8/6/21

UNIT-1

CLASS TEST.

V.VIDHYA

ECE-B

113019106097

PART-A

1. SLEW RATE & CAUSES:

Slew rate is maximum rate of change of output voltage with respeck to time. Specified in V/MS.

REASON FOR SLEW RATE: usually a capacitor within O. outside an op-amp oscillation. This capacitor, which prevents to output voltage from fast changing input. The rate at which the volt across the capacitor increases $dv_c/dt = I/C$

where: I = maximum amount furnished by op-amp to capacitor C. Op amp should have the either a higher current or small compensating capacitors.

2, IDEAL CHARACTERISTICS OF OP-AMP:

- Infinite voltage gain A.
- Zero output resistance Ro, so that the output can drive an infinite number of other drives.
- Infinite common mode rejection ratio, so that the output common mode noise voltage is zero.

- Infinite slew rate, so that output voltage changes occur simultaneously with input voltage changes.
- Infinite bandwidth so that any frequency signals from 0 to ∞ Hz can be amplified without attenuation.

PART-B

1. Explain the dc characteristics of op-amp.

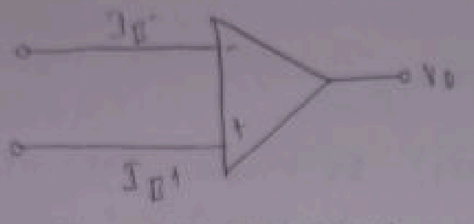
DC output voltages are:

- Input bias current
- Input offset current
- Input offset voltage
- Thermal drift.

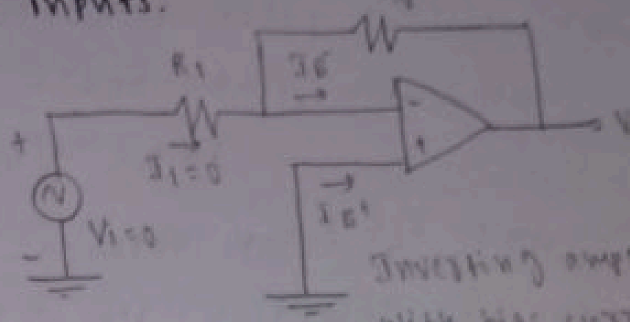
→ **INPUT BIAS CURRENT:**

- Op-amp's input is differential amplifier, which may be made of BJT or FET.
- In an ideal op-amp we assumed that no current is drawn from the input terminals the base currents entering into the inverting + non-inverting terminals.

• Even though both the transistors are identical, I_B^- and I_B^+ are not exactly equal due to internal imbalance b/w the two inputs.



Input bias current

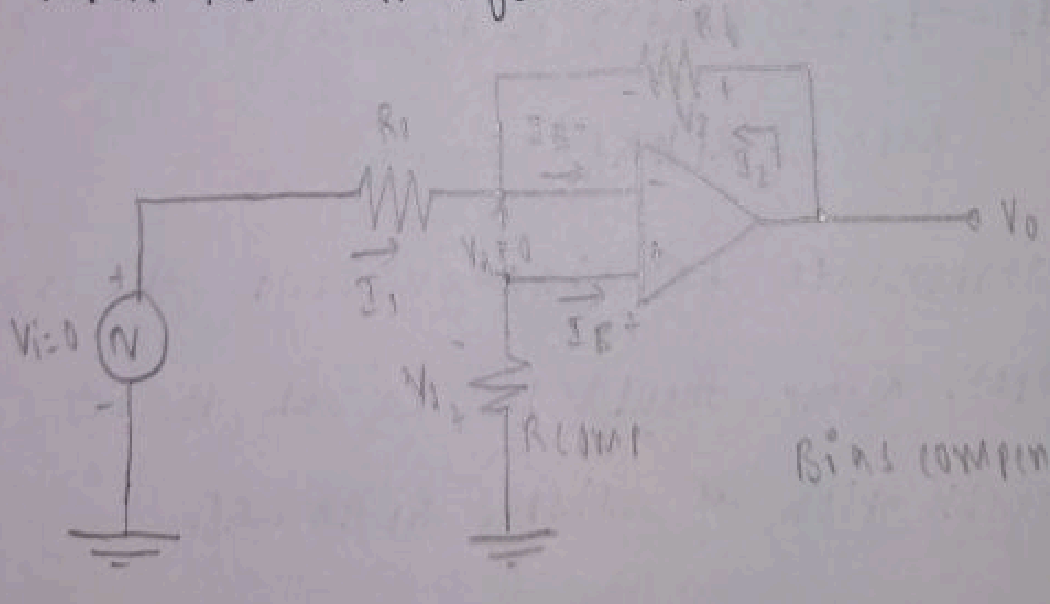


Inverting amplifier with bias current

• Input voltage $V_i = 0V$, $I_B = \frac{I_B^+ + I_B^-}{2}$. The output V_0 should be $(V_0 = 0)$ but for $I_B = 500nA \Rightarrow V_0 = 500nA \times 1M = 500mV$.

• The output is driven to 500mV with zero input because of bias currents

• This can be compensated by a compensation resistor Rcomp has been added between the non-inverting input terminal & grounded.



Bias compensated circuit

current I_{B+} flowing through compensating resistor R_{comp} then by KVL, $V_0 = V_2 - V_1$ —— ①

By selecting proper value of R_{comp} V_2 can be cancelled with V_1 and $V_0 = 0$.

$$I_{B+} = V_1 / R_{comp} \quad —— ②$$

The node 'a' is at voltage $(-V_1)$ because the voltage at the non-inverting i/p terminal is $(-V_1)$

$$I_1 = V_1 / R_1 \quad —— ③$$

$$I_2 = V_2 / R_f \quad —— ④$$

For compensation: V_0 should equal to zero: $(V_0 = 0, V_i = 0)$

from eq ③ $V_2 = V_1$ so,

$$I_2 = V_1 / R_f \quad —— ⑤$$

KCL at node 'a' gives

$$I_{B-} = I_2 + I_1 = (V_1/R_f) + (V_1/R_n) / R_1 R_f \quad —— (5)$$

Assume $I_{B-} = I_{B+} = I$ & using ② & ⑤ we get

$$R_{comp} = R_1 \| R_f \quad —— ⑥$$

i.e to compensate for bias current the compensating resistor, R_{comp} should be equal to the parallel combination of resistor R_1 and R_f.

INPUT OFFSET CURRENT:

→ Bias current compensation will work if both bias currents I_B+ and I_B- are equal

→ Since the input transistor cannot be made identical. There will always be some small difference between I_B+ and I_B-.

$$|I_{os}| = I_B+ - I_B- \quad \text{—— (7)}$$

Offset current I_{os} for BJT op-amp is 200nA & for FET op-amp is 10PA. Even with bias current compensation, offset current will produce an output voltage when $V_i = 0$.

$$V_1 = I_B+ R_{comp} \quad \text{—— (8)}$$

$$I_1 = V_1 / R_1 \quad \text{—— (9)}$$

KCL at node a gives,

$$I_2 = (I_B^- - I_1) = I_B^- - (I_B^+ R_{comp} / R_1)$$

Again $V_0 = V_2 R_1 - V_1$

$$V_0 = I_2 R_f - I_B + R_{comp}$$

$$V_0 = 1M\Omega \times 200nA$$

$$V_0 = 200mV \text{ with } V_i = 0$$

→ R_1 large the feedback resistor R_f must also be high, so as to obtain reasonable gain.

→ The feedback network is a good solution, this will allow large feedback resistance, while keeping the resistance to ground low (in dotted line)

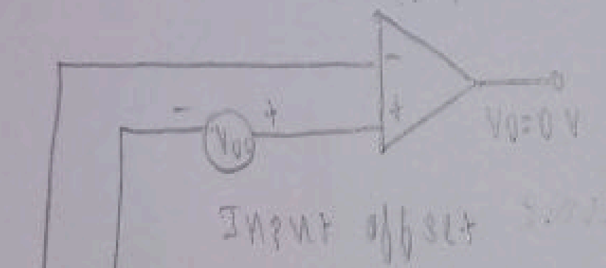
$$R_f = \frac{R_t^2 + 2R_t R_s}{R_s}$$

to design t-network $R_t << R_f/2$

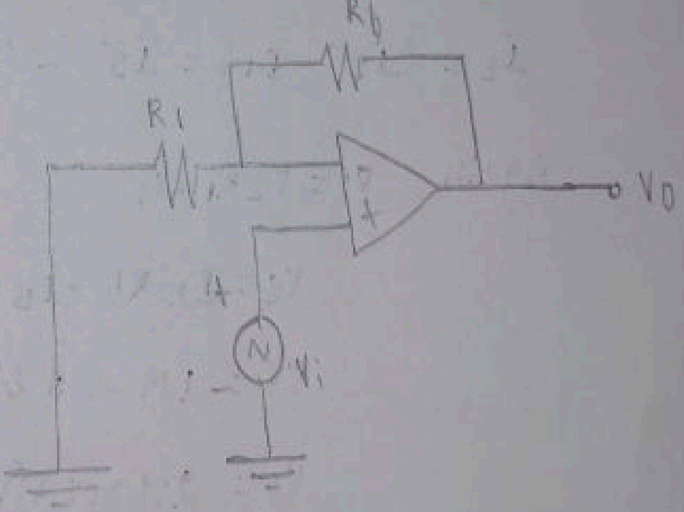
$$R_s = \frac{R_t^2}{R_f - 2R_t}.$$

INPUT OFFSET VOLTAGE:

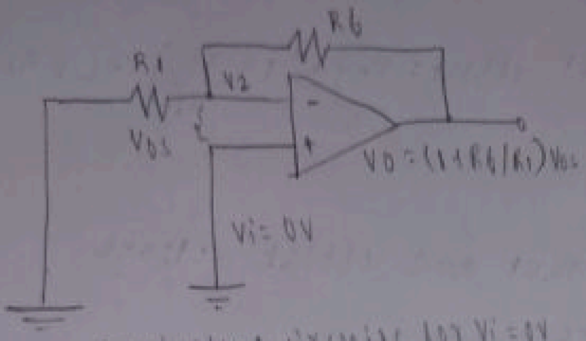
Above compensating techniques, it is found the output voltage still not be zero with zero input voltage. Imbalances inside the op-amp & one may have to apply a small voltage at the input terminal to make output $(V_0) = 0$.



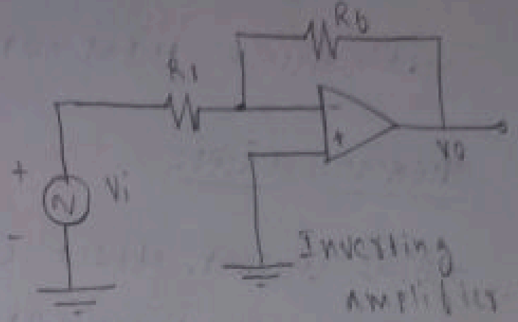
Input offset voltage



Non-Inverting amplifier



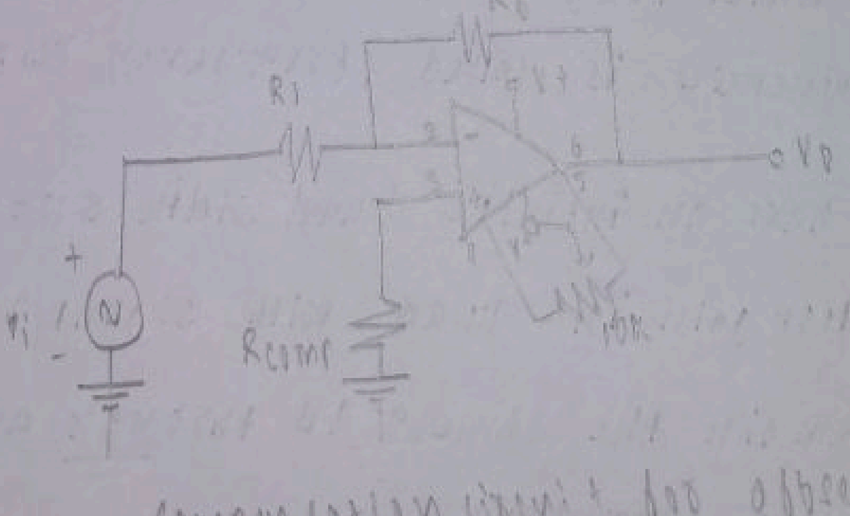
Equivalent circuit for Vi = 0V



Inverting amplifier

TOTAL OUTPUT OFFSET VOLTAGE:

Total output offset voltage could be either more or less than the offset voltage produced at the output due to input bias current or input offset voltage; this is maximum offset voltage at the output of a inverting and non-inverting amplifier without any compensation technique used is given by many op-amps provide offset compensation pins to nullify the offset voltage.



Compensation circuit for offset voltage

With R_{comp}, total output offset: $V_{OT} = \left(1 + \frac{R_f}{R_1}\right) V_{OS} + R_f I_B$

<u>THERMAL DRIFT:</u>

→ Bias current, offset current and offset voltage change with temperature

→ A circuit nulled at 25°C may not remain, so when the temperature rises to 35°C. This is called drift.

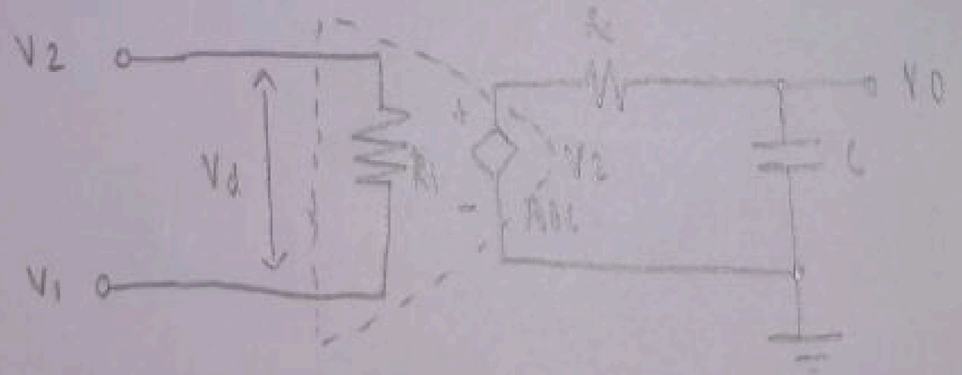
→ Offset current drift is expressed in nA/°C.

2, Explain the frequency response of op-amp with its equivalent circuit?

- The variation in operating frequency all cause variations in gain magnitude and its phase angle.
- The manner in which the gain of the op-amp responds to different frequencies is called frequency response.
- Op-amp should have an infinite band width $BW = \infty$ (i.e) if its open loop gain in 90dB with signal its gain should remain the same 90dB through audio and onto high radio frequency.
- Op-amp gain decreases at higher frequency to decrease gain after a certain frequency reached.

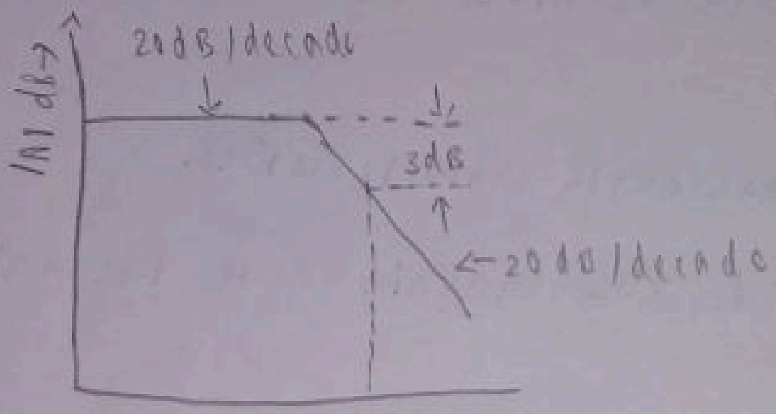
- There must be a capacitive component in the equivalent circuit of the op-amp.
- For an op-amp with only one break frequency all the capacitors effects can be represented by a single capacitor
- There is one pole due to $R_0 C$ and one -20dB/decade.
- Open loop voltage gain of an op-amp with only one corner frequency is obtained.
- f_1 is the corner frequency or upper 3dB frequency of the op-amp.
- The magnitude and phase angle characteristics:

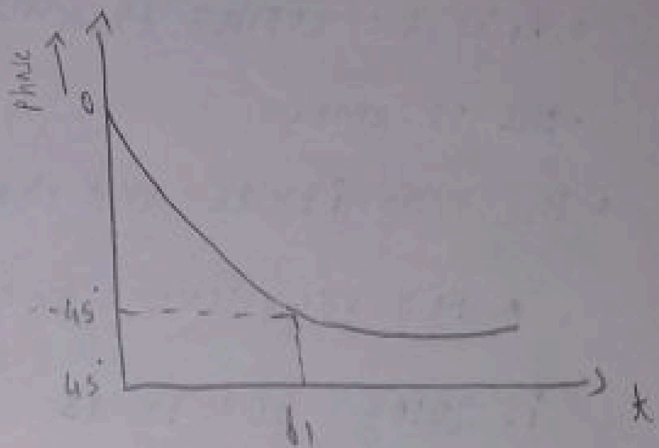
  * For frequency $f << f_1$ the magnitude of the gain is $20 \log A_{OL}$ in dB
  * At frequency $f = f_1$ the gain in 3dB down from the dc value of A_{OL} in dB. This frequency f_1 is called corner frequency.



Equivalent circuit of practical circuit

- For the phase characteristics that the phase angle is zero at frequency $f=0$.
- At the corner frequency f_1 the phase angle is -45° (lagging & an infinite frequency the phase angle is -90°)
- It frequency is taken as the decade below the corner frequency and infinite frequency is one decade above the corner frequency.





Frequency response of op-amp.

Roll off rate of op-amp gain