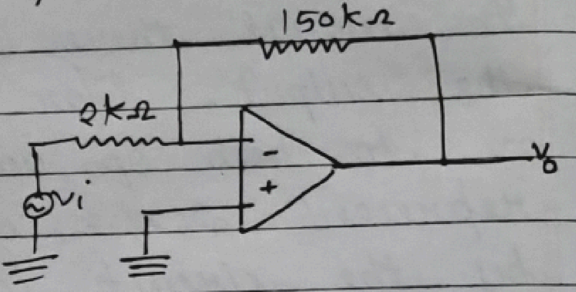
$$V_o = V_{IO} \frac{A}{1 + A\left(\frac{R_1}{R_1+R_f}\right)} \simeq V_{IO} \frac{A}{A\left[R_1/(R_1+R_f)\right]}$$

$$\boxed{V_o(\text{off set}) = V_{IO} \frac{R_1+R_f}{R_1}}$$

Above equation shows how the output offset results from a specified Input offset voltage for a typical amplifier connection of the op-amp

Question 1:- Calculate the output off set voltage of the circuit. The output Amp specilists $V_{IO} = 1.2 mV$.



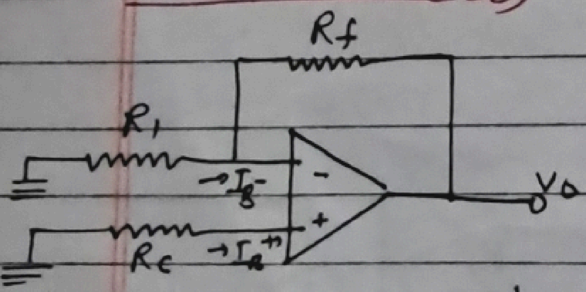
Solution :- we know that;

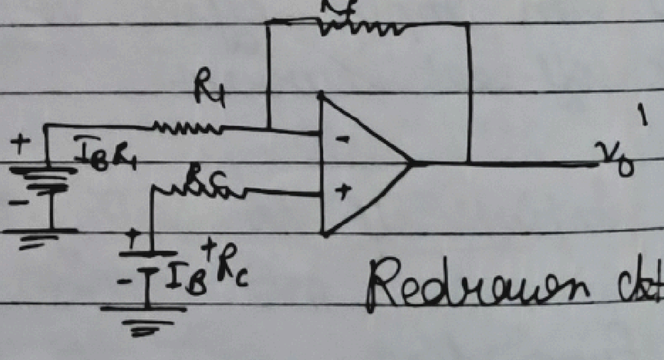
$$V_o(\text{off set}) = V_{IO} \frac{R_1+R_f}{R_1}$$

$$= 1.2mV\left[\frac{2k\Omega + 150k\Omega}{2k\Omega}\right]$$

$$= 91.2mV$$ Ans

2. Output Offset Voltage Due To Input OffSet Current (I_{IO}) :-





op-amp connection showing Input bias Current.

An output offset voltage will also result due to any difference in dc bias current at both inputs. Since the two input transistors are never exactly matched each will operate at a slightly different current. An output offset can be determined as follows. The output voltage due to input bias current I_{IB}^{+} denoted V_o^{+} is given by:-

$$V_o^{+} = I_{IB}^{+} R_C \left(1 + \frac{R_f}{R_1}\right) \quad \text{—— (1)}$$

The output voltage due to I_{IB}^{-} denoted by V_o^{-} is given by:-

$$V_o^{-} = I_{IB}^{-} R_1 \left(-\frac{R_f}{R_1}\right)$$

Total offset voltage :- V_o/ V_{offset} due to I_{IB}^{+} & I_{IB}^{-}

$$= I_{IB}^{+} R_C \left(1 + \frac{R_C}{R_1}\right) - I_{IB}^{-} R_1 \left(\frac{R_f}{R_1}\right) \quad \text{—— (2)}$$

and the offset current I_{IO} :-

$$I_{IO} = I_{IB}^{+} - I_{IB}^{-}$$

but $R_C \cong R_1$

so eq^n (2) can be written as:-

$$V_o\,(\text{off set}) = I_{IB}^{+} (R_1 + R_f) - I_{IB}^{-} R_f$$

$$= I_{IB}^{+} R_f - I_{IB}^{-} R_f$$

$$= R_f \,(I_{IB}^{+} - I_{IB}^{-})$$

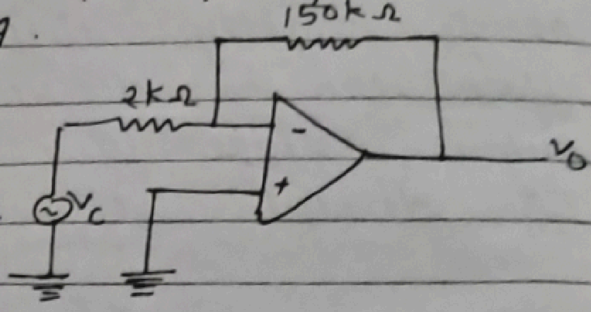
$$\boxed{V_o\,(\text{off set due to } I_{IO}) = I_{IO} R_f} \quad \text{—— (3)}$$

Total off set voltage :-

$|V_o\,(\text{off set})| = |V_o\,(\text{off set due to } V_{IO})| + |V_o\,(\text{off set due to } I_{IO})|$

It may be +ive or -ive.

Question- Calculate the off set voltage for the ckt of figure below for op-amp specification listing $I_{IO} = 100nA$.



Solution :- $V_o = I_{IO} \times R_f$

$V_o = 100nA \times 150k\Omega$

$= 100\times10^{-9}A \times 150\times10^{-3}\Omega$

$= 15\times10^{-3}$

$= 15mV$

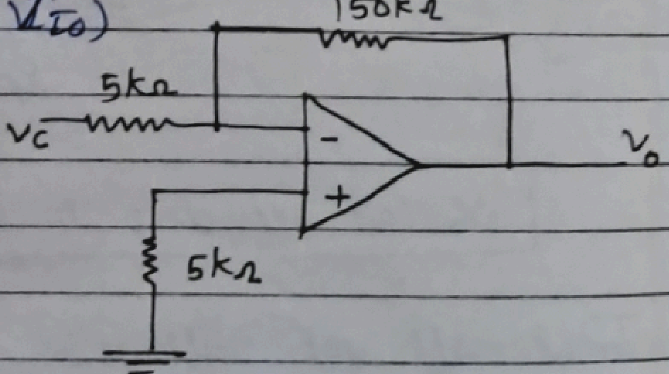
Total off set due to V_{IO} & I_{IO} :-

Since the op-amp output may have an output off set voltage due to both factors covered above the total output off set voltage can be expressed as

$$|V_o(\text{off set})| = |V_o(\text{off set due to } V_{IO})| + |V_o(\text{off set due to } I_{IO})|$$

may be +ive or -ive.

Question :- Calculate the total off set voltage for the circuit for an op-amp specified value of Input off set voltage $V_{IO} = 4mV$ and Input off set current $I_{IO} = 150nA$.



Solution :- V_o (off set due to V_{IO})

$= V_{IO}\dfrac{R_1+R_f}{R_1}$

$= 4mV\left[\dfrac{5k\Omega + 500k\Omega}{5k\Omega}\right]$

$= 4\times101 = 404mV$

we also know V_o (off set due to I_{IO}) $= I_{IO}\times R_f$

$= 150nA \times 500k\Omega = 75mV$

Now total off set $V_o = 404mV + 75mV$

$= 479mV$. Ans

Input Bias Current (I_{IB}):-

An Input bias current (I_{IB}) is the average of two Input bias current i.e; I_{IB}^{+} and I_{IB}^{-}

$$I_{IB} = \frac{I_{IB}^{+} + I_{IB}^{-}}{2}$$

One could determines the separate Input bias currents using the specified values I_{IO} & I_{IB}. It can be shown that for $I_{IB}^{+} > I_{IB}^{-}$

$$I_{IB}^{+} = I_{IB} + \frac{I_{IO}}{2} \quad \& \quad I_{IB}^{-} = I_{IB} - \frac{I_{IO}}{2}$$

Question:- Calculate the Input bias current as each Input of an op-amp having specified values of $I_{IO} = 5nA$ and $I_{IB} = 30nA$.

Solution:- we know that;

$$I_{IB}^{+} = I_{IB} + \frac{I_{IO}}{2}$$

$$I_{IB}^{+} = 30nA + \frac{5nA}{2} = 32.5nA$$

$$I_{IB}^{-} = I_{IB} - \frac{I_{IO}}{2} = 30nA - \frac{5nA}{2} = 27.5nA$$

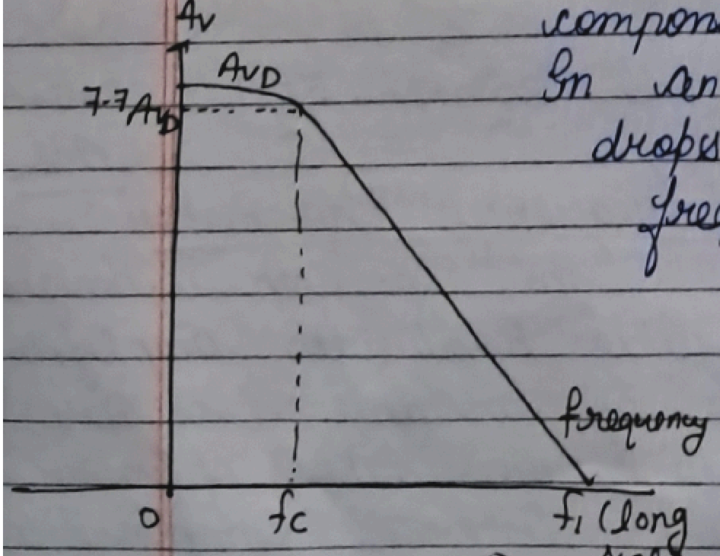
Ans

Op-Amp Specification Frequency Parameter:-

An op-amp is designed to be a high gain wide bandwidth amplifier. This operation tends to be unstable (oscillate) due to +ive feedback. To ensure stable operation op-amp are built with Internal compensation circuitry, which also causes the very high open loop gain to diminish with increasing frequency. This gain reduction is referred to as roll off. In most op-amps roll off occurs at a rate of 20dB per decade (-20dB/decade) or 6dB per octave (-6 DB/ decade).

Note :- Note that although op-amp specifica-tions lists an open-loop voltage gain (A_{VD}) the user typically connects the op-amp using feedback resistors to reduce the circuit voltage gain to a much smaller value (closed loop voltage gain A_c). A number of circuit improvements results from this gain reduction first amplifier voltage gain is more stable, second the input impedence of the ckt is increased over that the op-amp alone third the ckt of output impedence is reduced from that of the op-amp alone and finally the frequency response of circuit is increased over that of the op-amp alone.

1. Gain Bandwidth :- Because of the internal componsation circuitry included in an op-amp the voltage gain drops off set as the frequency increases. Above figure provides a plot of gain versus frequency for a typical op-amp. At low frequency down to dc operation the gain is that value large



Gain versus frequency plot

listed by the manufactures' specification A_{VD} (voltage differential gain) and is typically a very large value and is typically a very large value. As the frequency of the Input signal Increases open loop gain drops off untill It finally reaches the value of 1 (unity). The frequency at this gain value Is specified by the manufactures as the unity gain band width B_1. Although this value is a frequency at which the gain becomes 1 (unity) It can be considered a band width. Since the frequency band from 0Hz to the unity gain frequency is also a band width.

One would therefore refer to the point at which the gain reduces to 1 as the unity gain frequency (f_1) or unity gain band width(B_1). Another frequency of Interest is that at which the gain drops of by 3dB (or to 0.707 the dc gain A_{VD}). This belong to cutoff frequency of the op-amp f_c.

In fact the unity gain frequency and cut off frequency are related by :-

$$f_1 = A_{VD} f_c$$

where ;

f_1 = unity gain frequency
f_c = cut off
A_{VD} = op-amp gain.

unity gain frequency may also be called the gain band width product of the op amp.