

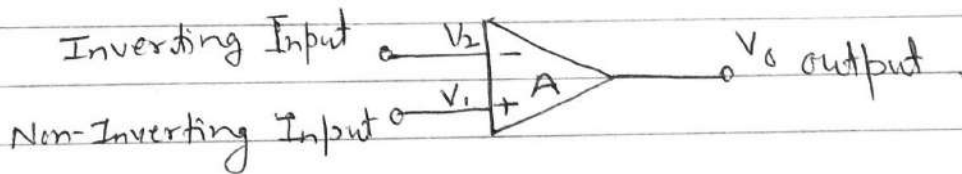
Unit 1:-

Operational amplifiers :-  (op-amp).

An operational amplifier is a direct-coupled high-gain amplifier.

1. The operational amplifier is a versatile device that can be used to amplify dc as well as ac input.
2. The op-amp was originally designed for performing mathematical operations such as addition, subtraction, multiplication and integration. Thus the name operational amplifier stems from its original use for these mathematical operation.

Symbol for the op-amp.



⇒ (+) input is the noninverting input. Any signal (AC or DC) applied to this input produces an inphase (or same polarity) signal at the output.

⇒ (-) input is the inverting input because any signal (AC or DC) applied to this input produces an 180° out of phase (opposite polarity) signal at the output.

V_1 = Voltage at the non-inverting input (Volts)

V_2 = Voltage at the inverting input (Volts)

V_o = output voltage (Volts)

All the voltages are measured with respect to ground.

A = large-signal voltage gain.

Integrated Circuits (IC)

IC - Integrated circuits, meaning that all the components in the circuit are fabricated on the same "chip".

Classification of IC's according to their mode of operation. IC's are of two basic types: Digital or linear.

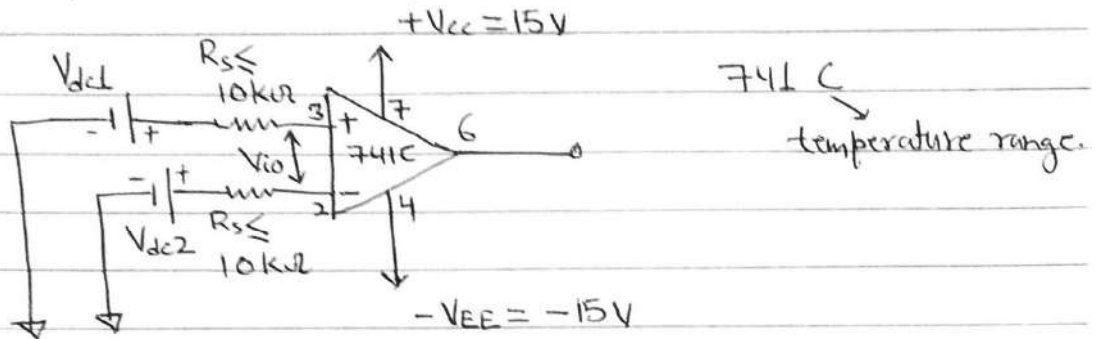
- (1) Digital ICs are complete functioning logic networks that are equivalents of basic transistor logic circuits. They are used to form such circuits as gates, counters, multiplexers, demultiplexers, shift registers and others. Digital Circuits are primarily concerned with only two levels of voltage "high" and "low".
- (2) Linear ICs are equivalents to discrete transistor networks, such as amplifiers, frequency multipliers, and modulators. That often require additional external components for satisfactory operation. Example, external resistors are necessary to control the voltage gain and frequency response of an op-amp.

Classification based on the number of components integrated on the same chip

Small-scale integration	SSI < 10 Components
Medium-scale integration	MSI < 100 Components.
Large-scale integration	LSI > 100 Components.
Very large-scale integration.	VLSI > 1000 Components

Few Electrical parameter of 741 (op-amp)

- (*) Input offset Voltage: - Input offset voltage is the voltage that must be applied between two input terminals of an op-amp to null the output

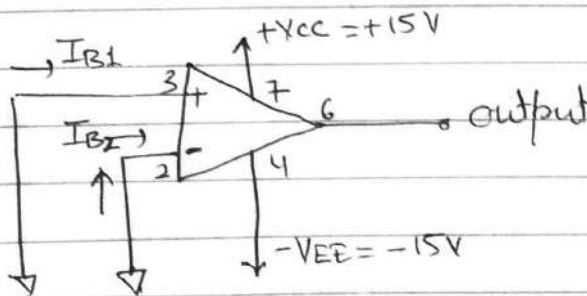


$$V_{io} = (V_{dc1} - V_{dc2})$$

Maximum V_{io} is 6mV dc for 741C. Smaller the value of V_{io} the better the input terminals are matched.

- (*) Input Bias Current: - Input bias current, I_B is the average of the currents that flow into the inverting and non-inverting input terminals of the op-amp.

$$I_B = \frac{I_{B1} + I_{B2}}{2}$$

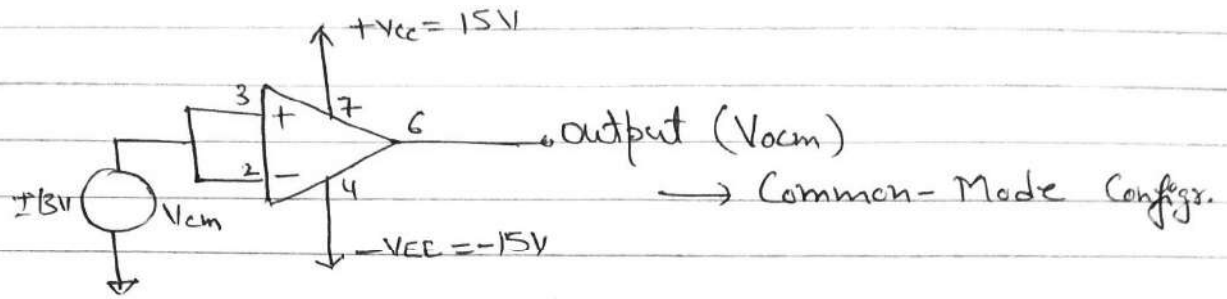


Maximum $I_B = 500\text{nA}$ for 741C

- (*) $I_{io} = |I_{B1} - I_{B2}| \rightarrow$ Input offset current

Maximum $I_{io} = 200\text{nA}$ for 741C.

* Common-Mode Rejection Ratio (CMRR) :-



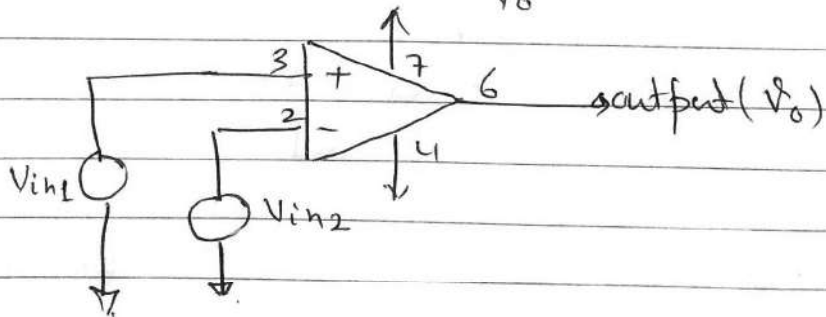
CMRR is defined as ratio of the differential voltage gain A_d to the common-mode voltage gain A_{cm}

$$CMRR = \frac{A_d}{A_{cm}} \quad A_d = A$$

$$A_{cm} = \frac{V_{ocm}}{V_{cm}}$$

Where V_{ocm} = output common-mode voltage.
 V_{cm} = Input common-mode voltage.
 A_{cm} = common-mode voltage gain.

$$A_d = A = \frac{(V_{in1} - V_{in2})}{V_o} = \frac{V_{in1}}{V_o}$$



Where V_{in1} → Input non-inverting voltage.
 V_{in2} → Input inverting voltage.
 V_o → output voltage.
 A_d → Differential voltage gain.

Generally the A_{cm} is very small and A_d is very large \therefore CMRR is very large.

CMRR is most often expressed in decibels (dB)

$$CMRR = 90 \text{ dB for } 741C.$$

(*) Slew Rate \rightarrow Slew rate (SR) is defined as the maximum rate of change of output voltage per unit of time and is expressed in volts per microsecond.

$$SR = \left. \frac{dV_o}{dt} \right|_{\max} \quad V/\mu s.$$

Slew rate indicates how rapidly the output of an op-amp change in response to change in the ~~input~~ input frequency.

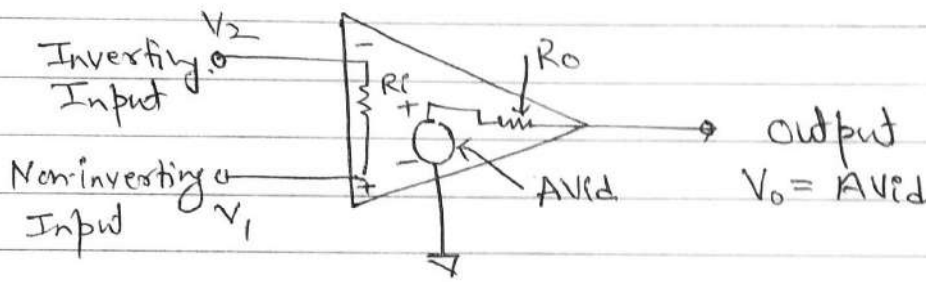
$$\text{Slew rate} = 0.5 \text{ V}/\mu s \quad \text{for } 741C \text{ (drawbacks)}$$

Characteristics of an ideal op-amp.

1. Infinite voltage gain A .
2. Infinite input resistance R_i so that almost any signal source can drive it and there is no loading of the preceding stage.
3. Zero output resistance R_o so that the output can drive an infinite number of other devices.
4. Zero output voltage when input voltage is zero.
5. Infinite bandwidth so that any frequency signal from 0 to ∞ Hz can be amplified without attenuation.

6. Infinite common-mode rejection ratio so that the output common-mode noise voltage is zero.
7. Infinite slew rate so that output voltage occurs simultaneously with input voltage changes.

Equivalent circuit of an op-amp.



$$V_o = A V_{id} = A(V_1 - V_2)$$

A = large-signal voltage gain

V_{id} = difference input voltage.

V_1 = Voltage of the non-inverting input terminal w.r.t.g.

V_2 = Voltage of the inverting input terminal w.r.t. ground.

Ideal Voltage transfer curve.

