Baku Higher Oil School

Course: ANALOG ELECTRONICS

LABORATORY REPORT

Experiment Title: **Amplifier low frequency response**

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Introduction

The primary objective of this report is to provide information about lab work namely “Amplifier low frequency response”. The major aim of the experiment carried out by me is to compute and measure the DC and AC parameters for a common-emitter (CE) BJT amplifier then compute and measure the three lower critical frequencies for a CE amplifier and use them to compute the overall lower critical frequency, then measure it. I build the amplifier and measure & calculate some parameters such as $V_B, V_C, I_E, V_E, V_{CE}, A_V, r_e, V_{out}$. We carried out this experiment via help of different equipment and devices (BJT, resistors, capacitors and etc.) and they should be as accurate as possible. Our goal was getting amplified signal in the output while we put weaker signal in the input. By doing this experiment, we will create different BJT amplifiers. After that, we find the equivalent resistance that represents the AC charge and discharge path for each capacitor. Next, I measure and compute the lower critical frequency for each capacitor from the equation below:

$$f = \frac{1}{2\pi R_{eq} C}$$

In this report, I will introduce how experiment is carried out. Additionally, some issues and problems will be considered in the report. There are some errors in measurements because of the non-ideal condition, however we try to understand how all changes happen. At the end, there will be some discussions about values, in order to provide report with more accurate information.

Theory

As our main aim in this lab work is to amplify the signal and find the lower critical frequency of CE BJT amplifier, we must tune our BJT transistor to active mode using DC source and some resistors. Of course, we need also some signal to amplify that is why we use AC source. Additionally, some capacitors (coupling and bypass capacitors) is used to isolate AC from DC effects. In this report, I will mainly focus on the effects of the coupling and bypass capacitors.
Generally, in amplifiers, the coupling and bypass capacitors appear to be shorts to ac at the midband frequencies. At low frequencies the capacitive reactance of these capacitors affect the gain and phase shift of signals, so they must be

taken into account. The frequency response of an amplifier is the change in gain or phase shift over a specified range of input signal frequencies.

Recall from basic circuit theory that $X_C = \frac{1}{2\pi f C}$. This formula shows that the capacitive reactance varies inversely with frequency. At lower frequencies the reactance is greater, and it decreases as the frequency increases. At lower frequencies—for example, audio frequencies below 10 Hz—capacitively coupled amplifiers have less voltage gain than they have at higher frequencies. The reason is that at lower frequencies more signal voltage is dropped across C1 and C3 because their reactances are higher. This higher signal voltage drop at lower frequencies reduces the voltage gain. Also, a phase shift is introduced by the coupling capacitors because C1 forms a lead circuit with the Rin of the amplifier and C3 forms a lead circuit with RL in series with RC or RD.

At lower frequencies, the reactance of the bypass capacitor, C2, becomes significant and the emitter (or FET source terminal) is no longer at AC ground. The capacitive reactance XC2 in parallel with RE (or RS) creates an impedance that reduces the gain

The voltage gain and phase shift of capacitively coupled amplifiers are affected when the signal frequency is below a critical value. At low frequencies, the reactance of the coupling capacitors becomes significant, resulting in a reduction in voltage gain and an increase in phase shift.

Experimental technique

For this experiment, I used BJT transistor namely BC108B, because I could not find BC140 type transistor in MultiSim catalog. β_{DC} value for this device are changing between minimum and maximum, that is why I choose typical value for BC108B as 290. The figure below shows the minimum and maximum β_{DC} value for them in the conditions of

$I_C = 2\ mA\ and\ V_{CE} = 5\ V$

h_{FE}	DC current gain	I_C = 2 mA; V_{CE} = 5 V			
	BC107A; BC108A		110	180	220
	BC107B; BC108B; BC109B		200	290	450

Fig.1: *β_{DC} value for BC108B type BJT*

Apparatus

Resistors: one 10 Ω, one 47 Ω, one 560 Ω, one 1 kΩ, one 3.9 kΩ, two 10.0 kΩ, one 68 kΩ.
Capacitors: one 0.22 uF, one 1.0 uF, one 100 uF.
One BC108B type npn BJT transistor.

In this circuit below, AC source is presented in equivalent RMS value.

$$V_{pp} = 450mV\ for\ common - emmitter\ amplifier\ V_{rms} = 159.1mV$$

Setup

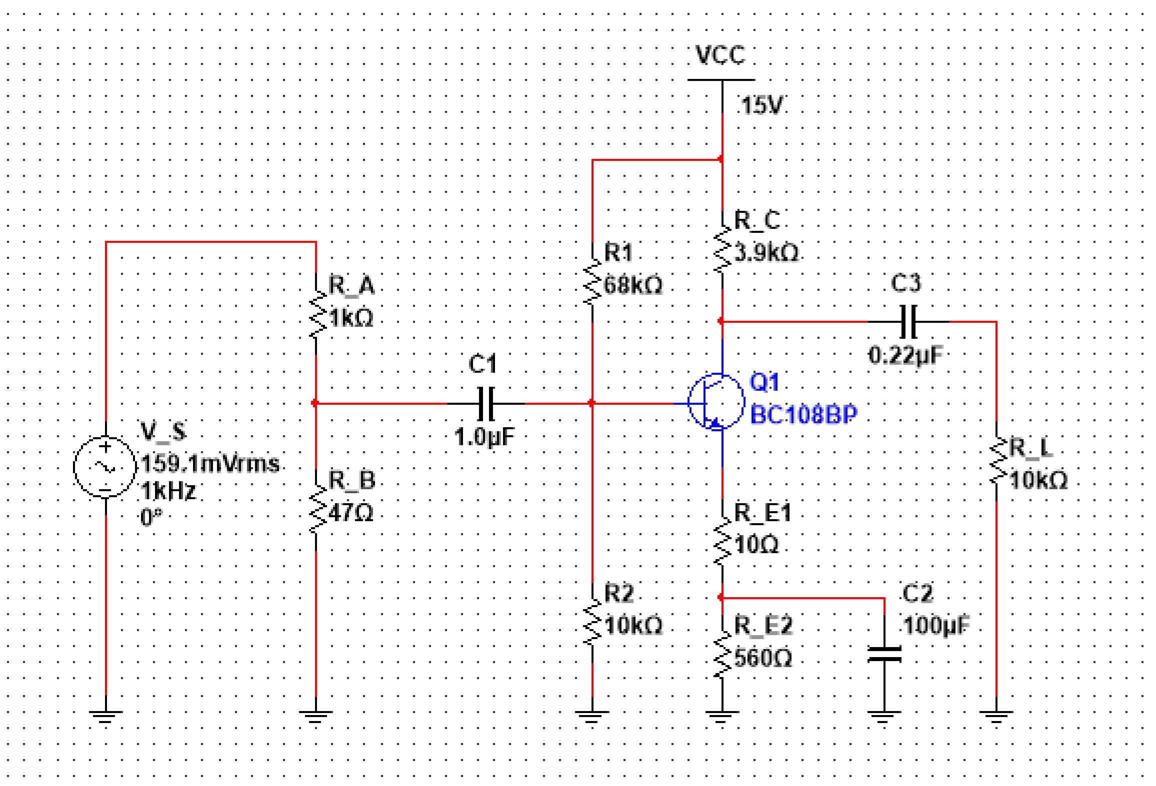

Fig.2: *Experimental setup for common-emitter amplifier*

Results - Experimental and Derived

In this laboratory work, I could finish lab work successfully. Firstly, I want to write about Common-Emitter Amplifier analysis part. For calculation, I used the equations below and got the answers as shown in table 1.

$$V_B = \frac{V_{cc} * R_2}{R_1 + R_2} \quad ; \quad V_E = V_B - 0.7 \quad ; \quad I_E = \frac{V_E}{R_{E1} + R_{E2}} \quad ; \quad I_C \approx I_E \quad ;$$

$$V_C = V_{CC} - R_C * I_C \quad ; \quad V_{CE} = V_C - V_E \quad ; \quad r_e = \frac{25\ mV}{I_E} \quad ; \quad R_C = R_c || R_L \quad ;$$

$$A_v = \frac{R_C}{R_{E1} + r_e} \quad ; \quad V_{out} = A_v * V_{in}$$

Parameter	Computed values	Measured values
V_B	1.923 V	1.861 V
V_E	1.223 V	1.204 V
I_E	2.146 mA	
V_C	6.631 V	6.789 V
V_{CE}	5.408 V	5.585 V
r_e	11.650 Ohm	
A_V	129.79	115.69
V_{out}	917.6 mV (rms)	817.9 mV (rms)

Table.1: *Common-Emitter Amplifier analysis results*

Secondly, I want to compute the lower frequency response, for this purpose it is necessary to find the equivalent resistance that represents the ac charge and discharge path for each capacitor. I compute equivalent resistances seen by each capacitor. I used the equations at Thomas Floyd: Electronic devices page 512-530 and got the answers as shown in the table 2.

$$R_{eq_{C1}} = R_1 || R_2 || (\beta(r_e + R_{E1})) \quad ; \quad R_{eq_{C2}} = \left(r_e + R_{E1} + \frac{R_{th}}{\beta}\right) || R_{E2} \quad ;$$

$$R_{eq_{C3}} = R_C + R_L$$

Capacitor	R_{eq}
C_1	3.65 kOhm
C_2	47.34 Ohm
C_3	13.9 kOhm

Table.2: *Equivalent resistances seen by each capacitor*

Thirdly, I want to compute the lower critical frequency for each capacitor from the equation $f = \frac{1}{2\pi R_{eq} C}$

The overall critical frequency of amplifier will be higher than the highest frequency determined for each individual capacitor. To obtain a rough estimate of upper cutoff, you can simply add the three critical frequencies; the actual frequency will be lower that this estimate. I got the answers as shown in the table 3.

Capacitor	$f_{critical}$ *computed*	$f_{critical}$ measured
C_1	43.6 Hz	43 Hz
C_2	33.6 Hz	65 Hz
C_3	52 Hz	52 Hz
Overall	129.2 Hz	125 Hz

Table.3: *Critical frequencies seen by each capacitor and overall*

Also, I measured critical frequencies using the given instruction below and wrote the figures in the table 3.

5. To measure the critical frequency due to C1, you need to isolate this capacitor by "swamping" out the effect of C2 and C3. Place a 1000 uF capacitor across C2 and another 1000 uF capacitor across C3; this causes their frequency response to have little effect on the output. Observe the signal in mid-band (around 10 kHz) and adjust the signal for 5.0 vertical divisions on the scope face. The output should appear undistorted. Reduce the generator frequency until the output falls to 70.7% (approximately 3.5 divisions) of the voltage in mid-band. This frequency is the lower critical frequency due to C1. Measure and record the value in Table 3.

6. Using the 1000 uF capacitors, isolate C2 by placing large capacitors in parallel with C1 and C3. Measure and record the critical frequency for C2 in Table 3.

7. Measure the critical frequency for C3 by the same method. Record the value in Table 3.

8. Remove the large capacitors and measure the overall critical frequency of the amplifier. Record the value in Table 3.

Discussion of the results

Firstly, I want to mention that measured values are not significantly different from the calculated results which is positive sign for our experiment. However there are some little difference between them because of the non-ideal conditions and errors while doing the experiment. From the DC part of our analysis I got some figures which proofs that, our transistor is in active mode. I also calculated and measured the AC values of the circuit and found that, the gain of our amplifier is approximately 130 which means that, input amplified 130 times.

In the critical frequency part, I get the same results (calculated and measured) for $C_1\ and\ C_3$ but different for C_2. I think it is due to effects of $R_A\ and\ R_B$. I did not consider $R_A\ and\ R_B$ for calculating $R_{eq_{C2}}$ maybe that is why there is a gap between calculated and measured results of C_2.

9. Assume you need to raise the lower critical frequency to 300 Hz. Calculate the value of a bypass capacitor, C2, for the circuit in Figure 1 that will accomplish this.

For this question, I used the equations below

$$f_{cr(C2)} = f_{cr} - (f_{cr(C1)} + f_{cr(C3)})$$

$$C_2 = \frac{1}{2\pi R_{eq_{C2}} f_{cr(C2)}}$$

As a result I got the value of $C_2 = 16.45\ \mu F$

10. What change would you make to the circuit to lower the frequency response in the CE in Figure 1 by a factor of five?

As I understand from the question, I can answer this question theoretically such that, according to the formula $f = \frac{1}{2\pi R_{eq} C}$ if we decrease the value of C five times, the value of frequency will increase five times.

Questions

There was no question (more accurately under the “Questions” title) to answer (I answered 2 questions in Discussion part).

Conclusion

Briefly, I want to add my personal feelings about the experiment carried out by me and have to express that such kinds of experimentations make us learn more profoundly, deep dive the corresponding subject and do some research in order to grasp what is going on behind the process. Furthermore, the most important factors in carrying out this experiment is that depending on the capacitors we can get different critical frequencies in result. However main purpose of the circuit is to amplify the signal, we can get different critical frequencies by changing capacitors. Although differences between calculated and measured results are small, I could not avoid these tiny gaps. The major thing that is derived from this experiment for us is that whenever we take shortages and errors into account we get our results more or less the same as we expected.

Reference

Leaflet of the Laboratory experiment
Electronic devices (Floyd 9th edition), page 506-563
https://www.electronics-tutorials.ws