ECSE331 Lab 6

Design of a BJT Amplifier

ECSE331

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ECSE331 Lab-6 Report

***Abstract* — In this lab, a BJT amplifier with a voltage gain magnitude of 50V/V ± 10% and a bandwidth of no less than 10KHz will be designed. Instead of following a given set of steps, we solved this design problem using our unique design method.**

I. INTRODUCTION

This lab report will provide a design procedure for a BJT amplifier that has at least 10KHz bandwidth and an input resistance of no less than 1KΩ. This BJT amplifier should also realize a voltage gain of 50V/V (with a 10% gain tolerance) while driving a 10KΩ load. The amplifier will be able to operate with a signal with an RMS level of 0.1V. A 2N2222A npn transistor and several resistors will be used in our design.

II. EXPERIMENT RESULTS

A. Design procedure

In order to avoid the unexpected distortion of the output signal, we decided to use the CE amplifier with an unbypassed emitter resistance as shown in figure 1. Firstly, we performed the DC analysis to determine the bias point. Under the DC condition, the circuit will be like figure 2.

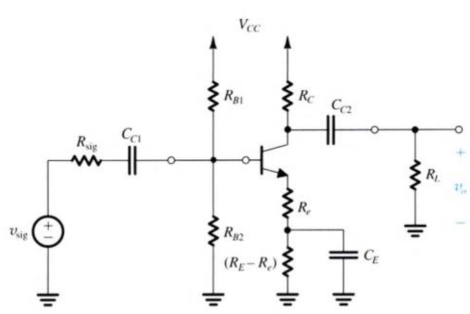

Fig. 1. CE BJT amplifier circuit with emitter resistance.[1]

The base voltage will be set to 2.25V so that $\frac{R_{B1}}{R_{B2}} = \frac{9-2.25}{2.25} = 3$. It is safe to assume that the current across these resistors is $\frac{1}{10}$ of the emitter current. We can derive the relationship between R_{B2} and R_E by the following simplified analysis assuming the BJT follows a 0.6V voltage drop model.

$I_{B2} = \frac{I_E}{10} = \frac{V_E}{10R_E} = \frac{2.25-0.6}{10R_E} = \frac{0.165}{R_E}$.
$\frac{V_B}{R_2} = \frac{2.25}{R_2} = \frac{0.165}{R_E}$ by KCL. We can get that approximate relationship between R_E and R_2: $R_E = \frac{11}{150}R_2$. We'll also set $V_C = 3V$. Then using KCL and assume I_B is very small, we'll get $R_c = \frac{3}{1.65}R_E$.

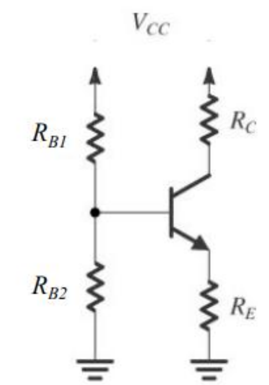

Fig. 2. CE BJT amplifier circuit with DC condition.[1]

Then we'll perform the AC small signal analysis based on the figure 3.

We'll find $G = \frac{\alpha*(R_C||R_L)}{R_e+r_e}$. Where $r_e = \frac{V_T}{I_C} = \frac{25*10^{-3}}{3/R_C}$ under our previous DC set-up. If we choose $R_{B1} = 60k\Omega$, we can get $R_{B2} = \frac{1}{3}R_{B1} = 20k\Omega$, $R_E = \frac{11}{150}R_2 = 1467\Omega$,
$R_C = \frac{3}{1.65}R_E = 2667\Omega$. Plugging the values of $G = 50V/V, R_C = 2667\Omega, R_L = 10k\Omega$,
$r_e = \frac{25*10^{-3}}{3/R_C} = 22\Omega$.
We'll get the value for $R_e = 21.255\Omega$.

When we choose R_e=21.255 to assemble the circuit, there's a distortion of the output. We decided to lower the value of the unbypassed resistance R_e to 15Ω by trial and error until the distortion disappears. However, this will also affect the gain of our circuit. In order to achieve the gain, there are also slight adjustments to the theoretical resistance by trial and error.

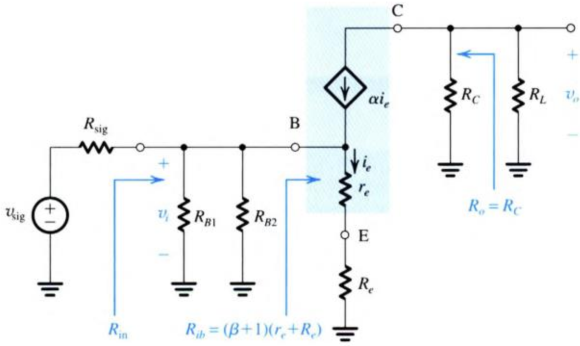

Fig. 3. Small signal model for CE amplifier.[1]

Our final choices of resistances are R_{B1}=60kΩ, R_{B2} = 18.8kΩ, R_C = 3200Ω, R_e = 15Ω, $R_E - R_e$ = 1500Ω. All the capacitors are 100μF. We also decided to not put R_{sig} since it will have a very small effect on the total gain. This set of choices will help us achieve a gain of around 50 V/V and there's no distortion of the output when the input signal has 0.1V peak to peak value.

B. Performance test

After simulating our design for the BJT amplifier and constructing the circuit, we tested it to ensure it met the specifications.

To do so, we tested our circuit with a 0.1Vpp input signal, and we have a 10KΩ load resistor connected to our circuit.

a). A voltage gain of the magnitude of 50V/V ± 10%

At room temperature (26°C), we tested the voltage gain of our circuit using the bode analyzer. From the bode plot (Fig. 4), we found the voltage gain of our amplifier:

$$Gain = 10^{\frac{Gain(dB)}{20}} = 10^{\frac{33.253dB}{20}} = 45.988V/V$$

The bode plot also proved that our BJT amplifier is capable of performing amplification over a 10KHz bandwidth.

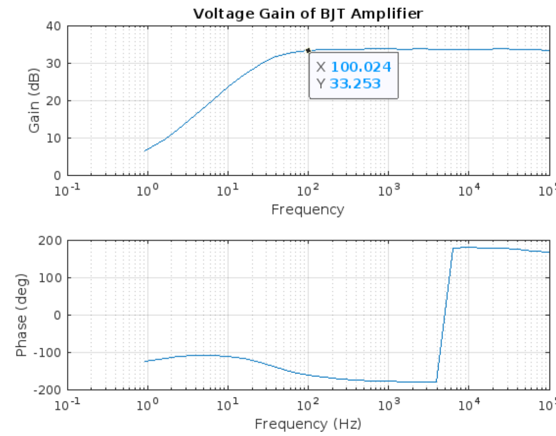

Fig. 4. Voltage gain of the BJT amplifier (bode analyzer)

We also used the oscilloscope to measure and calculate its gain (Fig. 5):

$$|Gain| = |\frac{V_{out}}{V_{in}}| = |\frac{2.081V}{-0.042V}| = 49.548V/V$$

However, since the input is small and there is a lot of noise, this result is not as accurate as the one we derived from the bode analyzer.

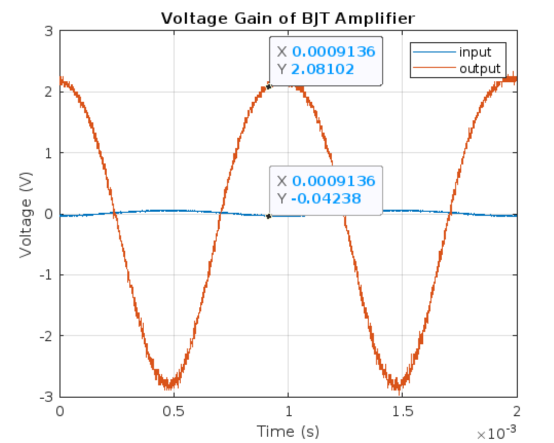

Fig. 5. Voltage gain of the BJT amplifier (oscilloscope)

b). An input resistance of no less than 1KΩ

Then we tested the input resistance of our BJT amplifier. As shown in Fig. 6, its input resistance is 3.6879KΩ, which is higher than 1KΩ.

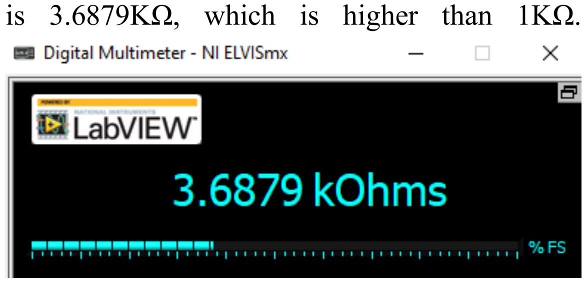

Fig. 6. Input resistance of BJT Amplifier

Hence, the BJT amplifier we designed is proven to meet all the specifications and is able to operate as expected.

C. Temperature effects on the BJT

After making sure our BJT amplifier met all the requirements, we investigated the temperature characteristic of our amplifier with the same input signal. In this part, we did not use the bode analyzer to get the gain of the amplifier. Using the bode analyzer to measure the gain takes a long time, and the temperature of BJT (when not at room temperature) will change a lot within this period.

From Part B, we got the voltage gain of our BJT amplifier at room temperature, which is 45.988V/V. We measured it again using the oscilloscope in this part. From Fig. 7, we calculated the magnitude of the voltage gain of the amplifier:

$$|Gain| = |\frac{V_{out}}{V_{in}}| = |\frac{2.2997V}{-0.0509V}| = 45.181V/V$$

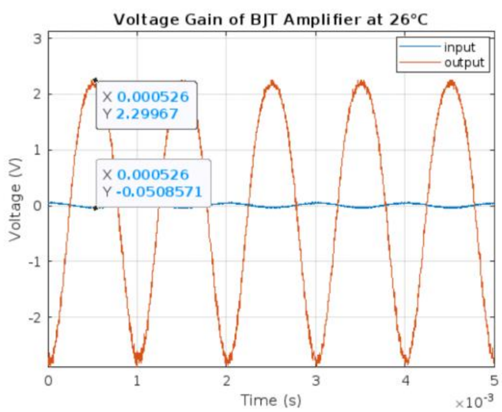

Fig. 7. The behavior of the BJT Amplifier at 26°C

This result is slightly different from the one we derived from the bode analyzer in part B (a). The reason for this is the same: the input is very small, and there is a lot of noise.

We then heated the amplifier to 50°C with a hot-air blowgun. From Fig. 8, we calculated the magnitude of the voltage gain of the amplifier:

$$|Gain| = |\frac{V_{out}}{V_{in}}| = |\frac{2.081V}{-0.051V}| = 40.803V/V$$

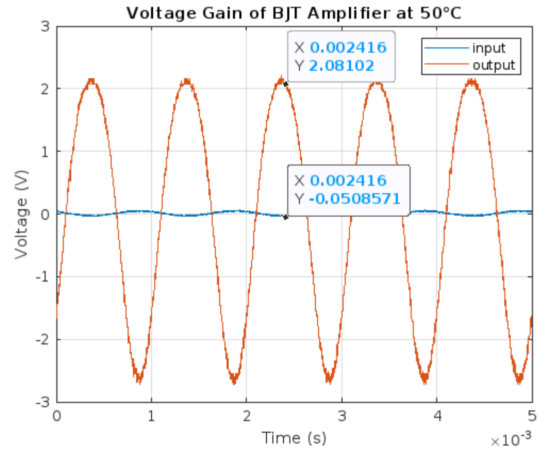

Fig. 8. The behavior of the BJT Amplifier at 50°C

Then we blew the freeze-spray coolant to the BJT amplifier to cool it down to 2°C. From Fig. 9, we calculated the magnitude of the voltage gain of the amplifier:

$$|Gain| = |\frac{V_{out}}{V_{in}}| = |\frac{2.165V}{-0.042V}| = 51.548V/V$$

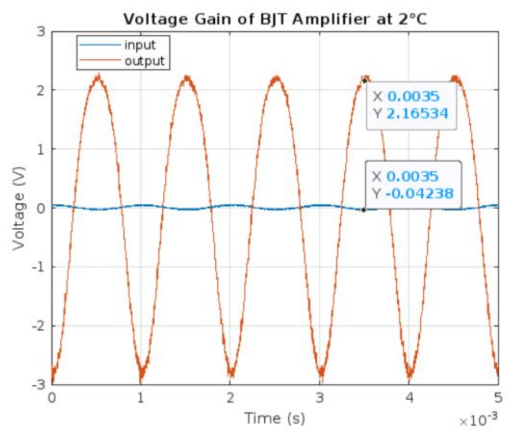

Fig. 9. The behavior of the BJT Amplifier at 2°C

From our measured gain at different temperatures, we found the magnitude of the voltage gain of our BJT amplifier will decrease as temperature increases.

III. CONCLUSION

In this lab, we designed a BJT amplifier, with a voltage gain magnitude of 50V/V ± 10% and a bandwidth of no less than 10KHz, following our design procedure. We tested the BJT amplifier to make sure it satisfied all the specifications. Then we measured its voltage gain magnitude, and we noticed its voltage gain magnitude would decrease with increasing temperatures.

REFERENCE

[1]. A. S. Sedra and K. C. Smith, *Microelectronic Circuits,* 7^{th} ed. New York, NY: Oxford University Press, 2014.