EEE-2103: Electronic Devices and Circuits

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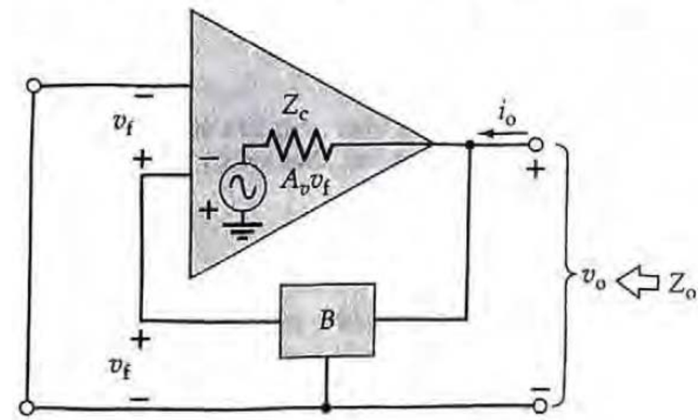
Series Voltage Negative Feedback

Output impedance:

Output voltage v_o produces feedback voltage v_f
v_f generates voltage $A_v v_f$ in series with Z_c
Z_c = output impedance without feedback

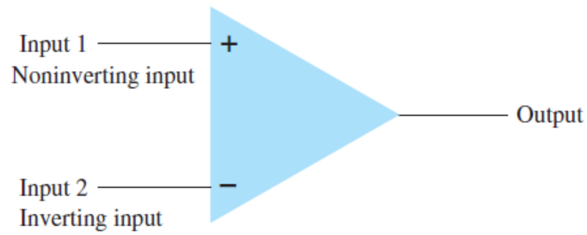


$v_o = i_o Z_c - A_v v_f$
$i_o Z_c = v_o + A_v v_f = v_o + A_v B v_o = v_o(1 + A_v B)$
$Z_o = v_o / i_o = \frac{Z_c}{1 + A_v B}$

Operational Amplifiers (Op-Amps)

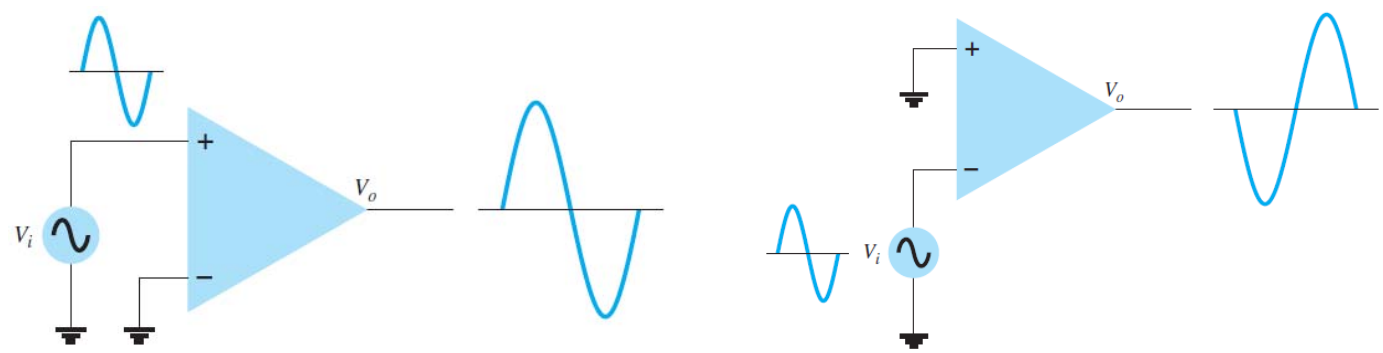
Op-amp → very high gain differential amplifier,
high input impedance,
low output impedance.

Uses → provide voltage amplitude changes,
oscillators,
filter circuits,
instrumentation circuits.



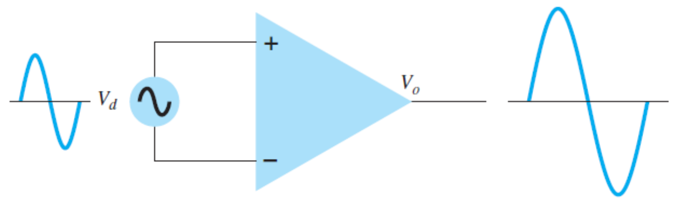
Signal is applied to + → same polarity (or phase) output
Signal is applied to – → opposite polarity (or phase) output

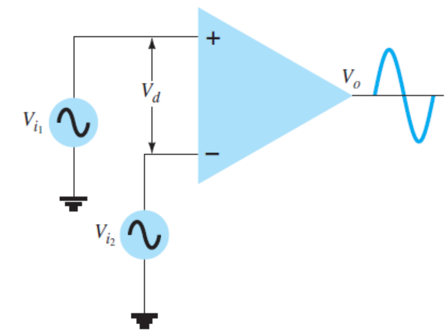
Single-Ended Input →



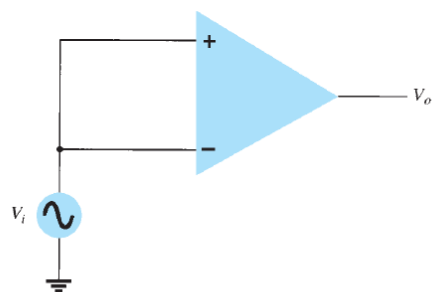
Operational Amplifiers (Op-Amps)

Double-Ended (Differential) Input →





Common-Mode Operation →



Common-Mode Rejection →

difference signal at inputs are highly amplified,
common signals at inputs are slightly amplified = rejected.
noise is common to both inputs.
differential connection provides → attenuation of unwanted input
amplification of difference input.

Voltage Follower Circuits

Suppose, $V_o > V_i$ →

$V_{B2} = V_2 > V_{B1} = V_i$

I_{C2} would be increased

V_{RC} will be increased

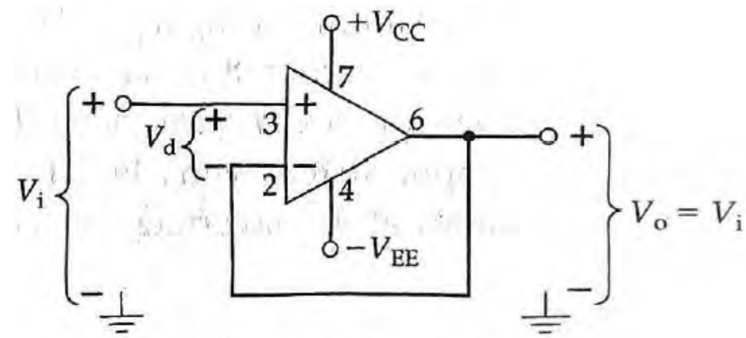
V_{B3} will be reduced → $V_o = V_i$

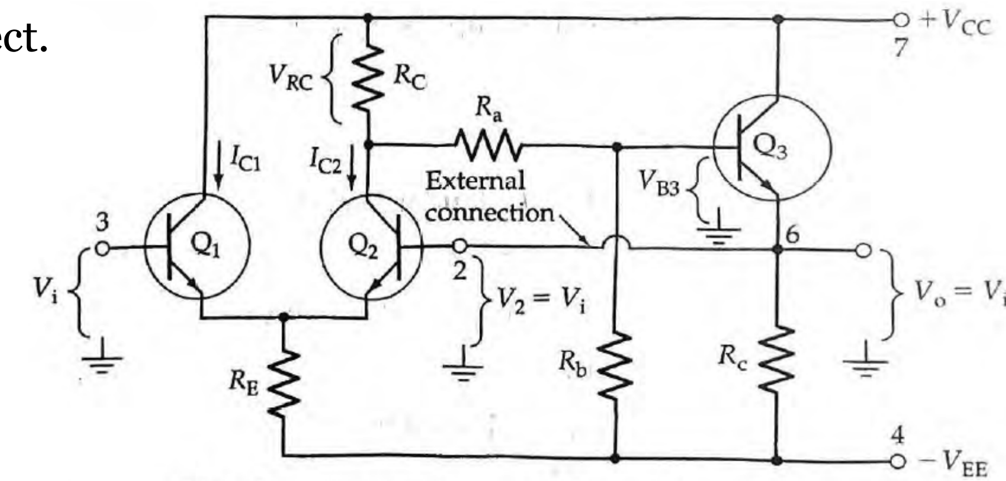
Suppose, $V_o < V_i$ →

$V_o = V_i$ due to similar -ve feedback effect.

When V_i at 3 is increased or decreased →

V_o follows V_i perfectly.





Non-Inverting Amplifiers

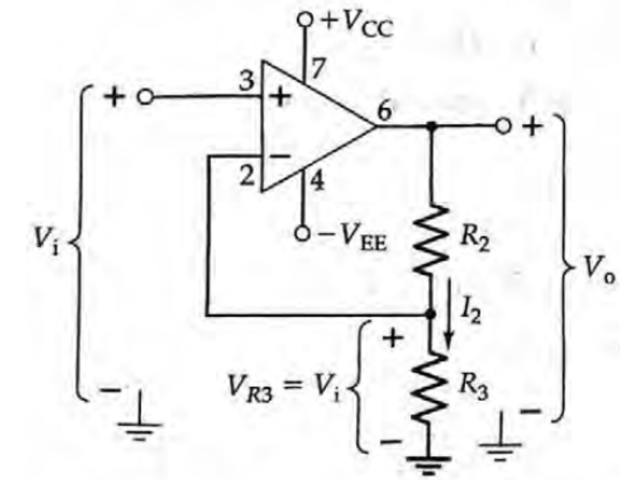
Portion of V_o is fed back to inverting input.
V_o changes as necessary → $V_{R3} = V_i = I_2 R_3$
I_2 >> op-amp input bias current

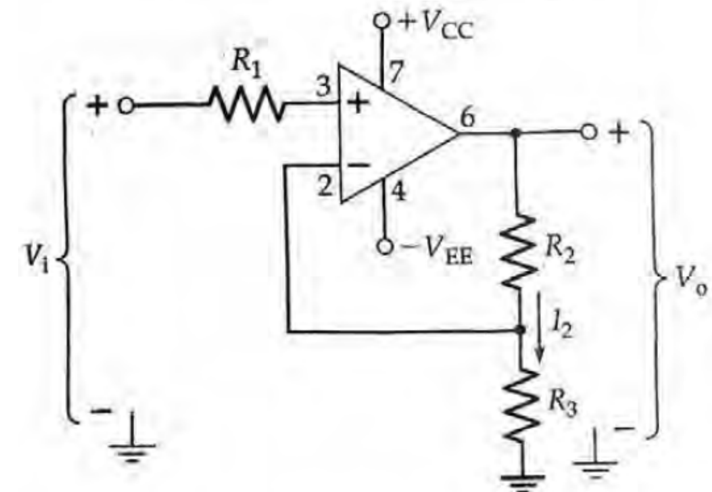
$I_2 = \frac{V_O}{R_2 + R_3}$

Circuit voltage gain, $A_{CL} = \frac{V_O}{V_i} = \frac{I_2(R_2+R_3)}{I_2 R_3} = \frac{R_2+R_3}{R_3}$

V_{R1} is produced by input bias current.

$R_1 = R_2 || R_3$

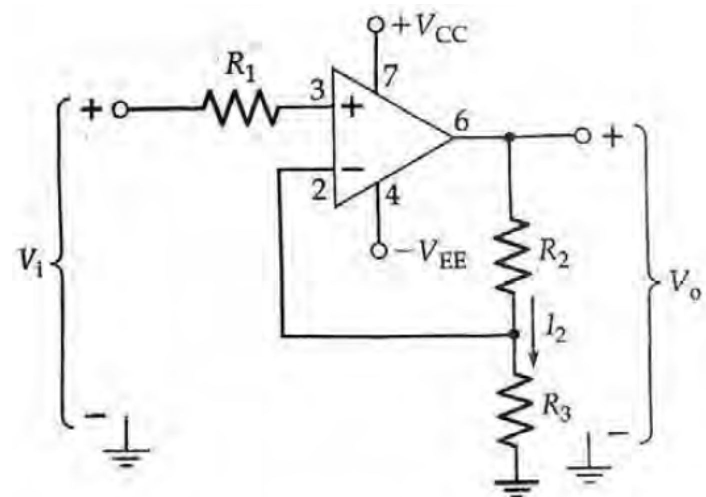




Non-Inverting Amplifiers

Problem-45:

Design a direct-coupled non-inverting amplifier using 741 op-amp. The output voltage is to be 2 V when the input is 50 mV. Also, calculate typical input and output impedances for the amplifier. Assume $I_{B(max)}$ = 500 nA, A_v = 200000, r_i = 2 MΩ, r_o = 75 Ω.



$I_{2(min)} = 100 I_{B(max)} = 100\times(500\times10^{-9}) = 50\ \mu A$

$R_3 = V_i/I_2 = (50\times10^{-3})/(50\times10^{-6}) = 1\ k\Omega$

$R_2 + R_3 = V_o/I_2 = 2/(50\times10^{-6}) = 40\ k\Omega$

$R_2 = (R_2 + R_3) - R_3 = 40 - 1 = 39\ k\Omega$

$R_1 = R_2 || R_3 = 39||1 \approx 1\ k\Omega$

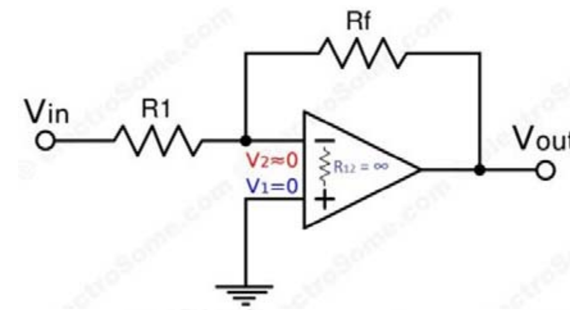
$$B = \frac{R_3}{R_2+R_3} = \frac{1}{39+1} = \frac{1}{40}$$

$$Z_i = (1 + A_v B) r_i = \left[1 + 200000\frac{1}{40}\right]\times2\times10^{6} \approx 10000\ M\Omega$$

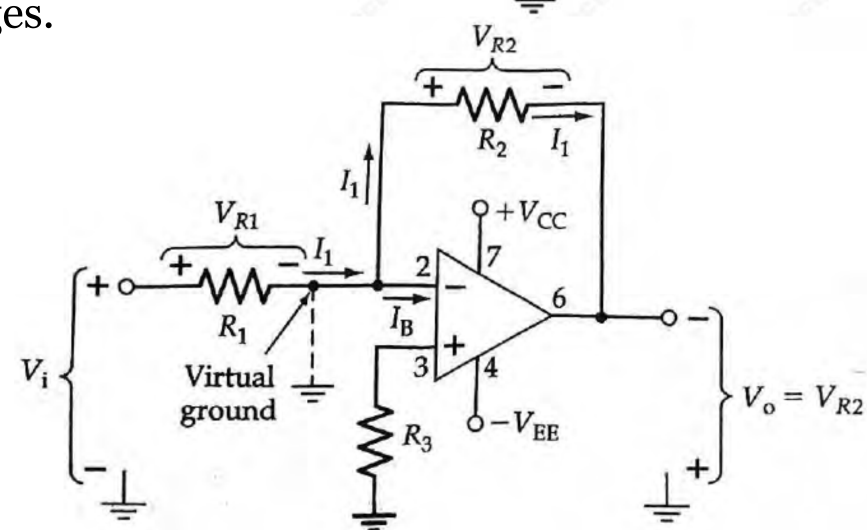
$$Z_o = \frac{r_0}{1+A_v B} = \frac{75}{1+(200000/40)} \approx 0.015\ \Omega$$

Inverting Amplifiers

Non-inverting input terminal is grounded via R_3
Inverting input terminal → voltage ≈ ground.
virtual ground.



Very small input voltage difference is amplified by open-loop gain.
Portion of V_o is fed back via R_2 and R_1 to correct changes.



Circuit input current, $I_1 = V_{R1}/R_1 = V_i/R_1$ $[V_{R1} = V_i]$
I_1 >> input bias current I_B
$V_{R2} = I_1R_2$
$V_o = -I_1R_2$

Circuit voltage gain, $A_{CL} = V_o/V_i = -I_1R_2/I_1R_1 = -R_2/R_1$

Input impedance, $Z_i = R_1$

Inverting Amplifiers

Problem-47:

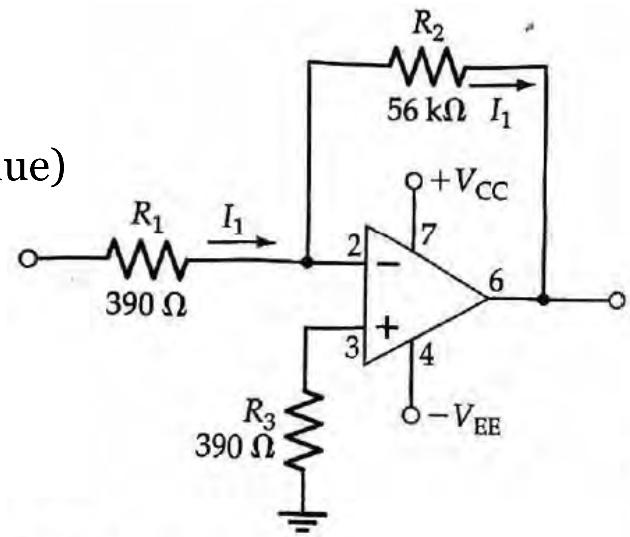
Design a direct-coupled inverting amplifier using a 741 op-amp. The input voltage amplitude is 20 mV and the voltage gain is to be 144. Assume $I_{B(max)}$ = 500 nA.

$I_{1(min)} = 100 I_{B(max)} = 100\times(500\times10^{-9}) = 50\ \mu A$

$R_1 = V_i/I_1 = (20\times10^{-3})/(50\times10^{-6}) = 400\ \Omega$ (use 390 Ω standard value)

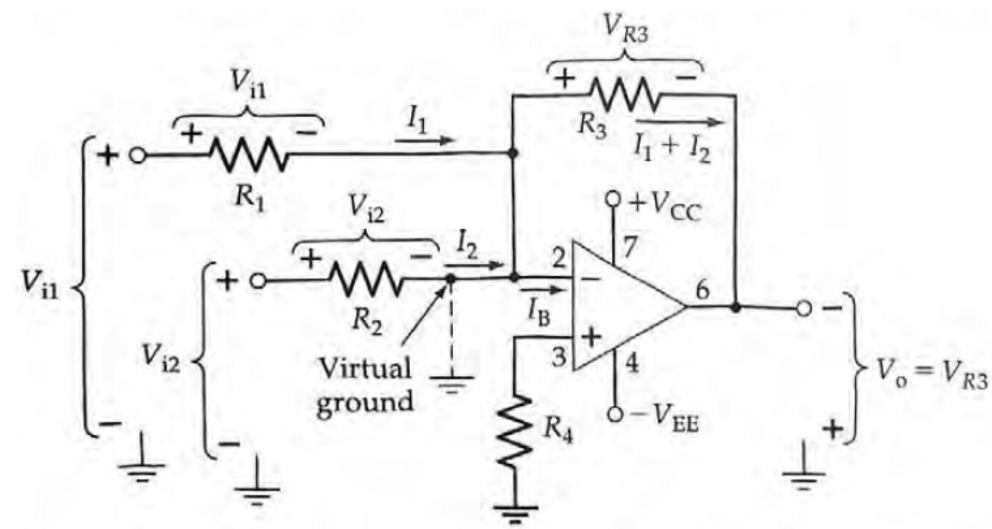
$R_2 = A_{CL}R_1 = 144\times390 = 56.2\ k\Omega$ (use 56 kΩ standard value)

$R_3 = R_1||R_2 = 390||(56\times10^3) \approx 390\ \Omega$



Summing Amplifiers

2 inputs applied to R_1 and R_2
2 input voltages, V_{i1} and V_{i2}
2 input currents → $I_1 = V_{i1}/R_1$
$I_2 = V_{i2}/R_2$



Output voltage,

$$V_o = -(I_1 + I_2)R_3$$

$$= -\left[\frac{V_{i1}}{R_1} + \frac{V_{i2}}{R_2}\right]R_3$$

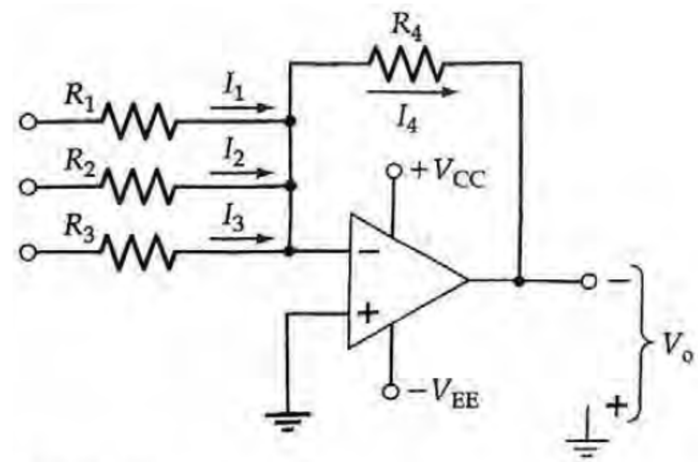
$$= -\frac{R_3}{R_1}[V_{i1} + V_{i2}] \qquad [R_1 = R_2]$$

$$= -[V_{i1} + V_{i2}] \qquad [R_1 = R_2 = R_3]$$

Summing Amplifiers

Problem-48:

Design a three-input summing amplifier using an op-amp and to have a voltage gain of 3. Calculate the resistor currents and the output voltage when all three inputs are 1 V.



Select R_4 = 1 MΩ

Let, $R_1 = R_2 = R_3 = R_4/A_{CL} = 1\times10^6/3$

$= 333$ kΩ (use 330 kΩ standard value)

$I_1 = I_2 = I_3 = V_i/R_1 = 1/(330\times10^3) = 3.03\ \mu A$

$I_4 = I_1 + I_2 + I_3 = 3.03 + 3.03 + 3.03 = 9.09\ \mu A$

$V_o = -I_4R_4 = -9.09\times10^{-6}\times1\times10^6 = -9.09$ V