BJT Amplifier project with Multisim

By Harshraj Parmar

1. Brief introduction of BJT Amplifier

In this project, I was exploring how choosing specific resistors and capacitor values will affect certain aspects of the BJT amplifiers and how that can be used to create an amplifier with required properties. I will be taking advantage of the properties of the bipolar junction transistors (BJT) in active mode. 2N3904 NPN bipolar junction transistors were used with different components like Resistors from the E24 Series and Capacitors. This project helped me have a better grasp of BJT behavior, specifically in terms of how we can manipulate the capacitor and resistor values to change voltage biasing and how this will affect the output signal under different conditions and how each component plays an important role.

2. Description of conditions and limitations.

The objective of this design project is to create an amplifier using BJT and other components under the following conditions:

- ☐ Power supply: **+10V relative to the ground;**
- ☐ No-load voltage gain (1kHz): **$|A_{VO}|$ = 50 (± 10%);**
- ☐ Maximum no-load output voltage swing at 1kHz: **no smaller than 8 Vpp;**
- ☐ Maximum loaded output voltage swing (1kHz & R_L = 1k): **no smaller than 4 Vpp;**
- ☐ Input resistance at 1kHz: **no smaller than 20k;**
- ☐ Amplifier type: **Inverting or non inverting;**
- ☐ Types of transistors: **BJT;**
- ☐ Resistors permitted: **values smaller than 220k from E24 Series;**
- ☐ Capacitor permitted: **0.1, 1, 2.2, 4.7, 10, 47, 100, 220 all in uF**

3. Circuit diagram used for simulation.

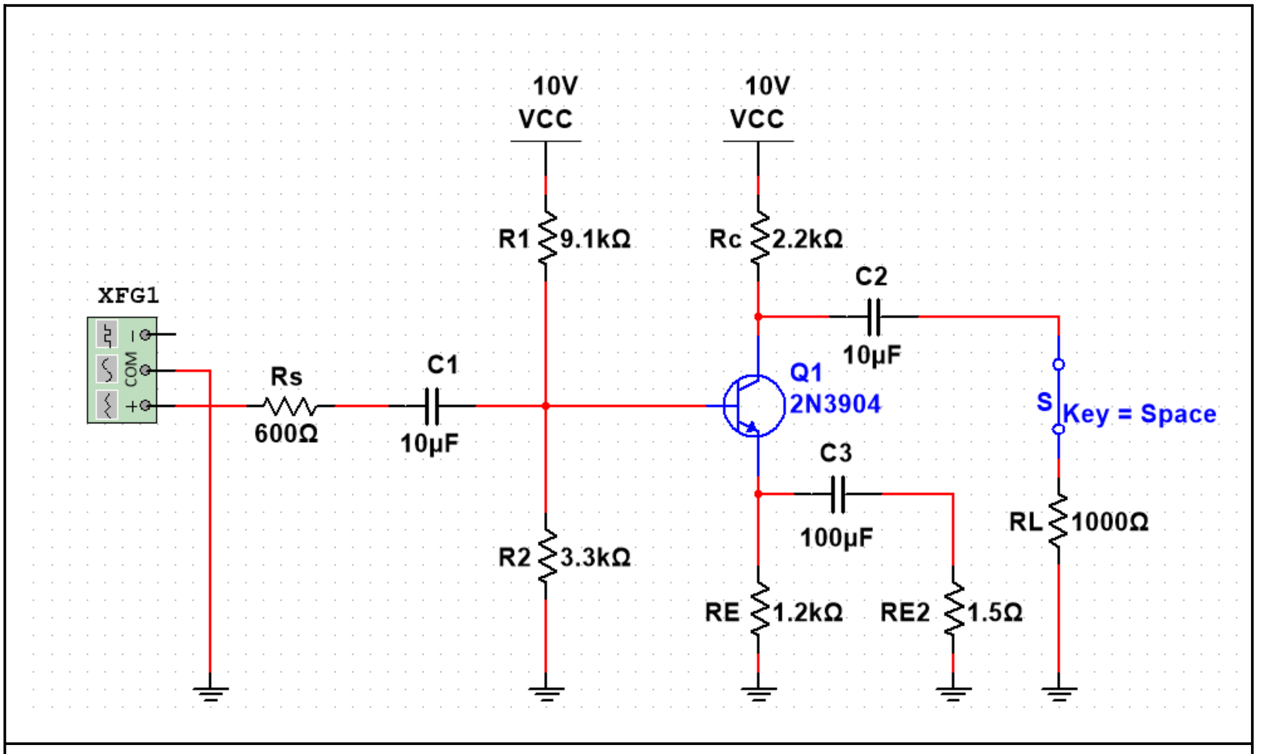

Figure 1: Single stage CE amplifier

4. Justification for design choice.

For this design project, the choice of a single-stage common emitter BJT amplifier was chosen, the CE amplifier has the capability to achieve a high voltage gain while still achieving the specified requirements. I used a simple and straightforward design which used components like resistors from the E24 series as required and capacitors which had values like permitted, this amplifier configuration was able to achieve the desired high voltage gain and also behaved like an inverting amplifier, which matches with the project specifications. Through manual calculations which are in this report the amplifier was calculated to ensure an 8-volt peak-to-peak voltage swing without load, and a peak-to-peak voltage greater than 4 volts under load conditions, maintaining an approximate gain of 50. The quiescent current drawn from the 10-volt power supply was also kept below 10 mA to ensure it matches with the requirements. Despite meeting most requirements, one challenge I encountered was the relatively low input resistance of the amplifier and slight distortions in the graph as well as the loaded voltage gain. However the overall majority of the project objectives were successfully achieved, showing the CE amplifier was a good configuration to use in the design.

5. Manual calculations for design.

Figure 2: Manual calculations for DC and small signal circuit.

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$V_{cc} = 10V$

$R_E = 1.2k \quad R_C = 2.2k$

$R_1 = 9.1k \quad R_2 = 3.3k$

$V_B \approx \frac{R_2}{R_1+R_2} V_{cc} \approx 2.66 \text{ V}$

$V_c \approx 6.364 \text{ V}$

$V_E \approx I_E R_E \approx 2.016 \text{ V}$

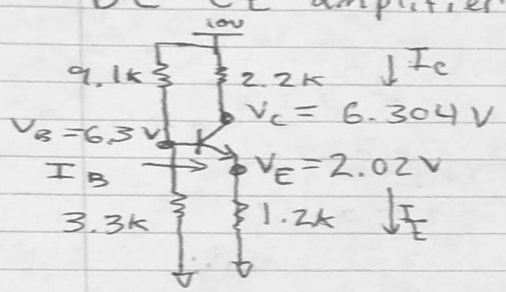
$I_C = 1.68 mA$

$\frac{V_{cc} - V_c}{2.2k} = 1.68 mA$

$I_E = 1.69 mA$

$I_B = 10\mu A$

DC CE amplifier: Capacitors are open



$\beta = \frac{I_c}{I_B} \approx 170$

For Resistor values I tested many to see how each one affects swing, voltage gain and current.

$R_{E2} = 1.5\Omega$ this resistor was added to improved the distortion caused by the amplifier.

$g_m = \frac{d\,i_c}{dV_{BE}} = \frac{i_c}{V_t} = \frac{1.68 \cdot 10^{-3} A}{0.026 \text{ V}} = 0.0646$

$r_{be} \approx \frac{\beta}{g_m} = 2,600\,\Omega$

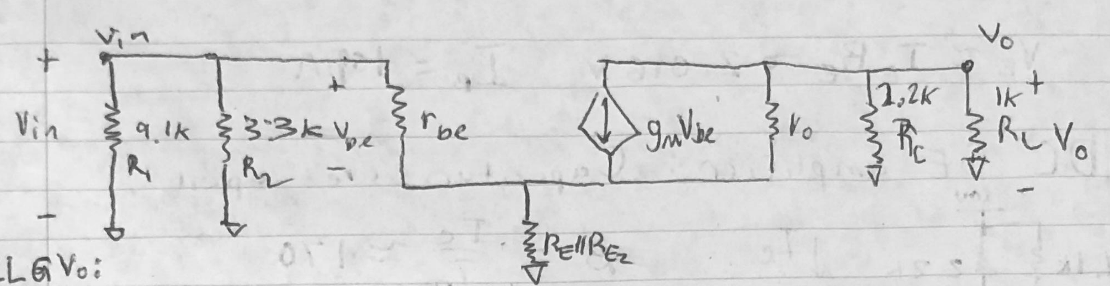
Using the calculated DC currents we have found r_{be} and g_m.

Small Signal Analysis

$V_{in} = \frac{R_{in}}{R_{in}+R_s} V_s$ $\quad R_{in} = R_1 \| R_2 \| (1+g_m R_E) r_{be}$

$R_{in} \approx 2390\ \Omega$

$V_{in} \approx 0.85 V_s$



KCL @ Vo:

$g_L V_o + g_C V_o + g_o V_o + g_m V_{be} = 0$

KCL @ $V_{in} G_1 + V_{in} G_2 + (V_{in} - V_E) g_{be}$

$V_E = R_E \| R_{E2} I_E$

$V_E = R_E \| R_{E2} (\beta+1) I_B$

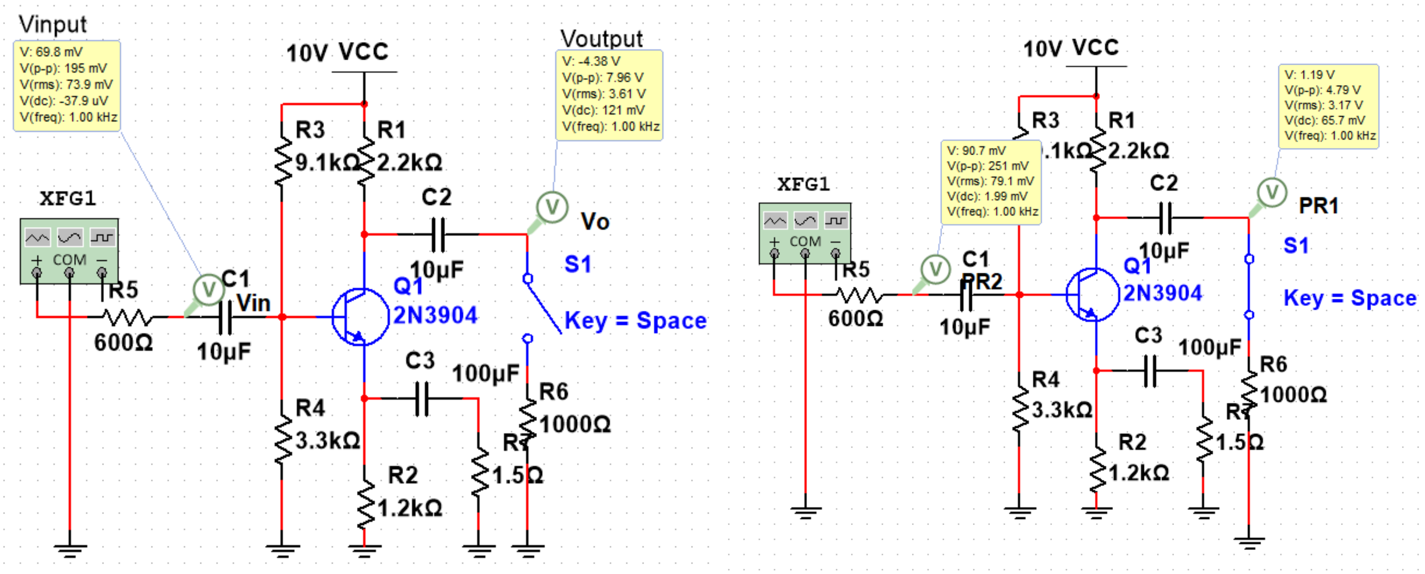
$$A_{v_{Load}} \approx \frac{-g_m (R_C \| R_L)}{1 + g_m (R_E \| R_{E2})} \approx 34.1$$

$$A_{v_{noload}} \approx \frac{-g_m (R_C)}{1 + g_m (R_E \| R_{E2})} \approx 52.8$$

For capacitor values I tested a couple to see how it would affect swing and gain.

For this design project, I did the manual calculations on paper and I condensed the important information onto this report. First I tested different resistor values and changed the voltage biasing at the collector, emitter and base depending on what's the resistor value I chose while making sure that all the DC currents were below 10 mA. I also used the DC values to calculate the AC parameters which are needed like beta which is the current gain, the transconductance gain and the base emitter resistance used to calculate Rin, the issue is that Rin was not 20k like specified. Then I did a small signal analysis of my circuit to calculate the Gain of the common emitter amplifier. I tested more about this amplifier in my simulation which is the next section.

5. Simulation for design.



Simulation 1 and 2: V_{input} and V_{output} for load and no load simulated to measure gain.