Applications of
Linear Integrated Circuits

Applications of Linear Integrated Circuits: Adder, Integrator, Differentiator, Difference amplifier and Instrumentation amplifier, Converters: Current to voltage and voltage to current converters, Active Filters: First order filters, second order low pass, high pass, band pass and band reject filters, Oscillators: RC phase shift oscillator, Wien bridge oscillator, Square wave generator.

Special Purpose Integrated Circuits: Functional block diagram, working, design and applications of Timer 555 (Monostable & Astable), Functional block diagram, working and applications of VCO 566, PLL 565, Fixed and variable Voltage regulators.

Integrator:

- It is the circuit in which the output voltage waveform is the integral of the input voltage waveform.
- Such a circuit is obtained by using a basic inverting configuration, if the feedback resistor R_F is replaced by a capacitor C_F.
- The integrator circuit does the integration of the input voltage waveform.

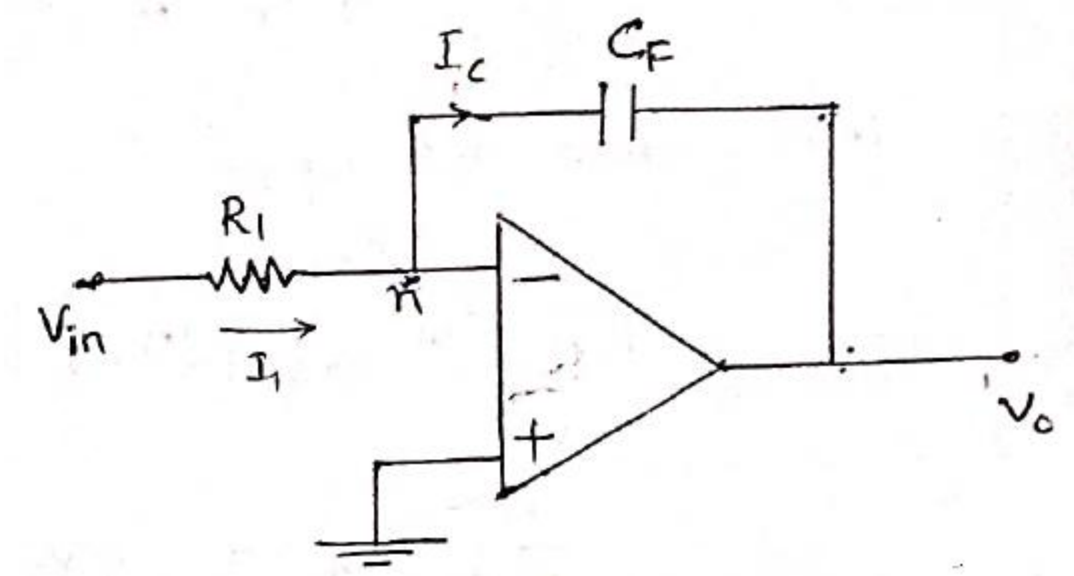
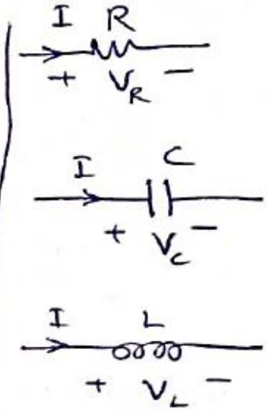


Fig: Integrator Circuit

Apply KCL at node ‘n’.

impedance		
R		$V_R = IR$
$\frac{1}{j\omega C}$		$V_C = \frac{1}{C}\int I\,dt$
$j\omega L$		$V_L = L\frac{dI}{dt}$



$$I_1 = I_C$$

But $$I_1 = \frac{V_{in} - V_n}{R_1}$$

Since $V_n = V_p = 0$,

$$I_1 = \frac{V_{in}}{R_1} \quad \text{——— (1)}$$

And $$I_C = C_F \frac{d}{dt}(V_n - V_o)$$

$$I_C = -C_F \frac{dV_o}{dt} \quad \text{——— (2)}$$

From (1) & (2), $$\frac{V_{in}}{R_1} = -C_F \frac{dV_o}{dt}$$

Integrate the above equation on both the sides

$$\int_0^t dv_o = -\frac{1}{R_1 C_F} \int_0^t v_{in}\, dt$$

$$V_o(t) = -\frac{1}{R_1 C_F} \int_0^t V_{in}(t)\,dt + V_o(0)$$

where $V_o(0)$ = integration constant

= The value of V_o at the time $t = 0$

The above eqn shows

V_o is directly α to the -ve integral of V_{in}

inversely α to the time const. $R_1 C_F$

Transfer Function:

The equation for $V_o(t)$ can be written in phasor notation as

$$V_o(s) = \frac{-1}{R_1 C_F} \left[\frac{1}{s} V_{in}(s) \right]$$

$$T(s) = \frac{-1}{s R_1 C_F} \qquad s = j\omega$$

$$T(j\omega) = \frac{-1}{j\omega R_1 C_F}$$

Amplitude $|T(j\omega)| = \frac{\pm 1}{\omega R_1 C_F}$

The frequency at which gain is unity is $f_0 = \frac{1}{2\pi R_1 C_F}$

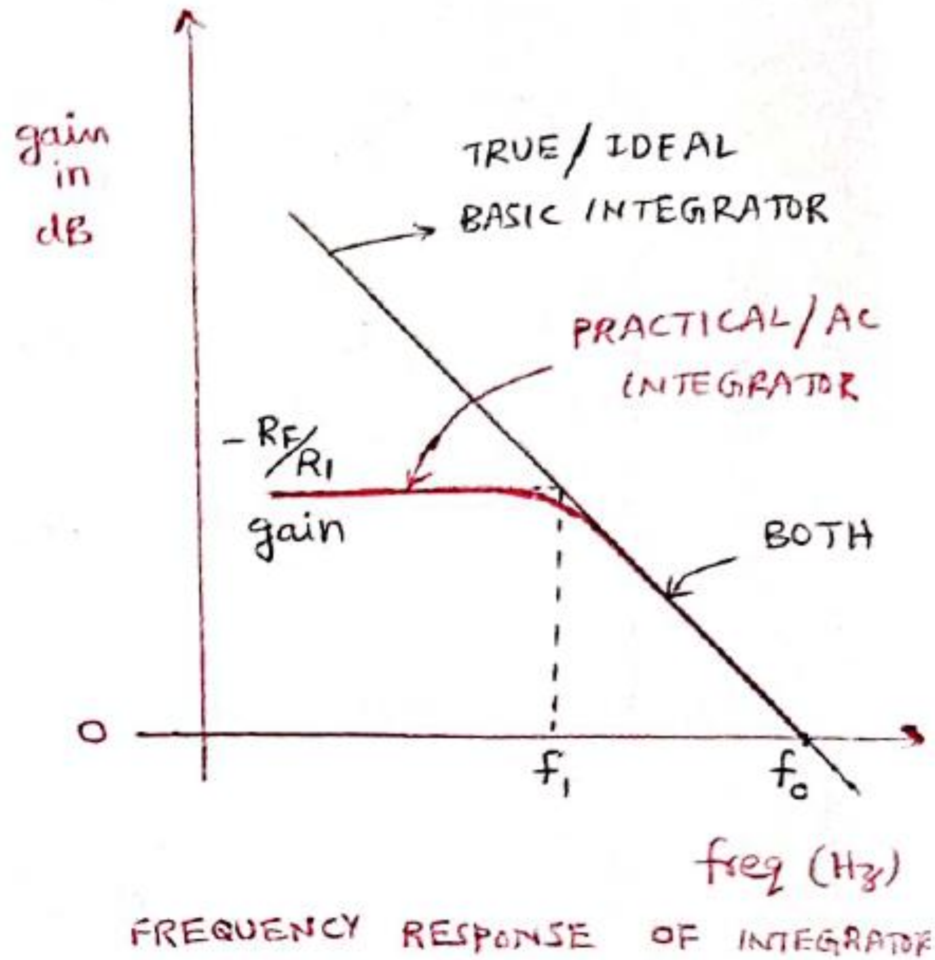
0 dB

The amplitude vs frequency response of the true integrator is shown in the following figure.

It has infinite gain at $\omega=0$;

So the system is unstable.

To reduce the gain at dc or at low frequencies, a resistor R_F is connected across the capacitor C_F as shown in the figure.



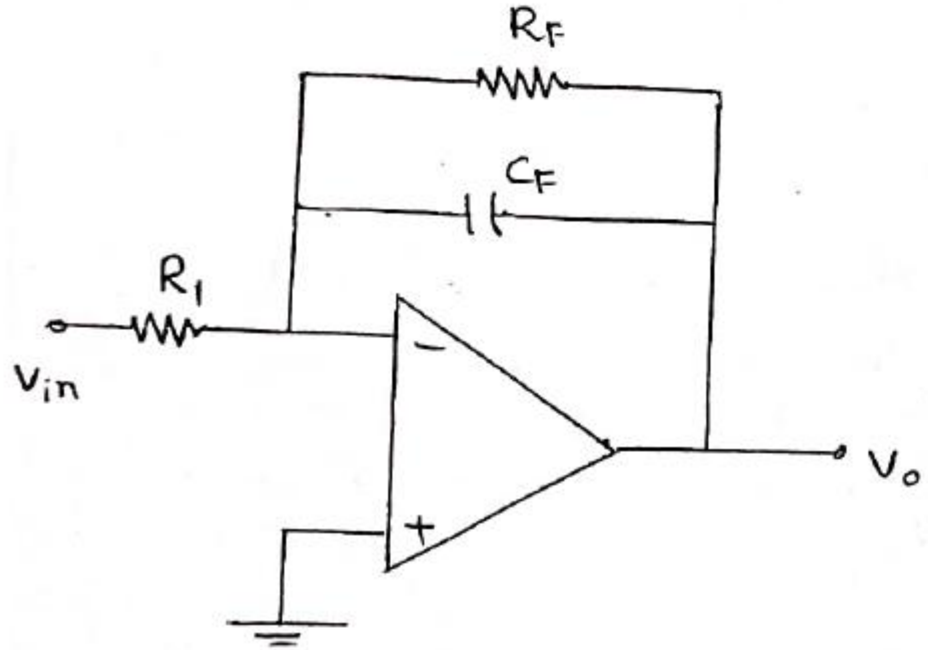


Fig: Practical integrator circuit

$$v_o = -\frac{Z_F}{R_1} V_{in}$$

where $Z_F = R_F \parallel C_F$

$$Z_F = \frac{R_F}{1 + j\omega C_F R_F}$$

so that $$\frac{v_o}{v_{in}} = \frac{-Z_F}{R_1}$$

The transfer function is given by

$$T(j\omega) = -\frac{R_F}{R_1} \cdot \frac{1}{1+j\omega C_F R_F}$$

At ω=0;

$$\text{the gain} = \frac{-R_F}{R_1} \quad (\text{constant})$$

$$\text{Amplitude} \quad |T(j\omega)| = \frac{R_F}{\sqrt{R_1^2\left[1+\omega^2 C_F^2 R_F^2\right]}}$$

$$\rightarrow \quad |T(j\omega)| = \frac{R_F}{\sqrt{R_1^2\left[1+j\left(f/f_1\right)^2\right]}} \quad \text{where } f_1 = \frac{1}{2\pi R_F C_F}$$

The gain is constant ($= \frac{R_F}{R_1}$) upto the frepuency f_1.

FOR $f < f_1$, it acts as a constant gain A

FOR $f > f_1$ it acts as a integrator

TIME CONSTANT $T = R_F C_F$

Differentiator:

If the resistor R_1 and C_F of the integrator are interchanged, we obtain the differentiator circuit.

The output is the derivative of the input waveform.

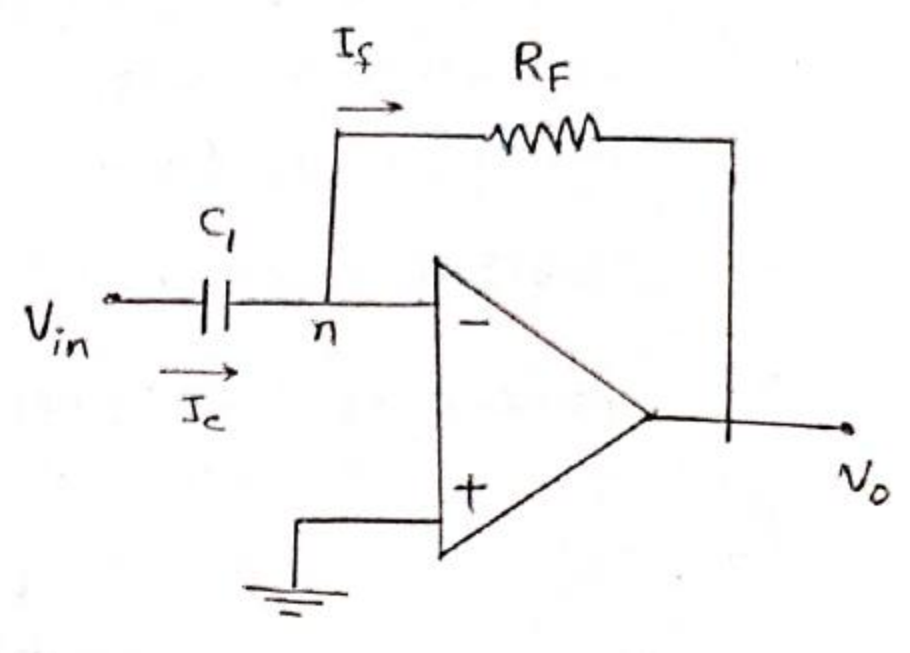


Fig: Differentiator circuit

Apply KCL at node ‘n’

$$I_c = I_f$$

where $I_c = C_1 \frac{d}{dt}(V_{in} - V_n)$

$$= C_1 \frac{dV_{in}}{dt} \quad (\because V_n = 0)$$

and $I_f = \frac{V_n - V_o}{R_F} = \frac{-V_o}{R_F}$

$$\therefore \frac{-V_o}{R_F} = C_1 . \frac{dV_{in}}{dt}$$

$$V_o = -R_F C_1 \frac{dV_{in}}{dt}$$

The output equals to the $R_F C_1$ times the negative instantaneous rate of change of input voltage with time.

The transfer function for the above equation can be written as

$$v_o(s) = -R_F C_1 \cdot s V_{in}(s)$$

$$T(s) = \frac{V_o(s)}{V_{in}(s)} = -s R_F C_1$$

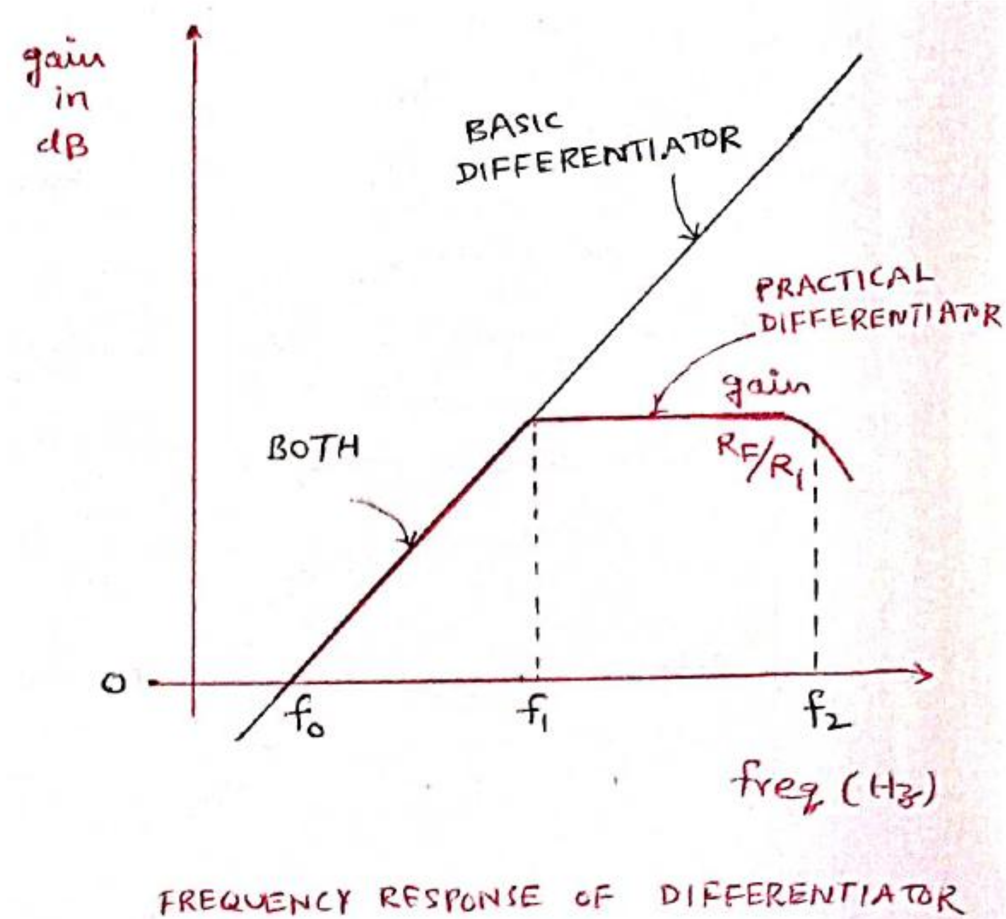
$$T(j\omega) = -j\omega R_F C_1$$

$$\text{gain} = |T(j\omega)| = \omega R_F C_1$$

The frequency at which gain = 1 is $f_o = \dfrac{1}{2\pi R_F C_1}$

The gain increases as frequency increases, this makes the circuit unstable.

The gain vs frequency of the basic differentiator is shown in the figure



The gain increases as the frequency increases.

To reduce the gain at higher frequencies, a resistor R_1 is connected in series with the C_1as shown in the figure.

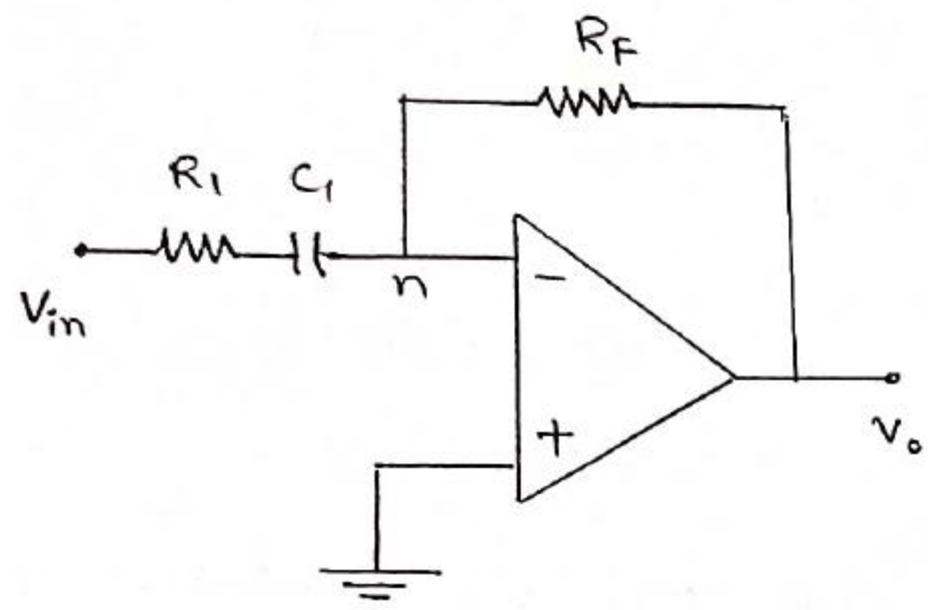


Fig: Practical differentiator circuit

Apply KCL at node ‘n’.

$$\frac{V_n - V_{in}}{Z_1} + \frac{V_n - V_o}{R_F} = 0$$

$$\frac{-V_{in}}{R_1 + \frac{1}{j\omega C_1}} + \frac{-V_o}{R_F} = 0 \quad (\because V_n = 0)$$

$$\Rightarrow \quad v_o = \frac{-j\omega R_F C_1}{1 + j\omega C_1 R_1} V_{in}$$

The transfer function is given by

$$T(j\omega) = \frac{-j\omega R_F C_1}{1 + j\omega R_1 C_1}$$

$$\text{Amplitude/gain} = |T(j\omega)| = \frac{\omega R_F C_1}{\sqrt{1 + \omega^2 R_1^2 C_1^2}}$$

At higher frequencies, [ω is very large]

$$\text{gain} = \frac{R_F}{R_1} \rightarrow \text{constant.}$$

The gain is constant $= \frac{R_F}{R_1}$ from frepuency $f_1 = \frac{1}{2\pi R_1 C_1}$

FOR $f_0 < f < f_1$, It acts as a basic differentiator

FOR $f > f_1$, It acts as an A' with gain $\frac{R_F}{R_1}$

For good differentiater,

$$T \geq R_F C_1$$

$$f_1 = 10 f_0$$

$$C_1 = 0.1 \mu F$$

Instrumentation Amplifier:

In many industrial and consumer applications, the measurement and control of physical conditions are very important.

For example measurement and control of temperature, humidity, light sensitivity, water flow etc. These physical quantities are usually measured with the help of transducer.

The output of the transducer has to be amplified so that it can drive the indicator or display system. This function is performed by instrumentation amplifier.

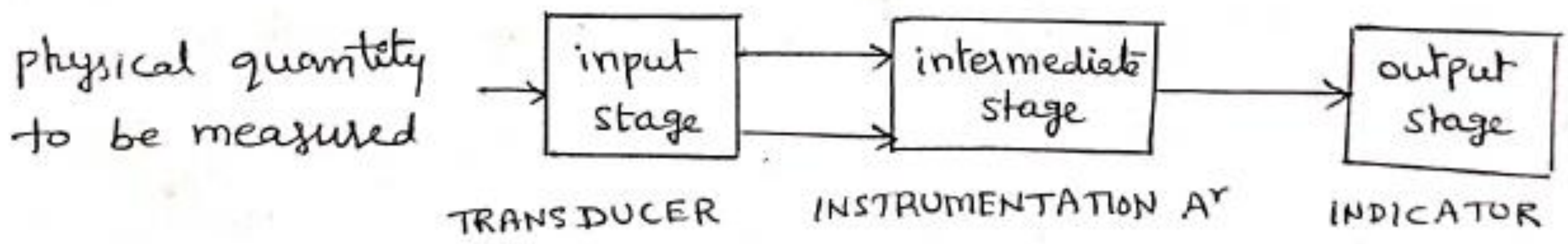


Fig (instrumentation system)

The input stage has a transducer. The output stage may use devices such as meters, oscilloscopes, or magnetic records.

Instrument amplifier is used to amplify the low level output signal of the transducer, so that it can drive the indicator or display.

Important features of instrumentation amplifier are

1. It should have differential inputs.
2. High CMRR
3. High input impedance
4. High gain accuracy
5. Low dc offset

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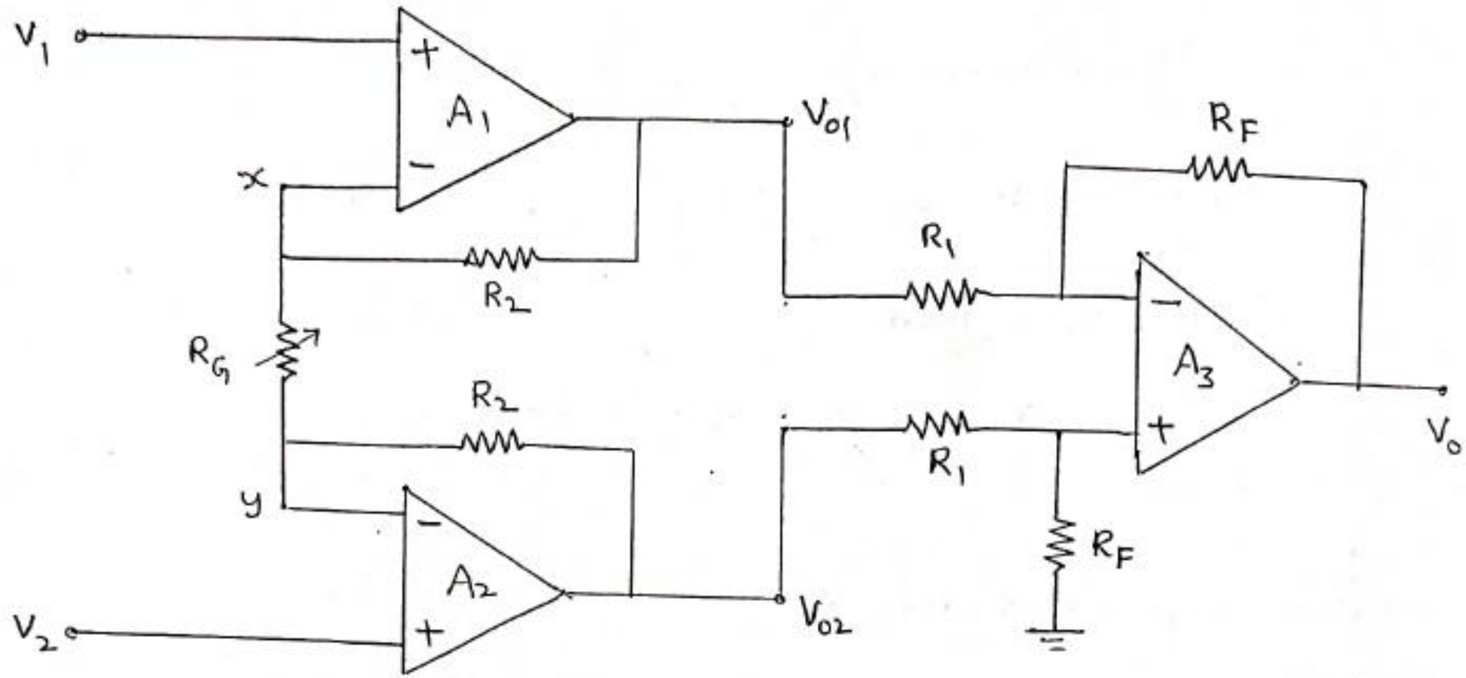


Fig (instrumentation Amplifier)

if A_1 and A_2 are ideal then $V_x = V_1$ and $V_y = V_2$

The inverting terminal of A_1 is fed a voltage V_1 through R_G
The inverting terminal of A_2 is fed a voltage V_2 through R_G

Apply KCL @ node x

$$\frac{V_x - V_{o1}}{R_2} + \frac{V_x - V_y}{R_G} = 0$$

$$\frac{V_{o1}}{R_2} = \frac{V_1}{R_2} + \frac{V_1}{R_G} - \frac{V_2}{R_G} \quad \left(\because \begin{array}{l} V_x = V_1 \\ V_y = V_2 \end{array}\right)$$

$$\Rightarrow \quad V_{o1} = \left(1 + \frac{R_2}{R_G}\right) V_1 - \frac{R_2}{R_G} V_2$$

Apply KCL @ node y

$$\frac{V_y - V_{o2}}{R_2} + \frac{V_y - V_x}{R_G} = 0$$

$$\Rightarrow \quad V_{o2} = -\frac{R_2}{R_G} V_1 + \left(1 + \frac{R_2}{R_G}\right) V_2$$

The next section is a differential A^r.

The differential A^r output $V_o = \frac{R_F}{R_1}\left[V_{o2} - V_{o1}\right]$

$$\Rightarrow V_o = \frac{R_F}{R_1}\left[V_2 - V_1 + 2\frac{R_2}{R_G}(V_2 - V_1)\right]$$

$$V_o = \frac{R_F}{R_1}\left(1 + \frac{2R_2}{R_G}\right)(V_2 - V_1)$$

The overall gain $= \frac{V_o}{V_2 - V_1} = \frac{R_F}{R_1}\left(1 + \frac{2R_2}{R_G}\right)$

The gain can be adjusted without distrubing ckt symmetry by varying the resistor R_G.

Current to voltage converter:

The current to voltage converter accepts an input current I_S and produces an output voltage V_o which is proportional to the input current.

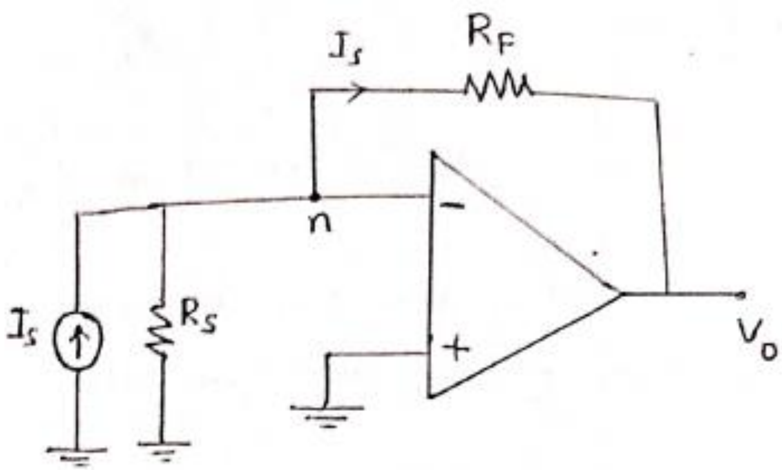


Fig: Current to voltage converter

Due to virtual ground V_n=0

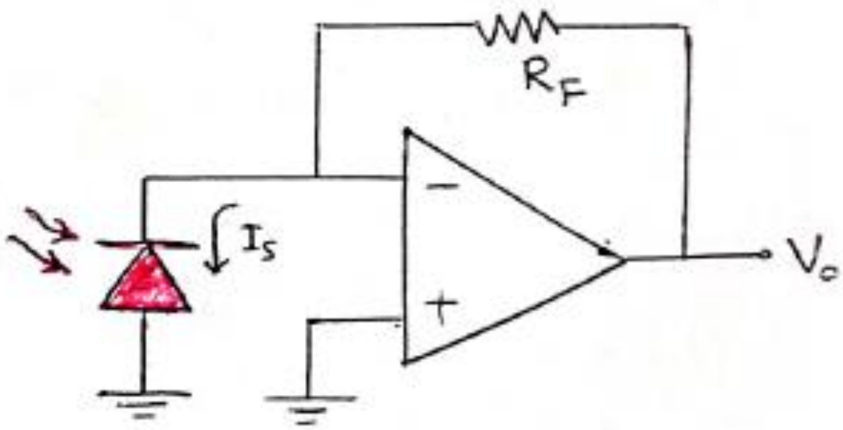
Thus the current through R_S = 0

So I_S flows through R_F .

Therefore the output voltage is $V_o = - I_S R_F$

Photo Detector amplifier:

- The current to voltage conversion principle is used in many special purpose amplifiers such as photo conductive and photo voltaic detectors. Photo detectors are transducers that produce electric current in response to incident light.



- A trans resistance amplifier is used to convert current to voltage.
- Si photo diode is commonly used photo detector. This diode gives an output current that is proportional to an incident light energy.
- The current through this device can be converted into voltage by using a current to voltage converter and there by the amount of light on the photo device can be measured.

Voltage to current converter:

The voltage to current converter accepts input voltage V_S and produces an output current I_o which is proportional to V_S.

There are two types of voltage to current converters.

(a) Voltage to current converter with floating load.

(b) Voltage to current converter with grounded load.

A floating load refers to the situation where both of its terminals are un committed. In V-I converter with floating load configuration, the load RL itself acts as a feedback element and is not grounded.

A grounded load refers to the situation where one of its terminals is already committed to ground.

(a) Voltage to current converter with floating load:

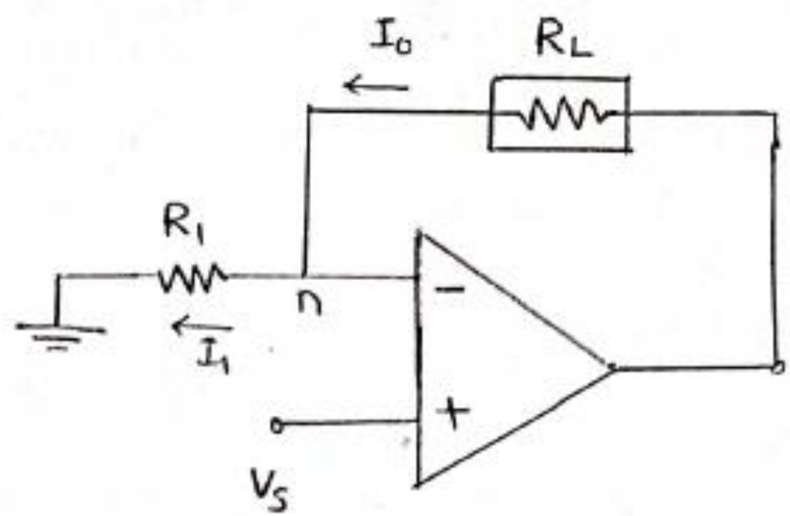
From figure,

$$V_n = V_s$$

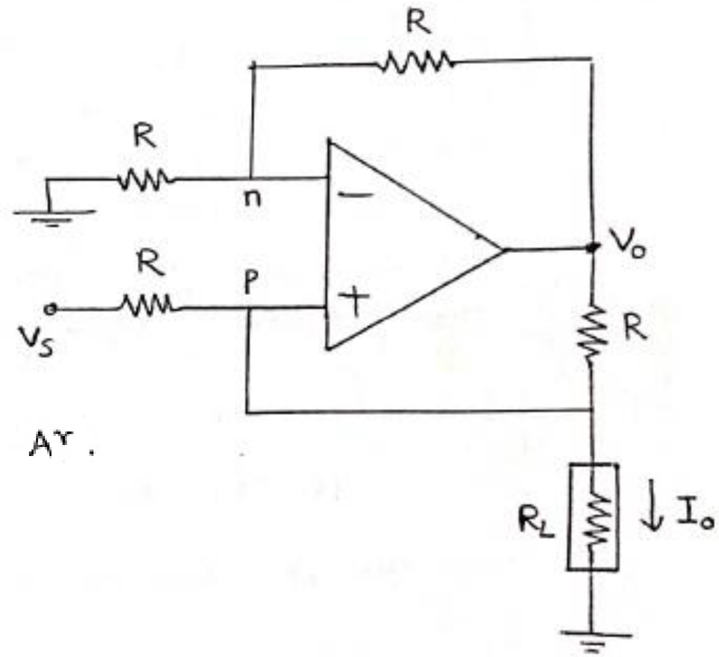
Apply KCL @ node n.

$$I_0 = I_1$$

$$\Rightarrow I_0 = \frac{V_n}{R_1} = \frac{V_s}{R_1}$$



(b) Voltage to current converter with grounded load:



Apply KCL @ node p

$$\frac{V_p - V_s}{R} + \frac{V_p - V_o}{R} + I_o = 0$$

w.r.to V_o, the op-Amp acts as a non inverting Ar.

$$\Rightarrow V_o = \left(1 + \frac{R_F}{R_1}\right) V_p$$

$$= \left(1 + R/R\right) V_p$$

$$= 2V_p.$$

So that, $$\frac{V_p - V_s}{R} + \frac{V_p - 2V_p}{R} + I_o = 0$$

$$\Rightarrow \frac{V_p - V_s + V_p - 2V_p}{R} + I_o = 0$$

$$\Rightarrow I_o = \frac{V_s}{R}.$$

Active Filters:

- These filters are used in the circuits which require the separation of signals according to their frequencies.
- Filters are most widely used in communication and signal processing.
- These filters are built from

  (i) Passive RLC Filters

  (ii)Crystals

  (iii) Resistors, capacitors and Op-amps(Active filters)

Under active filters, we have low pass, high pass, band pass and band reject filters.

RC active Filters:

The active filters have their own limitations. High frequency response is limited by the gain bandwidth product and slew rate of the op-amp.

The high frequency active filters are more expensive than the passive filters.

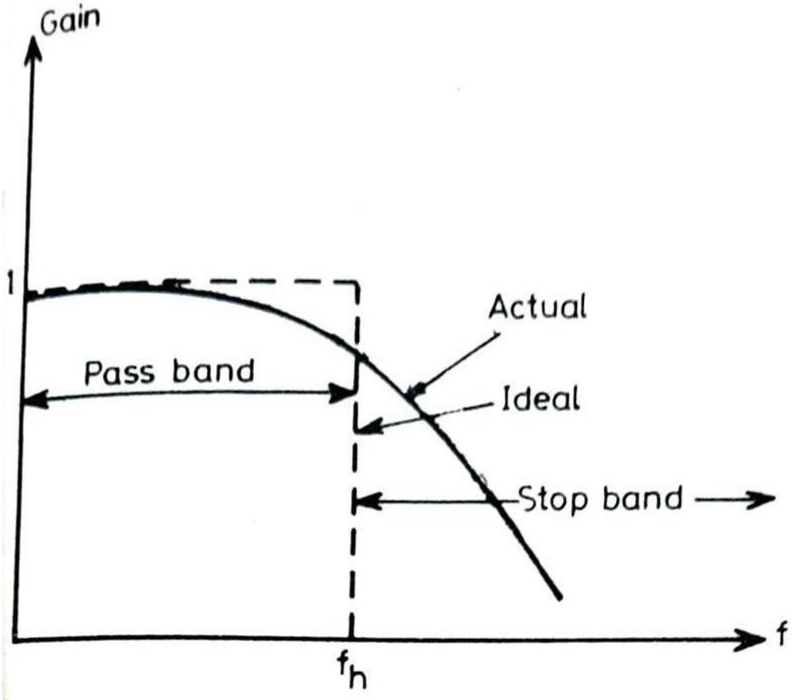
The most commonly used filters are

(a) Low Pass Filters (LPF)

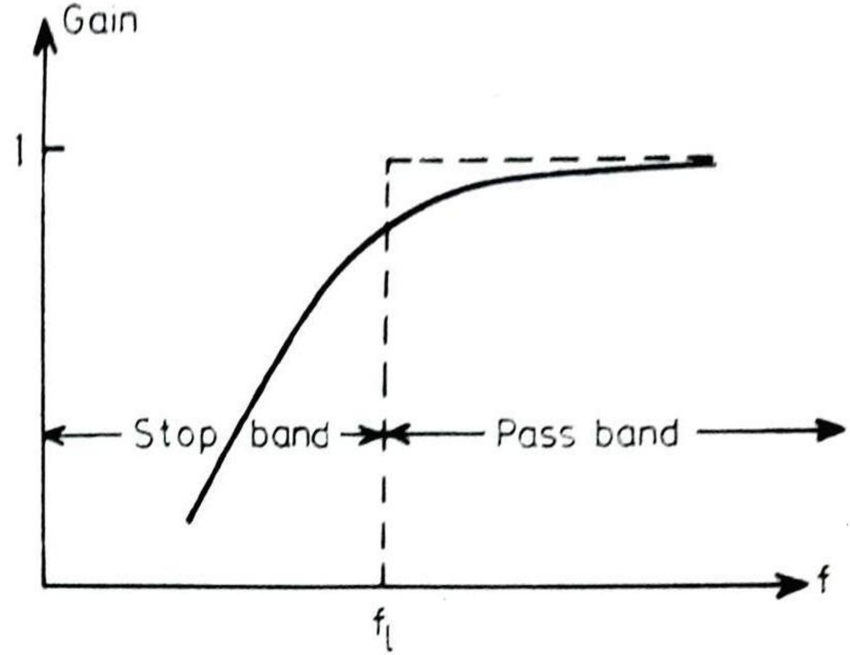
(b) High Pass Filters (HPF)

(c) Band Pass Filters (BPF)

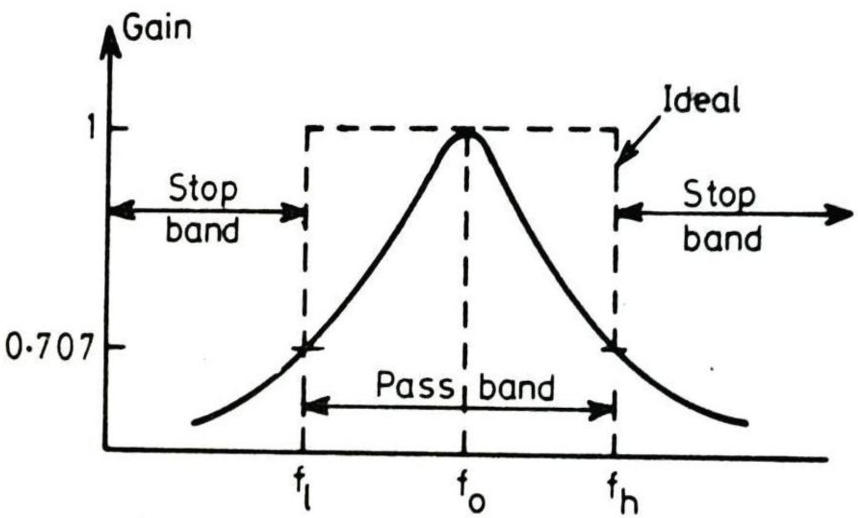
(d) Band Reject Filter / Band Stop Filter



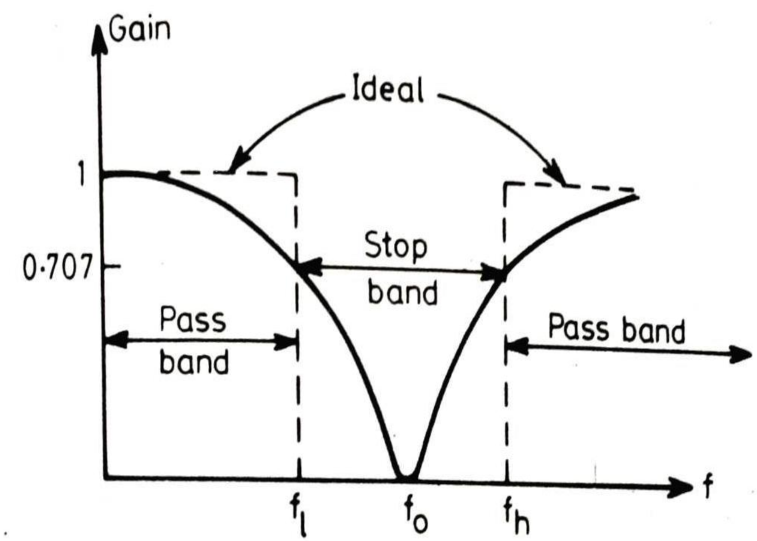
Low Pass Filter



High Pass Filter



Band Pass Filter



Band Stop Filter

Active filters are specified by the voltage transfer function.

$$H(s) = \frac{V_o(s)}{V_i(s)}$$

Under steady state condition (i.e., s=jω)

$$H(j\omega) = \left| H(j\omega) \right| e^{j\phi(\omega)}$$

where $|H(j\omega)|$ is the magnitude or the gain function and $\phi(\omega)$ is the phase function. Usually the magnitude response is given in dB as

$$20 \log \left| H(j\omega) \right|$$

Sometimes, active filters are specified by a loss function $V_i(s)/V_o(s)$. The use of loss function is a carry over from passive filter design.

First order Low pass filter:

Active filters may be of different orders and types.

A first order filter consists of a single RC network connected to the non inverting input terminal of the op-amp as shown in figure.

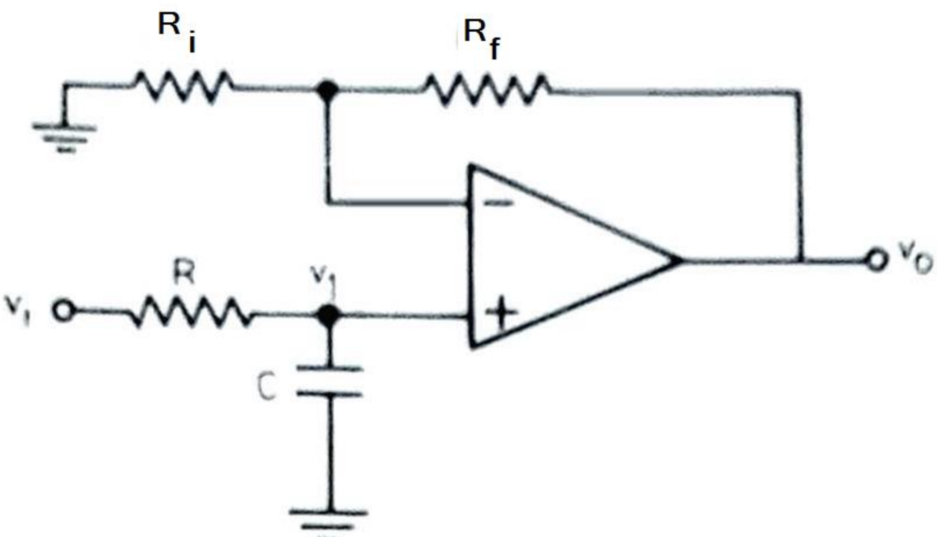


Fig: First order low pass filter

The voltage v_1 across the capacitor C in the s-domain is

$$V_1(s) = \frac{\frac{1}{sC}}{R + \frac{1}{sC}} V_i(s)$$

$$\frac{V_1(s)}{V_i(s)} = \frac{1}{RCs + 1}$$

where $V(s)$ is the Laplace transform of v in time domain.

The closed loop gain A_o of the op-amp is,

$$A_o = \frac{V_o(s)}{V_1(s)} = \left(1 + \frac{R_f}{R_i}\right)$$

The overall transfer function from the above two equations is given by

$$H(s) = \frac{V_o(s)}{V_i(s)} = \frac{V_o(s)}{V_1(s)} \cdot \frac{V_1(s)}{V_i(s)} = \frac{A_o}{RCs + 1}$$

$$H(s) = \frac{V_o(s)}{V_i(s)} = \frac{V_o(s)}{V_1(s)} \cdot \frac{V_1(s)}{V_i(s)} = \frac{A_o}{RCs + 1}$$

Let $\omega_h = \frac{1}{RC}$

Therefore, $H(s) = \frac{V_o(s)}{V_i(s)} = \frac{A_o}{\frac{s}{\omega_h} + 1} = \frac{A_o \omega_h}{s + \omega_h}$

The above equation is the standard form of the transfer function of a first order low-pass system.

The frequency response is determined by putting, s=jω in the above equation

$$H(j\omega) = \frac{A_o}{1 + j\omega RC} = \frac{A_o}{1 + j(f/f_h)}$$

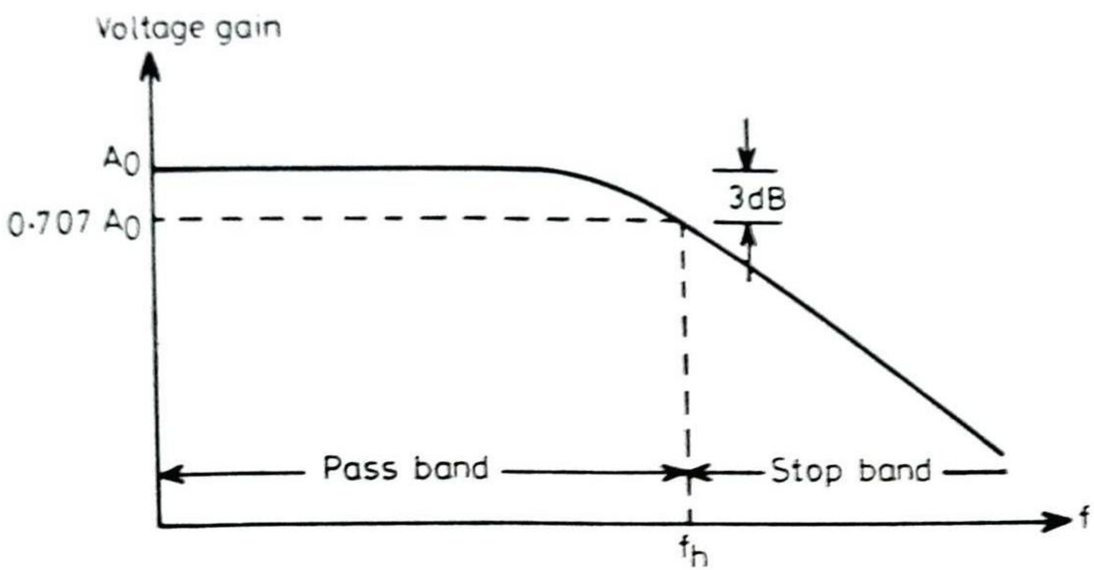
where $f_h = \frac{1}{2\pi RC}$ and $f = \frac{\omega}{2\pi}$

At very low frequency, i.e. $f << f_h$ $\quad |H(j\omega)| \simeq A_o$

$$\text{At } f = f_h \qquad |H(j\omega)| = \frac{A_o}{\sqrt{2}} = 0.707\, A_o$$

At very high frequency i.e. $f >> f_h$ $\quad |H(j\omega)| << A_o \simeq 0$

The frequency response of the first order low pass filter is shown in the following figure



Second order Active filter:

An improved filter response can be obtained by using a second order active filter.

The results that are derived here are used for the analysis of low pass and high pass filters.

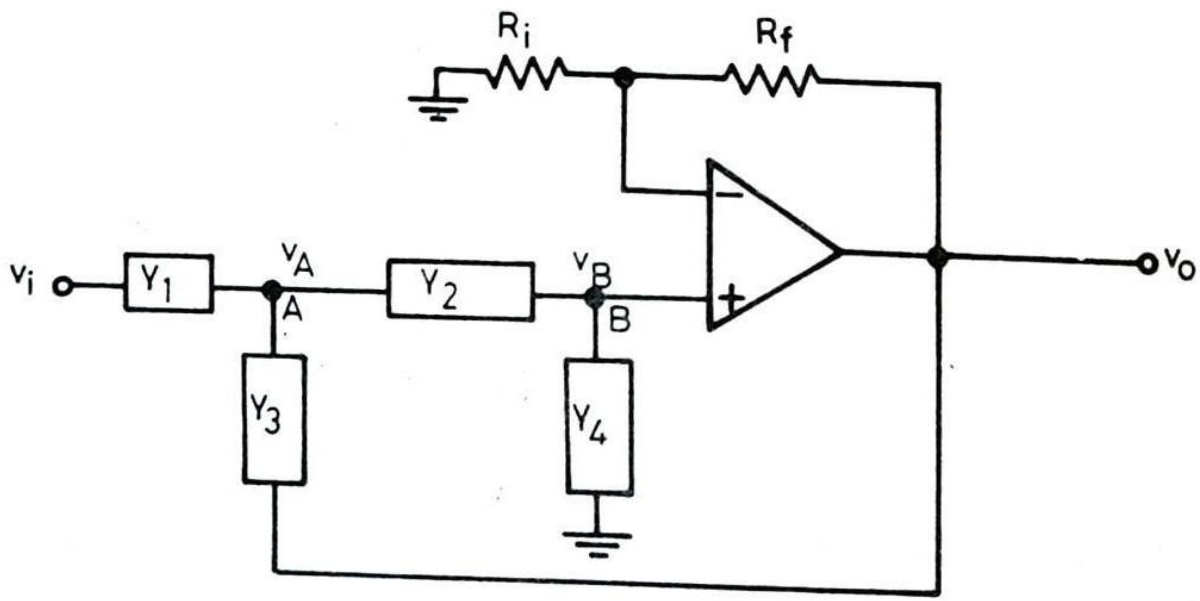


Fig. Sallen Key filter (General second order filter)

The op-amp is connected as non-inverting amplifier and hence,

$$v_o = \left(1 + \frac{R_f}{R_i}\right) v_B = A_o\, v_B \qquad \text{where, } A_o = 1 + \frac{R_f}{R_i}$$

v_B is the voltage at node B.

Kirchhoff's current law (KCL) at node A gives

$$v_i Y_1 = v_A (Y_1 + Y_2 + Y_3) - v_o Y_3 - v_B Y_2$$

$$= v_A (Y_1 + Y_2 + Y_3) - v_o Y_3 - \frac{v_o Y_2}{A_o}$$

where v_A is the voltage at node A.

KCL at node B gives,

$$v_A Y_2 = v_B (Y_2 + Y_4) = \frac{v_o (Y_2 + Y_4)}{A_o}$$

$$v_A = \frac{v_o (Y_2 + Y_4)}{A_o Y_2}$$

By simplifying the above two equations, we get

$$\frac{v_o}{v_i} = \frac{A_o Y_1 Y_2}{Y_1 Y_2 + Y_4 (Y_1 + Y_2 + Y_3) + Y_2 Y_3 (1 - A_o)}$$

To make a low pass filter, choose, $Y_1 = Y_2 = 1/R$ and $Y_3 = Y_4 = sC$ as shown in

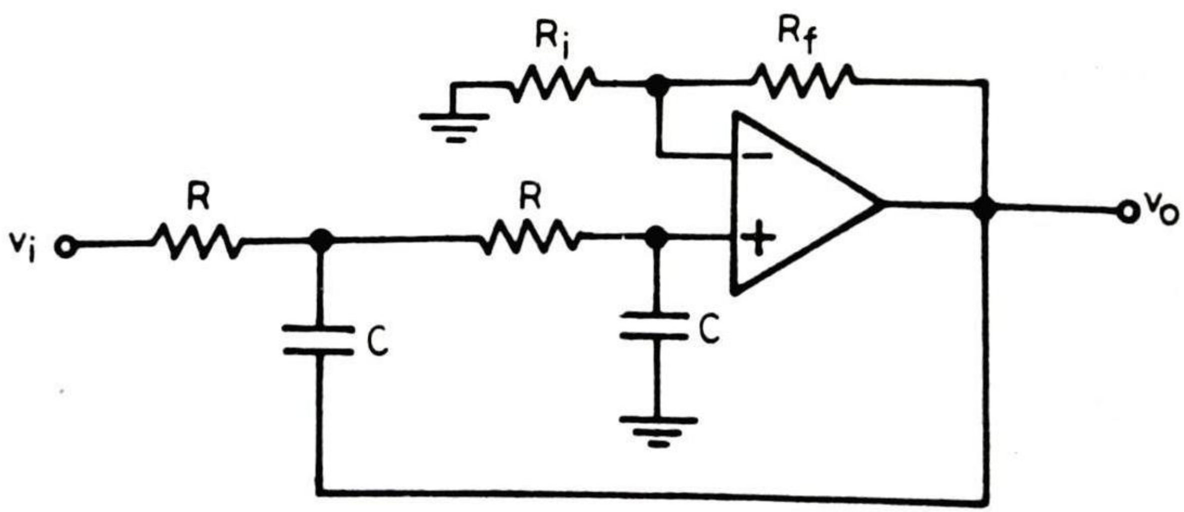


Fig. Second order low-pass filter

For simplicity equal components has been used, we get the transfer function H(s) of a low pass filter as,

$$H(s) = \frac{A_o}{s^2 C^2 R^2 + sCR(3 - A_o) + 1}$$

From the above equation, $H(0) = A_o$ for s=0 and $H(\infty) = 0$ for $s= \infty$, and it is the configuration for a low pass filter.

The transfer function of low pass second order system (electrical, mechanical, hydraulic or chemical) can be written as

$$H(s) = \frac{A_o \omega_h^2}{s^2 + \alpha \omega_h s + \omega_h^2}$$

Where, A_o is the gain,

ω_h is the upper cut off frequency in radians/sec

α is the damping coefficient

Comparing the above two equations, we get

$$\omega_h = \frac{1}{RC}$$

$$\alpha = (3 - A_o)$$

That is, the value of the damping coefficient α for low pass active RC filter can be determind by the value of A_o chosen.

Putting s= jω, in H(s), we get

$$H(j\omega) = \frac{A_o}{(j\,\omega / \omega_h)^2 + j\,\alpha\,(\omega/\omega_h) + 1}$$

the normalized expression for low pass filter is

$$H(j\omega) = \frac{A_o}{s^2 + \alpha\,s + 1}$$

where normalized frequency $s = j\left(\frac{\omega}{\omega_h}\right)$

The expression for magnitude in dB is given by

$$20\log\left|H(j\omega)\right| = 20\log\left|\frac{A_o}{1 + j\alpha(\omega/\omega_h) + (j\omega/\omega_h)^2}\right|$$

$$= 20\log\left(\frac{A_o}{\sqrt{\left(1 - \frac{\omega^2}{\omega_h^2}\right)^2 + \left(\alpha\frac{\omega}{\omega_h}\right)^2}}\right)$$

$$20\log\left|H(j\omega)\right| = 20\log\left|\frac{V_o}{V_i}\right| = 20\log\frac{A_o}{\sqrt{1 + \left(\frac{\omega}{\omega_h}\right)^4}}$$

For the n^{th} order generalized filter, the normalized transfer function is given by

$$\left|\frac{H(j\omega)}{A_o}\right| = \frac{1}{\sqrt{1 + \left(\frac{\omega}{\omega_h}\right)^{2n}}}$$

Higher order Low pass filter:

Higher order filters can be built by cascading a proper number of first and second order filters. The transfer function is given by

$$H(s) = \underbrace{\frac{A_{o1}}{s^2 + \alpha_1 s + 1}}_{\text{second order section}} \cdot \underbrace{\frac{A_{o2}}{s^2 + \alpha_2 s + 1}}_{\text{another second order section}} \cdot \underbrace{\frac{A_o}{s + 1}}_{\text{first order section}}$$

High pass active filter:

High pass filter is the complement of the low pass filter and can be obtained by interchanging R and C.

$$H(s) = \frac{A_o s^2}{s^2 + (3 - A_o)\,\omega_1 s + \omega_1^2}$$

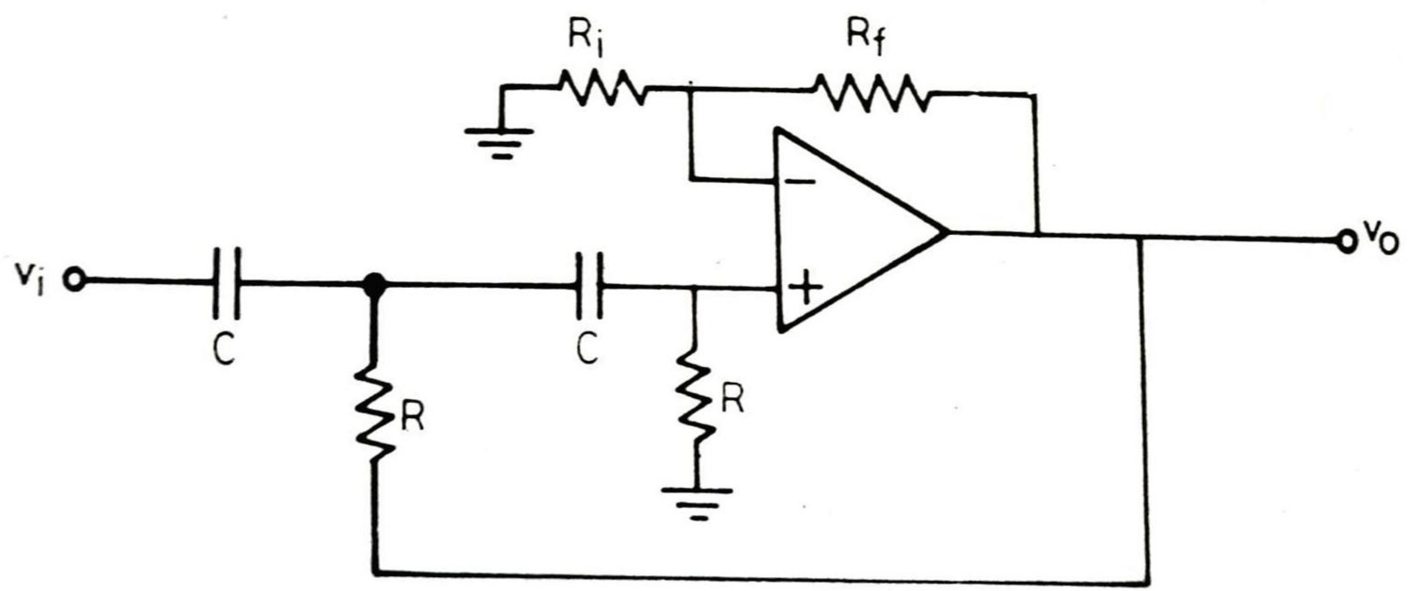


Fig. Second order high pass filter

$$\text{where } \omega_1 = \frac{1}{RC}$$

$$H(s) = \frac{A_o}{1 + \frac{\omega_1}{s}(3 - A_o) + \left(\frac{\omega_1}{s}\right)^2}$$

For ω=0, we get H = 0 and ω=∞ , we get H=A_o. So the circuit behaves like a high pass filter.

The lower cut off frequency is given by

$$f_1 = f_{3dB} = \frac{1}{2\pi RC}$$

Putting s=j ω, and 3-A_o = α = 1.414 in the above equation, we get

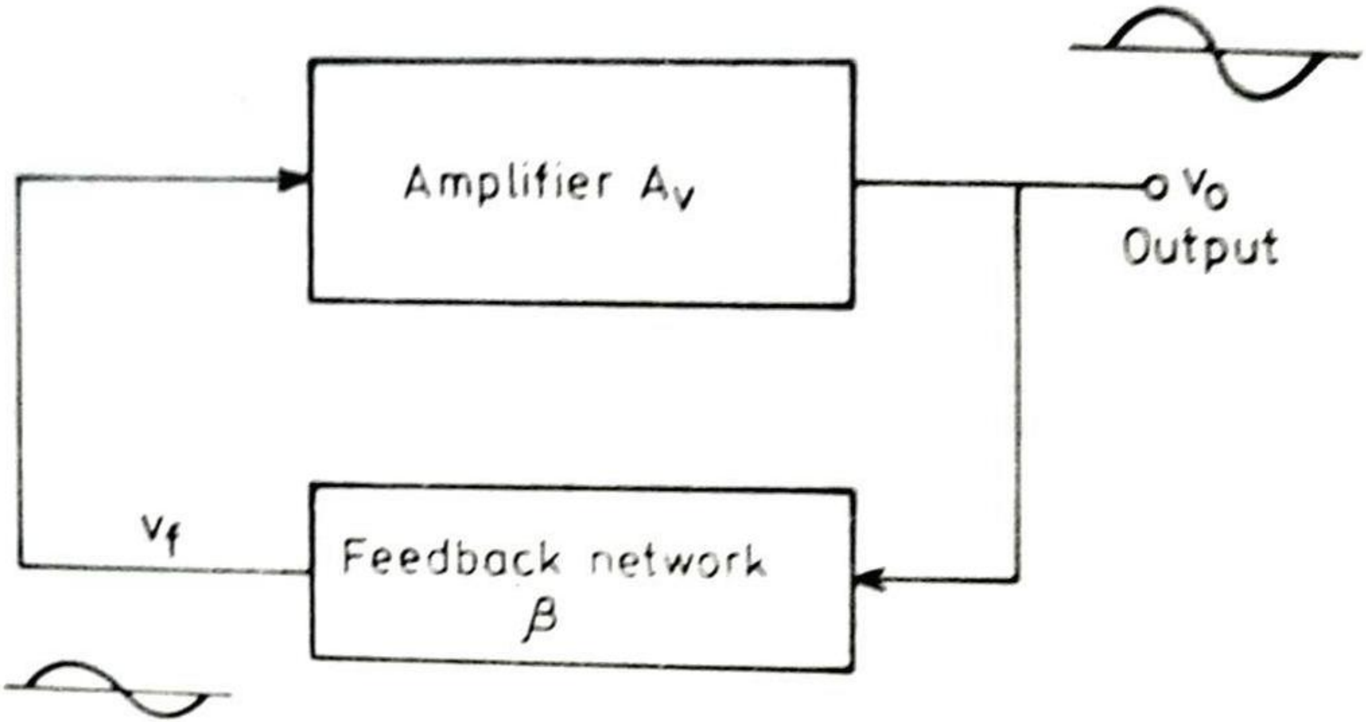
$$\left|H(j\omega)\right| = \left|\frac{V_o}{V_i}\right| = \frac{A_o}{\sqrt{1 + (f_1/f)^4}}$$

$$\text{Hence} \quad \left|\frac{H(j\omega)}{A_o}\right| = \frac{1}{\sqrt{1+\left(\frac{f_1}{f}\right)^4}}$$

For the n^{th} order generalized filter, the normalized transfer function is given by

$$\left|\frac{H(j\omega)}{A_o}\right| = \frac{1}{\sqrt{1+\left(\frac{f_1}{f}\right)^{2n}}}$$

Sine wave generators:



Block diagram of a feedback oscillator

For sustained oscillation, $A_v\beta = 1$. That is, the magnitude condition $|A_v\beta| = 1$ and the phase condition, $\angle A_v\beta = 0°$ or $360°$ must be simultaneously satisfied in the circuit.

There are different types of sine-wave oscillators available according to the range of frequency, namely *RC* oscillators for audio frequency and *LC* oscillators for radio frequency range. Here we will discuss only two types of audio frequency *RC* oscillators.

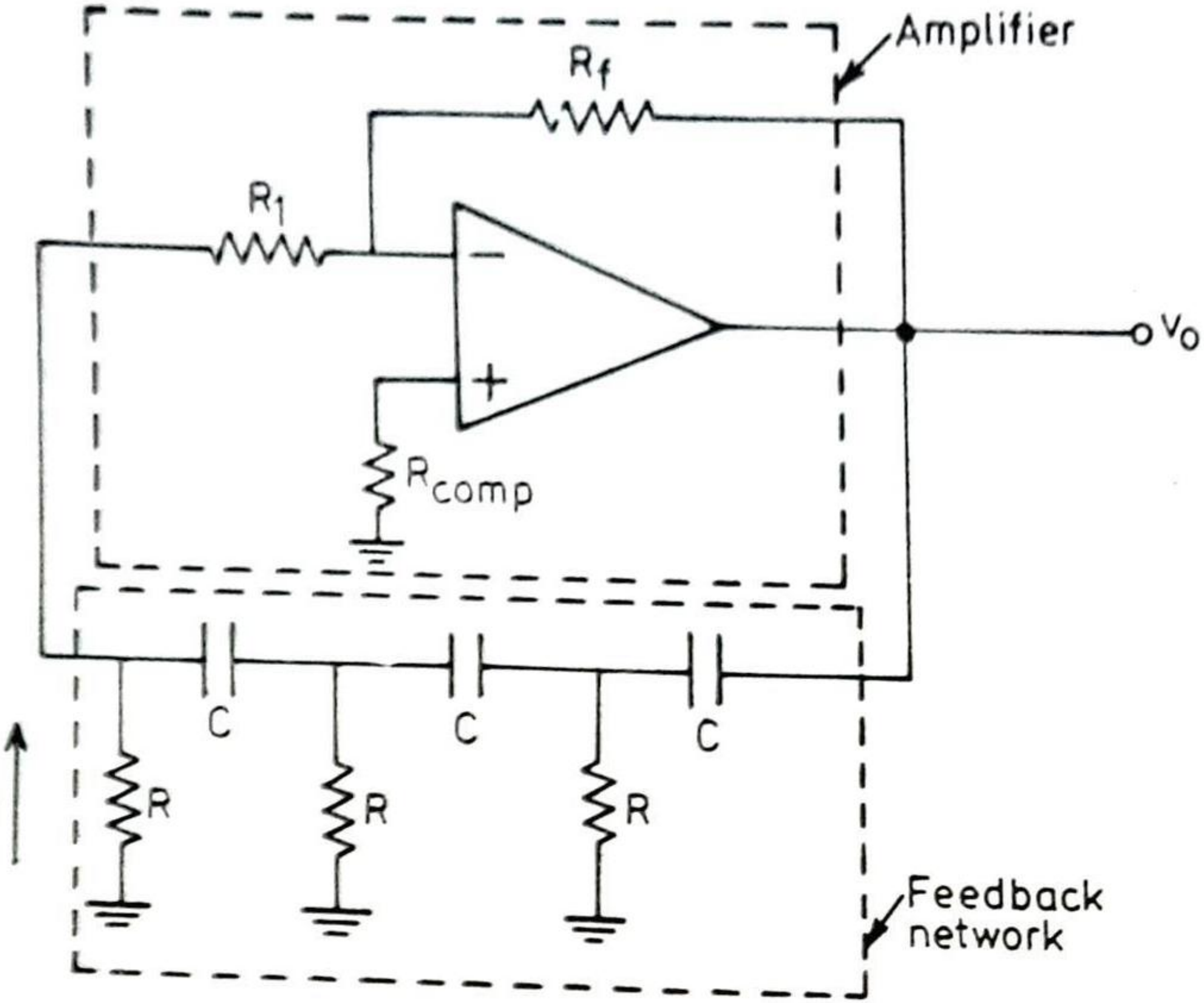
Phase shift oscillator:

$$\beta = \frac{v_f}{v_o} = \frac{1}{1 + 6/sRC + 5/s^2R^2C^2 + 1/s^3R^3C^3}$$

Letting $s = j\omega$,

$$\beta = \frac{1}{1 - 5(f_1/f)^2 - j[6(f_1/f) - (f_1/f)^3]}$$

•



Phase shift oscillator

where $f_1 = \dfrac{1}{2\pi RC}$

For $A_v \beta = 1$, β should be real. So the imaginary term in Eq. must be equal to zero, that is,

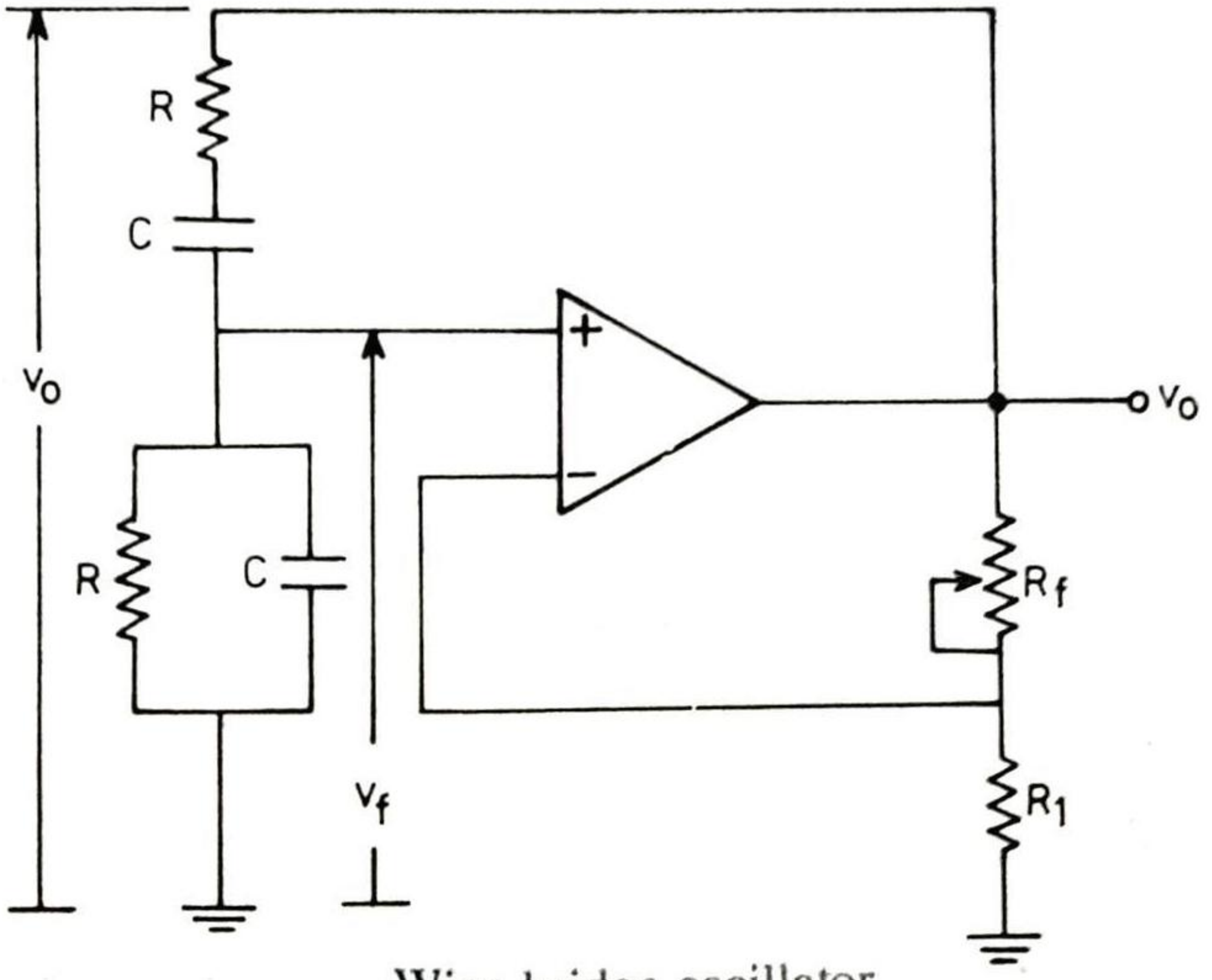
$$6(f_1/f) - (f_1/f)^3 = 0$$

$$f_1/f = \sqrt{6}$$

The frequency of the oscillation f_o is given by,

$$f_o = \frac{1}{\sqrt{6}\,(2\pi RC)}$$

Wien bridge oscillator:



Wien bridge oscillator

From the feedback network, the feedback factor β is,

$$\beta = \frac{v_f}{v_o} = \frac{R/(1+j\,\omega RC)}{[(R-j/\omega C)+R/(1+j\omega RC)]}$$

$$= \frac{R}{3R + j(\omega R^2 C - 1/\omega C)}$$

For $A_v\beta = 1$, β must be real. That is the imaginary term in Eq. must be zero.

$$\omega R^2 C - \frac{1}{\omega C} = 0$$

$$\omega = \frac{1}{RC}$$

The frequency of oscillation f_o is, $f_o = \dfrac{1}{2\pi RC}$

555 Timer:

- It is a highly stable device for generating accurate time delay or oscillation.
- This 555 timer can provide time delay ranging from micro seconds to hours.
- 555 timer can be used with supply voltage in the range of +5V to +18V and can drive load up to 200mA.
- 555 timer is used in various applications such as oscillator, pulse generator, ramp, square wave generator, mono stable multivibrator, burglar alarm, traffic light control and voltage monitor.

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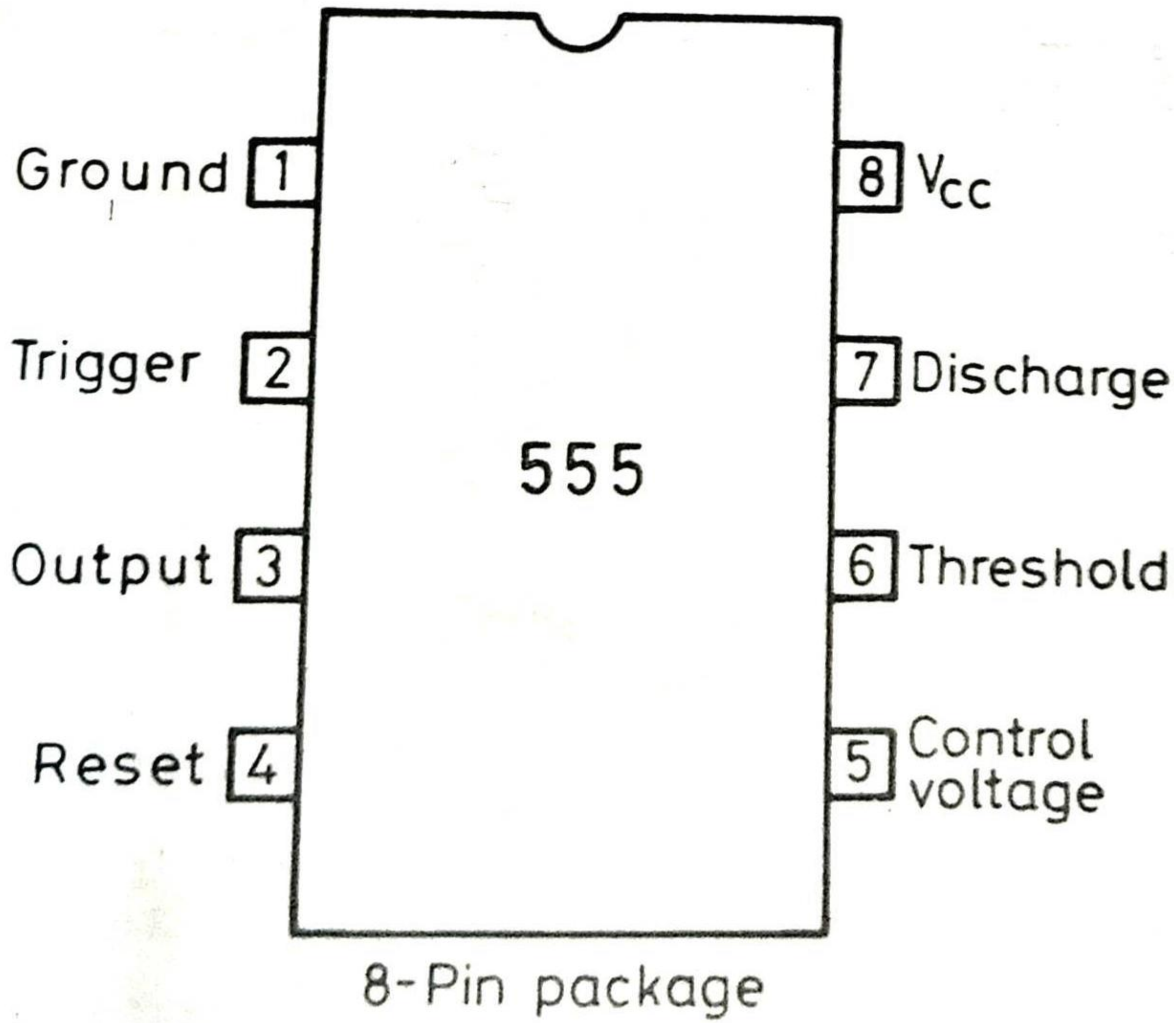

Fig. Pin diagram

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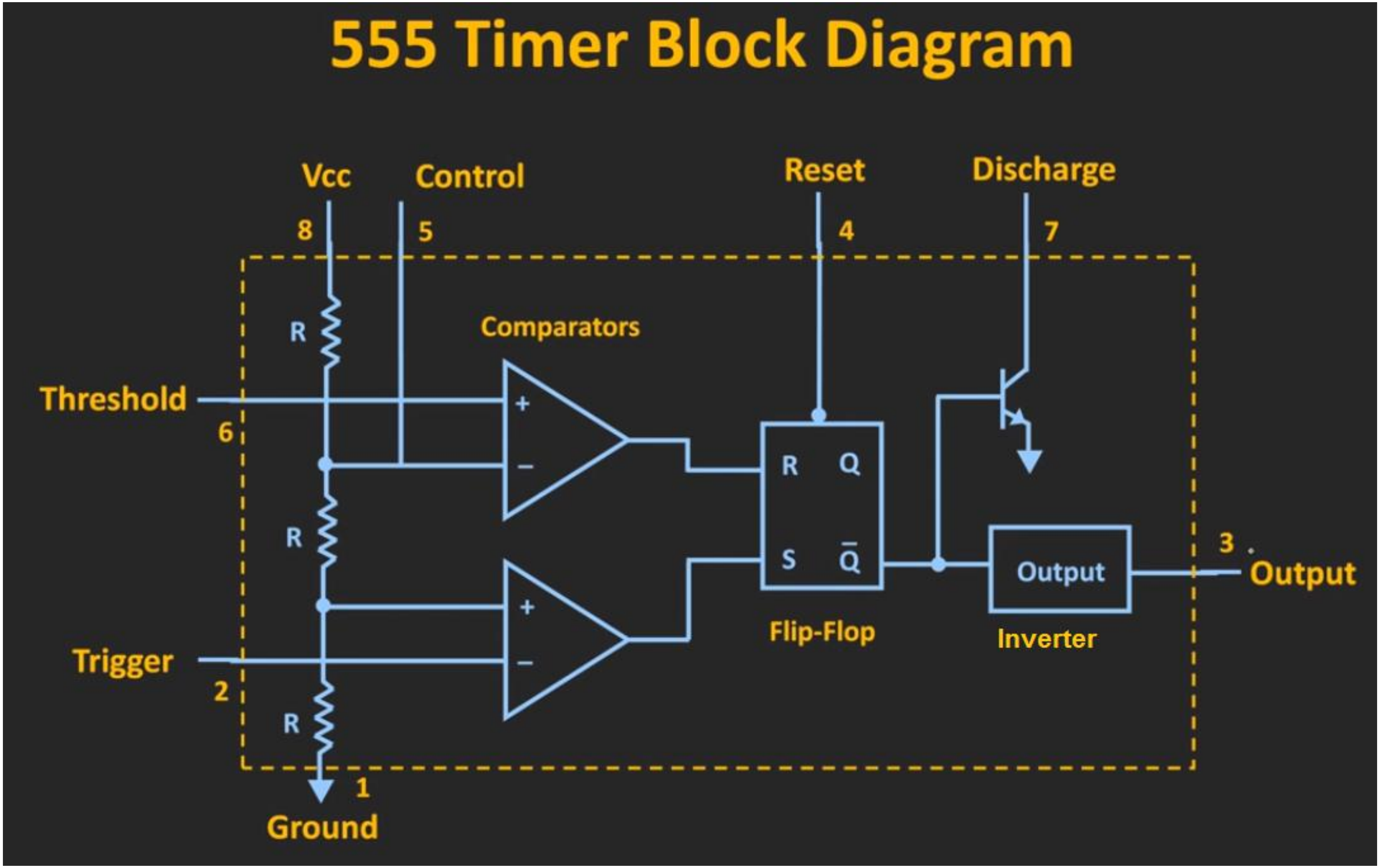
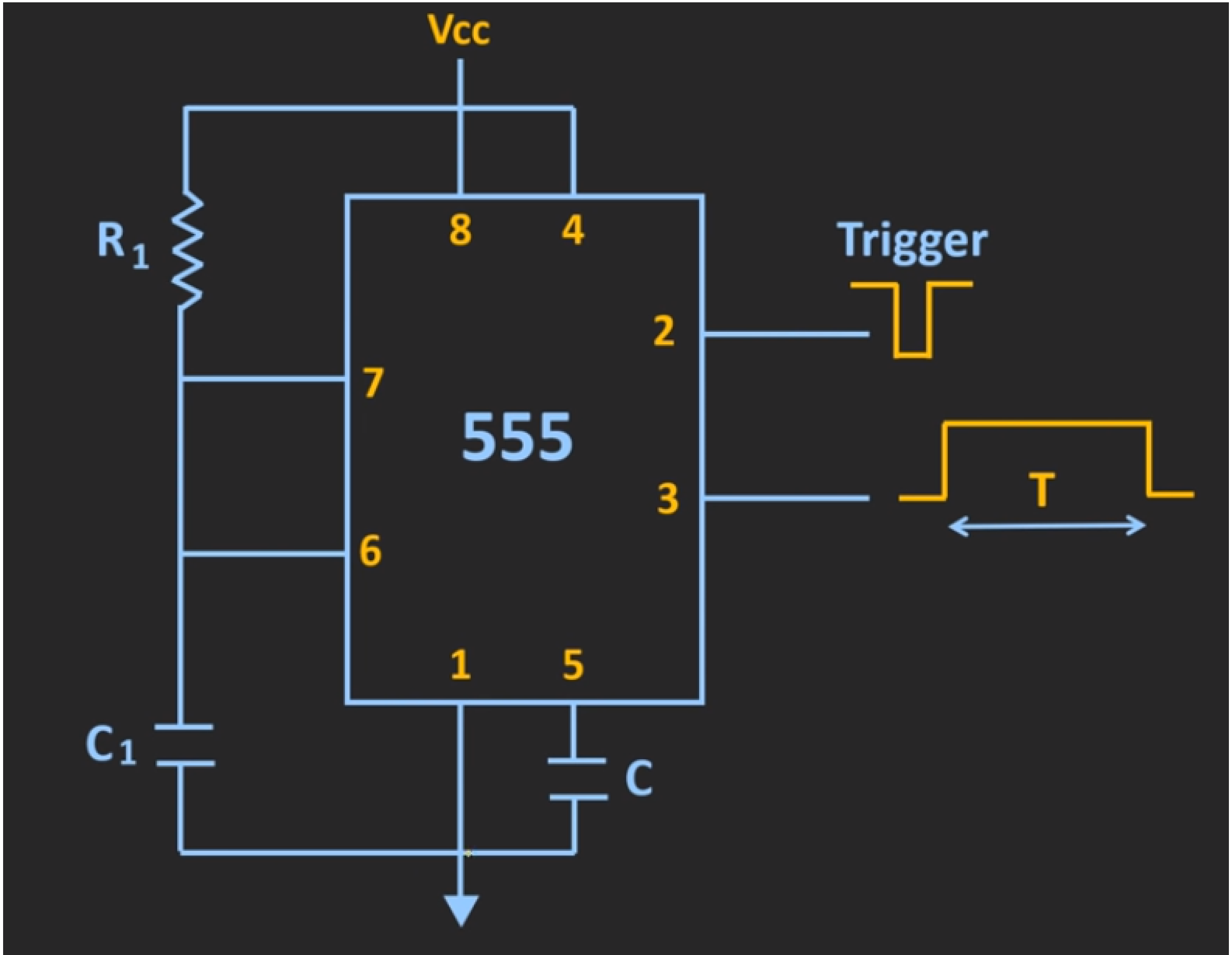


555 Timer Block Diagram
Vcc
Control
Reset
Discharge
8
5
4
7
R
Comparators
Threshold
6
+
–
R
Q
R
S
Q̄
Output
3
Output
+
–
Flip-Flop
Inverter
Trigger
2
R
1
Ground

Monostable multivibrator:

Monostable has one stable state.



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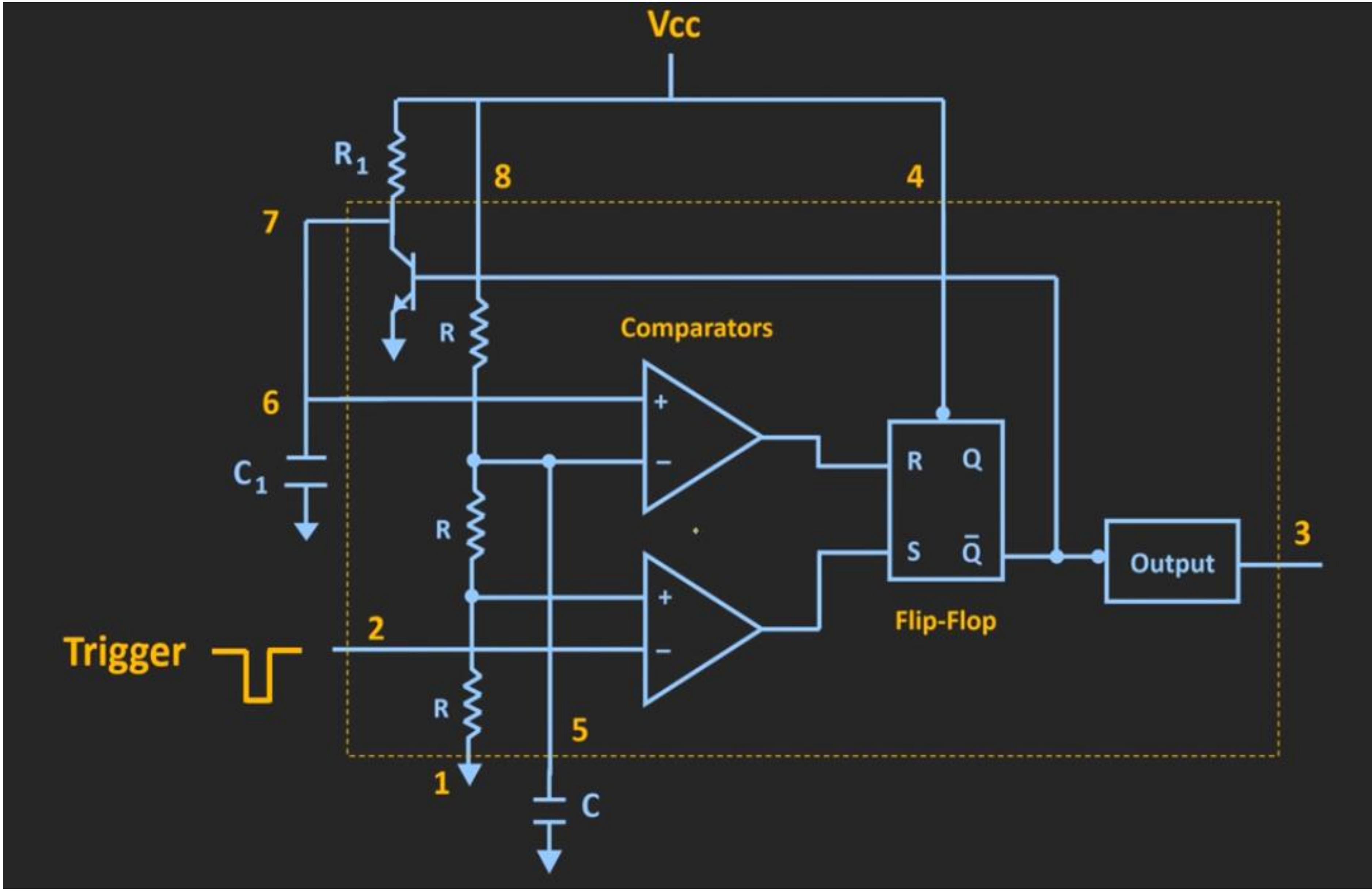


Vcc
R1
8
4
7
R
Comparators
6
C1
R
Q
R
S
Q̄
3
Output
Trigger
2
R
5
1
C
Flip-Flop

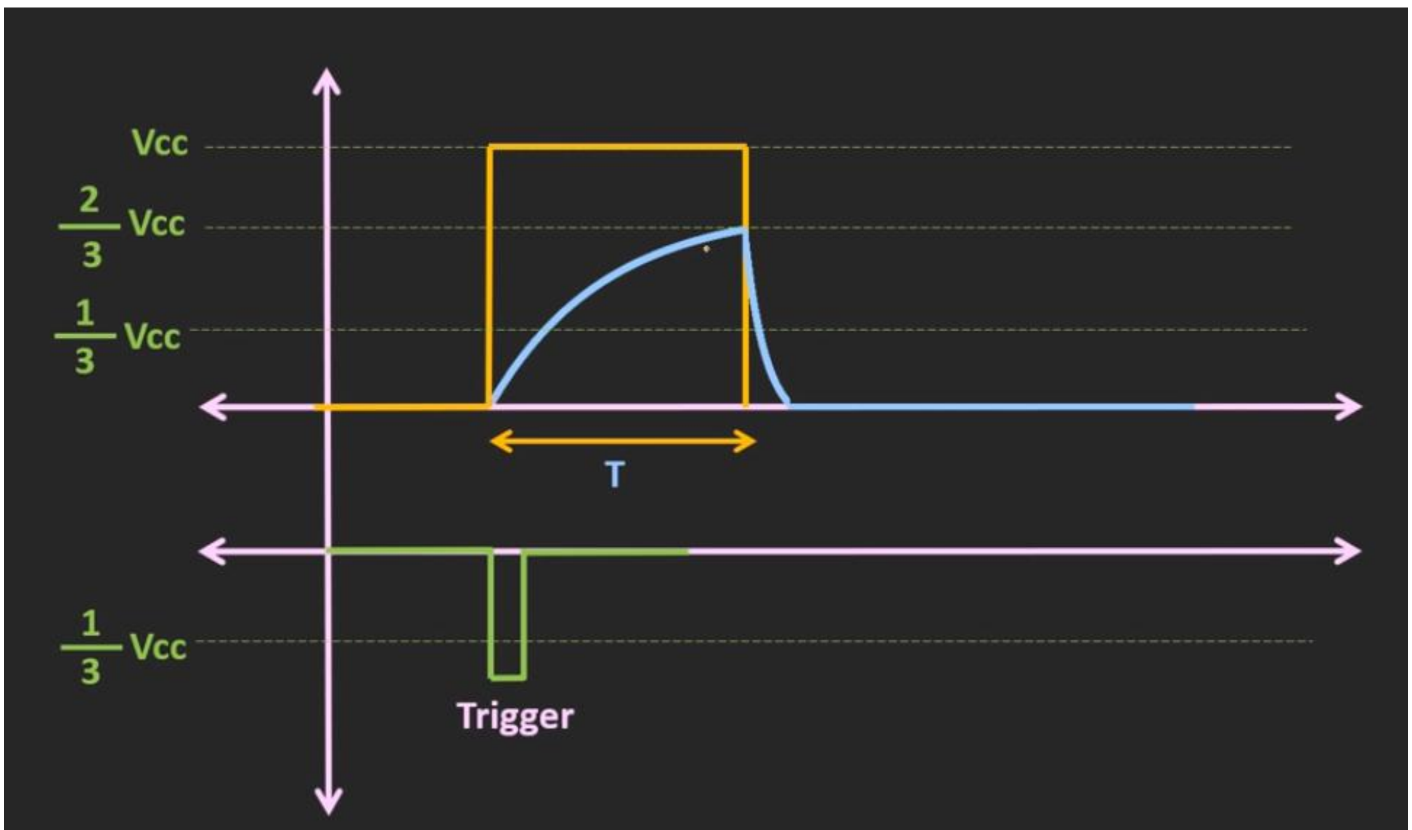
$$v_c = V_{cc}\,(1 - e^{-t/RC})$$

At $t = T$, $v_c = (2/3)\ V_{cc}$

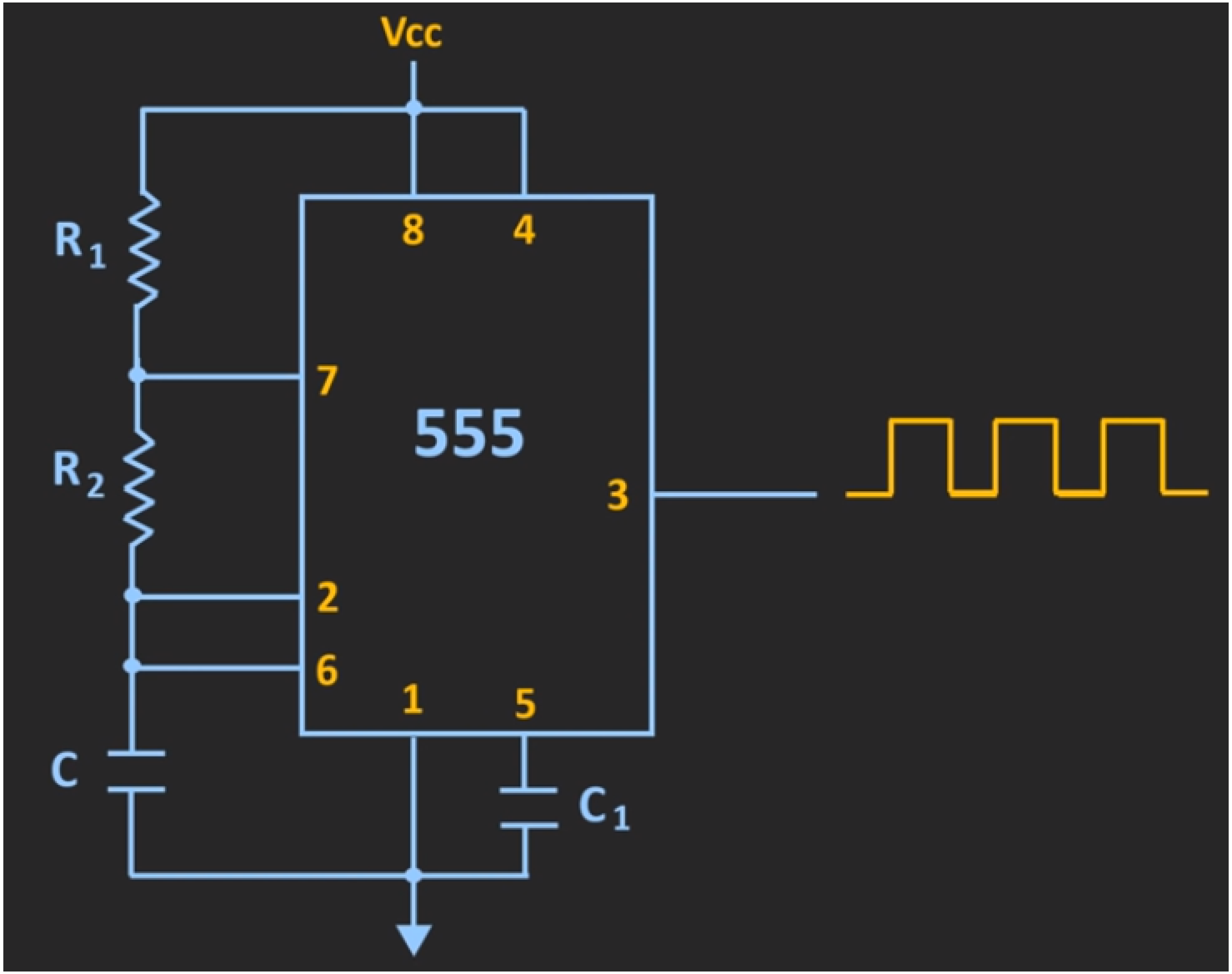
Therefore, $$\frac{2}{3} V_{cc} = V_{cc}\,(1 - e^{-T/RC})$$

$$T = RC\ ln\,(1/3)$$

$$T = 1.1\,RC \text{ (seconds)}$$



Astable Multivibrator:



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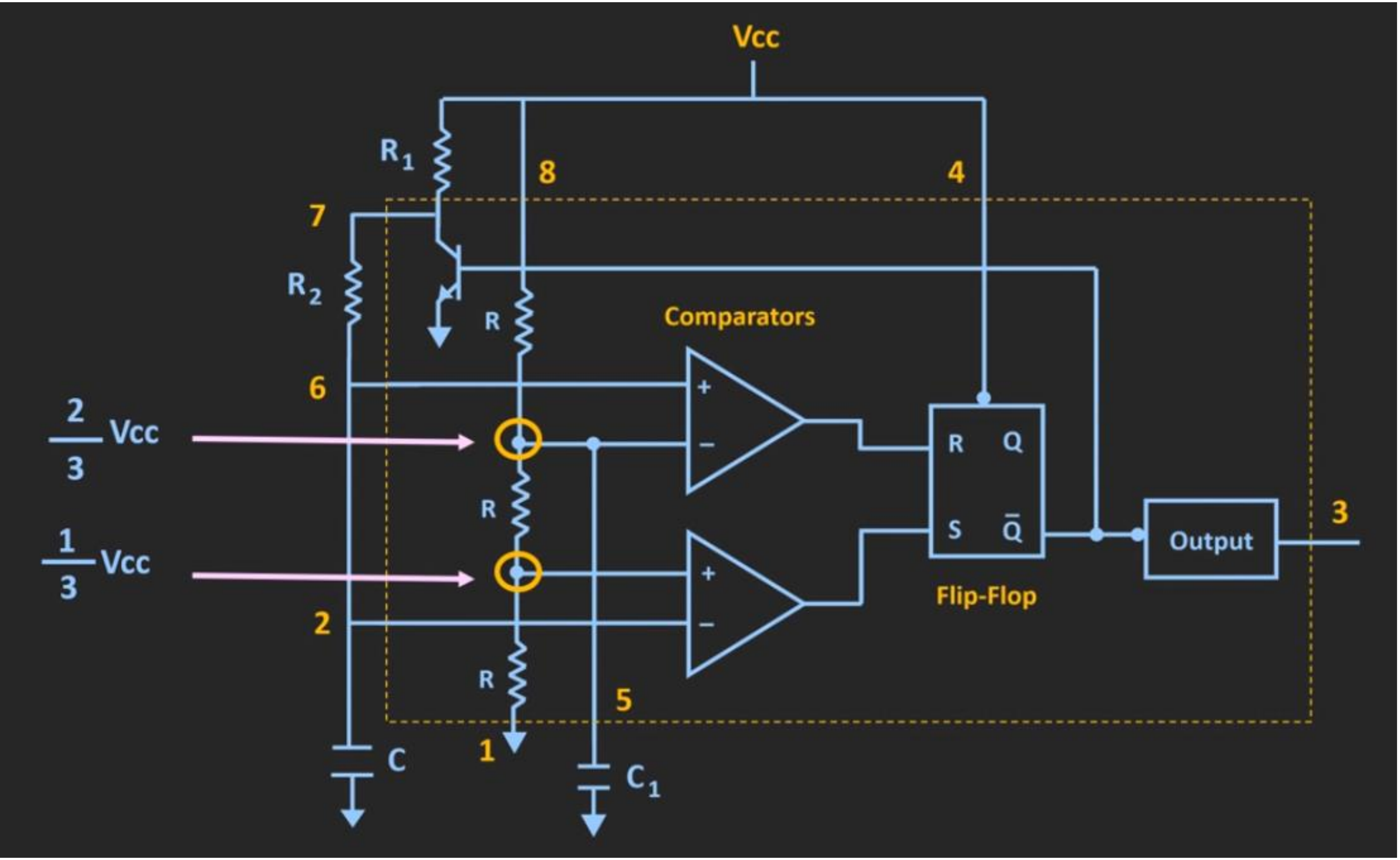
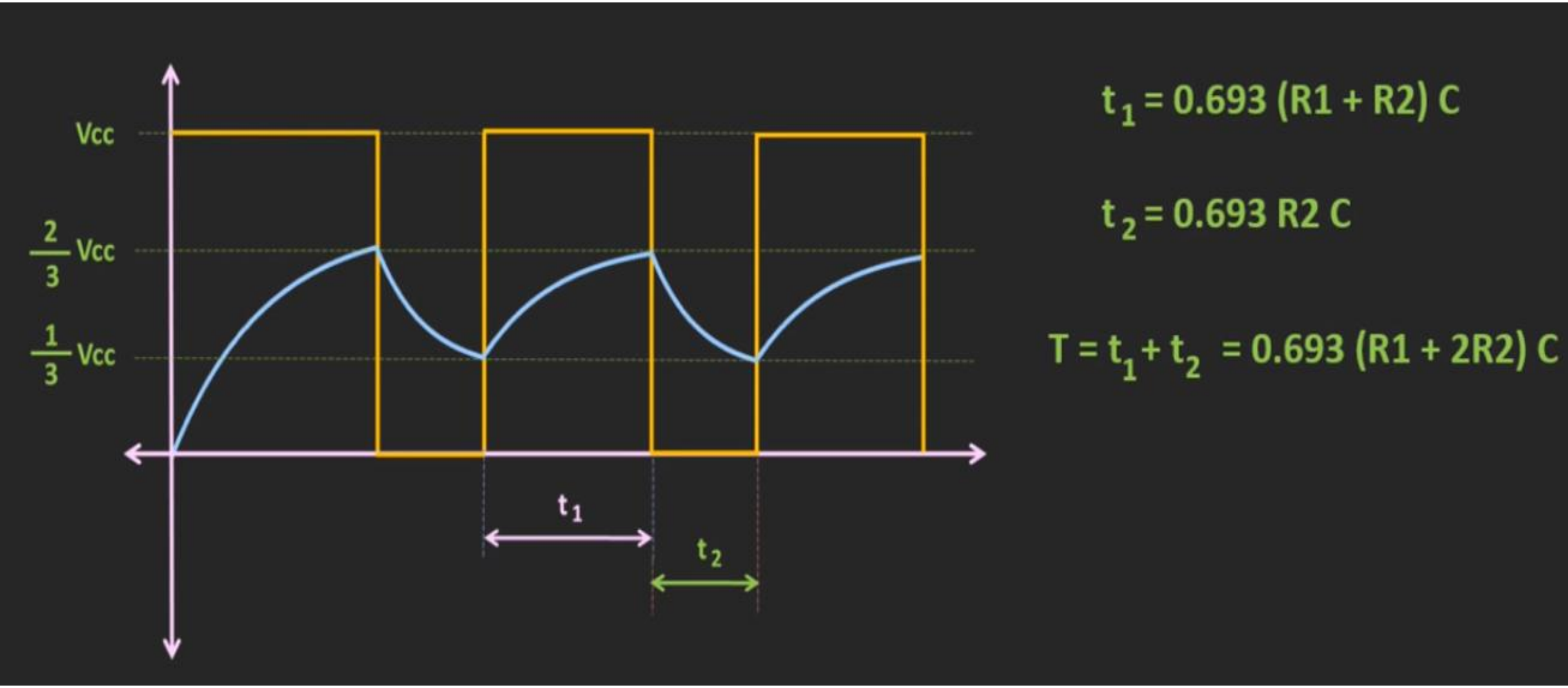


Vcc
R1
8
4
7
R2
R
Comparators
6
2/3 Vcc
R
Q
R
S
Q̄
Output
3
1/3 Vcc
Flip-Flop
2
R
5
C
1
C1



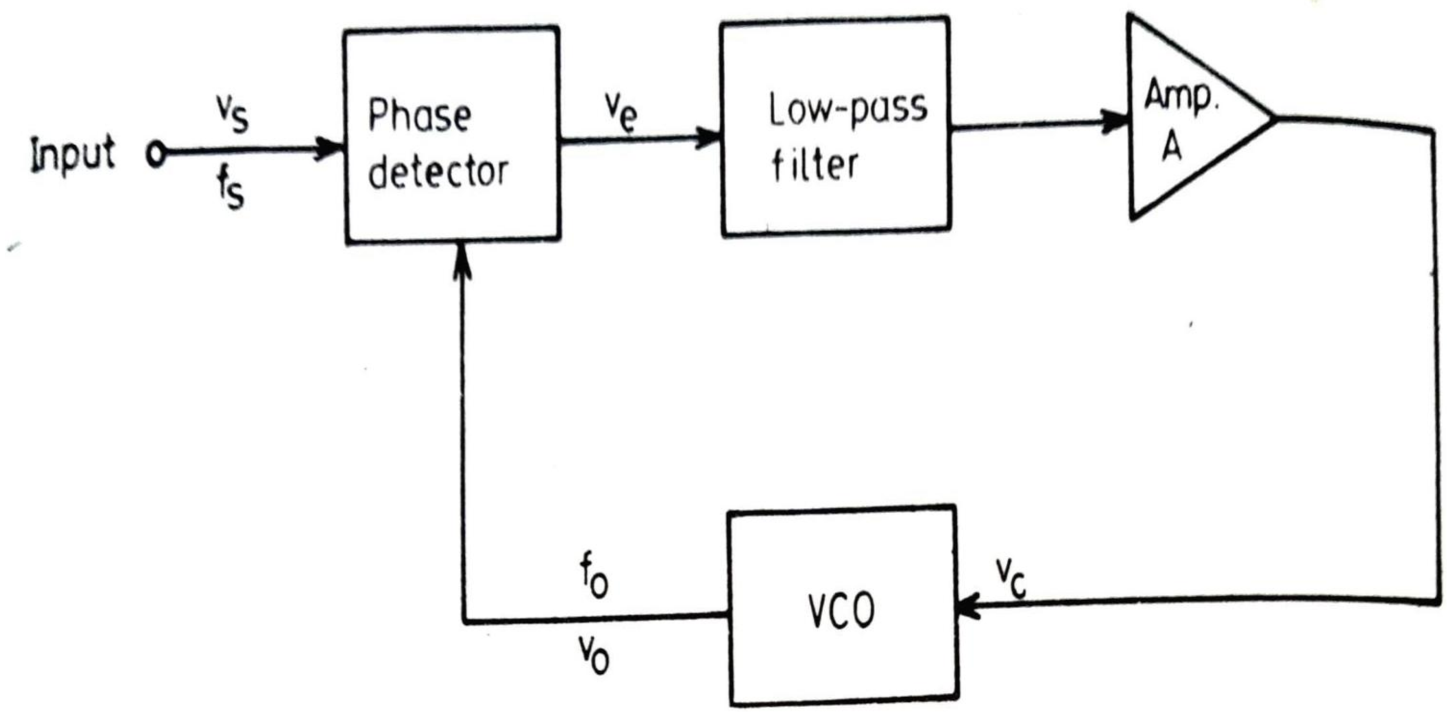
Vcc
2/3 Vcc
1/3 Vcc
t1
t2
t1 = 0.693 (R1 + R2) C
t2 = 0.693 R2 C
T = t1 + t2 = 0.693 (R1 + 2R2) C

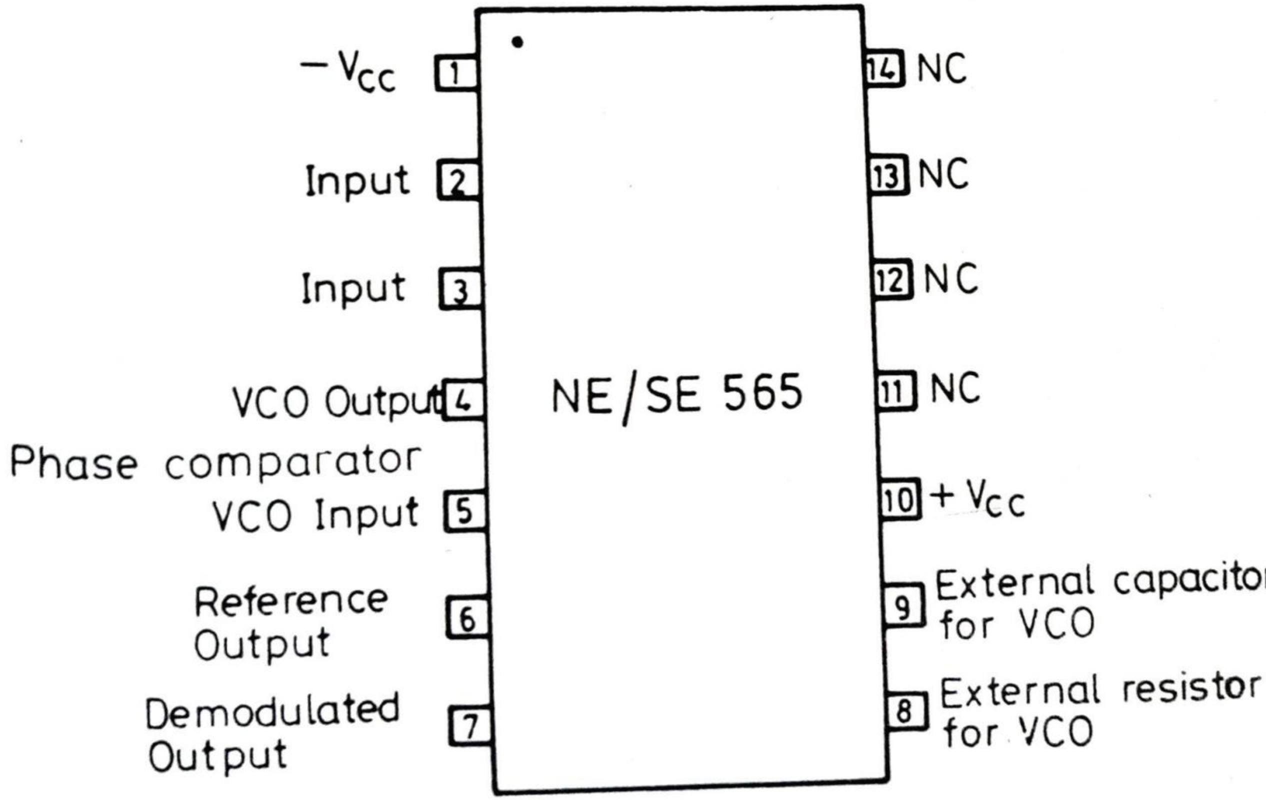
Phase Locked Loop (PLL):

- It is an important building block of linear systems.
- It is used in satellite communication systems, air borne navigational systems, FM communication systems.

Basic Principles:

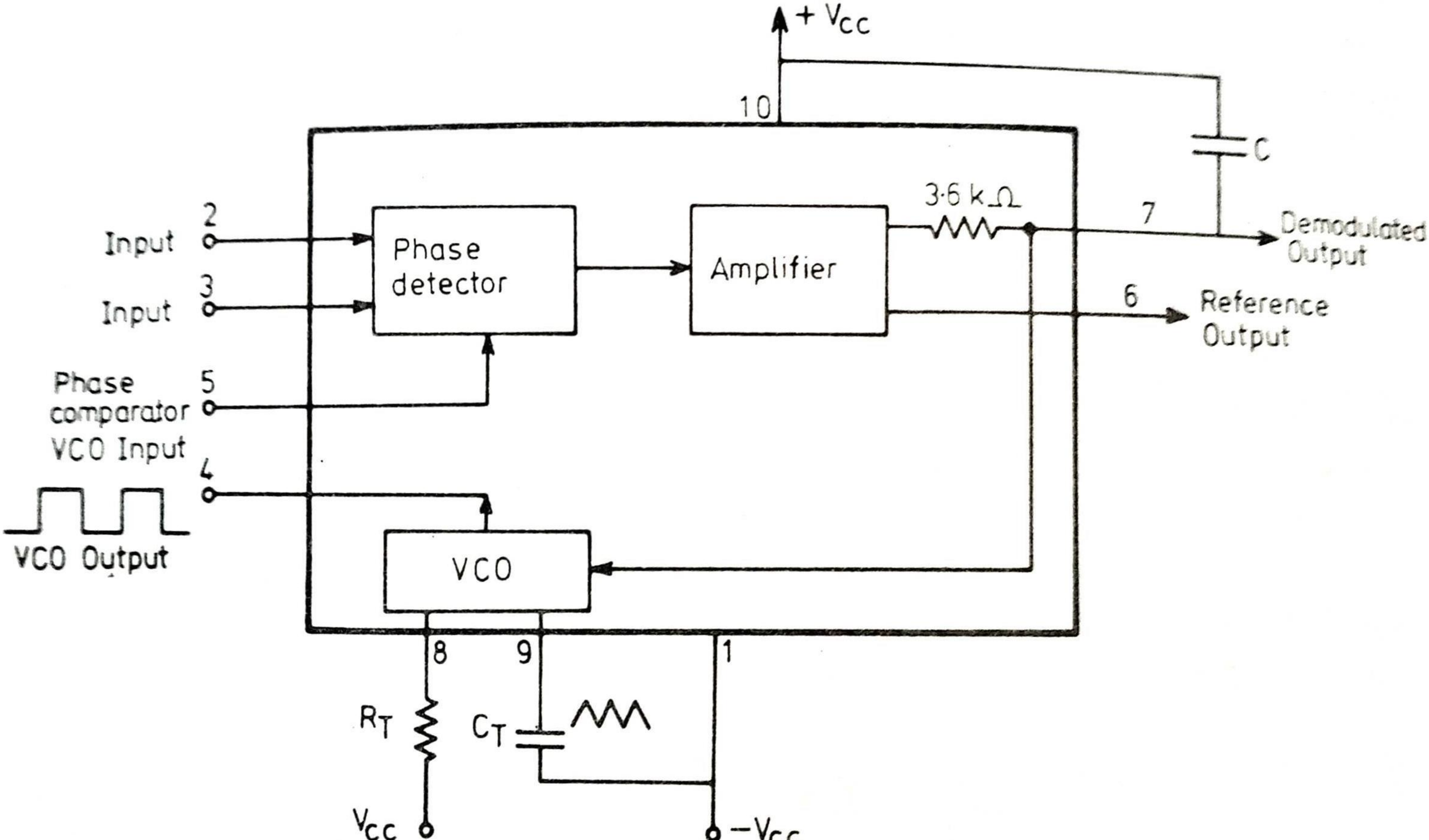
The basic blocks in the PLL is shown in the following figure.



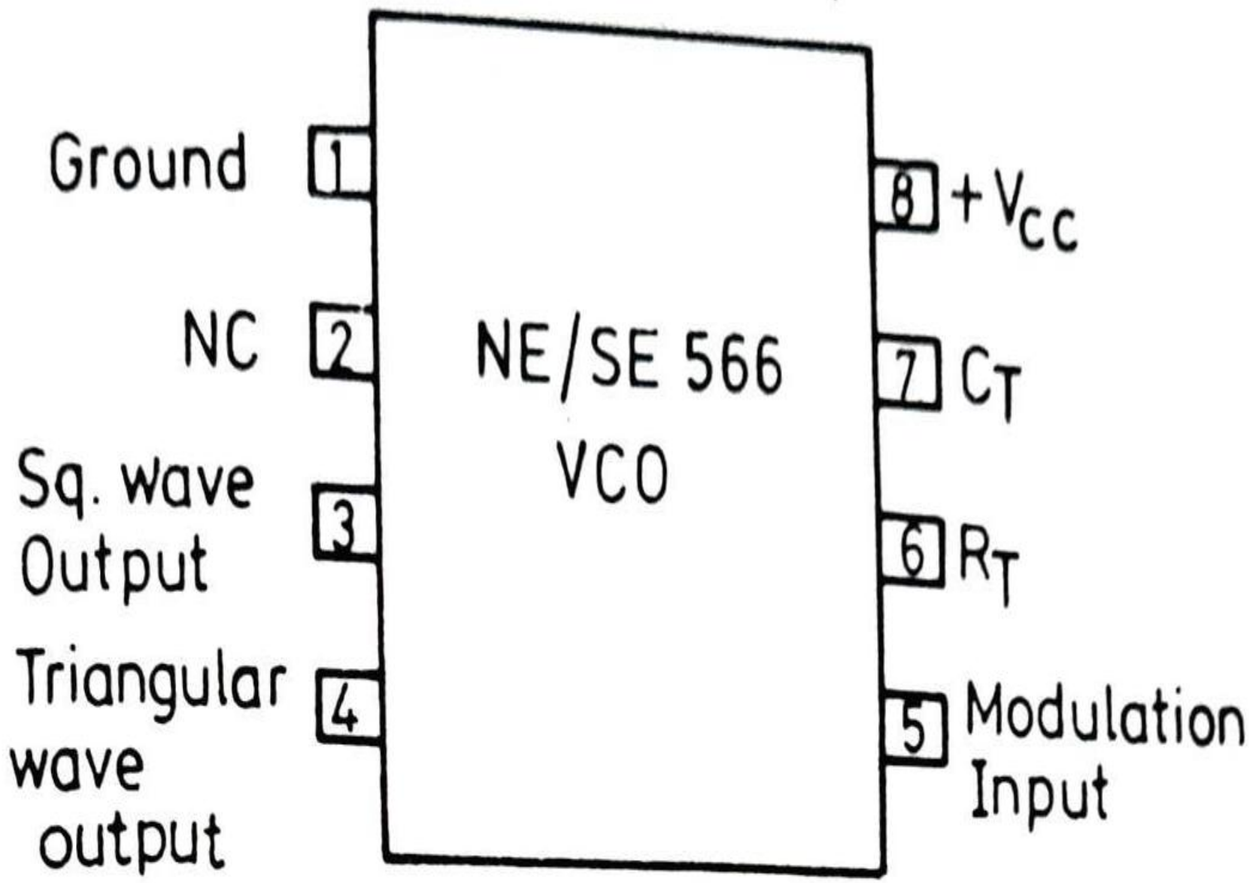


Pin diagram

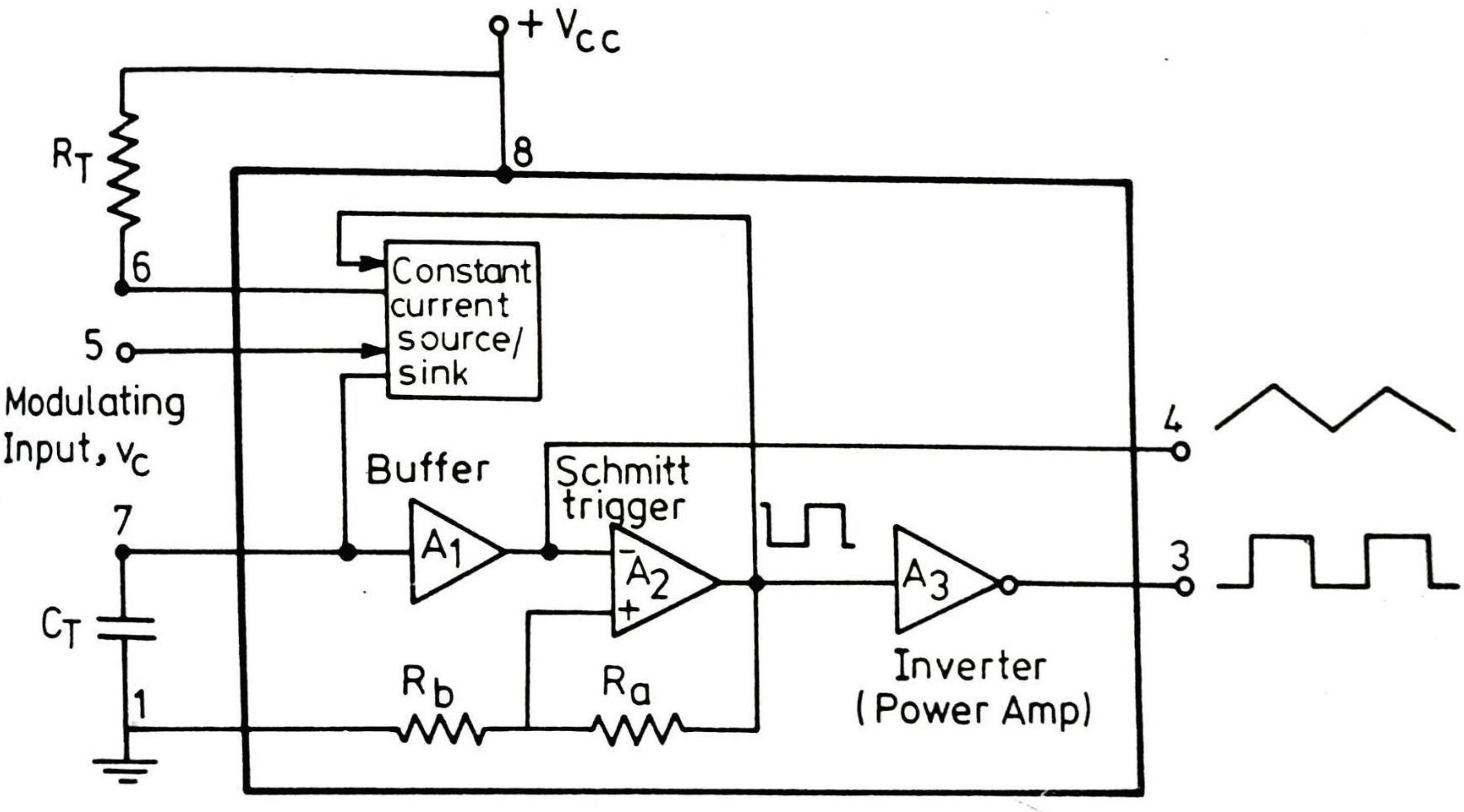
$$f_o = \frac{0.25}{R_T C_T} \text{ Hz}$$


+ V_{CC}
10
C
3·6 kΩ
7
Demodulated Output
6
Reference Output
2
Input
3
Input
Phase detector
Amplifier
5
Phase comparator VCO Input
4
VCO Output
VCO
8
9
1
R_T
C_T
V_{CC}
$-V_{CC}$

Voltage Controlled Oscillator (VCO):



Voltage controlled oscillator Pin configuration



Voltage controlled oscillator Block diagram