EE 204 - Analog Circuits
Lecture 7

Harsh S Roniyar

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Contents

1 OpAmp - Operational Amplifier

OpAmp is widely regarded as the First Analog Computer. Discovery of the OpAmp led to a lot of future development in the field of Analog Electronics.

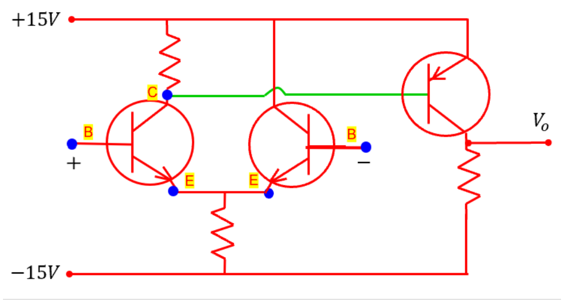

Figure 1: First Operational Amplifier (OpAmp)

1.1 Analysis of OpAmp circuit

Now, we will analyse the OpAmp circuit with various possibilities and the received output.

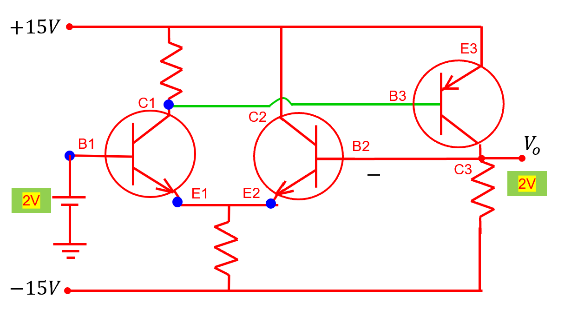

Figure 2: OpAmp Circuit

If I apply 2V DC at B1 then I will get 2V DC at V_0 which will not change with respect to the source voltage or change in base-emitter voltage.

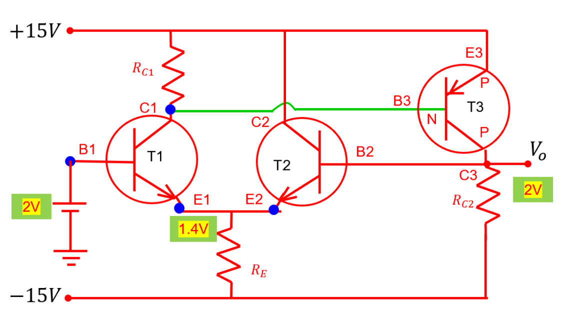

Figure 3: OpAmp Circuit

If I apply 2V DC at B1 the E1 will be 1.4V because base-emitter voltage difference is 0.6V. There will be current through R_E is partly coming through C1E1 and partly coming from C2E2.

There will be current through R_{C1} hence there will be a voltage drop across R_{C1}. Voltage drop across R_{C1} is nothing but the base emitter voltage of T3.

Once the voltage drop across R_{C1} reaches to 0.6V, the T3 starts conducting. Positive voltage starts increasing at C3 and hence the base of T2 will get more voltage.

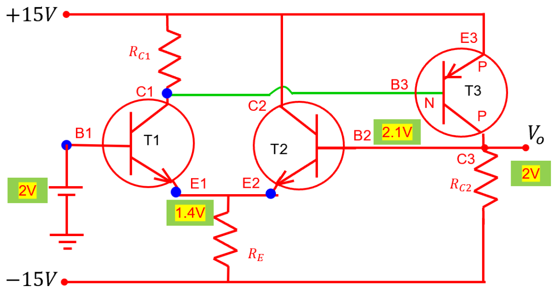

Figure 4: OpAmp Circuit

1.1.1 CASE I: V(B2) > 2V

Assume voltage at B2 is more than 2V, say 2.1V

E2 is sitting at 1.4V and B2 is sitting at 2.1V. Hence, the base-emitter voltage of T2 is 0.7V which is very large. Therefore, enormous current will flow through the transistor T2.

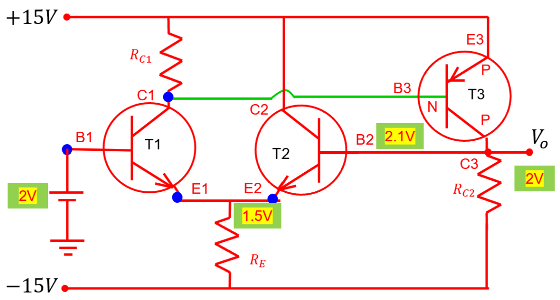

Figure 5: OpAmp Circuit

Consequently, enormous current will flow through R_E hence voltage at E2 will increase and will become 1.5V. The T1 is not going to conduct anymore because the base-emitter voltage of T1 is 0.5V.

Hence, no current will flow through R_{C1} and voltage across it will be zero, indicating that the base emitter voltage of T3 is zero and hence T3 is not going to conduct.

As a result of this, C3 will decrease leading to a decrease in B2.

This as a result has regulated the voltage in some sense.

1.1.2 CASE II: V(B2) < 2V

Assume voltage at B2 is below 2V, say 1.9V

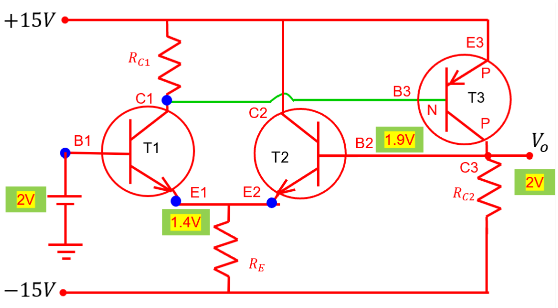

Figure 6: OpAmp Circuit

B1 is at 2V hence E1 will be at 1.4V. Hence, T2 is not going to conduct due to base-emitter voltage of 0.5V. Therefore, heavy current flows through T1 and R_{C1}.

Voltage at C1 increases that increases B2 and C3 with V_0.

Thus, the voltage has again been regulated.

1.2 Temperature Drift

With change in temperature, the junction potential also changes leading to a change in the base-emitter voltage.

For example, at 65° only 0.5V base-emitter voltage is required for both transistors.

1.3 Change in Supply Voltage

If we change the supply voltage, the voltages in the circuit will also change at different places.

Let's consider an example when we have increased the supply voltage from +15V to +20V.

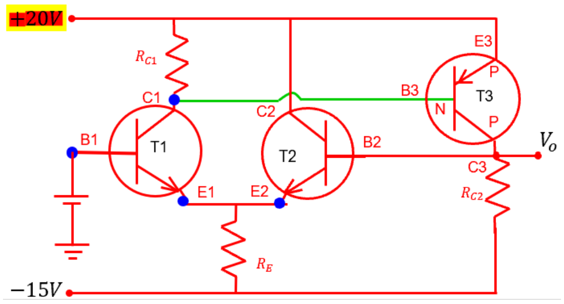

Figure 7: OpAmp Circuit

If supply voltage increases to 20V, then T1 will conduct high voltage hence C1 will increase with B3. T3 will conduct high voltage, hence C3 will increase with B2. E2 will increase with E1. T1 will conduct less due to a decrease in the base-emitter voltage. Also, voltage at C1 will decrease and as a result B3 and C3.

2 OpAmp - The Amplifer

So finally, we begin with the most important reason for which an OpAmp is used, the amplifier. To begin with, how do we amplify the signal?

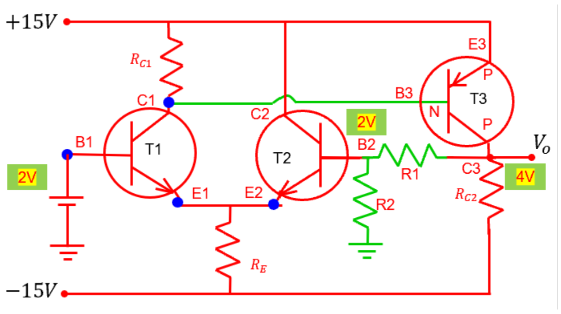

Figure 8: OpAmp as an Amplifier

To do this, we connect two resistors at the B2 terminal. Now, depending on the arrangement of the two resistors we land up at broadly two types of Amplifers:

1. Non-Inverting Amplifier
2. Inverting Amplifier

2.1 Non-Inverting Amplifier

We assign values to both the resistors using KVL and KCL relations to get the desired gain in voltage.

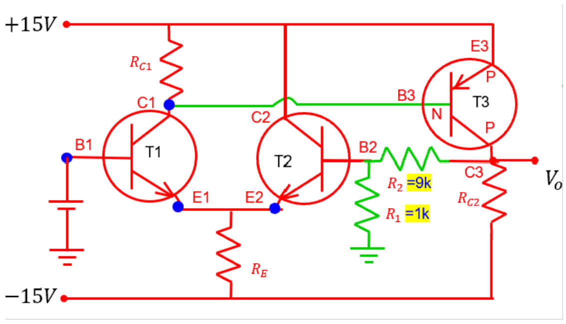

Figure 9: Non-Inverting Amplifier (Gain 10)

Since, drawing the whole circuit always can be troublesome, we represent an OpAmp as shown in the following diagram

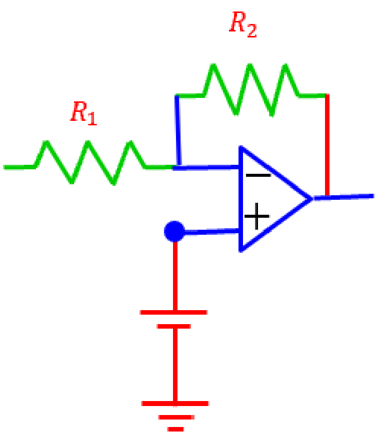

Figure 10: Representation of a Non-Inverting Amplifier

2.2 Inverting Amplifier

This also operates in a similar way as Non-Inverting Amplifier except for the fact that it also inverts the sign of the input while amplification. This is achieved by connecting R1 with a battery/voltage/power source.

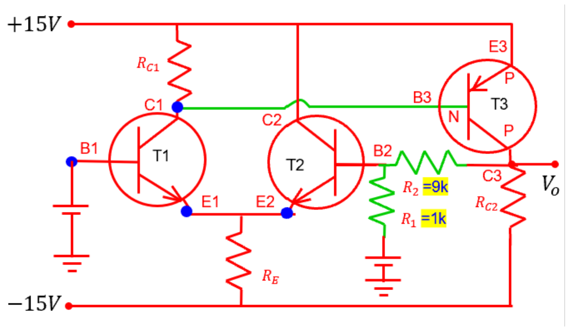

Figure 11: Inverting Amplifier (Gain 10)

A representation similar to Non-Inverting Amplifier for the Inverting Amplifier is also shown below

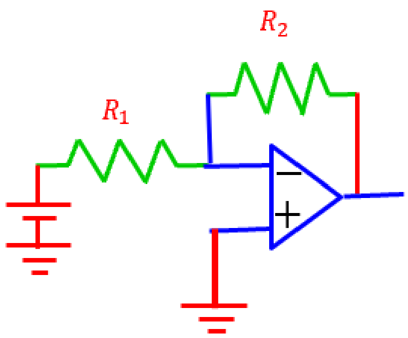

Figure 12: Representation of a Inverting Amplifier

3 Voltage Regulator

Now we move on to the voltage regulator which used a Zener diode to regulate the output voltage for different changes in the input voltage.

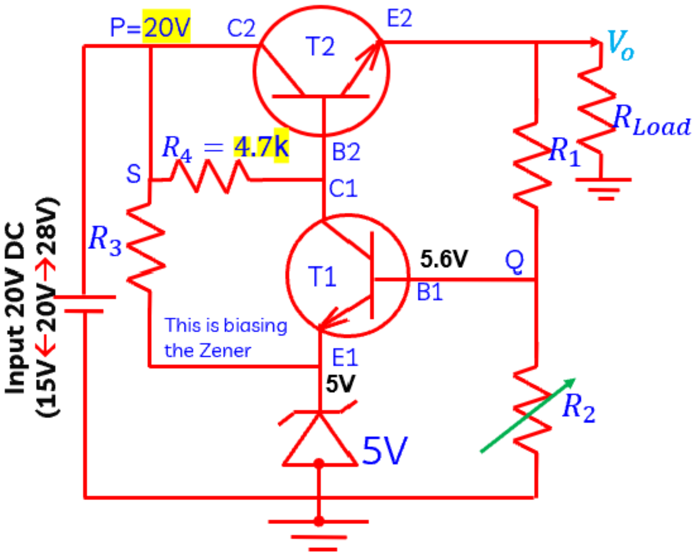

Figure 13: Voltage Regulator using Zener Diode

This is the circuit diagram of the voltage regulator, which works on the principle that any change in the input voltage will bring about voltage drop across R4.

In the figure above, if the voltage at B1 increases beyond 5.6V, a large current will flow through the transistor, and hence through R4, thus leading to a comparatively lesser potential at C1. Whereas if the voltage is lower than 5.6V, then lesser current will flow through R4 causing smaller drop of voltage across it, and in the end voltage remains stabilised.

This is the basic operation of a Voltage Regulator. Some of the drawbacks of such a Voltage Regulator are:

- Base-Emitter temperature drift
- Change in Supply Voltage

In both these situations, the output is changing, in the first case with respect to temperature, and in the second situation with respect to changes in the supply voltage.