2

Analog Circuits & Components

2.1> Introduction

Circuit → It is closed path through a series of electronic components in which current flows through.

Electric Circuit

- Analog Circuit
- Digital Circuit

Analog Circuit

→ Voltage is continuous and can have any value over a specified range.

→ More sensitive to noise or disturbance than digital.

Digital Circuit

→ Voltage signal is usually represented by just two different level. (eg 0 & 5 Volt)

→ Small disturbance have no effect.

When voltage or current varies sinusoidally with time it is called an alternating current (AC) circuit.

2.2> Analog Circuit Elements

Circuit Components

- Passive Type
- Active type

Passive Type

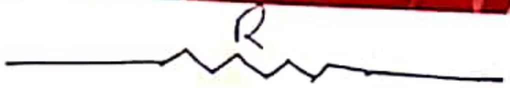
→ Requires no external power to operate.

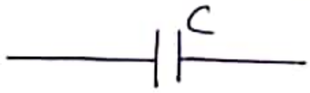
→ eg: resistors, capacitors

Active type

→ Requires power to operate

→ eg: Operational amplifier.

Resistors 

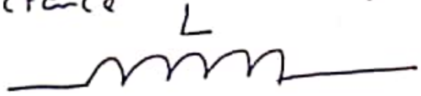
Capacitor 

Ideal Voltage Source 

{battery}

Ideal Current Source 

→ {Ideal because they do not have internal resistance, capacitance or Inductance}

Inductor 

① Resistors

→ Elements that dissipate Energy.

- Fixed type
  - Surface mount
  - Wire wound
  - Thick film
  - Carbon Composite ⟸ Most Common, $0\Omega \rightarrow 20M\Omega$
- Variable type
  - Rheostats (2-Terminal)
  - Potentiometer (3 Terminal)

② Capacitor

→ Energy storing element.

- Capacitor
  - Ceramic Type → Capacitance less than $0.1 \mu F$.
  - Electrolyte Type → up to several 1000 μF.

③ Inductor

→ Energy storing Element.

→ Practically included in Solenoids & motors.

23> Mechanical Switch

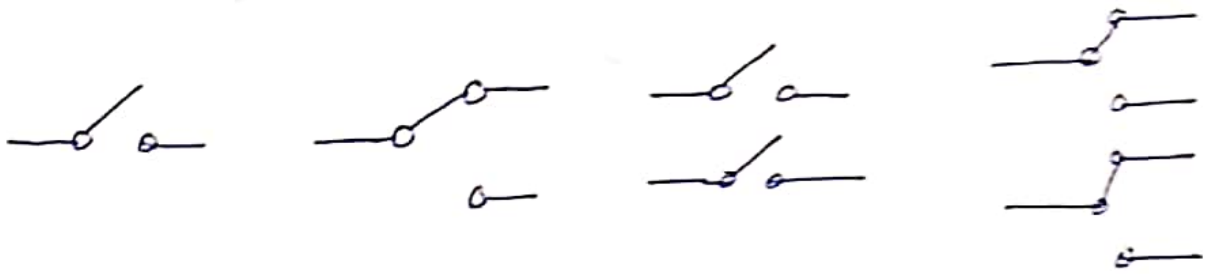
→ Device that make or break Contact in electrical circuit.

Toggle | Push button | Rocker | Slide

⇒ Toggle Switch are Specified in terms of their number of poles & throw.

poles: no of circuit that can be completed by the same switching action

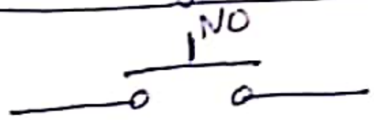
throw: number of individual contacts for each pole

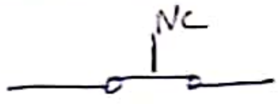


(a) SPST (b) SPDT (c) DPST (d) DPDT

Push button

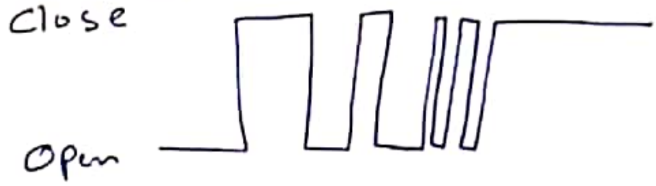
Normally open (NO) | Normally Closed (NC)





⇒ Push-button switch are normally used as reset switches or doorbell switch.

One $\boxed{\text{disadvantage}}$ of mechanical switches is switch bouncing.



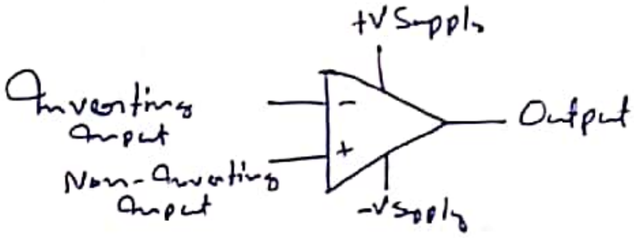
{Switch bouncing}

→ The most common approach to solve this problem is to provide for each switch a debouncing circuit that makes use of flip-flop circuit element.

2.9) Operational Amplifiers

↳ Active analog circuit component.

→ Widely used in amplification & Signal-Conditioning circuit.



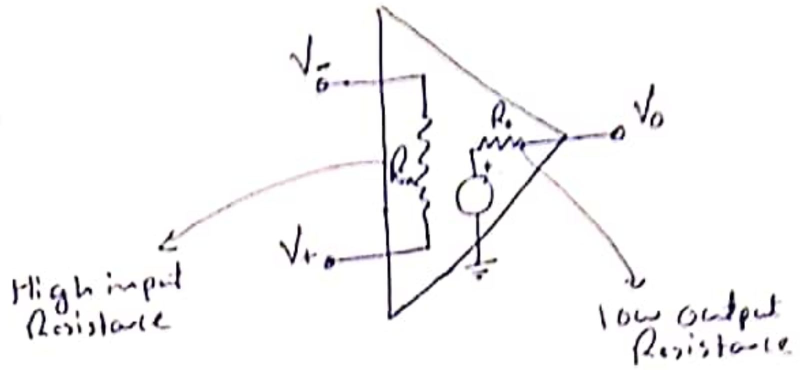
→ There are two other connections to the op-amp (Called the balance or null offset) that permit adjustment of the op-amp output, but they are typically not shown.

→ Commercially, op-Amps are available in a variety of forms.

eg: LM741 (8-pin IC) {National Semiconductor}

→ An op-amp is constructed from a number of components including transistors, diodes, capacitors and resistors.

An ideal op-amp can be modeled as:-



$$\boxed{V_0 = K_{OL} \times (V_+ - V_-)}$$

open loop gain of op-amp

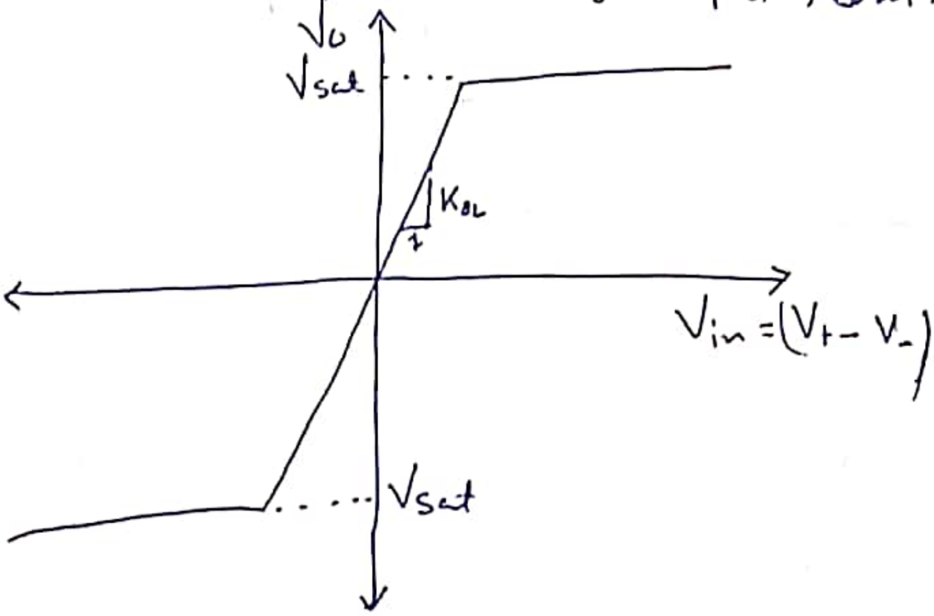
{usually 10^5 to 10^6}

⇒ Since the op-amp output is finite, but the op-amp has a very large gain, we assume $V_+ = V_-$.

Basic assumptions used to analyze ideal op-amp

→ $V_+ = V_-$

→ No current flows through input terminal.



Open-loop input/output relationship for an op-amp.

⇒ Op-amps have good frequency response characteristics and their bandwidth exceeds 1MHz.

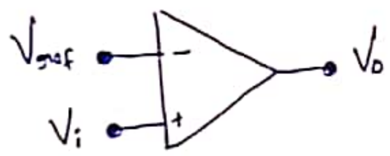
⇒ Op-amps can perform various operations such as :-

i) Comparison
ii) Amplification
iii) Inversion
iv) Summation
v) Integration
vi) differentiation
vii) filtering

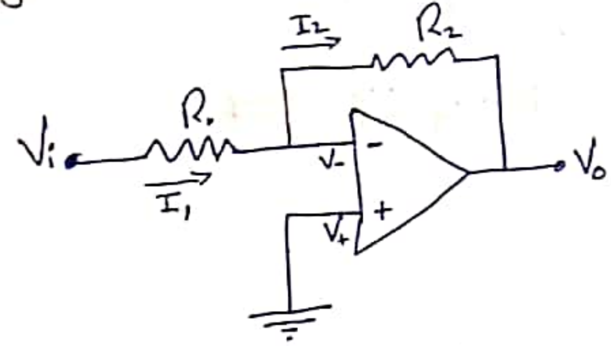
① Comparator Op-Amp

"A Comparator is used to compare two voltage signals, and switch the output to $+V_{sat}$ if one of the signals is large than the other, and to $-V_{sat}$ otherwise"

$$V_o = \begin{cases} V_{sat} & V_i > V_{ref} \\ -V_{sat} & V_i < V_{ref} \end{cases}$$



② Inverting Op-Amp



⇒ Since the non-inverting input is connected to ground

$$V_- = V_+ = 0$$

⇒ No current flows between the inverting & non inverting input.

$$I_1 = I_2$$

$$I_1 = \frac{V_i}{R_1}$$

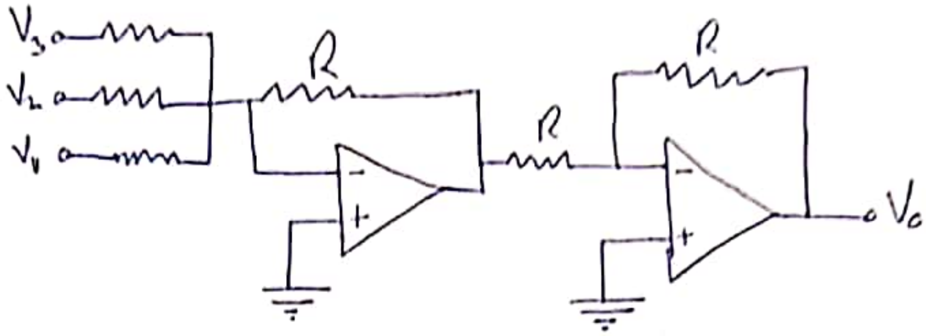
$$I_2 = \frac{-V_o}{R_2}$$

$$\Rightarrow \frac{V_i}{R_1} = \frac{-V_o}{R_2} \Rightarrow \boxed{V_o = -\left(\frac{R_2}{R_1}\right) V_i}$$

⇒ Thus the circuit inverts the input voltage & amplifies it by a factor equal to the ratio of the resistance of R_2 to R_1.

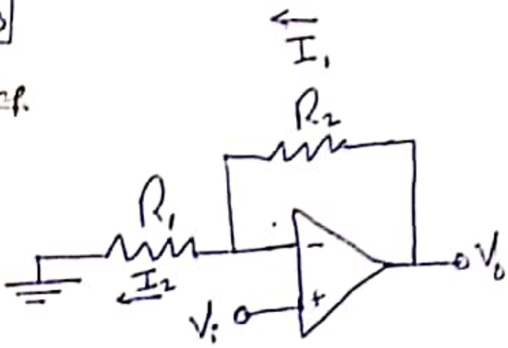
<u>Application</u>: Signal inversion ⇒ Output will have 180° phase shift with the input.

③ <u>Summing Circuit</u>



$$\boxed{V_o = V_1 + V_2 + V_3}$$

④ <u>Non inverting Op-Amp.</u>



$$\boxed{V_i = V_+ = V_-}$$

$$I_1 = \frac{V_o - V_-}{R_2} = \frac{V_o - V_i}{R_2}$$

$$I_2 = \frac{V_-}{R_1} = \frac{V_i}{R_1}$$

$$\boxed{I_1 = I_2} \Rightarrow \frac{V_o}{R_2} - \frac{V_i}{R_2} = \frac{V_i}{R_1}$$

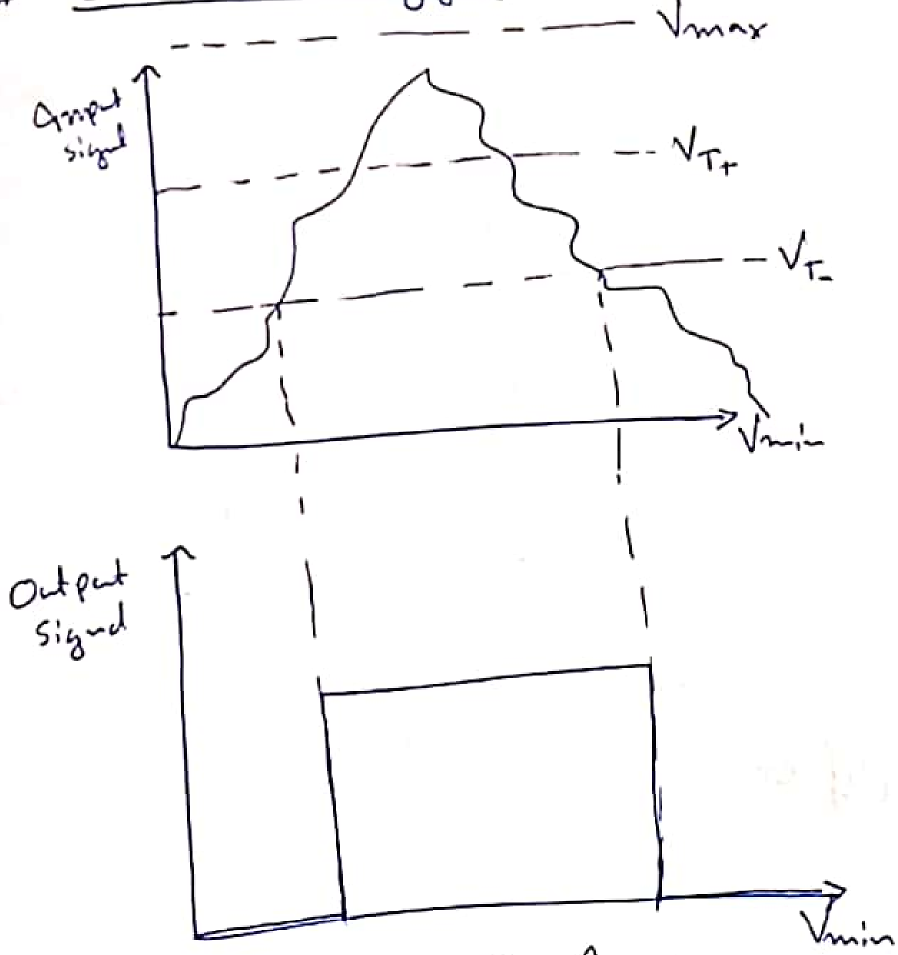
$$V_o = V_i R_2 \left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

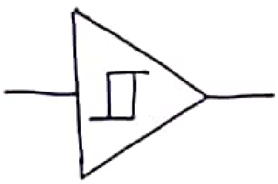
⑤

$$\boxed{V_o = \left(1 + \frac{R_2}{R_1}\right) V_i}$$

⇒ This circuit is known as a voltage follower.

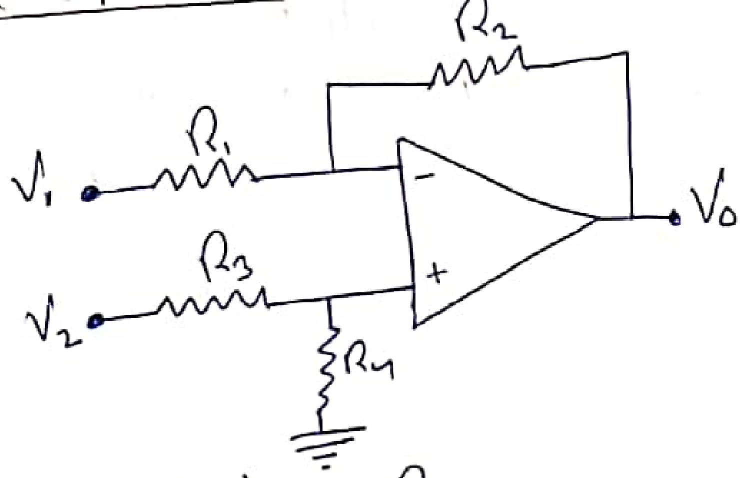
Schmitt trigger





Symbol

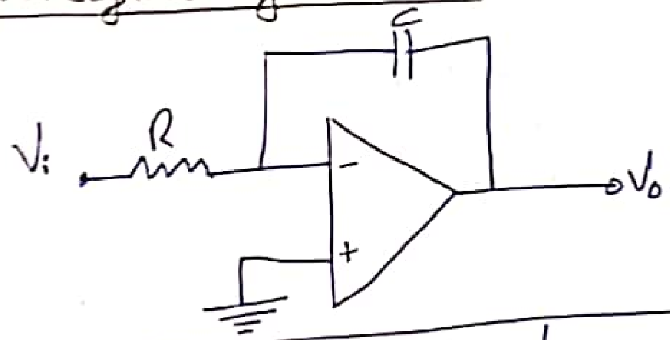
5 Differential Op-Amp



$$V_o = \frac{R_4}{R_3 + R_4}\left(1 + \frac{R_2}{R_1}\right)V_2 - \frac{R_2}{R_1}V_1$$

$$\boxed{V_o = \frac{R_2}{R_1}(V_2 - V_1)}$$ $\left\{ \text{Putting } R_3 = R_1,\ R_4 = R_2 \right\}$

⑥ Integrating Op-Amp



$$\Rightarrow \boxed{V_o(t) = V_o(0) - \frac{1}{RC}\int_0^{t_1} V_i(t)\,dt}$$

Note: If the Capacitor and the resistor were interchanged in this circuit, the op-amp will act as $\boxed{\text{differentiator}}$ of the input signal.

$$\boxed{V_o = -RC\,\frac{dV_i(t)}{dt}}$$

⑦ Power Amplifier

Power op-amp → op-amp with higher current output rating. ~~are available~~

eg = OPA547 (by Texas Instruments)

⇒ Due to their large output current, power op-amp are available in packages with a built in copper tab to allow easy mounting to a heat sink for good thermal performance.

2.10> Grounding

→ Ground Voltage or zero Voltage is commonly used as reference.

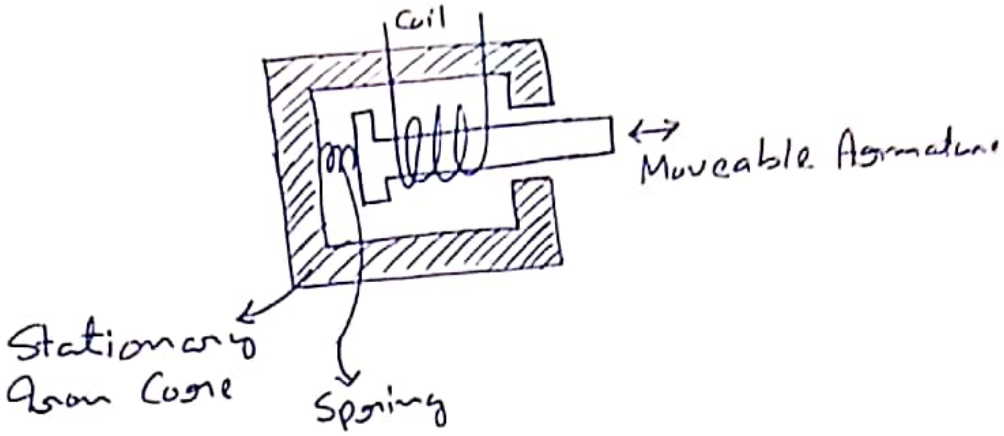
2.11> Solenoids & Relays

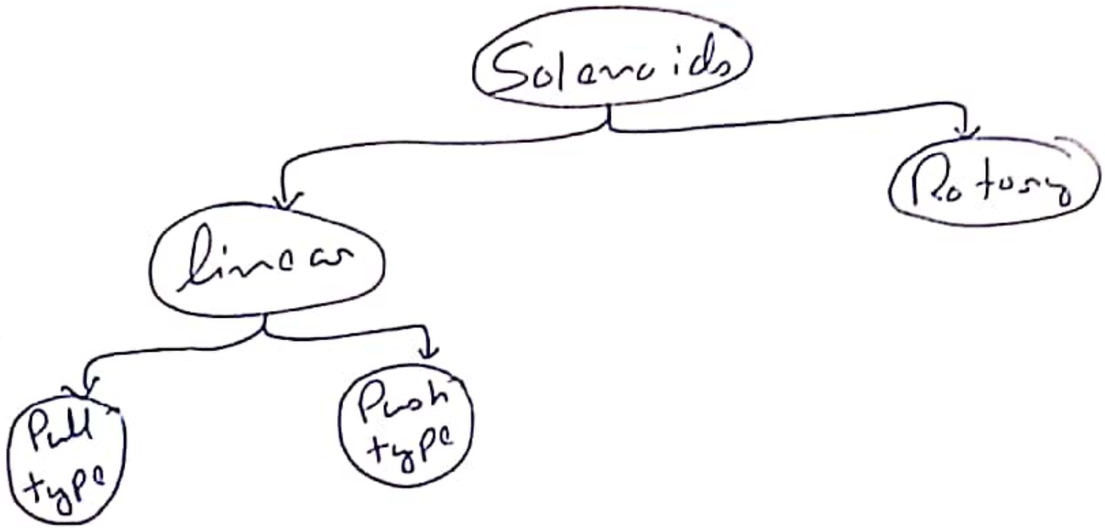
* Solenoids

→ It is commonly used for on-off applications such as locking or triggering.
eg ⇒ Electromechanical relays, door locks etc.

→ It is an electrically actuated mechanical device that has two stage:

(1) Retracted
(2) Extended





★ Electromechanical Relays

→ Electrically actuated Switches that use a Solenoid to make or break the mechanical Contact between electrical leads.

→ One disadvantage of electromechanical relays is their relatively long switching time.

↳ This is in Contrast to Solid State transistors, which have nanoseconds switching time.
