UNIT-5

(Lecture-6)

OP-AMP CIRCUITS

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(with op-amp treated as a block)

1.0 IC op-amp and its ideal properties:

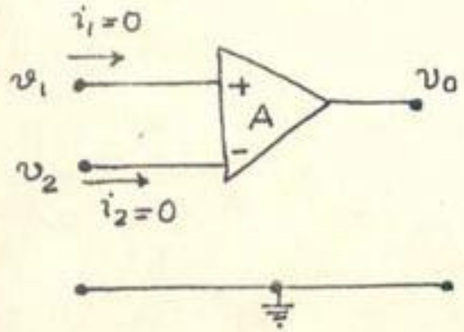
The integrated circuit op-amp is the most prominent and versatile building block of analog circuits. Although initially op-amp was employed to perform various mathematical **operations** like integration, addition, sign changing, function generation etc. (commonly employed for analog computation) from which the generic name ***operational amplifier*** was derived, with the availability of integrated circuit (IC) op-amp as an off-the-shelf item it has now found numerous other applications in many diverse areas of signal processing, instrumentation and measurement, communication etc.

Here, we are mainly concerned with the study of some basic building blocks which can be realised with IC op-amps.

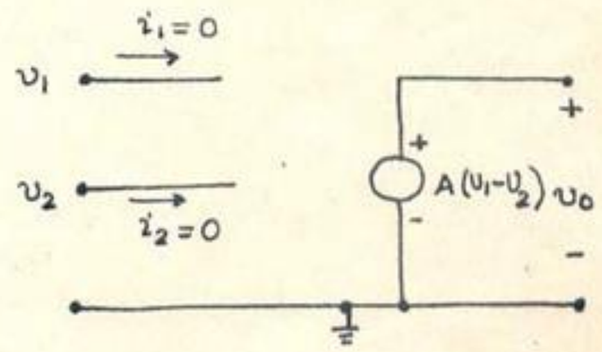
An operational amplifier is basically a very high gain differential amplifier with the following ideal properties:

- infinite voltage gain (ie $A \to \infty$)
- Infinite input impedance (ie input terminals draw zero current when connected to soure)
- zero output impedance (ie it acts as an ideal voltage source w.r.t output terminal)
- infinite bandwidth (ie gain remains constant from zero frequency to infinity)
- zero offset voltage (ie $V_0 = 0$ when $V_1 = 0 = V_2$)
- zero drift (ie parameters not changing with temperature

(a)



(b)



$i_1 = 0$

$i_2 = 0$

$v_0 = A(v_1 - v_2)$

Fig. 1 (a) ideal op-amp (b) equivalent circuit of an ideal op-amp

An ideal op-amp can be regarded as a differential input VCVS. A large variety of IC op-amps are available out of which the internally compensated types such as μA741, 747, LM 324, LF356 have been the more popular ones. The pin configuration for 741 type op-amp is given in Fig. 2, and its important parameters are given in Table 1.

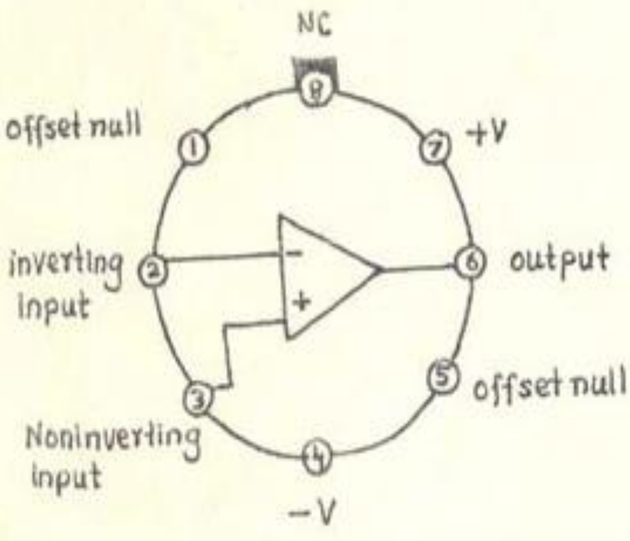


Fig. 2 Pin configuration of 741 type IC op-amp (metal can package)

Table 1 Parameters of 741 op-amp

Parameter	741(c)(typical)
Voltage gain	2×10^5
Input impedance	2 MΩ
output impedance	75 Ω
offset voltage	2 mV
bandwidth (unity gain bandwidth)	1 MHz

2. Basic Analog circuits using op-amps :

In the following we show different controlled sources and other useful circuits can be realised by using IC op-amps. Although in some synthesis techniques the op-amp may be directly used as an infinite-gain VCVS in its own right, it is normally customary to use this device as finite gain VCVS

VCVS circuits : Consider the 3-port VCVS of Fig. 3 . Assuming ideal op-amp (ie $Z_{in} = \infty$, $Z_o = 0$, $A \to \infty$) the node equation at node m is

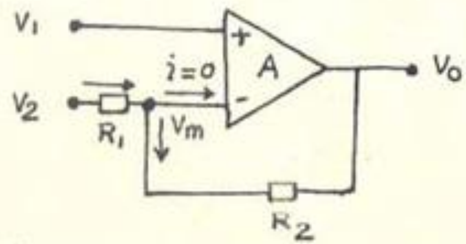


Fig. 3 Three-port VCVS

$$\frac{V_2 - V_m}{R_1} = \frac{V_m - V_o}{R_2} \qquad (1)$$

solving for v_m gives, $v_m = \frac{R_2}{R_1+R_2} V_2 + \frac{R_1}{R_1+R_2} V_o \qquad (2)$

also $(V_1 - V_m)A = V_o$

or $(V_1 - V_m) = \frac{V_o}{A}$ which means $V_1 = V_m$ as $A \to \infty \qquad (3)$

Equation (3) implies a very important property of an ideal op-amp, that due to infinite gain *voltages at the two input terminals of the op-amp are forced to be equal*. Thus, the input terminals of the op-amp exhibit a 'virtual short'. When one of these input terminals is connected to ground the other terminal acts as the 'virtual ground'.

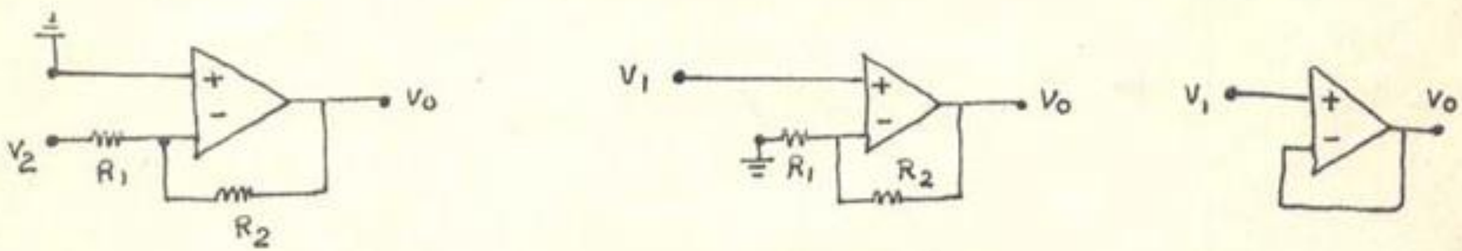
From (2) and (3)

$$V_o = \left(1 + \frac{R_2}{R_1}\right) V_1 - \frac{R_2}{R_1} V_2 \qquad (4)$$

case 1 : $V_1 = 0$ then the circuit assumes the form of Fig. 4 (a) and from (4)

$$V_o = -\frac{R_2}{R_1} V_2 \qquad (6)$$

Thus the circuit acts as an inverting VCVS (or inverting amplifier) of gain $-\frac{R_2}{R_1}$.



(a) (b) (c)

Fig. 4 (a) Inverting amplifier gain $= -\frac{R_2}{R_1}$ (b) noninverting amplifier; gain $= \left(1 + \frac{R_2}{R_1}\right)$ (c) voltage follower; gain $= 1$

case 2 : $V_2 = 0$, then circuit acts as noninverting amplifier with gain $= \left(1+\frac{R_2}{R_1}\right)$ since (4) reduces to

$$V_0 = \left(1+\frac{R_2}{R_1}\right)V_1 \qquad (7)$$

with resulting circuit shown in Fig. 4(b).

case 3 : If R_2 is shorted and R_1 is opened in Fig. 3, the circuit shown in Fig. 4 (c) results for which (from (4))

$$V_0 = V_1 \qquad (8)$$

and the circuit acts as a unity gain voltage follower.

Note that all the three VCVS of Fig. 4 have (ideally) zero output impedance; the noninverting VCVS of Fig. 4 (b) and unity gain VCVS of Fig. 4 (c) have (ideally) infinite Z_{in} but Z_{in} for the inverting VCVS is finite and approximately equal to

$$Z_{in} \approx R_1 \qquad (9)$$