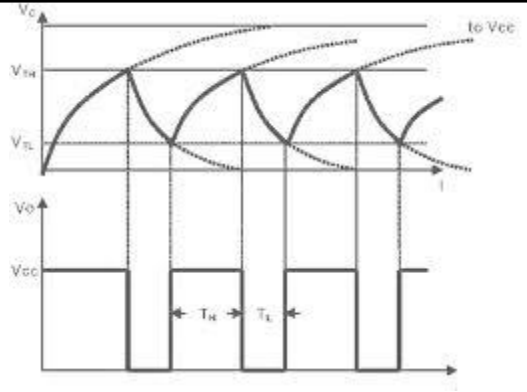
- **ASTABLE MODE**




C → charging R1 & R2
→ discharging through R2

**In astable mode, the 555 timer puts out a continuous stream of rectangular pulses having a specified frequency. Resistor R1 is connected between VCC and the discharge pin (pin 7) and another resistor (R2) is connected between the discharge pin (pin 7), and the trigger (pin 2) and threshold (pin 6) pins that share a common node. Hence the capacitor is charged through R1 and R2, and discharged only through R2, since pin 7 has low impedance to ground during output low intervals of the cycle, therefore discharging the capacitor.**

**In the astable mode, the frequency of the pulse stream depends on the values of R1, R2 and C:**



**Uses include LED and lamp flashers, pulse generation, logic clocks, tone generation, security alarms, PPM**

$$T_{ON} = t_1 = 0.693(R_1 + R_2).C$$

and

$$t_2 = 0.693 \times R_2 \times C$$

**$T = t1 + t2 = 0.693\ (R_1 + 2R_2)\ C$**

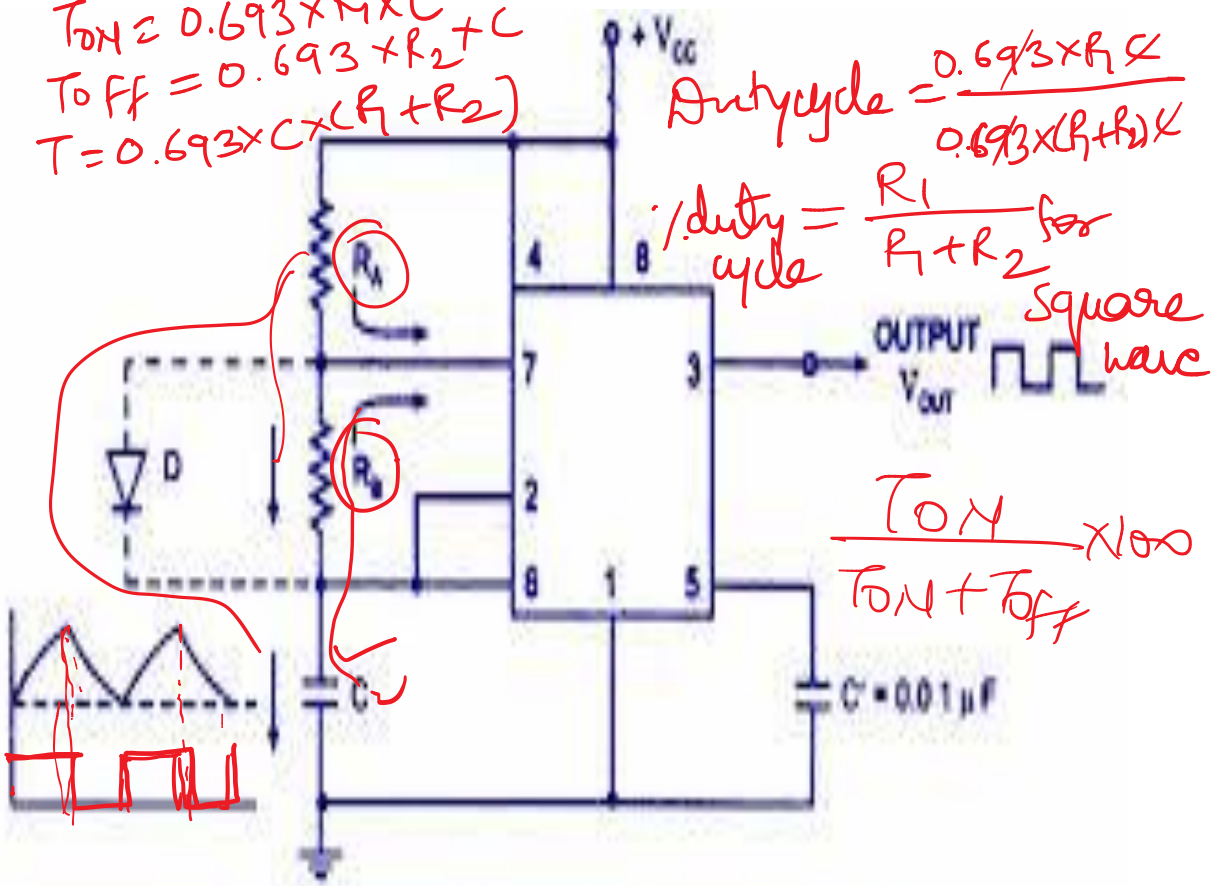
**$f = 1/T = 1.44/\ (R_1 + 2R_2)C$**

Duty cycle is the ratio of time t1 during which output is high to the total time period T. It is expressed in percentage.

**% Duty cycle = R1+R2/(R1+2R2) x 100**

The duty cycle of the square wave is 50%.
According to this, for square wave, R1 should be equal to zero.
But with R1=0, terminal 7 is directly connected to +Vcc.
When capacitor discharges through R2 and Q1 (pin 7), an extra current is supplied to Q1 by Vcc through a short between 7 and +Vcc.
This may damage Q1 and then Timer IC.

# Astable multivibrator as square wave oscillator




Circuit of The Timer 555 as an Astable Multivibrator

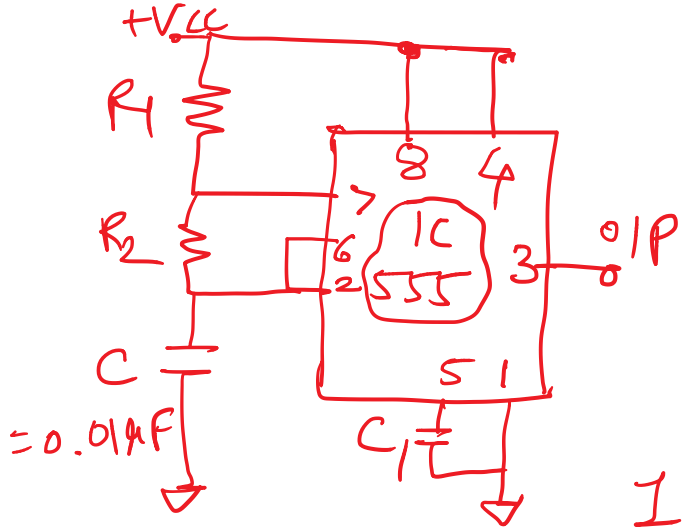
Without reducing R1-0, square wave can be generated.

A diode is connected across RB.

Capacitor C charges through RA and diode D upto 2/3VCC and discharges through RB and terminal 7 (Q1) until capacitor voltage is approximately 1/3Vcc.

To obtain a square wave output (50% duty cycle), RA must be a combination of fixed resistor and potentiometer so that potentiometer can be adjusted to obtain square wave.

The timer IC 555 is used as astable multivibrator. It is designed to have a square wave output with 50% cycle of 1 kHz. The timing capacity used is 0.01 μF. Find the values of the resistors required. Draw the circuit.




$C = 0.01\,\mu F$

$f_o = 1\,kHz$

duty cycle = 50%

$R_1 = ?$

$R_2 = ?$

$$f_o = \frac{1.45}{(R_1 + 2R_2).C}$$

$$1 \times 10^3 = \frac{1.45}{(R_1 + 2R_2) \times 0.01 \times 10^{-6}}$$

$$R_1 + 2R_2 = 145 \times 10^3 \quad \text{— (1)}$$

$$\therefore \text{Duty cycle} = \frac{R_1 + R_2}{R_1 + 2R_2} \times 100$$

$$50 = \frac{R_1 + R_2}{R + 2R_2} \times 100$$

$$50 = \frac{R_1 + R_2}{145 \times 10^3} \times 100$$

$$R_1 + R_2 = 72.5 \times 10^3 \quad \text{— (2)}$$

$R_1 + 2R_2 = 145 \times 10^3$ — (1)

$R_1 + R_2 = 72.5 \times 10^3$ — (2)

Solving (1) & (2)

(1) − (2)

$$R_2 = 72.5 \times 10^3\ \Omega$$

If we choose $R_1 = 0$ it is not a feasible value

∴ For 50% duty cycle, specific formula is

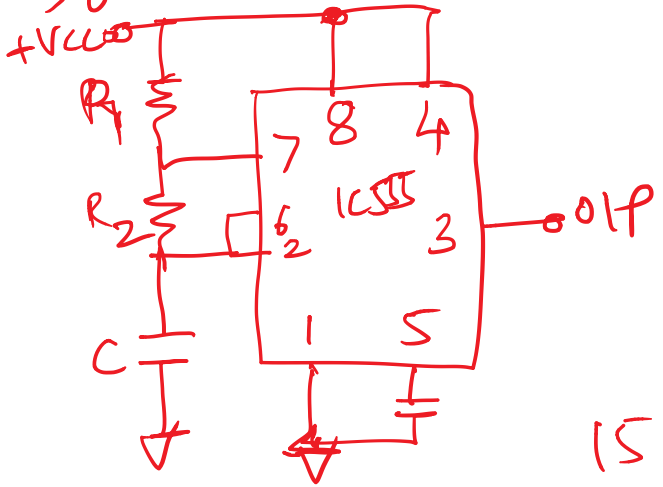
$$50 = \frac{R_1}{R_1 + R_2} \times 100$$

$$50R_1 + 50R_2 = 100R_1$$

$$R_1 = R_2$$

$$\therefore R_1 = 72.5 \times 10^3\ \Omega$$

# Design Astable Multivibrator using IC555 having $f_0 = 15\ kHz$ & 60% duty cycle.




$f_0 = 15\ kHz$

$\%D = 60\%$

$$f_0 = \frac{1.45}{(R_1 + 2R_2)C}$$

Assume $C = 0.01\ \mu F$

$$15 \times 10^3 = \frac{1.45}{(R_1 + 2R_2) \times 0.01 \times 10^{-6}}$$

$$R_1 + 2R_2 = 9.66 \times 10^3 \quad \text{---(1)}$$

$$\%D = \frac{R_1 + R_2}{R_1 + 2R_2} \times 100$$

$$60 = \frac{R_1 + R_2}{9.66 \times 10^3} \times 100$$

$R_1 + R_2 =$ ---(2)

$R_1 =$

$R_2 =$

Now find values of R1,R2 from above steps.

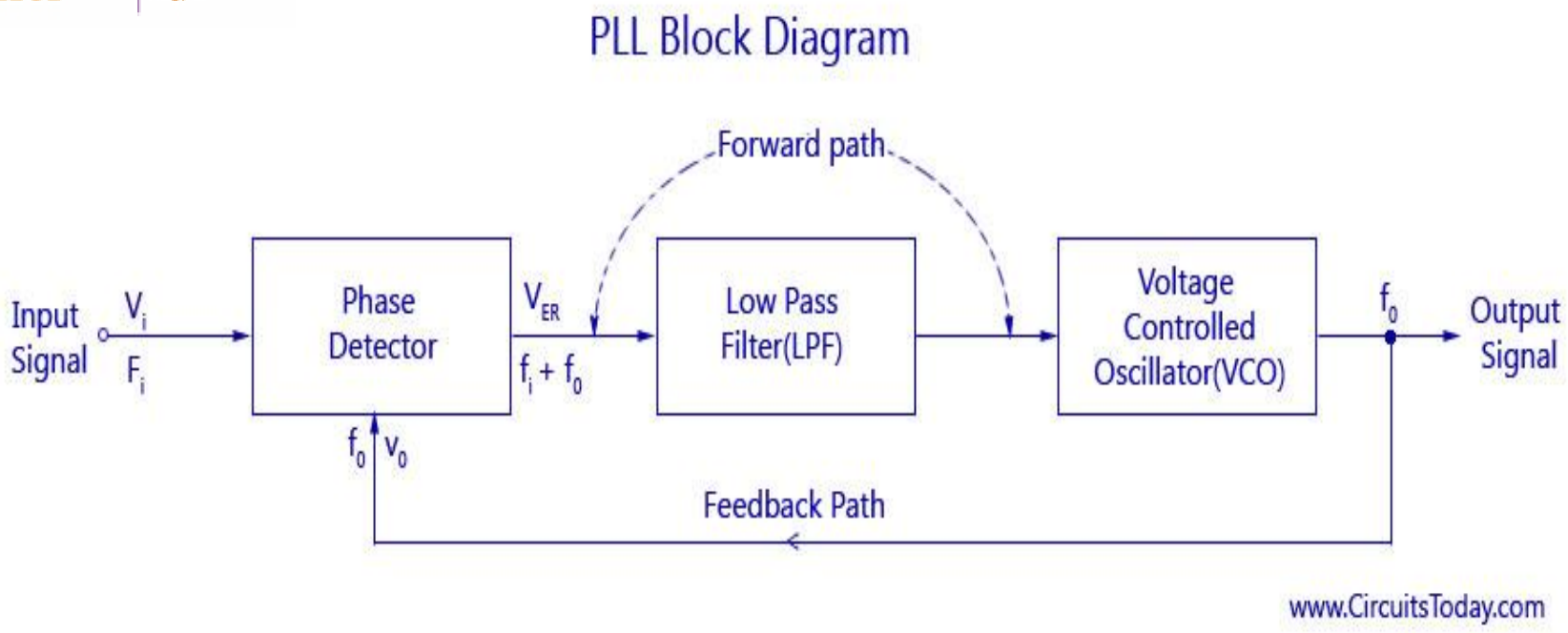
# PHASE LOCKED LOOPS

# Phase Locked Loops
## Introduction

- Phase Locked Loops consists of
- ✓ Phase Detector
- ✓ Low Pass Filter
- ✓ Voltage Controlled Oscillator

Used in

- FM Modulation, Demodulation,
- FSK,
- TV and FM Tuners
- Motor speed control




Three states of Phase Locked Loop:

✓Free Running : before the input is applied.

✓Capture : After input is applied. VCO frequency starts to change.

✓Phase lock : When VCO frequency is equal to input frequency. When phase locked, loop tracks any change in input frequency through its repetitive action.

•Phase Detector :

✓It compares the input frequency with feedback frequency .

✓Its output is proportional to phase difference between input & output frequency.

✓Output is a dc voltage.

✓The output of phase detector is applied to low pass filter

•Low Pass Filter :

✓removes high frequency noise and produces a dc level.

✓This dc output is given as input to Voltage Controlled Oscillator.

•VCO :

✓Its output frequency is directly proportional to input dc level.

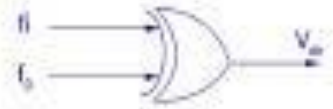
✓VCO frequency compared with input frequency and adjusted until it is equal to input frequency.

# Phase Detector



Types :

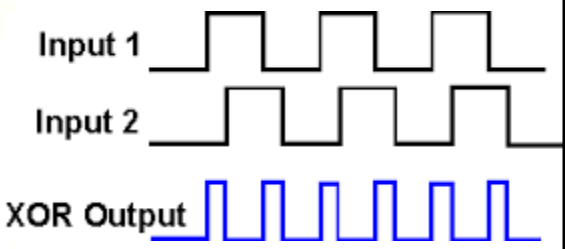
- ✓Exclusive OR
- ✓Edge Triggered
- ✓Monolithic




Exclusive - OR Phase Detector

| fi | fo | Output |
|---|---|---|
| Low | Low | Low |
| Low | High | High |
| High | Low | High |
| High | High | Low |

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•Exclusive OR Phase Detector uses Exclusive OR gate such as CMOS type 4070.

✓Ex-OR type phase detectors are used if input and output frequencies are square waves

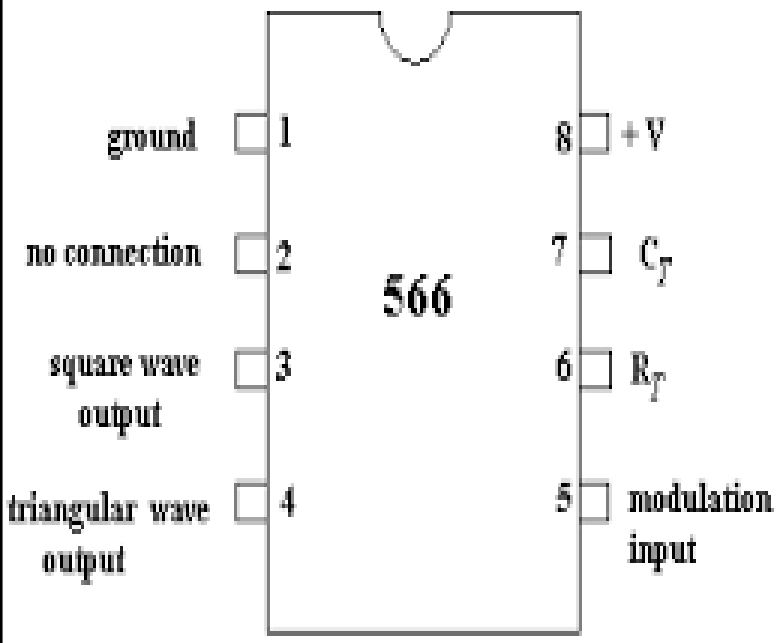
•Edge triggered phase detector is preferred if input and output frequencies are pulse waveforms with less than 50% duty cycles.

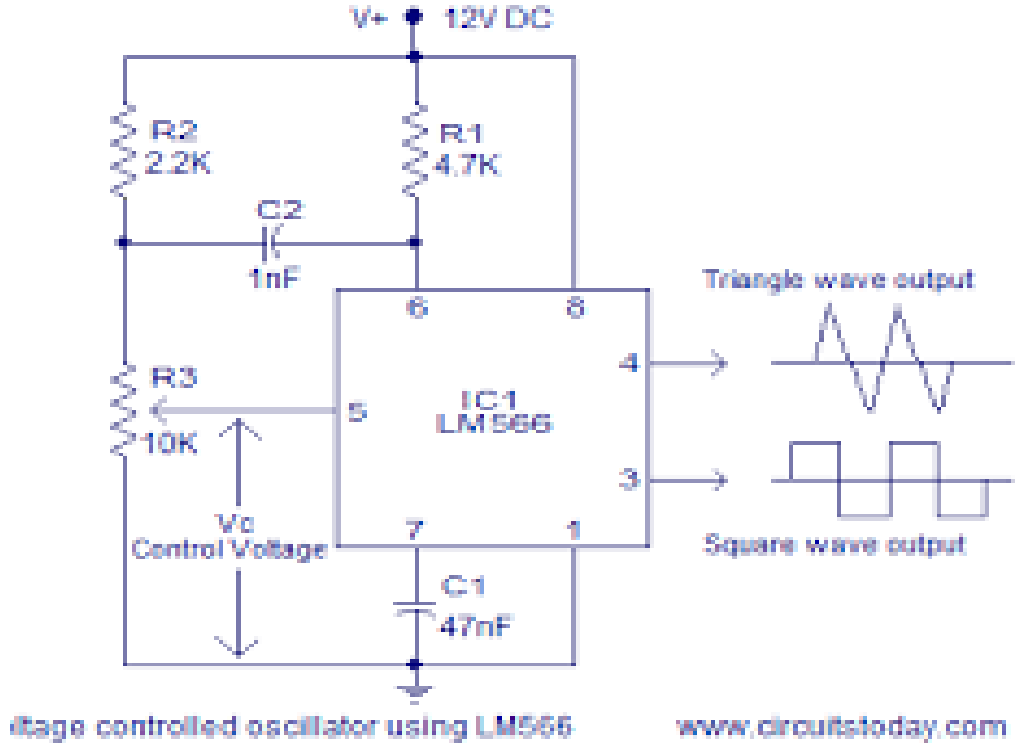
✓Uses R-S flip flop formed from a pair of cross sectional NOR gates (CD4001)

✓Exhibits better capture , tracking and locking characteristics than ex OR type.

**Both types sensitive to harmonics of input signal and changes in duty cycle. So monolithic phase detector is preferred.**

# Voltage Controlled Oscillator



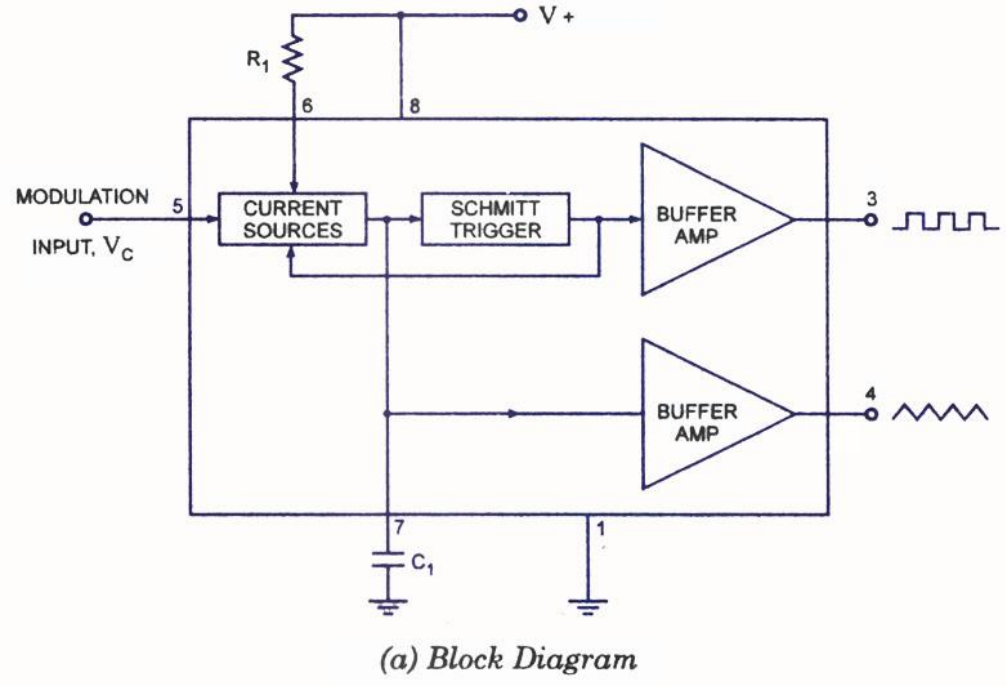




It provides simultaneous square wave and triangular wave outputs as a function of input voltage.

The frequency of oscillation is determined by external R1 and C1 and voltage Vc applied to control terminal 5.

**VCO is used in converting low frequency signals such as EEG or EKG into an audio frequency range which can then be used for diagnostic purposes.**

# Block Diagram of VCO

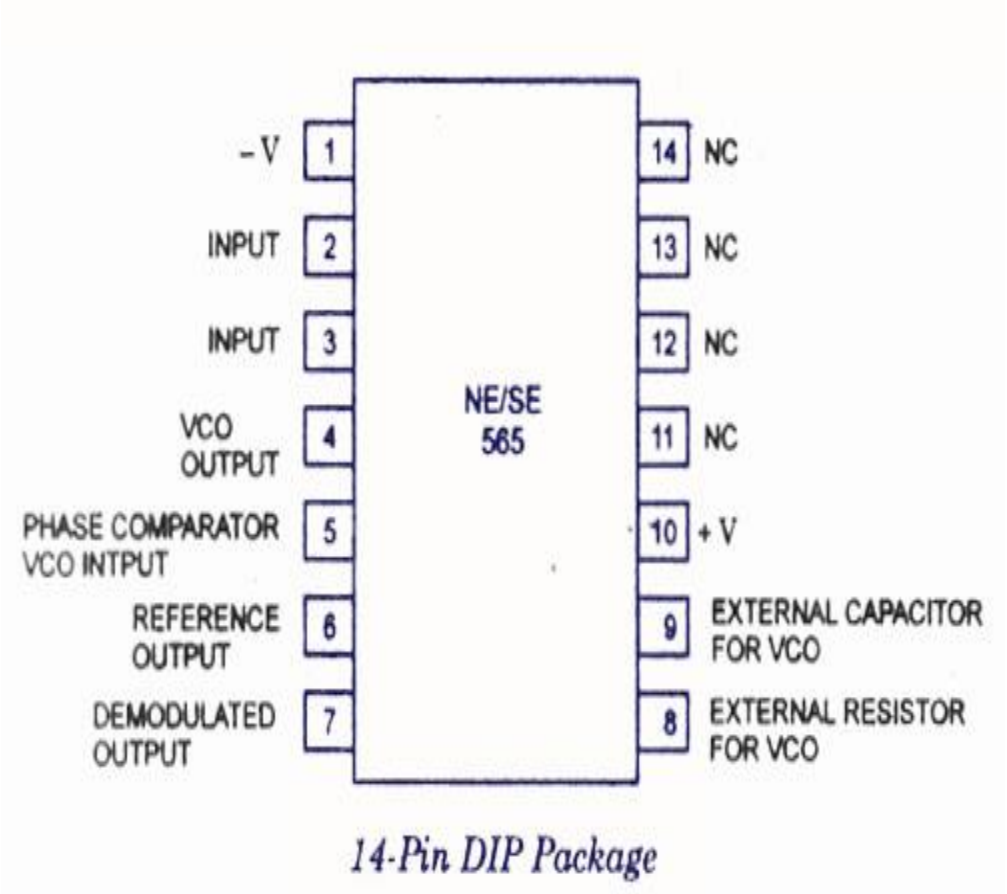



*(a) Block Diagram*

$$f_0 = 2(+V-Vc)/R1C1(+V)$$

- ✓Triangular wave is generated by alternately charging external capacitor C1 by one current source and then linearly discharging it by another.
- ✓The charge discharge levels are determined by schmitt trigger action.
- ✓Schmitt trigger also provides square wave output
- ✓Both the outputs are buffered so that output impedance of each is 50 Ω.
- ✓The typical amplitude of triangular wave is 2.4 V p-p and that of the square wave is 5.4 V p-p.

# IC 565 PLL




*14-Pin DIP Package*

Available in 14-pin DIP package and 10-pin metal can package.

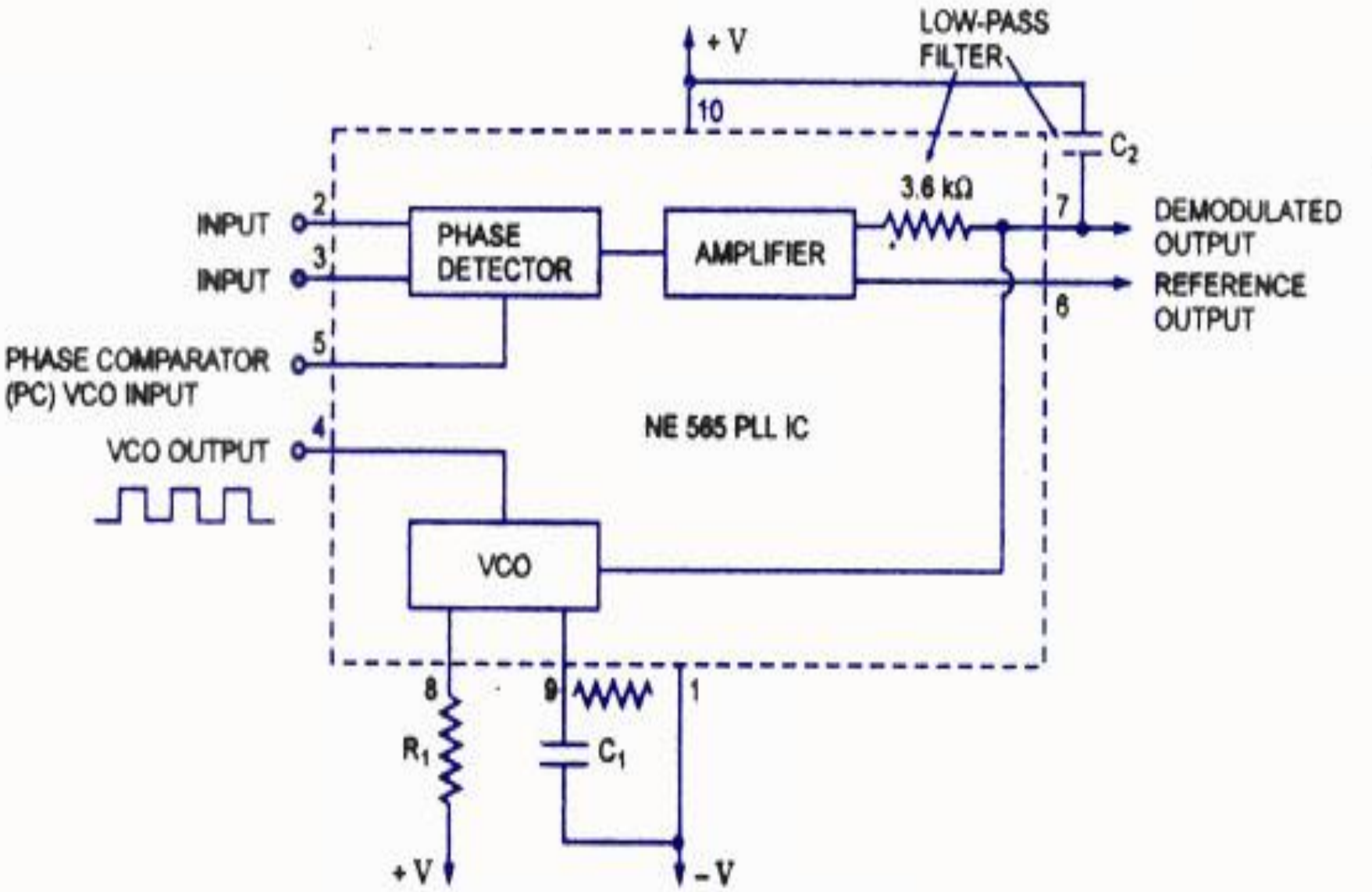
Signetics 560 series – Monolithic PLL

SE/NE 560, 561, 562,564,565,567 differ mainly in

- ✓**operating frequency range**
- ✓ **power supply requirements**
- ✓**frequency**
- ✓ **bandwidth adjustment range.**

**565- one of the most commonly used devices of 560 series.**

# Block Diagram of PLL 565



# PLL Contd…..

✓The VCO free-running frequency $F_{OUT}$ is adjusted externally with R1 & C1 to be at the center of the input frequency range.

✓ C1 can be any value, R1 must have a value between 2 K ohms and 20 K ohms.

✓Capacitor C2 connected between 7 & +V.

✓The filter capacitor C2 should be large enough to eliminate variations in the demodulated output voltage in order to stabilize the VCO frequency.

# PLL Contd.....

Center Frequency of PLL is determined by free running frequency of VCO.

$$\mathbf{F_{OUT} = 1.2/4R1C1\ Hz}$$

565 PLL can lock to and track an input signal over typically ±60% bandwidth w.r.t. $F_{OUT}$ as the center frequency.

The lock range and capture range are given by

$$\mathbf{F_L = \pm 8\ F_{OUT}/V \quad Hz}$$

where $\mathbf{V = (+V) - (-V)\ volt}$

$$\mathbf{Fc = \pm [fL/(2\pi)(3.6)(10^3)(C2)]^{1/2}}$$ where C2 is in farads.

# PLL Contd…….

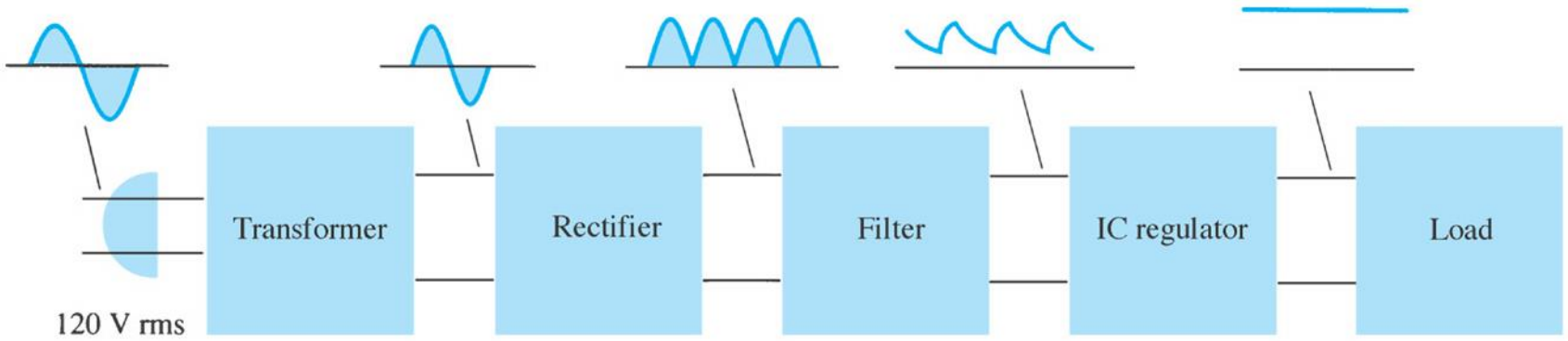
The important electrical characteristics of the 565 PLL are:

- ✓Operating frequency range: 0.001Hz to 500 Khz
- ✓Operating voltage range: ±6 to ±12v
- ✓Input level required for tracking: 10mv rms min to 3 Vpp max
- ✓ Input impedance: 10 K ohms typically
- ✓Output sink current: 1mA
- ✓Output source current: 10 mA

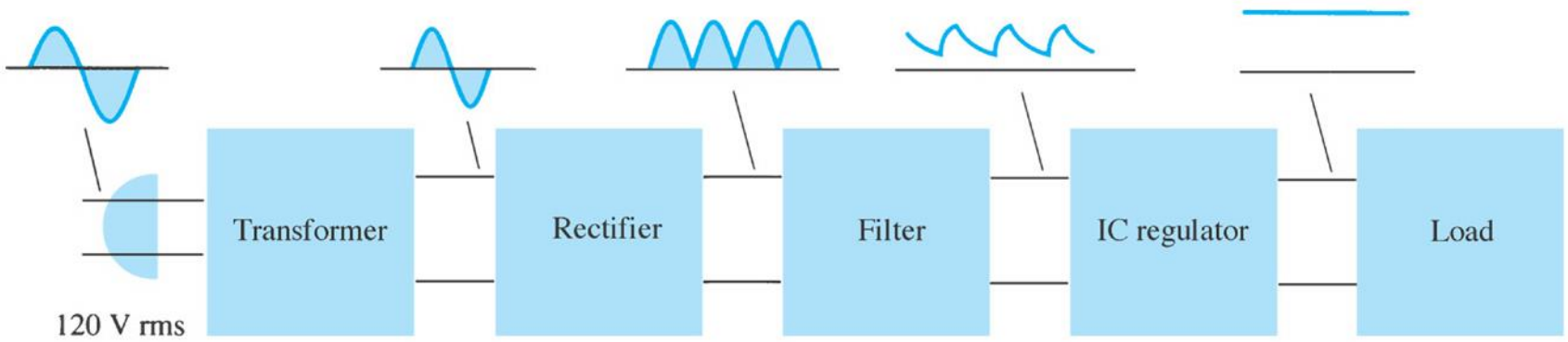
# Voltage Regulators

# Introduction

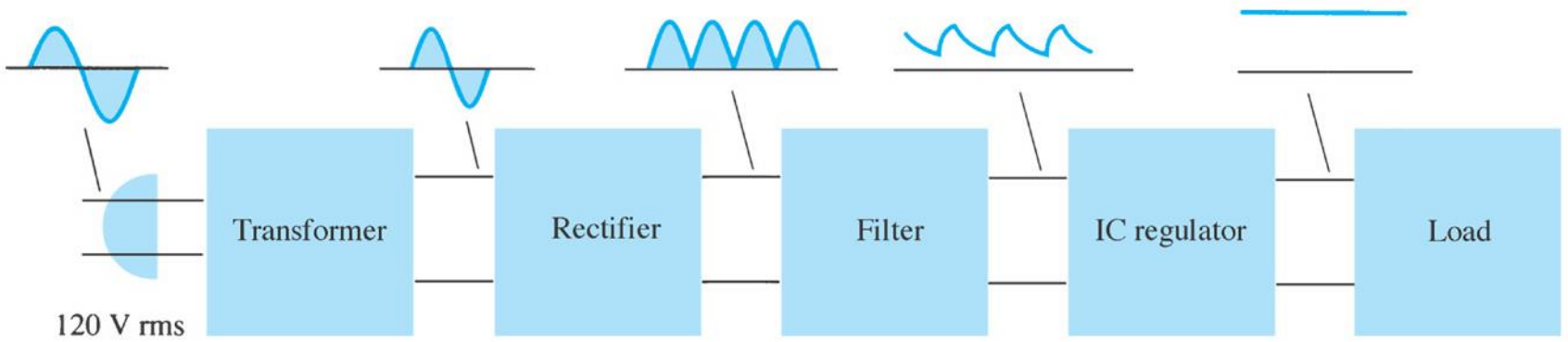
- Batteries are often shown on a schematic diagram as the source of DC voltage but usually the actual DC voltage source is a power supply.
- There are many types of power supply. Most are designed to convert high voltage AC mains electricity to a suitable low voltage supply for electronics circuits and other devices.
- A more reliable method of obtaining DC power is to transform, rectify, filter and regulate an AC line voltage.
- A power supply can by broken down into a series of blocks, each of which performs a particular function.



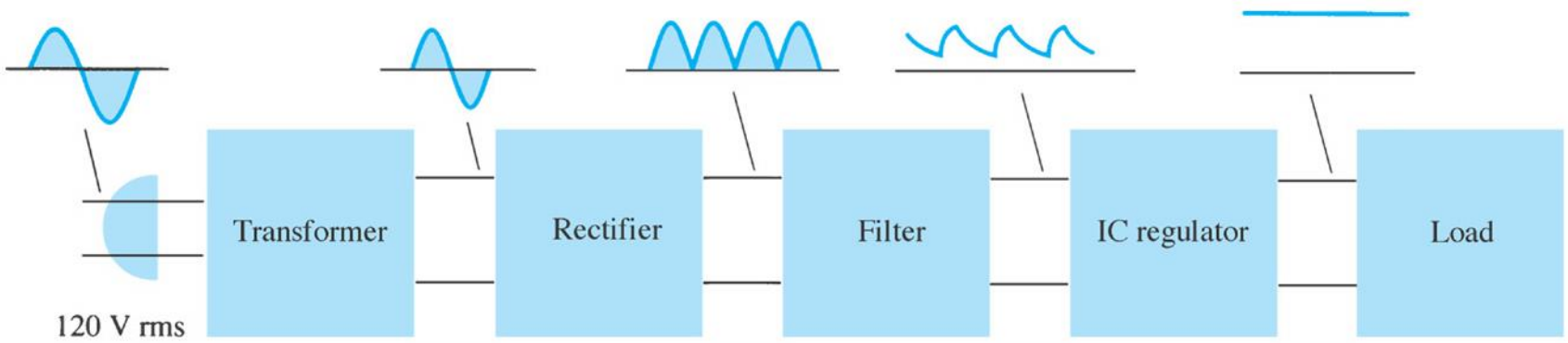

- ***Power supply***: a group of circuits that convert the ***standard ac voltage*** (120 V, 60 Hz) provided by the wall outlet to ***constant dc voltage***
- ***Transformer*** : a device that step up or step down the ***ac voltage*** provided by the wall outlet to a desired amplitude through the *action* of a *magnetic field*




- ***Rectifier***: a diode circuits that converts the ***ac input voltage*** to a ***pulsating dc voltage***
- The pulsating dc voltage is **only suitable** to be used as a battery charger, but **not good enough** to be used as a dc power supply in a radio, stereo system, computer and so on.




- There are two basic types of rectifier circuits:
  - Half-wave rectifier
  - Full-wave rectifier - Center-tapped & Bridge full-wave rectifier
- In summary, a full-wave rectified signal has **less ripple** than a half-wave rectified signal and is thus better to apply to a filter.




- ***Filter***: a circuit used to reduce the fluctuation in the rectified output voltage or ripple. This provides a ***steadier*** dc voltage.
- ***Regulator***: a circuit used to produce a ***constant*** dc output voltage by reducing the ripple to negligible amount. One part of power supply.

# IC Voltage Regulators

- Regulation circuits in integrated circuit form are widely used.
- Their operation is no different but they are treated as a single device with associated components.
- These are generally three terminal devices that provide a positive or negative output.
- Some types have variable voltage outputs.
- A typical 7800 series voltage regulator is used for positive voltages.
- The 7900 series are negative voltage regulators.
- These voltage regulators when used with heatsinks can safely produce current values of 1A and greater.
- The capacitors act as line filtration.

# IC Voltage Regulators

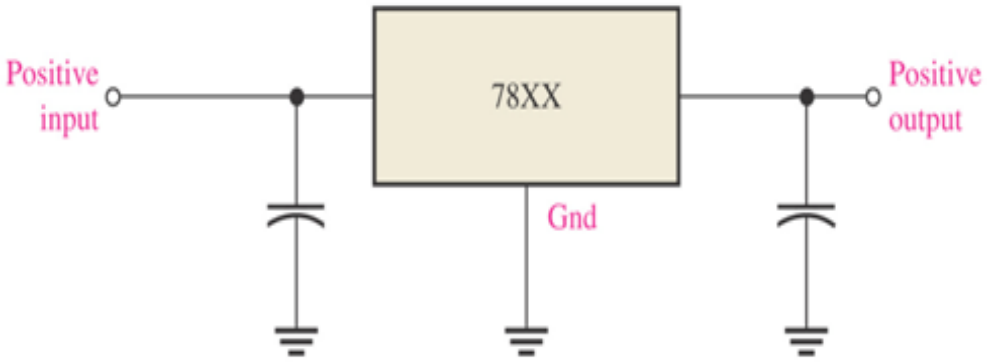
- Several types of both linear (series and shunt) and switching regulators are available in integrated circuit (IC) form.
- Single IC regulators contain the circuitry for:
  (1) reference source
  (2) comparator amplifier
  (3) control device
  (4) overload protection
- Generally, the linear regulators are three-terminal devices that provides either positive or negative output voltages that can be either fixed or adjustable.

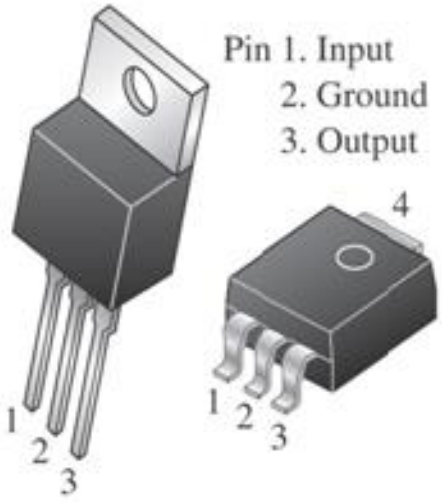
# Fixed Voltage Regulator

- The fixed voltage regulator has an unregulated dc input voltage $V_i$ applied to one input terminal, a regulated output dc voltage $V_o$ from a second terminal, and the third terminal connected to ground.

## Fixed-Positive Voltage Regulator

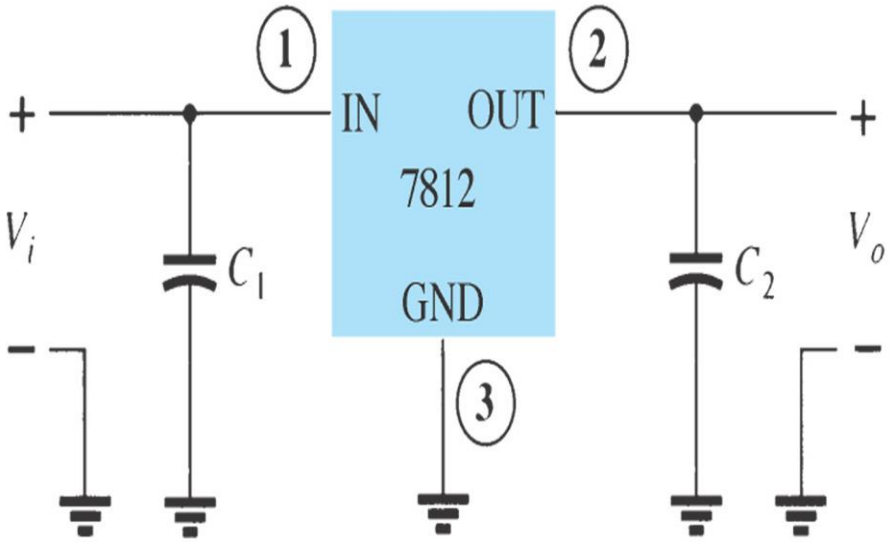
- The series 78XX regulators are the three-terminal devices that provide a fixed positive output voltage.



# Fixed Voltage Regulator

- An unregulated input voltage $V_i$ is filtered by a capacitor $C_1$ and connected to the IC's IN terminal.
- The IC's OUT terminal provides a regulated +12 V, which is filtered by capacitor $C_2$.
- The third IC terminal is connected to ground (GND)



# Fixed Voltage Regulator

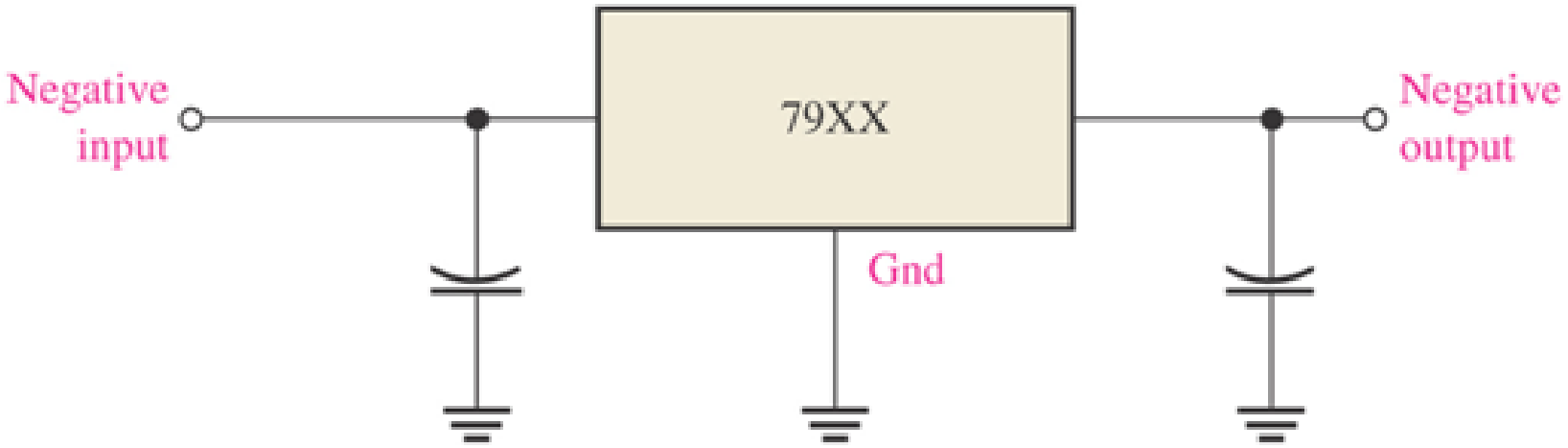
**Positive-Voltage** Regulators in the 78XX Series

| IC Part | Output Voltage (V) | Minimum $V_i$ (V) |
|---|---|---|
| 7805 | +5 | +7.3 |
| 7806 | +6 | +8.3 |
| 7808 | +8 | +10.5 |
| 7810 | +10 | +12.5 |
| 7812 | +12 | +14.5 |
| 7815 | +15 | +17.7 |
| 7818 | +18 | +21.0 |
| 7824 | +24 | +27.1 |

# Fixed Voltage Regulator

## Fixed-Negative Voltage Regulator

- The series 79XX regulators are the three-terminal IC regulators that provide a fixed negative output voltage.
- This series has the same features and characteristics as the series 78XX regulators except the pin numbers are different.



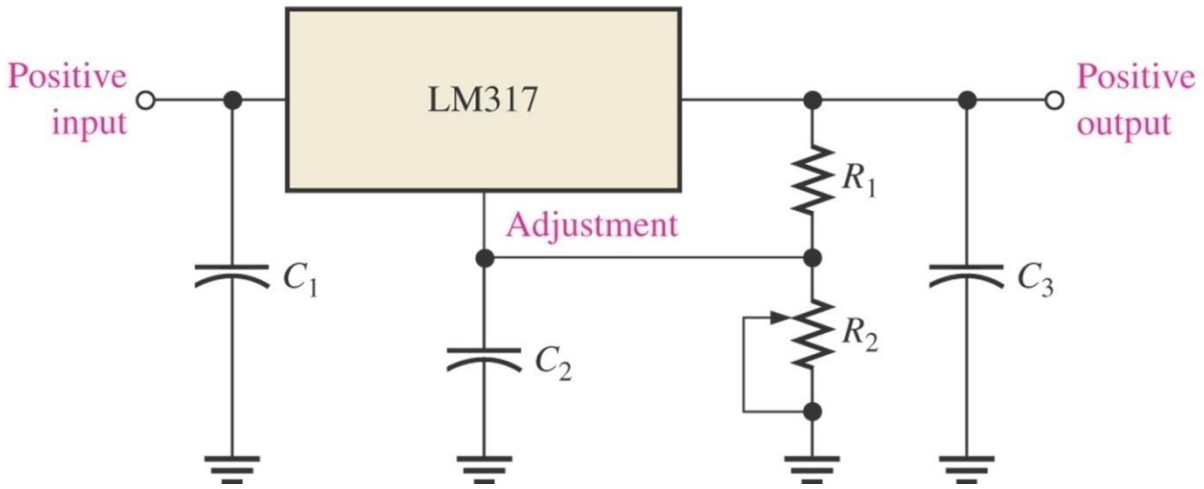
# Fixed Voltage Regulator

**Negative-Voltage** Regulators in the 79XX Series

| IC Part | Output Voltage (V) | Minimum $V_i$ (V) |
|---|---|---|
| 7905 | -5 | -7.3 |
| 7906 | -6 | -8.4 |
| 7908 | -8 | -10.5 |
| 7909 | -9 | -11.5 |
| 7912 | -12 | -14.6 |
| 7915 | -15 | -17.7 |
| 7918 | -18 | -20.8 |
| 7924 | -24 | -27.1 |

# Adjustable-Voltage Regulator

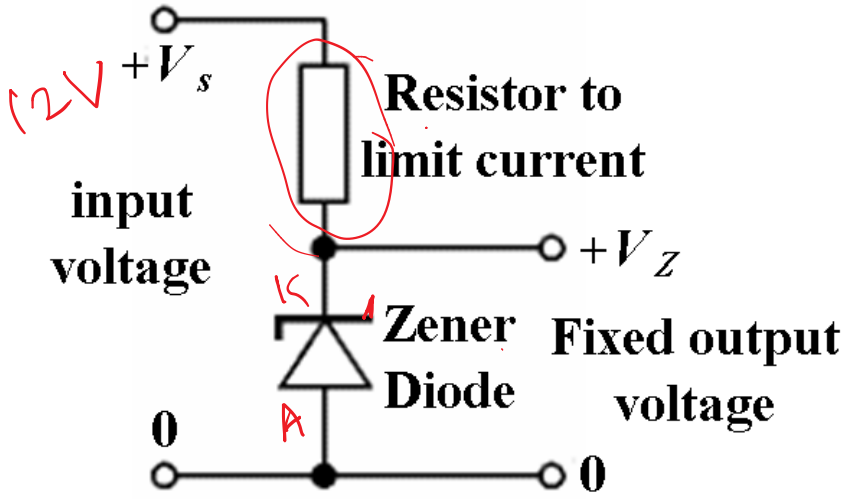
- Voltage regulators are also available in circuit configurations that allow to set the output voltage to a desired regulated value.
- The LM317 is an example of an adjustable-voltage regulator, can be operated over the range of voltage from 1.2 to 37 V.



***Regulator*** - Zener diode regulator

- For low current power supplies - a simple voltage regulator can be made with a resistor and a zener diode connected in reverse.
- Zener diodes are rated by their breakdown voltage $V_z$ and maximum power $P_z$ (typically 400mW or 1.3W)



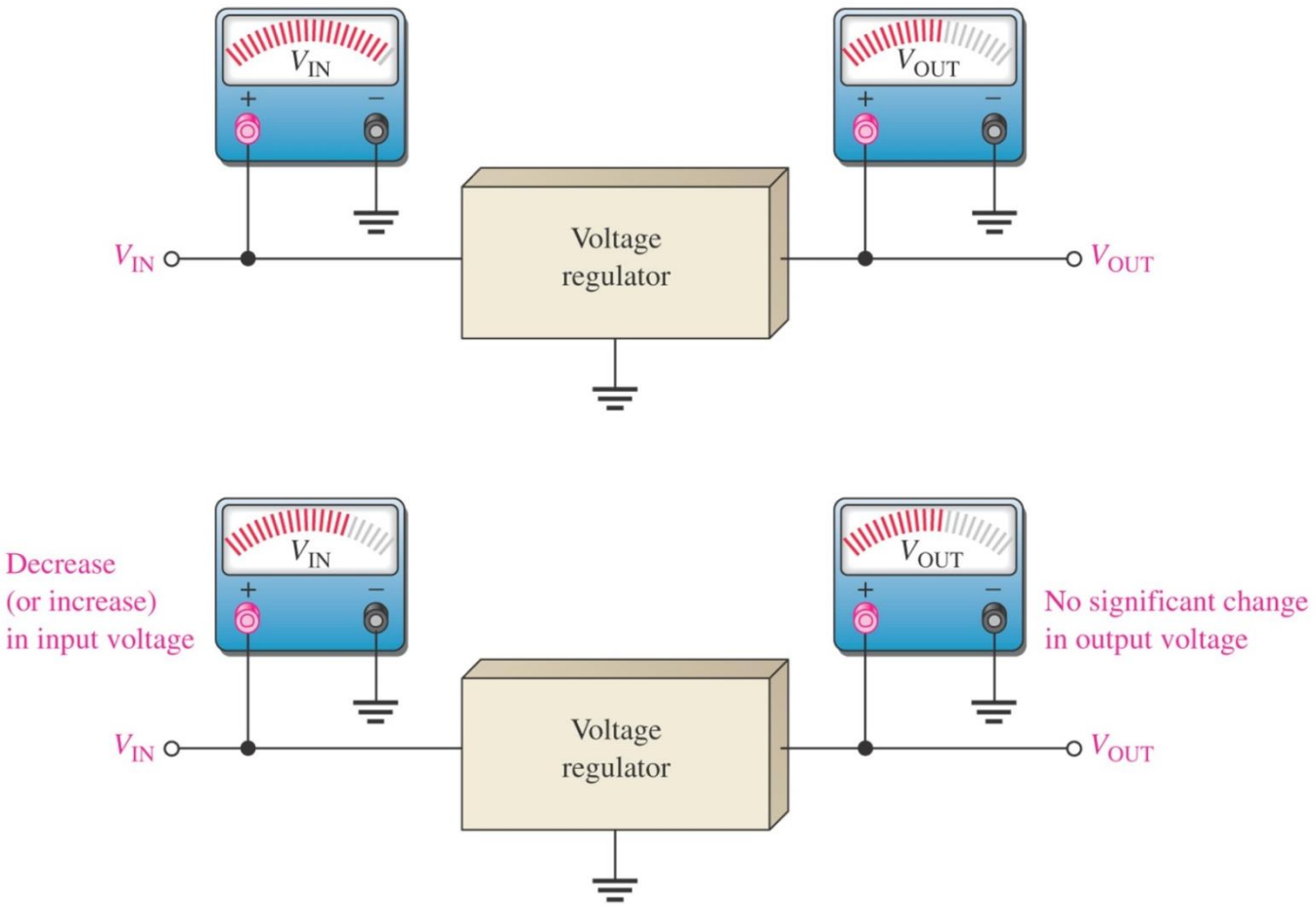
# Voltage Regulation



- Two basic categories of voltage regulation are:
  - line regulation
  - load regulation

- The purpose of **line regulation** is to maintain a nearly constant output voltage when the **input voltage** varies.
- The purpose of **load regulation** is to maintain a nearly constant output voltage when the **load** varies

# Line Regulation




Line regulation: A change in input (line) voltage does not significantly affect the output voltage of a regulator (within certain limits)

# Line Regulation

- Line regulation can be defined as the percentage change in the output voltage for a given change in the input voltage.

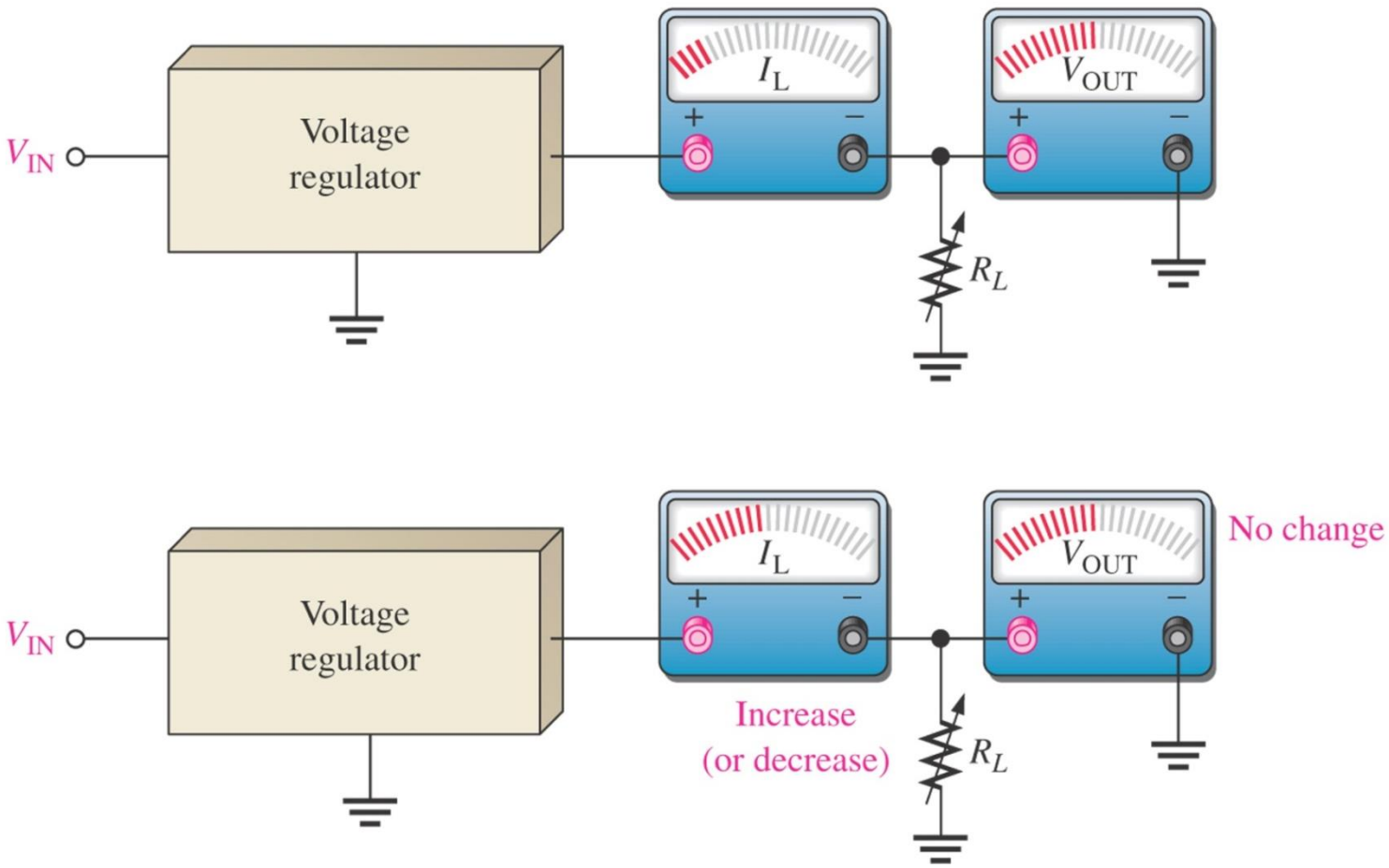
$$Line\ regulation = \left( \frac{\Delta V_{OUT}}{\Delta V_{IN}} \right) \times 100\%$$

$\Delta$ means "a change in"

- Line regulation can be calculated using the following formula:

$$Line\ regulation = \frac{\left( \Delta V_{OUT} / V_{OUT} \right) \times 100\%}{\Delta V_{IN}}$$

# Load Regulation




Load regulation: A change in load current (due to a varying $R_L$) has practically no effect on the output voltage of a regulator (within certain limits)

# Load Regulation

- Load regulation can be defined as the percentage change in the output voltage from no-load (NL) to full-load (FL).

$$Load\ regulation = \left( \frac{V_{NL} - V_{FL}}{V_{FL}} \right) \times 100\%$$

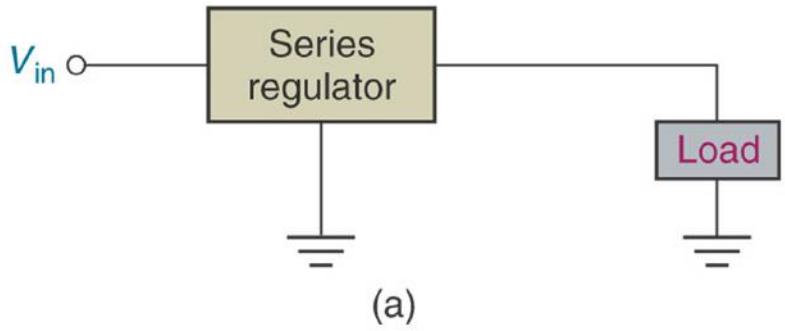
- Where:

  $V_{NL}$ = the no-load output voltage

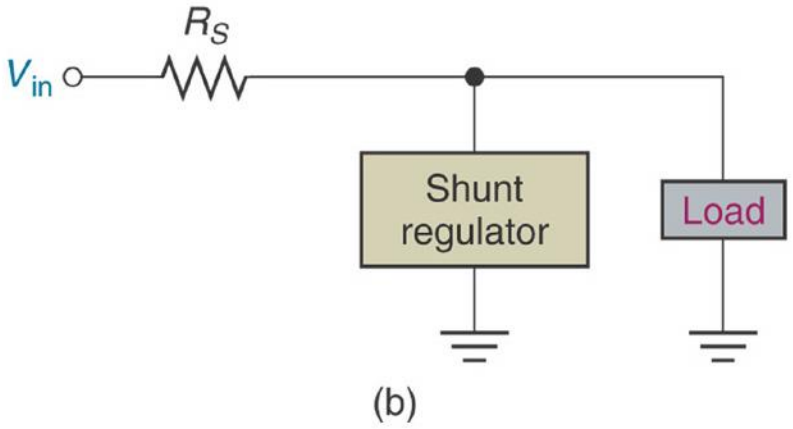
  $V_{FL}$ = the full-load output voltage

# Types of Regulators

- Fundamental classes of voltage regulators are **linear regulators** and **switching regulators**.
- Two basic types of linear regulator are the **series regulator** and the **shunt regulator** .
- The series regulator is connected in **series** with the load and the shunt regulator is connected in **parallel** with the load.



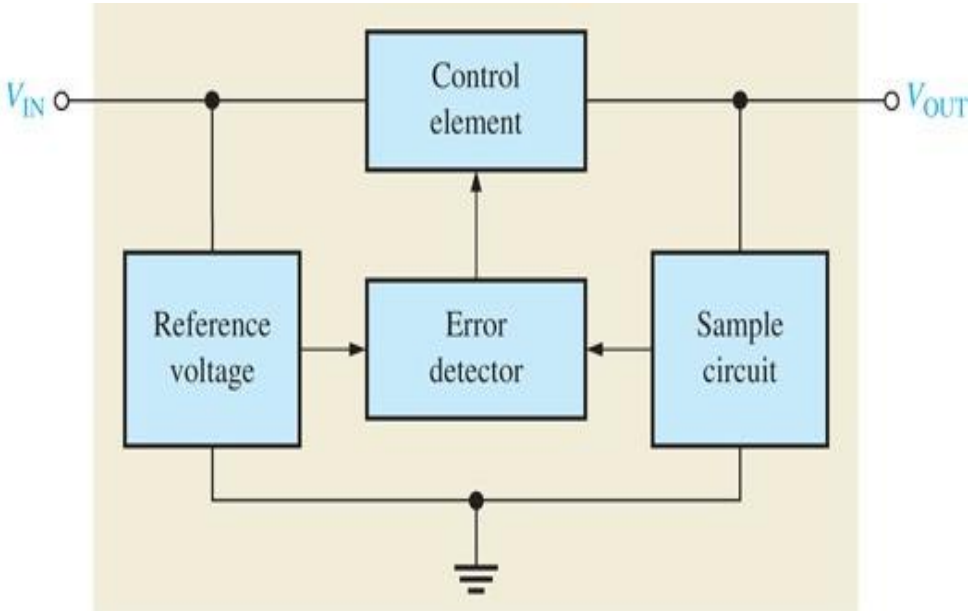

(a)




(b)

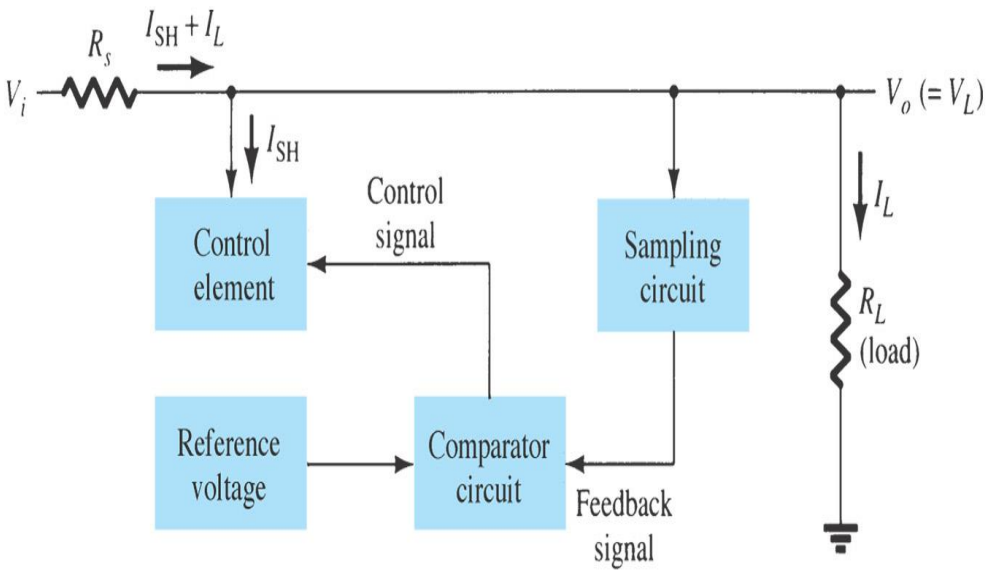
# Series Regulator Circuit

- **Control element** in series with load between input and output.
- Output **sample circuit** senses a change in output voltage.
- **Error detector** compares sample voltage with reference voltage → causes control element to compensate in order to maintain a constant output voltage.



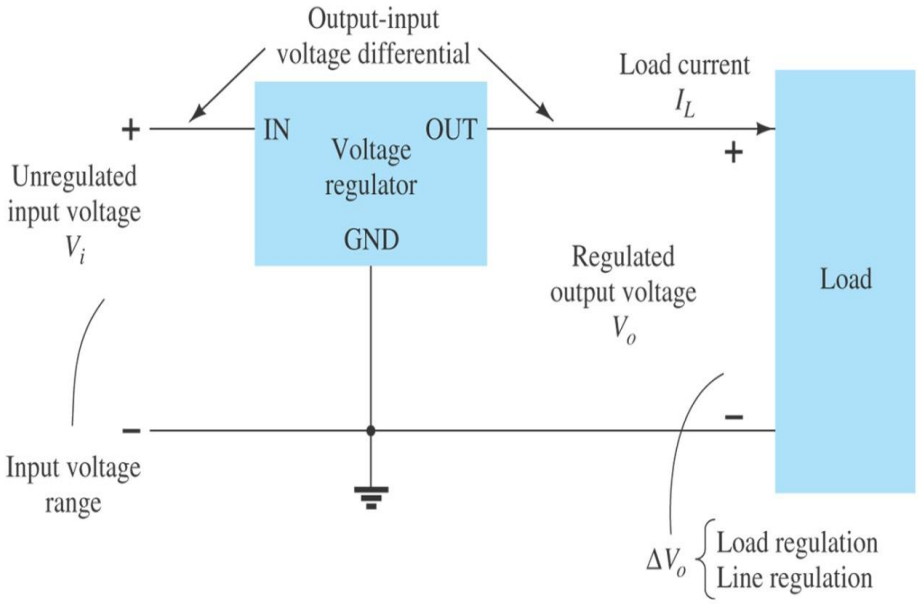
# Shunt Regulator Circuit

- The unregulated input voltage provides current to the load.
- Some of the current is pulled away by the **control element**.
- If the load voltage tries to change due to a change in the load resistance, the **sampling circuit** provides a feedback signal to a **comparator**.
- The resulting difference voltage then provides a control signal to vary the amount of the current shunted away from the load to maintain the regulated output voltage across the load.



# Switching Regulator

- The switching regulator is a type of regulator circuit which its efficient transfer of power to the load is greater than series and shunt regulators because the transistor is not always conducting.
- The switching regulator passes voltage to the load in pulses, which then filtered to provide a smooth dc voltage.



Switch Mode Power Supply (SMPS) or Switching Regulators :

⇒ limitations of ~~Seri~~ linear Regulators -

1) Because of use of transformer, the circuit becomes bulky

2) Since the frequency is 50 Hz, filter capacitor of large values are required to reduce the ripples (ac component present in dc signal output)

# Switching Regulator

Switching Mode Power Supply (SMPS)

- The switching regulator is **more efficient** than the linear series or shunt type.
- This type regulator is ideal for high current applications since less power is dissipated.
- Voltage regulation in a switching regulator is achieved by the on and off action limiting the amount of current flow based on the varying line and load conditions.
- With switching regulators 90% efficiencies can be achieved.

# Summary

- Voltage regulators keep a constant dc output despite input voltage or load changes.
- The two basic categories of voltage regulators are linear and switching.
- The two types of linear voltage regulators are series and shunt.
- The three types of switching are step-up, step-down, and inverting.

# Summary

- Switching regulators are more efficient than linear making them ideal for low voltage high current applications.
- IC regulators are available with fixed positive or negative output voltages or variable negative or positive output voltages.
- Both linear and switching type regulators are available in IC form.
- Current capacity of a voltage regulator can be increased with an external pass transistor.

# Thank You!