Lab Three
Fundamentals of Electronics
EECE2412/3

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Abstract

The goal of this laboratory experiment is to orient the performing individual with bipolar junction transistors (BJTs). Common regions (active, saturated, and cut-off) are explored, in addition to the effects of temperature variance on BJT performance. Finally, a light-emitting diode (LED) light-sensing circuit is constructed with a photocell.

KEYWORDS: BJT, active, saturated, cut-off, temperature variance, LED, photocell

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1 Equipment

Available equipment included:

- 2N3904 Bipolar Junction Transistors
- Light-Emitting Diodes (varying colors)
- Basic Circuit Components (Wires, Inductors, Capacitors, etc.)
- Keysight EDU36311A Dual DC Power Supply
- Photocell (Light-Varying Resistor)

2 Experimental Procedure

We begin by constructing the following circuit:

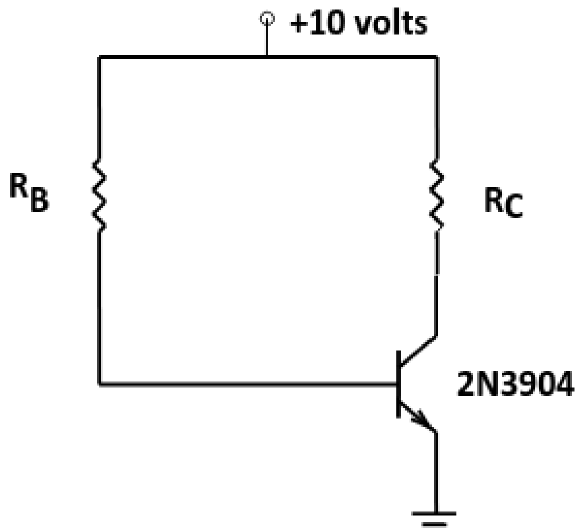

Figure 1: BJT Biasing Circuit

We proceed to test various configurations which place the 2N3904 in common regions, such as active, saturated, and cut-off.

2.1 The Forward-Active Region (with varying β)

Using the circuit shown in Figure 1, with $R_B = 316.7[\text{k}\Omega]$ and $R_C = 1.003[\text{k}\Omega]$, we place the BJT into its active region (supporting calculations are present in the pre-lab). Measuring V_{CE} and V_{BE} for both of our BJTs, we find:

$$V_{BE_1} = .708[\text{V}] \quad \text{and} \quad V_{CE_1} = 3.394[\text{V}]$$
$$V_{BE_2} = .704[\text{V}] \quad \text{and} \quad V_{CE_2} = 3.378[\text{V}]$$

We know the BJT is in its active region since, based on the above measurements, $V_{CE} > V_{BE}$ (or, alternatively $V_{BE} > 0$ and $V_{BC} < 0$).
Using the data from above, we may calculate I_B, I_C, and β:

$$I_{B_1} = \frac{10 - .708}{316.7k} \quad \text{and} \quad I_{C_1} = \frac{10 - 3.394}{1003}$$
$$\boxed{I_{B_1} = 29.34[\mu\text{A}] \quad \text{and} \quad I_{C_1} = 6.586[\text{mA}]}$$

$$I_{B_2} = \frac{10 - .704}{316.7k} \quad \text{and} \quad I_{C_1} = \frac{10 - 3.378}{1003}$$

$$\boxed{I_{B_1} = 29.353[\mu\text{A}] \quad \text{and} \quad I_{C_1} = 6.6022[\text{mA}]}$$

From this, we find the direct current (DC) gains:

$$\beta_1 = \frac{6.586}{.02934}$$

$$\boxed{\beta_1 = 224.47}$$

$$\beta_2 = \frac{6.6022}{.029353}$$

$$\boxed{\beta_2 = 224.92}$$

2.1.1 Using Curve Tracers

Per the curve tracer presented in class, we would expect $I_B = 40[\mu\text{A}]$ for our I_C value. This gives us a β of:

$$\beta_{curve} = \frac{6}{.04}$$

$$\boxed{\beta_{curve} = 150}$$

2.1.2 Tolerance and Standard Deviation of Gain

It would be difficult to design a circuit with $\beta = 150 \pm 1\%$ because, even within the same model of BJT, there is much variation; however, it should still be practical to meet this strict tolerance. This is further supported by the variance of β presented in the BJT data sheets attached to the laboratory experiment. Though the tested transistors are all within specification, there is a great amount of variance, which we can calculate using the standard deviation. We obtain two of each β value from other groups:

$$\beta_1 = 186, 196$$

$$\beta_2 = 201, 217$$

The average of the gains is:

$$\beta_1^{avg} = 202.16$$

$$\beta_2^{avg} = 214.31$$

Thus, we get standard deviations of:

$$\boxed{\sigma_{\beta_1} = 19.96 \quad \text{and } \sigma_{\beta_2} = 12.185}$$

We may see that these standard deviations are all, more or less, within 1% (for β_1 it is above for two of the three values), and, therefore, we should be able to design for such a tolerance.

2.1.3 Thermal Response

Using a can of refrigerant, we obtain new values:

$$V_{CE} = 3.78[\text{V}] \quad \text{and} \quad V_{BE} = .725[\text{V}]$$

This gives us:

$$\beta = \frac{\left(\frac{10-3.78}{1003}\right)}{\left(\frac{10-.725}{316700}\right)}$$

$$\boxed{\beta_{cold} = 211.48}$$

Per the data sheets, we would expect a drop in I_C, which would result in a decrease in β, as shown above. This would be unwanted in a car stereo system, as colder weather would mean that the amplification would not be as great, thus causing lower volumes.

2.2 BJT Saturation

As per the pre-lab, we know that $R_B \leq 208.66[\text{k}\Omega]$ will saturate the BJT. Thus, we select the closest available value: $R_B = 157[\text{k}\Omega]$. Measuring the saturation values, we find:

$$V_{CE_1}^{sat} = 45[\text{mV}] \quad \text{and} \quad V_{BE_1}^{sat} = .906[\text{V}]$$

$$V_{CE_2}^{sat} = 51.5[\text{mV}] \quad \text{and} \quad V_{BE_1}^{sat} = .94[\text{V}]$$

We see that there is a lot of variation between even the same model of BJT, and, thus, it is necessary to account for BJT-to-BJT variation. We may find the β values for this region:

$$I_{B_1} = \frac{10 - .906}{157000} \quad \text{and} \quad I_{C_1} = \frac{10 - .045}{1003}$$

$$\boxed{I_{B_1} = 57.92[\mu\text{A}] \quad \text{and} \quad I_{C_1} = 9.925[\text{mA}]}$$

$$I_{B_2} = \frac{10 - .94}{157000} \quad \text{and} \quad I_{C_2} = \frac{10 - .0515}{1003}$$

$$\boxed{I_{B_1} = 57.7[\mu\text{A}] \quad \text{and} \quad I_{C_1} = 9.9187[\text{mA}]}$$

This gives us:

$$\beta_1 = \frac{9.925}{.05792}$$

$$\boxed{\beta_1 = 171.36}$$

$$\beta_2 = \frac{9.9187}{.0577}$$

$$\boxed{\beta_2 = 171.90}$$

From this, we see that, if a high β is important in a circuit, we want to operate in the active, and not in the saturated region.

2.3 BJT Cut-Off

Using the different methods provided, we obtain:

$$V_{CE_1} = 10[\mathrm{V}]$$

$$V_{CE_2} = 9.638[\mathrm{V}]$$

$$V_{CE_3} = 4.572[\mathrm{V}] \quad (\text{when } R = 470[\Omega])$$

2.4 BJT Touch-Sensitive Switch

3 Conclusion