EE 204 - Analog Circuits
Lecture 6

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Contents

1 Transistor Amplifier

1.1 Overview of Transistor Amplifier

The transistor can be used as an amplifier in the active region or by biasing the circuit.

Biasing is a process of setting DC operating voltage or current to a desired value so as to control the DC input amplification.

This circuit was very useful for AC Amplification, and was also used in 2nd World War.

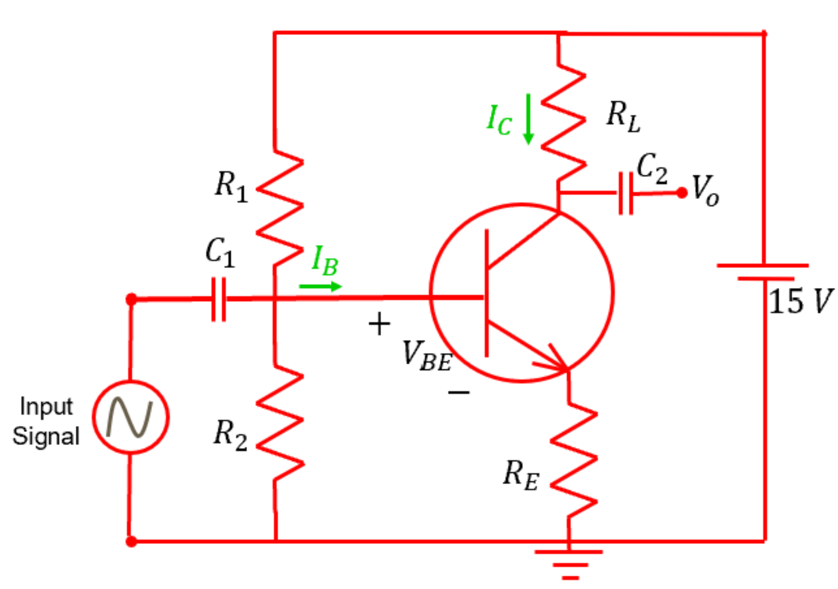

Figure 1: Transistor Amplifier Circuit (AC)

Now let's analyse the transistor circuit and understand its operation.

1.2 Analysis of Transistor Amplifier

In the circuit, R_1 and R_2 act as the voltage divider. This can be seen if we appply KVL on the outermost loop of the circuit.

For now, let's assume $R_1 = R_2 = 10k\Omega$

Then the voltage at the divider would be half $(\frac{1}{2})$ of the battery voltage. In this circuit, it would be $7.5V$.

If we connect the base of the transistor to the voltage divider, then the **applied bias** to the base would be 7.5V.

So the circuit now looks something like this with the biasing voltage applied.

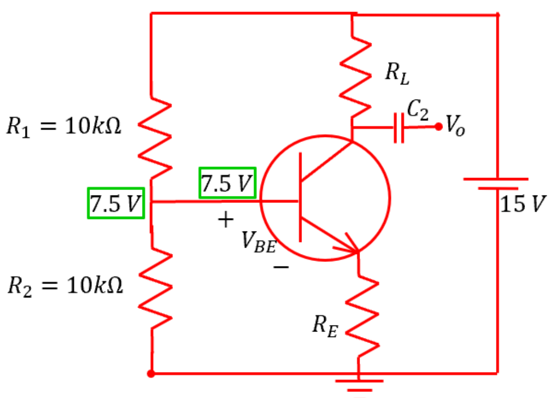

Figure 2: Biased Amplification Circuit

Now, our transistor is in the npn configuration as can be seen in the diagram, with a base-emitter voltage of $0.6V$ (V_{BE}). We have our Base Voltage to be $7.5V$ and $0.6V$ is the base-emitter voltage.

Therefore, the Emitter Voltage would be $7.5 - 0.6 = 6.9V$. Now, since we know the voltage drop at the emitter and if we now know R_E, we can find emitter current, I_E easily by dividing the potential drop across emitter by R_E.

Ideally,

$$I_E = I_C + I_B,$$

but I_B is very small compared to I_C.

Therefore, since we know I_E, we can find I_C ($I_E \approx I_C$). Subsequently, we can find the voltage drop across R_L.

And therefore, we know V_O.

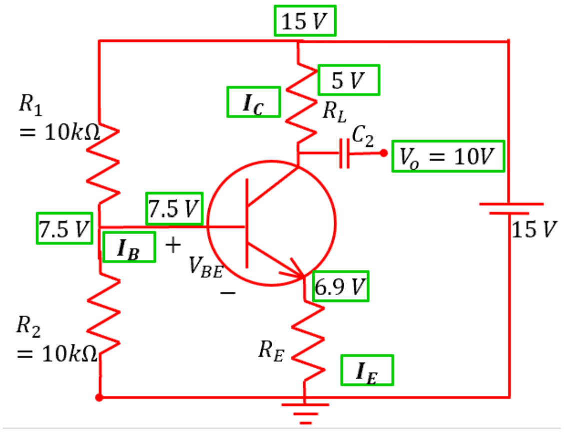

Figure 3: Resultant Transistor Circuit

To summarise, if I know the base voltage, immediately I can find emitter voltage and I_E and I_C. Hence, we know the voltage drop across R_L and the V_O.

1.3 Variation in AC Amplifier

Variation in base is done with AC + DC signals. Therefore, any variation in the base will reflect in the emitter voltage.

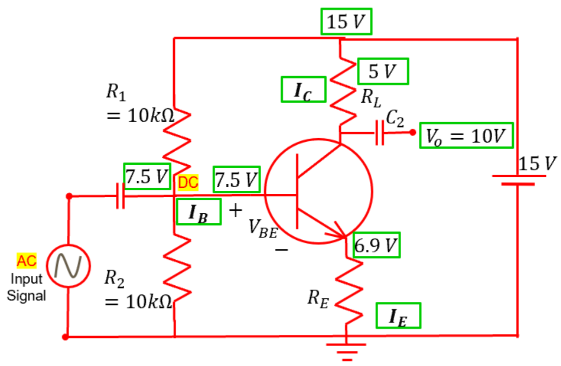

Figure 4: Resultant Transistor Circuit

For example, if base voltage $8V$ the emitter voltage will be $7.4V$. So, as a result the AC signal would reach the emitter as it is.

Whatever AC signal is given to the base that will appear across the emitter.

Usually, the AC input signal will be a small value, say $10mV$ (rms). Then, the AC will produce varying current in emitter terminal hence producing a varying current in R_L and the output V_O

The AC voltage across R_L will be high if R_L is high and low if R_L is low.

Therefore, we can determine the gain in the output AC with respect to the input AC signal by the ratio between R_L and R_E.

$$g = \frac{R_L}{R_E}$$

But, in real life we need to design our circuit with a certain gain value in mind for amplification. That, is we would need to back-calculate with respect to our desired gain value.

Say, we need a gain of 10. Then, we can fix R_L and R_E accordingly (say $10k\Omega$ and $1k\Omega$, or $20k\Omega$ and $2k\Omega$ respectively).

Then, we can figure out, emitter voltage and thus voltage at the base terminal by adding the V_{BE} to the emitter voltage.

Then, since R_1 and R_2 acts as potential divider, it should divide the $15V$ to give the base terminal voltage as calculated previously. But, we would need the current, flowing through the base. This, although, is very negligible, can be found using $\beta or h_{FE}$, which is the maximum current gain.

$$\beta = \frac{I_C \approx I_E}{I_B}$$

Thus, given the value of β we can calculate current through R_1 and R_2.

Therefore, we get our desired circuit which can give us an amplification of 10.

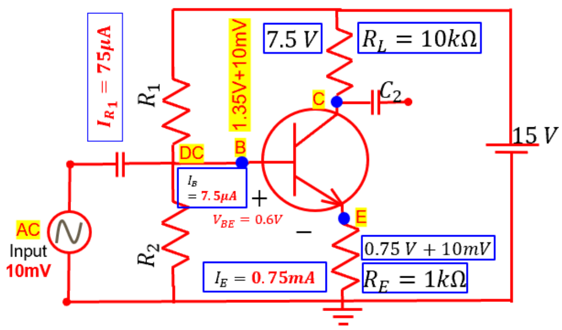

Figure 5: A Transistor Amplifier with a Gain of 10

Also, at the AC Output, there is a 180° phase shift with respect to the AC Input, because of decoupling using Capacitor filters. Thus, the Input-Output would be phase shifted by 180° or π^c.

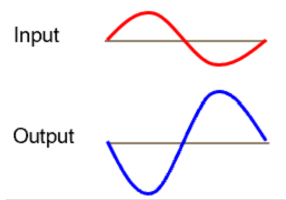

Figure 6: Input-Output Phase Shift

1.4 Using for DC Amplification

Using the circuit as is causes various problems, such as drift, temperature coefficient and some other factors.

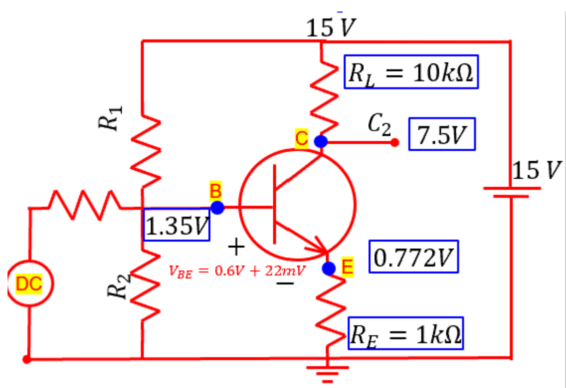

Figure 7: DC Amplification

Output voltage at Collector would change even if Supply voltage changes. This increases the voltage at E which leads to a reduction in the voltage at C.

Similarly, if the temperature changes, the V_{BE} changes since the temperature coefficient is relatively high at $-2.25mV/°C$.

1.5 Summing Transistor Amplifier

In order to find a solution of this problem, H Swartzal came up with a Summing Transistor Amplifier.

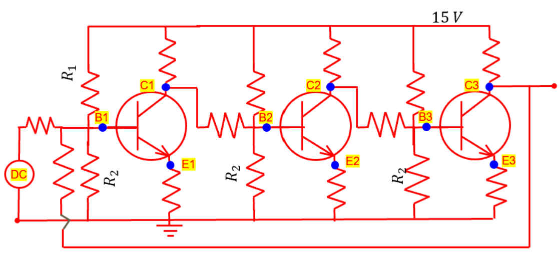

Figure 8: Summing Transistor Amplifier

This circuit helps to remove the earlier problems faced with a normal Transistor Amplifier, since using High-Low Outputs repeatedly in series helps us to control the final Output as per requirement.

2 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.

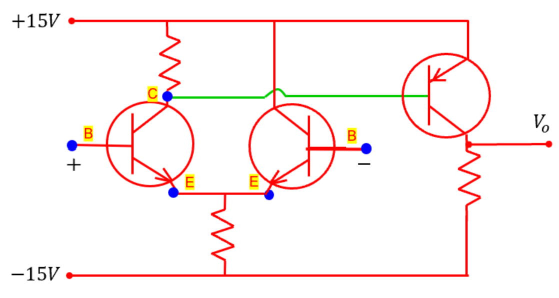

Figure 9: Operational Amplifier (OpAmp)

We will discuss this circuit in a lot more detail in the upcoming lectures.