National Aviation University

Department of Electronics, Robotics, Monitoring and IoT Technologies

Course: “Fundamentals of Analog Electronics”

Experiment 3

“Bipolar Junction Transistor Biasing”

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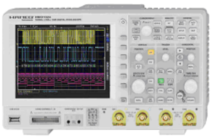
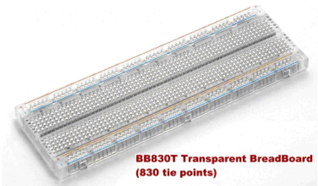
OBJECTIVES

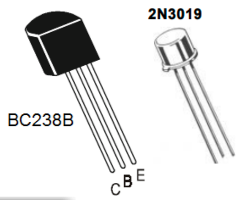
1. To study transistor biasing.
2. To study bias stability.
3. To simulate the bias circuits using MULTISIM software.

EQUIPMENT

1. Digital multimeter: Agilent 34401A
2. Solderless breadboard: BB830T
3. Oscilloscope: HAMEG HMO1024
4. Sinusoidal generator
5. Power Supply: 12V
6. BJT *n-p-n*: BC238B, 2N3019, 2N2222A.
7. Resistors: 75 kΩ, 8 kΩ, 7.2 kΩ, 1.2 kΩ, 100 Ω
8. Capacitor: 1×10µF







Theory

A typical BJT common-emitter (CE) amplifier circuit is shown Fig. 1.

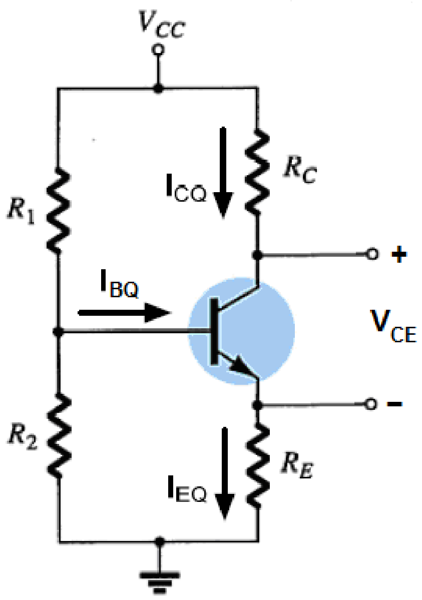


Fig. 1. Common-emitter amplifier with self-bias circuit

The input side of the circuit of Fig. 1 can be redrawn as shown in Fig. 2 for the purpose of the dc analysis.

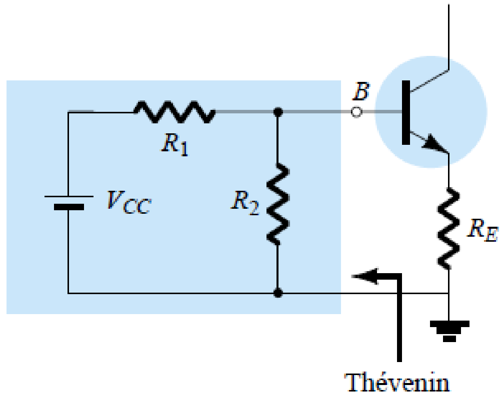


Fig. 2. Redrawn input circuit for dc analysis

The Thévenin equivalent network located to the left of the base terminal can then be found as follows:

• **Thevenin equivalent resistance** R_B=R_{Th}: The voltage source is replaced by a short-circuit equivalent as shown in Fig. 3.

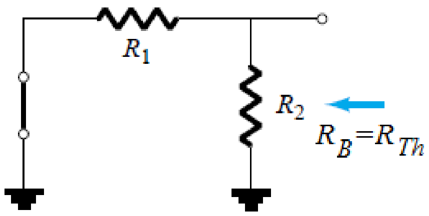


Fig. 3. Determining Thevenin resistance

From Fig. 3 follows that

$$R_B = R_{Th} = R_1 \| R_2$$

• **Thevenin equivalent voltage** V_{BB}=E_{Th}: The voltage source V_{CC} is returned to the network as shown in Fig. 4.

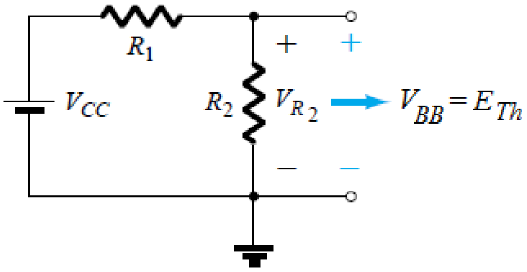


Fig. 4. Determining Thevenin voltage

The open-circuit Thévenin voltage of Fig. 4 is determined by applying the voltage-divider rule:

$$V_{BB} = E_{Th} = V_{CC} \times \frac{R_2}{R_1 + R_2}$$

For finding the base current at the operating point, I_{BQ}, the Thévenin network can then be redrawn as shown in Fig. 5.

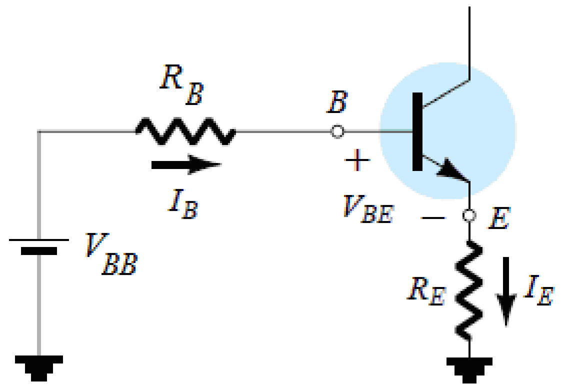


Fig. 5. Thevenin equivalent circuit of the amplifier input circuit

The current I_{BQ} is determined by first applying Kirchhoff's voltage law in the clockwise direction for the loop indicated:

$$V_{BB} - I_B R_B - V_{BE} - I_E R_E = 0$$

Substituting $I_E = (\beta+1) I_B$ and solving for I_B yields

$$I_{BQ} = \frac{V_{BB} - V_{BE}}{R_B + (\beta + 1) R_E}$$

Once I_B is known, the remaining quantities of the network can easily be found. The quiescent collector current is

$$I_{CQ} = \beta \cdot I_{BQ}$$

The collector-emitter voltage is found as

$$V_{CC} - I_{CQ} R_C - V_{CEQ} - I_{EQ} R_E = 0 \Rightarrow I_{EQ} = I_{CQ} + I_{BQ} = I_{CQ} + I_{CQ}/\beta = I_{CQ}(1 + 1/\beta) \approx I_{CQ} \Rightarrow$$

$$V_{CEQ} = V_{CC} - I_{CQ}(R_C + R_E)$$

Figure 6 shows a typical DC load line and a Q-point. The input AC signal disturbs the base current that in turn makes the Q-point move on the load line producing a proportionally larger disturbance in the collector current, thus producing amplification.

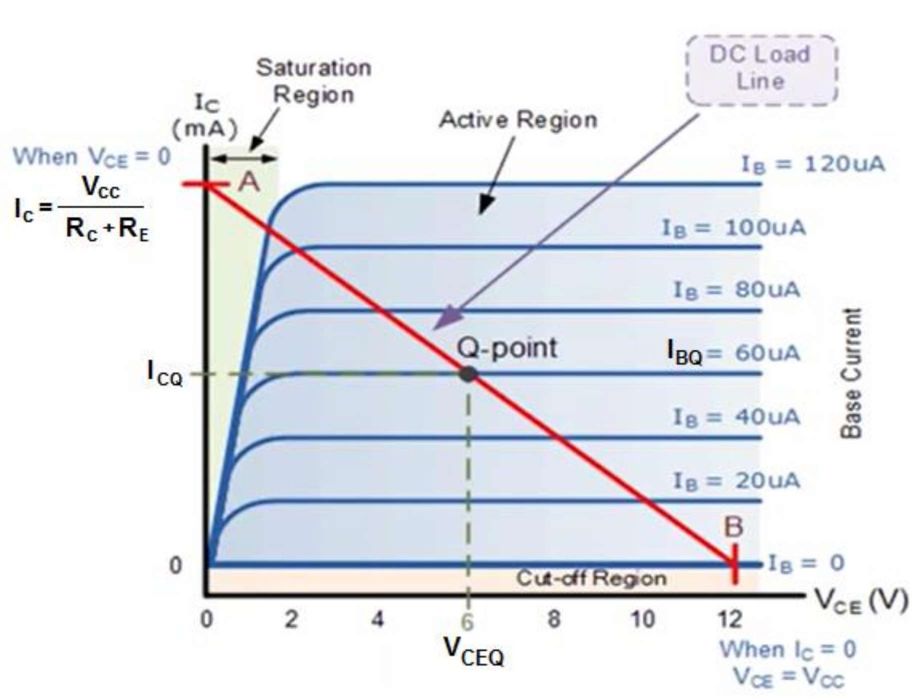


Fig. 6. DC load line

Figure 7 is the same as Fig. 1 with an AC input signal added.

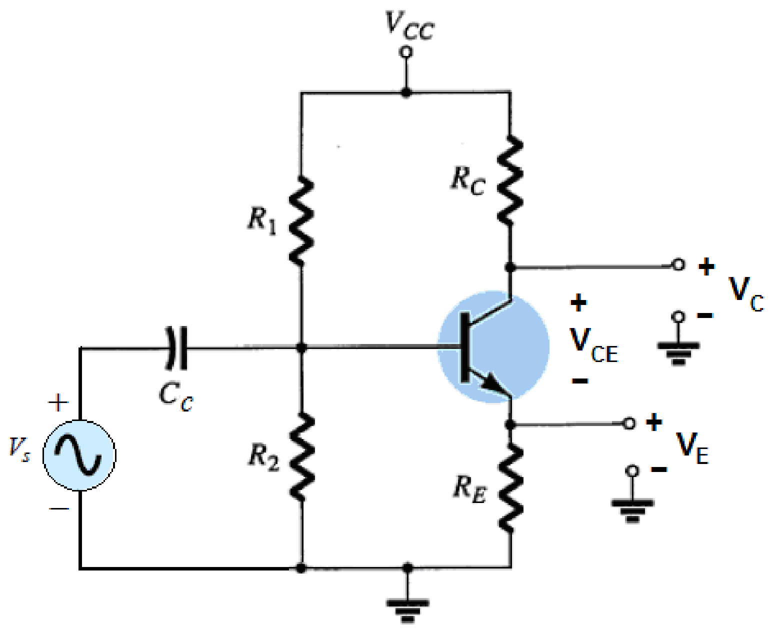


Fig. 7. Common-emitter amplifier with input source

Pre-laboratory work:

Assume V_{CC} = 12 V.

a) Consider the circuit in Fig. 8 with R_C = 1.2 kΩ, R_B = 7.2 kΩ, and R_E = 0 Ω.

b) Calculate V_{BB} so that I_{CQ} = 10 mA. Assume β = 160 and V_{BE} = 0.7 V.

c) Repeat (b) above if R_E =100 Ω, I_{CQ} = 3.9 mA and β = 315.

d) Consider the circuit in Fig. 7 with R_E = 100 Ω. Calculate the values for R_1, R_2 so that V_{BB} is like in (c).

e) Use a sinusoidal input (small-signal peak to peak voltage of 40 mV) in your circuit simulation by MULTISIM. Plot v_s, v_C, v_E, and v_{CE} versus time.

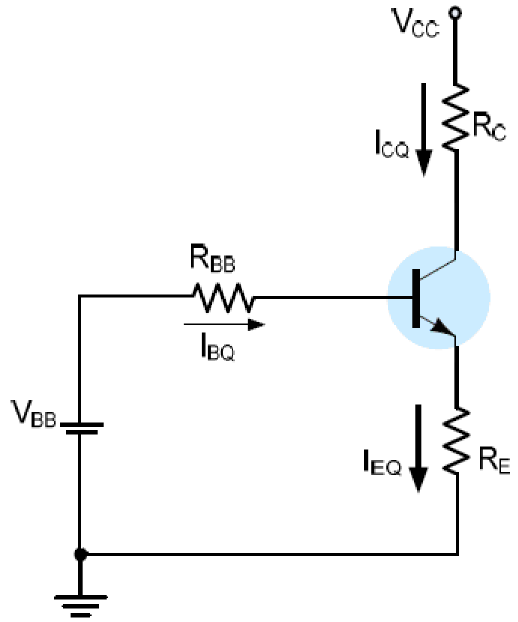


Fig. 8. CE amplifier circuit with the Thevenin equivalent at the input

Experimental Procedure:

The purpose of this experiment is to verify the theoretical and simulation results.

a) Connect the circuit of Fig. 8 with values in the pre-lab preparation (steps ***a*** and ***b***). Measure the Q-point and compare with expected value. Measure I_{CQ} and I_{BQ} and compute the current gain β.

b) Replace the transistor BC238B with the transistor 2N3019 and check if the I_{CQ} remains the same. Repeat with a third transistor 2N2222A. Does the collector current remain the same? Why or Why not?

c) Modify the circuit by inserting R_E as in the preparation and repeat part (*a*) above.

d) Connect the circuit in Fig. 7 using the values you have calculated in the preparation. Measure the Q-point and compare with expected value.

e) Connect and set the generator to a sinusoidal of 10 kHz. Use 10 μF for the capacitor C_c. Make sure the capacitor is connected with the correct polarity. Adjust the input amplitude so that none of the waveforms is clipped. Observe and include in your report the following waveforms: input voltage v_s, collector voltage v_C, emitter voltage v_E, and collector-emitter voltage v_{CE}.

Plot all those waveforms on a common time scale using several sinusoidal cycles (use of photographs is allowed).

Report:

In your lab report, include theoretical, simulated, and experimental results and make comment about discrepancies, as well as any other observations that you have.

Your report will also include the following information:

1. Date and time data were taken.
2. The pre-laboratory results.
3. The experimental procedures.
4. All calculations or simulation results for each step.
5. All plots or waveforms for each step.
6. Short summary discussing what was observed for each of the steps given in the experiment.
7. What you learned.

Reference

1. A.S. Sedra and K.S. Smith, "Microelectronic circuits", 5^{th} ed., New York: Oxford University Press, 2004, 1283 p.