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Baku Higher Oil School

Course: ANALOG ELECTRONICS

LABORATORY REPORT

Experiment Title: **Three Bias Circuits**

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Introduction

The primary objective of this report is to provide information about lab work namely “Three Bias Circuits”. The major aim of the experiment carried out by me is to understand the biasing using different bias circuits (fixed base bias, emitter-feedback base bias, voltage-divider bias, and collector-feedback bias) and different types of BJT transistors (BC108B & BC550B). I build the bias circuits and measure some parameters such as V_{R_B}, V_{R_C}, V_C. We carried out this experiment via help of different equipment and devices (2 type BJTs, resistors) and they should be as accurate as possible. By doing this experiment, we will create biased transistor.

Generally, transistor must be properly biased with a DC voltage in order to operate as a linear amplifier. The steady state operation of a transistor depends a great deal on its base current, collector voltage, and collector current values and therefore, if the transistor is to operate correctly as a linear amplifier, it must be properly biased around its operating point.

Establishing the correct operating point requires the selection of bias resistors and load resistors to provide the appropriate input current and collector voltage conditions. The correct biasing point for a bipolar transistor, either NPN or PNP, generally lies somewhere between the two extremes of operation with respect to it being either “fully-ON” or “fully-OFF” along its DC load line. This central operating point is called the “Quiescent Operating Point”, or Q-point for short.

When a bipolar transistor is biased so that the Q-point is near the middle of its operating range, that is approximately halfway between cut-off and saturation, it is said to be operating as a Class-A amplifier. This mode of operation allows the output voltage to increase and decrease around the amplifiers Q-point without distortion as the input signal swings through one complete cycle. In other words, the output is available for the full 360 degree of the input cycle.

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

Let’s start looking at the possible different transistor biasing arrangements:

- Fixed base bias
- Emitter-feedback base bias
- Voltage-divider bias
- Collector-feedback bias

The circuit is called as a “fixed base bias circuit”, because the transistors base current, I_B remains constant for given values of V_{CC}, and therefore the transistors operating point must also remain fixed. This two resistor biasing network is used to establish the initial operating region of the transistor using a fixed current bias. This type of transistor biasing arrangement is also beta dependent biasing as the steady-state condition of operation is a function of the transistors beta β_{DC} value, so the biasing point will vary over a wide range for transistors of the same type as the characteristics of the transistors will not be exactly the same.

Emitter-feedback bias is a form of base bias circuit but with increased stability due to the addition of an emitter resistor. As we will see from the tables of results, emitter-feedback base bias circuit is more stable to the changes of β_{DC} value than the fixed base bias circuit.

Voltage-divider bias circuit is the common emitter transistor configuration which is biased using a voltage divider network to increase stability. The name of this biasing configuration comes from the fact that the two resistors R_1 and R_2 form a voltage or potential divider network across the supply with their center point junction connected the transistors base terminal. This voltage divider biasing configuration is the most widely used transistor biasing method. The emitter diode of the transistor is forward biased by the voltage value developed across resistor R_2. Also, voltage divider network biasing makes the transistor circuit independent of changes in beta as the biasing voltages set at the transistors base, emitter, and collector terminals are not dependent on external circuit values. There are also have condition of stiffness which is supported by the inequality of $\beta * R_E \geq 10 * R_2$.

Collector-feedback configuration is another beta dependent biasing method which requires two resistors to provide the necessary DC bias for the transistor. The collector to base feedback configuration ensures that the transistor is always biased in the active region regardless of the value of Beta (β). The DC base bias voltage is derived from the collector voltage V_C, thus providing good stability. In this circuit, the base bias resistor, R_B is connected to the transistors collector C, instead of to the supply voltage V_{CC}. Now if the collector current increases, the collector voltage drops, reducing the base drive and thereby automatically reducing the collector current to keep the transistors Q-point fixed. Therefore this method of collector feedback biasing produces negative feedback round the transistor as there is a direct feedback from the output terminal to the input terminal via resistor, R_B.

Experimental technique

For this experiment, I used 2 type of transistors namely BC108B & BC550B, because I could not find BC140 type transistor in MultiSim catalog. Beta β_{DC} values for them are changing between minimum and maximum, that is why I choose typical values (which are given in datasheets) for BC108B & BC550B as 290 & 330, respectively. The figure below shows the β_{DC} values for them in the conditions of

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

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

Small–Signal Current Gain (I_C = 2.0 mAdc, V_{CE} = 5.0 V, f = 1.0 kHz)	BC549B/BC550B	h_{fe}	240	330	500	—
	BC549C/BC550C		450	600	900	

Fig.1: *Beta values for BC108B & BC550B type transistors*

Apparatus

Resistors: one 680 Ω, one 1.5 kΩ, one 2 kΩ, one 6.8 kΩ, one 33 kΩ, one 360 kΩ, one 1 MΩ
One BC108B npn transistor
One BC550B npn transistor

Setup

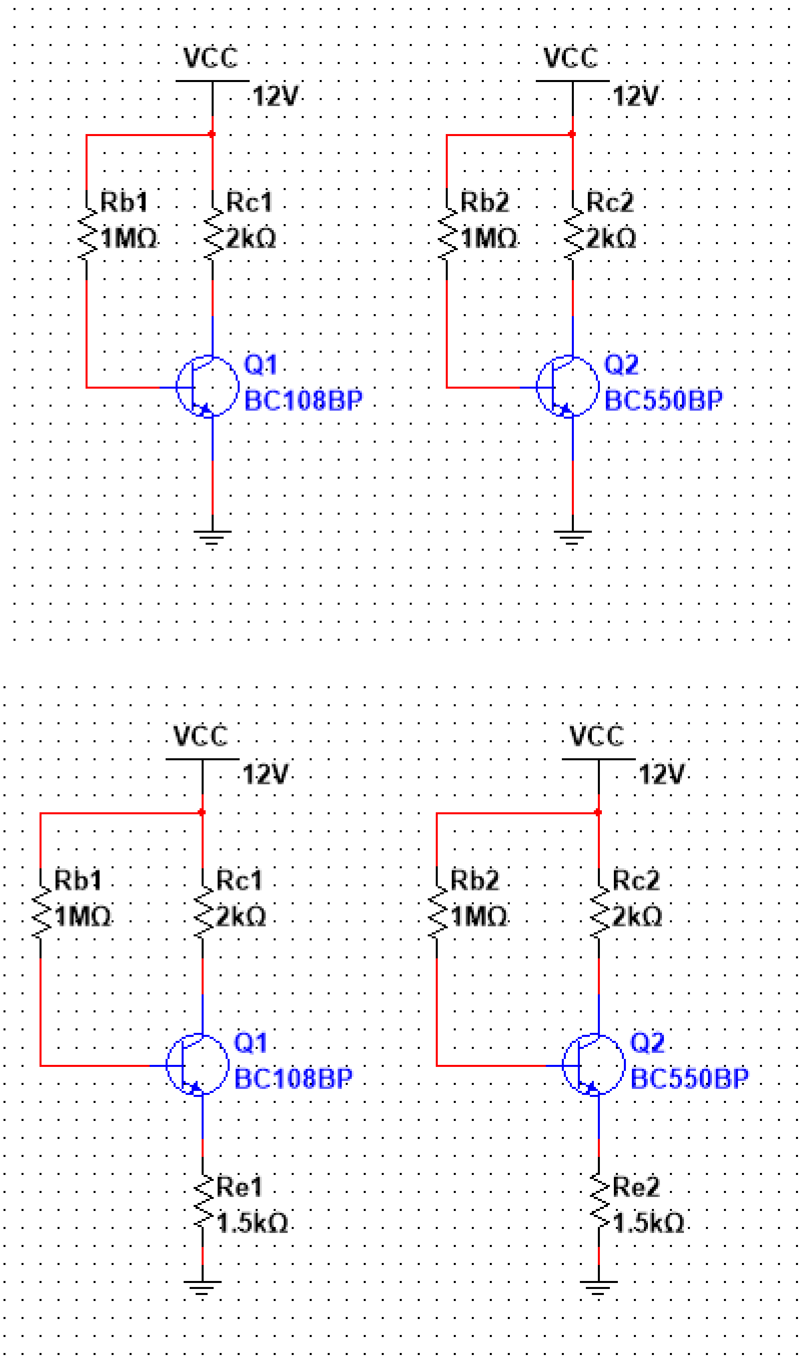

Fig.2: *Experimental setup for fixed base and emitter-feedback base bias circuits, respectively*

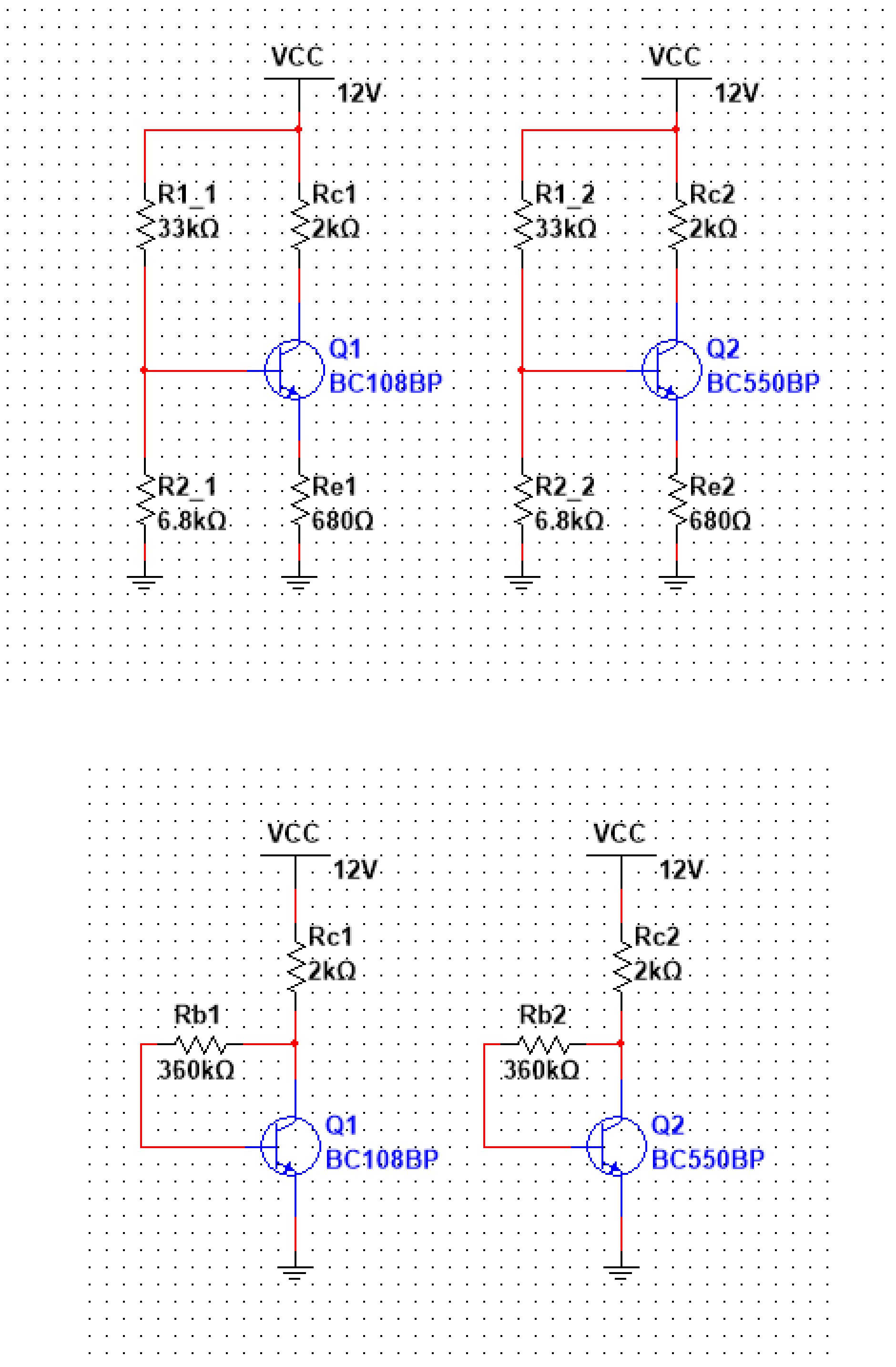

Fig.3: *Experimental setup for voltage-divider bias and collector-feedback base bias circuits, respectively*

Results - Experimental and Derived

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

$I_B = \frac{V_{cc} - V_{BE}}{R_B}$; $V_{R_B} = I_B * R_B$; $I_C = \beta_{DC} * I_B$; $V_{R_C} = I_C * R_C$;

$V_C = V_{cc} - I_C * R_C$

DC quantity	Computed value		Measured value	
	Q1	Q2	Q1	Q2
$\boldsymbol{V_{R_B}}$	11.3 V	11.3 V	11.328 V	11.328 V
$\boldsymbol{I_B}$	11.3 uA	11.3 uA		
$\boldsymbol{I_C}$	3.277 mA	3.729 mA		
$\boldsymbol{V_{R_C}}$	6.554 V	7.458 V	6.908 V	6.902 V
$\boldsymbol{V_C}$	5.446 V	4.542 V	5.026 V	5.098 V

Table.1: *Fixed Base Bias analysis results*

Secondly, I want to write about Emitter-Feedback Base Bias analysis part. For calculation, I used the equations below and got the answers as shown in the table 2.

$I_E = \frac{V_{cc} - V_{BE}}{R_E + \frac{R_B}{\beta_{DC}}}$; $I_B = \frac{I_E}{\beta_{DC}}$; $V_{R_B} = I_B * R_B$; $I_C \approx I_E$; $V_{R_C} = I_C * R_C$

$V_C = V_{cc} - I_C * R_C$

DC quantity	Computed value		Measured value	
	Q1	Q2	Q1	Q2
$\boldsymbol{V_{R_B}}$	7.876 V	7.558 V	7.859 V	7.859 V
$\boldsymbol{I_B}$	7.876 uA	7.558 uA		
$\boldsymbol{I_C}$	2.284 mA	2.494 mA		
$\boldsymbol{V_{R_C}}$	4.568 V	4.988 V	4.622 V	4.622 V
$\boldsymbol{V_C}$	7.432 V	7.012 V	7.378 V	7.378 V

Table.2: *Emitter-Feedback Base Bias analysis results*

Thirdly, I want to write about Voltage-Divider Bias analysis part. For calculation, I used the equations below, because this circuit is stiff ($\beta * R_E \geq 10 * R_2$). I got the answers as shown in the table 3.

$$V_B = \frac{V_{cc} * R_2}{R_1 + R_2} \;;\quad V_E = V_B - V_{BE} \;;\quad I_E = \frac{V_E}{R_E} \;;\quad I_C \approx I_E \;;\quad V_{R_C} = I_C * R_C \;;$$
$$V_C = V_{cc} - I_C * R_C$$

DC quantity	Computed value		Measured value	
	Q1	Q2	Q1	Q2
$\boldsymbol{V_B}$	2.05 V	2.05 V	2.013 V	2.013 V
$\boldsymbol{I_E}$	1.985 mA	1.985 mA	1.996 mA	1.996 mA
$\boldsymbol{I_C \approx I_E}$	1.985 mA	1.985 mA		
$\boldsymbol{V_{R_C}}$	3.97 V	3.97 V	3.979 V	3.979 V
$\boldsymbol{V_C}$	8.03 V	8.03 V	8.021 V	8.021 V

Table.3: *Voltage-Divider Bias analysis results*

Finally, I want to write about Collector-Feedback Bias analysis part. For calculation, I used the equations below and got the answers as shown in the table 4.

$$I_C = \frac{V_{cc} - V_{BE}}{R_C + \frac{R_B}{\beta_{DC}}} \;;\; V_{R_C} = I_C * R_C \;;\; V_C = V_{cc} - I_C * R_C$$

DC quantity	Computed value		Measured value	
	Q1	Q2	Q1	Q2
$\boldsymbol{I_C}$	3.486 mA	3.656 mA		
$\boldsymbol{V_{R_C}}$	6.972 V	7.312 V	7.125 V	7.125 V
$\boldsymbol{V_C}$	5.028 V	4.688 V	4.875 V	4.875 V

Table.4: *Collector-Feedback Bias results*

Discussion of the results

Firstly, I want to mention that, in Fixed Base Bias analysis part, we get the gap (approximately 1 V) between the values for Q1 and Q2 because of the difference in the Beta values (290 & 330) as Fixed Base Bias Circuit is Beta dependent.

Also there is a gap (around 0.5 V) between calculated and measured values. I think the main reason for this gap is the conditions in I_C and V_{CE}, more specifically in the experimental technique part (look at figure 1) I mentioned that the Beta values are true in the conditions of $I_C = 2mA \; and \; V_{CE} = 5V$. But in this circuit I_C is not equal to 2mA but approximately 3mA. Eventually, this fact cause the errors between calculated and measured values in all circuits, except Voltage-Divider Bias Circuit (because it is not dependent on Beta values).

In Emitter-Feedback Base Bias analysis part, we can see from the table that, there is also a gap (approximately 0.5 V) between Q1 and Q2 values, however this difference is smaller than that of Fixed Base Bias Circuit. It shows that Emitter-Feedback Base Bias Circuit is more independent than Fixed Base Bias Circuit. In other words, Beta values have more effect on Fixed Base Bias Circuit.

In Voltage-Divider Bias analysis part, there are also have condition of stiffness which is supported by the inequality of $\beta * R_E \geq 10 * R_2$. In Voltage-Divider Bias analysis part, there is no difference between the values of Q1 and Q2 because as seen from the formulas there is no dependence on Beta value. That is why, Voltage-Divider Bias Circuit is the most stable among the others in this experiment.

In Collector-Feedback Bias analysis part, we can see from the table that, there is also a gap (approximately 0.4 V) between Q1 and Q2 values, because of the Beta dependency.

Another interesting point for me in this experiment is that, there is almost no difference between measured Q1 and Q2 values although I used different transistors (BC108B & BC550B) in simulation. I searched the reason behind this issue and found that, the embedded Beta values for BC108B & BC550B in MultiSim Simulator are approximately the same. That is why simulation gives similar results for measured Q1 and Q2. Figure 2 shows the max and min Beta values for BC108B & BC550B in the MultiSim Simulator.

```
##################  Component  ##################

Database Name:                Master Database
Family Group:                 Transistors
Family:                       BJT_NPN
Name:                         BC108BP
Author:                       TL
Date:                         March 06, 1998
Function:
Description:                  Vceo=25
:                             Vcbo=30
:                             Ic(max)=0.2
:                             hFE(min)=110
:                             hFE(max)=800
##################  Component  ##################

Database Name:                Master Database
Family Group:                 Transistors
Family:                       BJT_NPN
Name:                         BC550BP
Author:                       TL
Date:                         April 06, 1998
Function:
Description:                  Vceo=45
:                             Vcbo=50
:                             Ic(max)=0.1
:                             hFE(min)=100
:                             hFE(max)=800
```

Fig.2: *Beta values for BC108B & BC550B type transistors in MultiSim*

Questions

There was no question to answer.

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 bias circuit we can get stable or unstable values in results. I learned the reasons why we bias the transistors, the different biasing techniques and their differences, the formulas which are important to calculate the values, the reasons why the calculated and measured values are a little bit different, and so on.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 229-257

https://www.electronics-tutorials.ws