Lab 3: Linear Power Supply with Zener Regulation

EE 3310L

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1. Introduction

The purpose of this lab is to construct a three-transistor circuit and measure its operating voltages and currents to verify that all transistors are in the active region and thus capable of small-signal linear amplification [1].

2. Experimental Methodology

The first step of the experiment is constructing the circuit following figure 1 below, while ensuring that none of the transistors have an h_{FE} less than 30 [1].

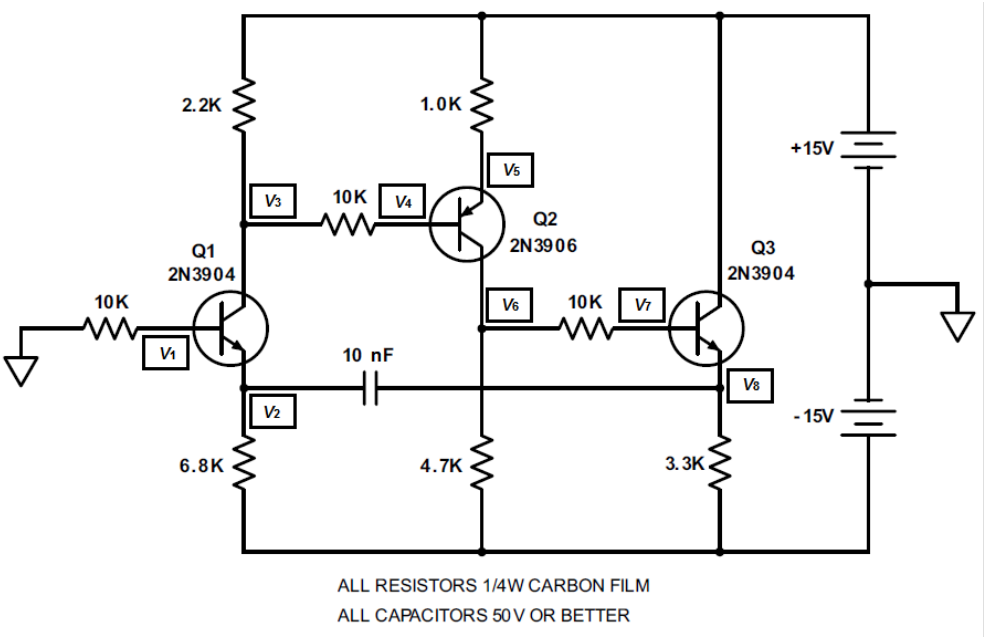

Figure 1. Circuit for exploring the waveform of a full-wave-rectified sine wave.

Each of the nodes then have their voltage measured and compared against the given table of node voltages as seen below in table 1, to ensure measured values are reasonably close [1].

Table 1: Given table of node voltages.

V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8
−63 mV	−0.74 V	10.4 V	10.6 V	11.3 V	2.1 V	1.6 V	0.82 V

3. Results and Description

The measured node voltages for the circuit seen in figure 1 above with transistor h_{FE} values of 201, 226, and 130 for transistors Q1, Q2, and Q3 respectively can be seen in table 2 below.

Table 2: Measured node voltages.

V1	*V2*	*V3*	*V4*	*V5*	*V6*	*V7*	*V8*
-0.108	-0.78	10.46	10.52	11.32	2.13	1.91	1.11

4. Discussion

The calculated values for V_B, V_C, V_E, V_{BE}, V_{CE}, I_B, I_C, I_E, and ß for transistors Q1, Q2, and Q3 can be seen in table 3 below.

Table 3: Calculated voltages, currents and ßs.

	VB	VC	VE	VBE	VCE	IB	IC	IE	ß
Q1	-0.11	10.46	-0.78	0.67	11.24	1.08E-05	2.09E-03	2.09E-03	193.63
equation	V1	V3	V2	VB1 - VE1	VC1 - VE1	(0-VB1)/10kΩ	=IE @ high ß	(VE1-(-15))/6.8kΩ	IC1/IB1
Q2	10.52	2.13	11.32	-0.80	-9.19	6.00E-06	3.68E-03	3.68E-03	613.33
equation	V4	V6	V5	VB2 - VE2	VC2 - VE2	(VB2-VC1)/10kΩ	=IE @ high ß	(15-VE2)/1kΩ	IC2/IB2
Q3	1.91	15.00	1.11	0.80	13.89	2.20E-05	4.88E-03	4.88E-03	221.90
equation	V7	+15V source	V8	VB3 - VE3	VC3 - VE3	(VC2-VB3)/10kΩ	=IE @ high ß	(VE3-(-15))/3.3kΩ	IC3/IB3

V_B, V_C, V_E for each transistor is from their respective measured node voltages. V_{BE} is calculated from equation 1 below.

$$V_{BE} = V_B - V_E \tag{1}$$

V_{CE} is calculated from equation 2 below.

$$V_{CE} = V_C - V_E \tag{2}$$

I_{B1} is calculated from equation 3 below. It is in this order to show that current is flowing towards the transistor.

$$I_{B1} = \frac{(0 - V_{B1})}{10000} \tag{3}$$

I_{B2} is calculated from equation 4 below. It is in this order to show that current is flowing away from the transistor.

$$I_{B2} = \frac{(V_{B2} - V_{C1})}{10000} \quad (4)$$

I_{B3} is calculated from equation 5 below. It is in this order to show that current is flowing towards the transistor.

$$I_{B3} = \frac{(V_{C2} - V_{B3})}{10000} \quad (5)$$

I_{B1} is calculated from equation 6 below. It is in this order to show that current is flowing away from the transistor.

$$I_{E1} = \frac{(V_{E1} - (-15))}{6800} \quad (6)$$

I_{B2} is calculated from equation 7 below. It is in this order to show that current is flowing towards the transistor.

$$I_{E2} = \frac{(15 - V_{E2})}{1000} \quad (7)$$

I_{B3} is calculated from equation 8 below. It is in this order to show that current is flowing away from the transistor.

$$I_{E3} = \frac{(V_{E3} - (-15))}{3300} \quad (8)$$

Due to each measured transistor having a ß value greater than 100, which means they have a sufficiently high ß value, I_C can be determined from equation 9 below.

$$I_C = I_E \tag{9}$$

ß values for each transistor can be calculated with equation 10 below.

$$ß = \frac{I_C}{I_B} \tag{10}$$

The calculated ß1 is similar to the measured ß value for Q1. ß2, however, is much larger than the measured ß value for Q2 and ß3 is moderately larger than the measured ß value for Q3.

A Multisim circuit simulation of the circuit from figure 1 with the mentioned ß values from the first paragraph of results and description can be seen below in figure 2.

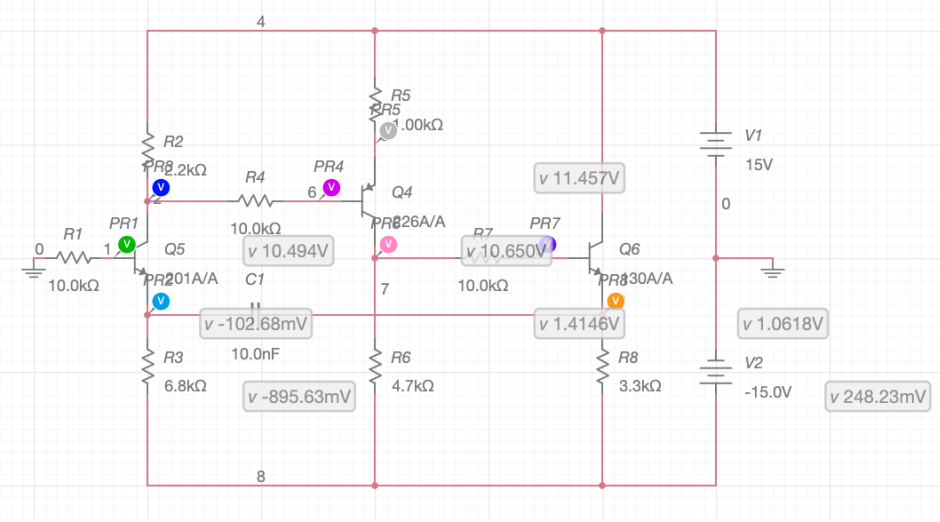

Figure 2: Multisim simulation of the circuit from figure 1.

The simulated node voltages on Multisim show that the simulated and measured node voltages were generally similar, except for voltages 6, 7, and 8 where the simulated voltages were a fair bit lower than the experimental values.

5. Summary and Conclusions

The most of lab itself is simple and straightforward to complete due to the instructions given. The lab was unclear about measuring the currents of the circuit as it was not mentioned in the procedure section and only mentioned in the postlab section. As such, for question 3 of the postlab, ß values were calculated with the calculated currents instead of measured currents.

Reference

[1] Tritschler, Joe. "BJT Voltages and Currents." N.p., n.d. Web. 03 Feb 2023.