EE 204 - Analog Circuits
Lecture 14

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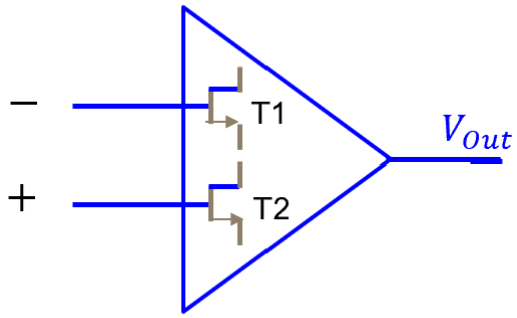
Contents

1 DC Offset in OpAmp

In this lecture, our main focus was on the DC offset in an operational amplifier. We looked at various cases where we introduced offset voltage and measured the output. Using this analysis for the specific cases, we were able to come up with graphs for gain-bandwidth, i.e. we plotted Gain (dB) v/s frequency. Later, we also come up with the notion of slew rate which would be used in subsequent lectures also.

1.1 Offset Voltage

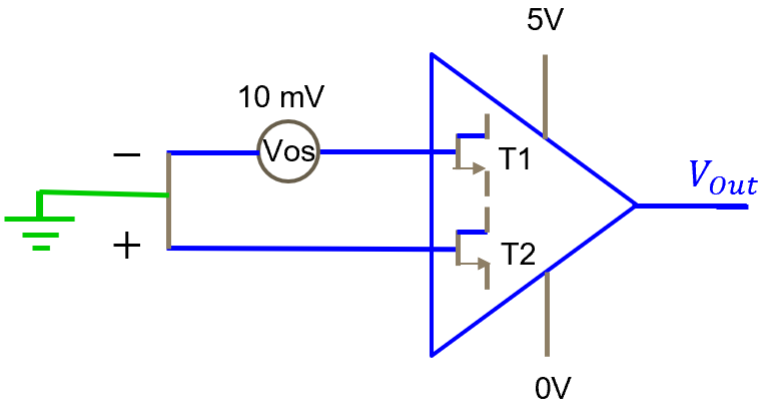
In practical Op-amps, there is some slight difference in the input even when there is no input by the mismatching nature of transistors, this is called the Offset voltage



As can be seen in the above figure, the NMOS transistors T1 and T2 are not exactly equal, they will have some mismatching behaviour, due to this there is an offset voltage at the input, in general.

1.2 Example 1

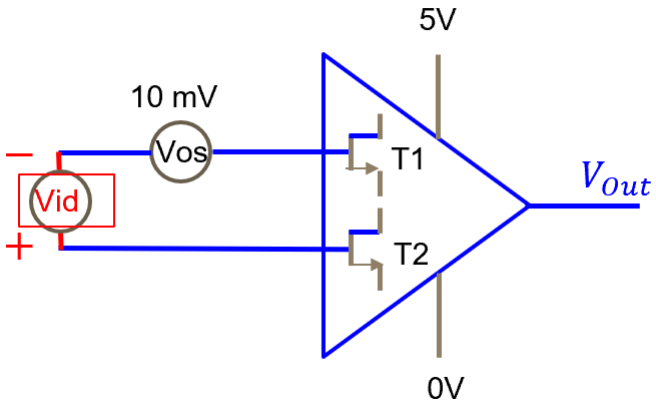
The following image shows the offset voltage as part of the circuit corresponding to which a differential voltage is generated between the two inputs.



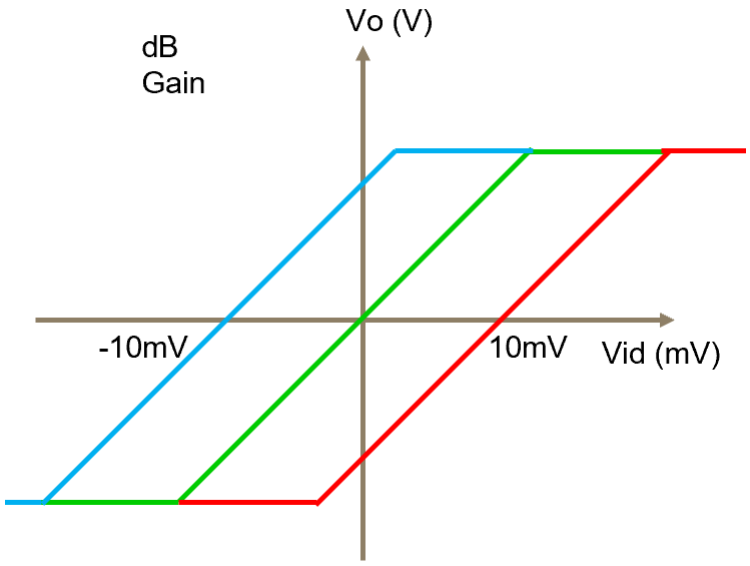
Analysis of the above example would conclude, that even though we would have expected the output to be the product of A_v and V_{os} (where, V_{os} represents the offset voltage), but since there is an upper limit of 5V, the output voltage cannot exceed that limit, and hence the V_{CC} value also needs to be taken into consideration when we calculate the output voltage.

1.3 Example 2

In the next example that we would analyse, we remove the common ground and connect a V_{id} between the two terminals of the OpAmp.



So, on adding this differential input, we calculate the output voltage using our previous analysis methods. The plot of the Output vs Input Differential voltage looks something like this, dependent on the voltage gain of the circuit

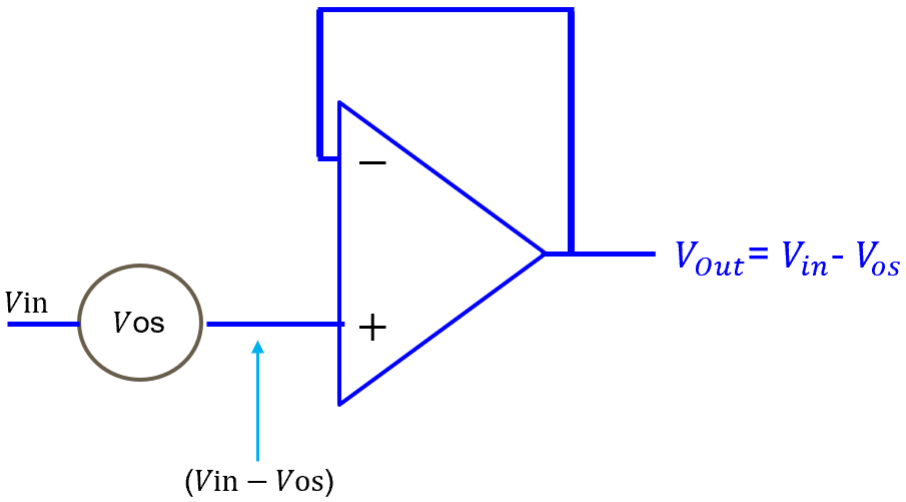


This gives us a way to counter Offset voltage by giving appropriate differential input.

1.4 Unity Gain Buffer

Now, we analyse the unity gain buffer with a DC offset voltage.

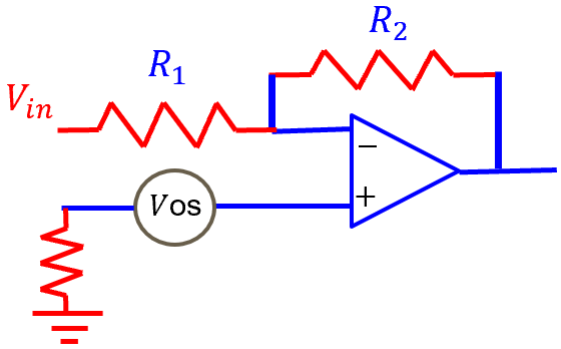
We observe that the offset changed the voltage at the non – inverting terminal of the opamp, thus causing a change in the voltage at the inverting terminal and thus at the output.



1.5 Inverting and Non-Inverting Amplifiers

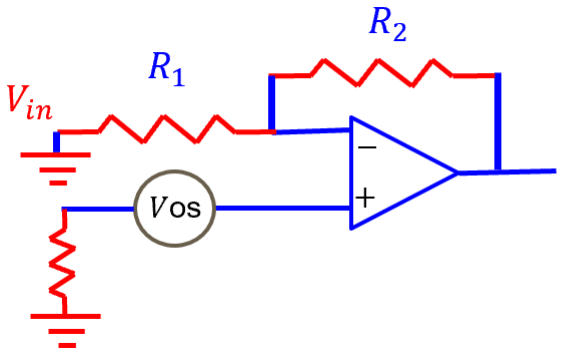
We move on to analysing the usual Inverting and Non-Inverting Amplifiers after the introduction of the offset voltage applied at different locations at the input side.

One such example is the following -



In this example, we can use the superposition principle to find the net Vout here by treating Vin and Vos as sources acting out independently.

This modifies the output voltage that we used to get in the regular case.

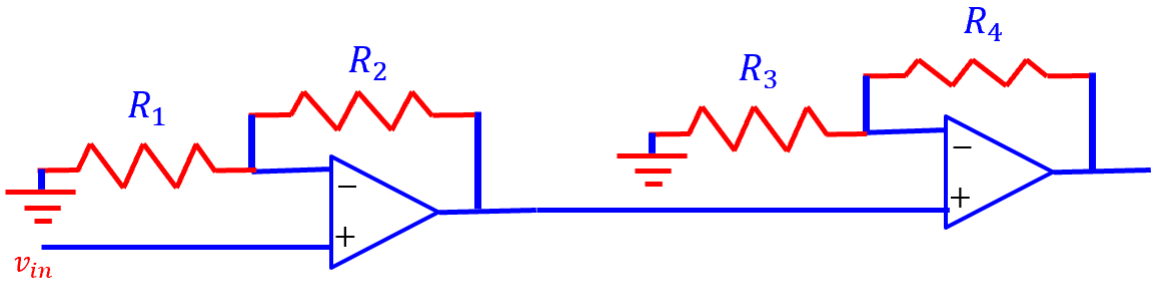


$$\text{Vout} = \left(-\frac{R_2}{R_1}\right) v_{in} + \left(1 + \frac{R_2}{R_1}\right) v_{os}$$

1.6 Multiple Amplifiers

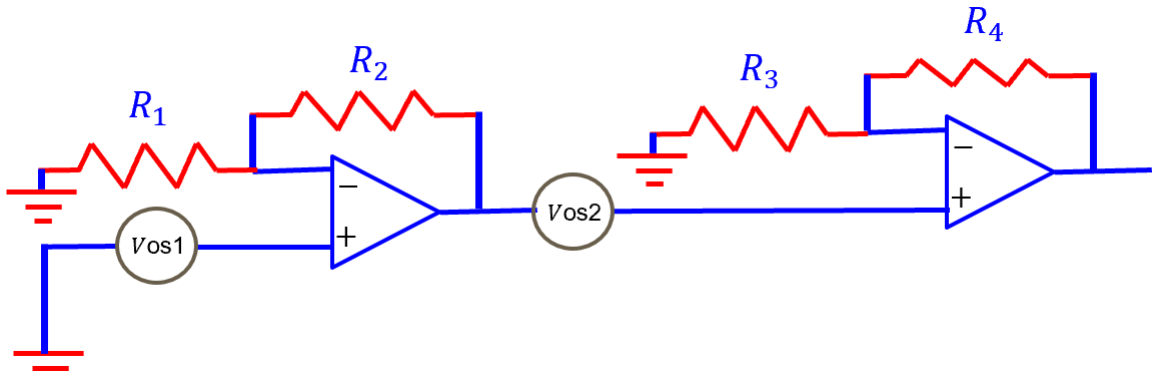
Now, we understand the impact of offset voltage on the output of multiple operational amplifiers (OpAmp) connected together.

In the regular case, we know that this configuration leads to a manifold gain in the voltage.



$$\text{Vout}=\left(1+\frac{R_2}{R_1}\right)\left(1+\frac{R_4}{R_4}\right)v_{in}$$

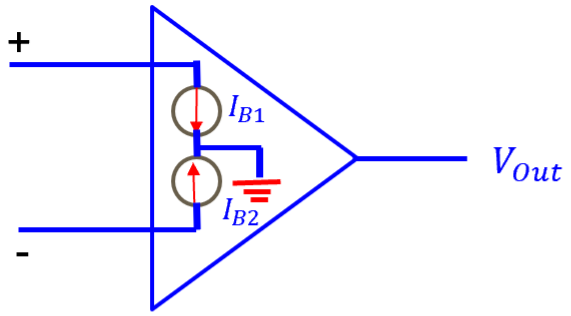
In the DC offset case, the diagram changes to the following At this point, we can increase the accuracy of our model further by including an offset voltage at both stages



$$\text{Vout}=\left(1+\frac{R_2}{R_1}\right)\left(1+\frac{R_4}{R_4}\right)v_{in}$$
$$\left(1+\frac{R_2}{R_1}\right)\left(1+\frac{R_4}{R_4}\right)v_{os1}$$
$$\left(1+\frac{R_4}{R_4}\right)v_{os2}$$

2 DC Input Bias Current

In ideal case, we assume 0 base current, but that is also not true in actual OpAmp

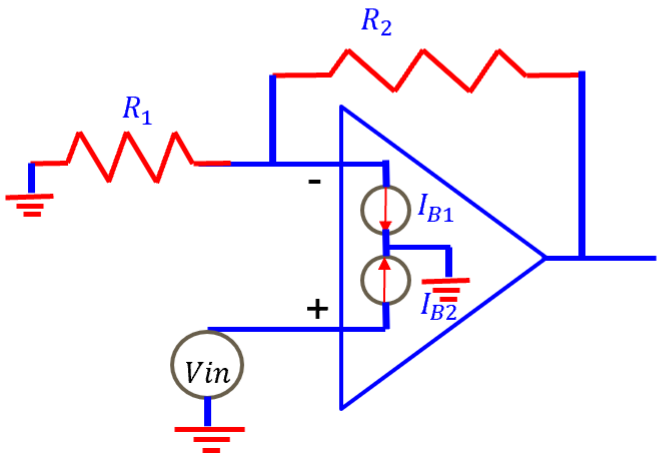


Average input bias current = $\frac{I_{B1} + I_{B2}}{2}$

Average input offset current = $I_{B1} - I_{B2}$

I_B=100 nA

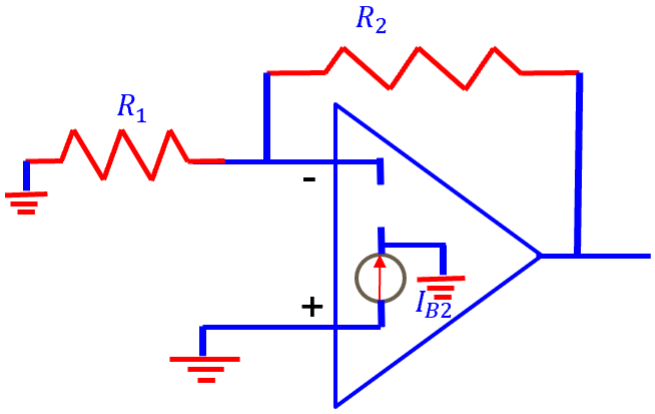
I_{os}=10 nA



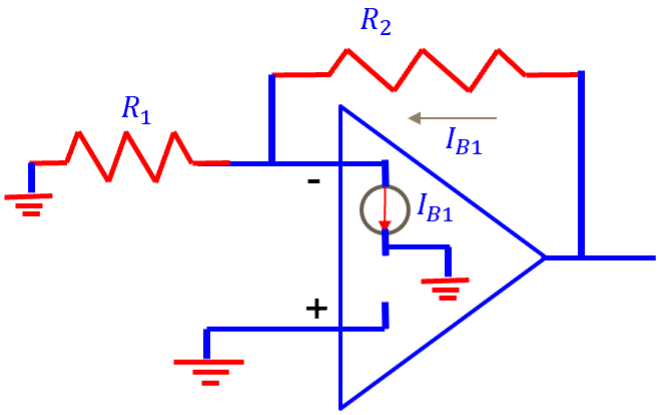
In ideal case $V_{Out} = \left(1 + \frac{R_2}{R_1}\right) V_{in}$

We then understood the individual contributions of I_{b1} and I_{b2} in this circuit that actually the impact of IB2 is null when there is no contribution from IB1. Whereas IB1 contributes to the gain.

2.1 Case I



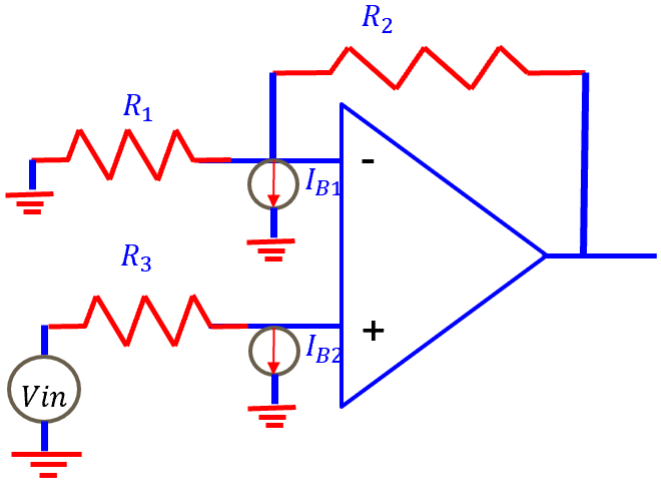
2.2 Case II



$$V_{Out} = \left(1 + \frac{R_2}{R_1}\right) V_{in} + R_2\, I_{B1}$$

2.3 Modified Bias Circuit

In order to maximize our effectiveness we use R_3 as shown if the following figure.



2.4 Slew Rate

Slew rate is the maximum rate at which an amplifier can respond to the sudden change of input level. Slew rate can distort (or limit) any signal amplified by an op-amp. The sinusoidal input signal multiplied by the gain of the op-amp results in a slope which is higher than the slew rate of the op-amp.