Writing Mechanics: 25/25
Technical Contents: 22/25
Results and Discussions: 22/25
Design/Lay-out/Testing: 25/25
Extra Credit: 5/5
Total: 99 /100

Electronics Lab #4

Introduction to Bipolar Junction Transistors

Hunter Dubel & Shubham Tandon

ELC333-01

Professor Ambrose Adegbege

March 30th, 2015

Content

Introduction

The objective of this laboratory experiment is to observe and experiment with a bipolar junction transistor (BJT). Unlike field-effect transistors, BJTs are controlled by current. The current is used to control the amount of current that flows between the emitter and the collector. BJT's consist of two different transistor types, the NPN transistor and the PNP transistor. Each transistor contains three regions, the base, emitter, and the collector. As part of the experimentation, a BJT will be used as a variable resistor, as a switch, and as an AND gate. When set up as a variable resistor, the lower the base input bias voltage is, the higher the emitter-to-collector resistance becomes. When this is at an extremely high value, the resistor becomes the equivalent of an open switch. When a BJT is used as a switch the voltage is set to either 0V or 5V. This causes the emitter-to-collector resistance to flip between zero ohms and an extremely high value to emulate the effect of a closed or an open switch.

Theoretical Basis

Equations

1. Current gain: $\beta = \frac{\Delta I_C}{\Delta I_B}|_{V_C=constant}$

2. $\Delta I_B = \frac{V_B - V_{BE}}{R}$

3. Piece-wise linear model of the BJT: $\begin{cases} \text{if } x_1 < x < x_2 \; then \; m_{1x} + b_1 \\ \text{if } x_2 < x < x_3 \; then \; m_{2x} + b_2 \\ \text{if } x_3 < x < x_4 \; then \; m_{3x} + b_3 \end{cases}$

List of Instruments Used

Agilent Multimeter

OrCad PSpice Software

List of Materials Used

Breadboard

Circuit Board Wires

Various Resistors

2N2222 BJT

LT03XX-41 Red Light Emitting Diode (LED)

Experimental Measurements

Part 1: BJT Current-Voltage Characteristics

For this lab experiment we used a 2N2222A BJT.

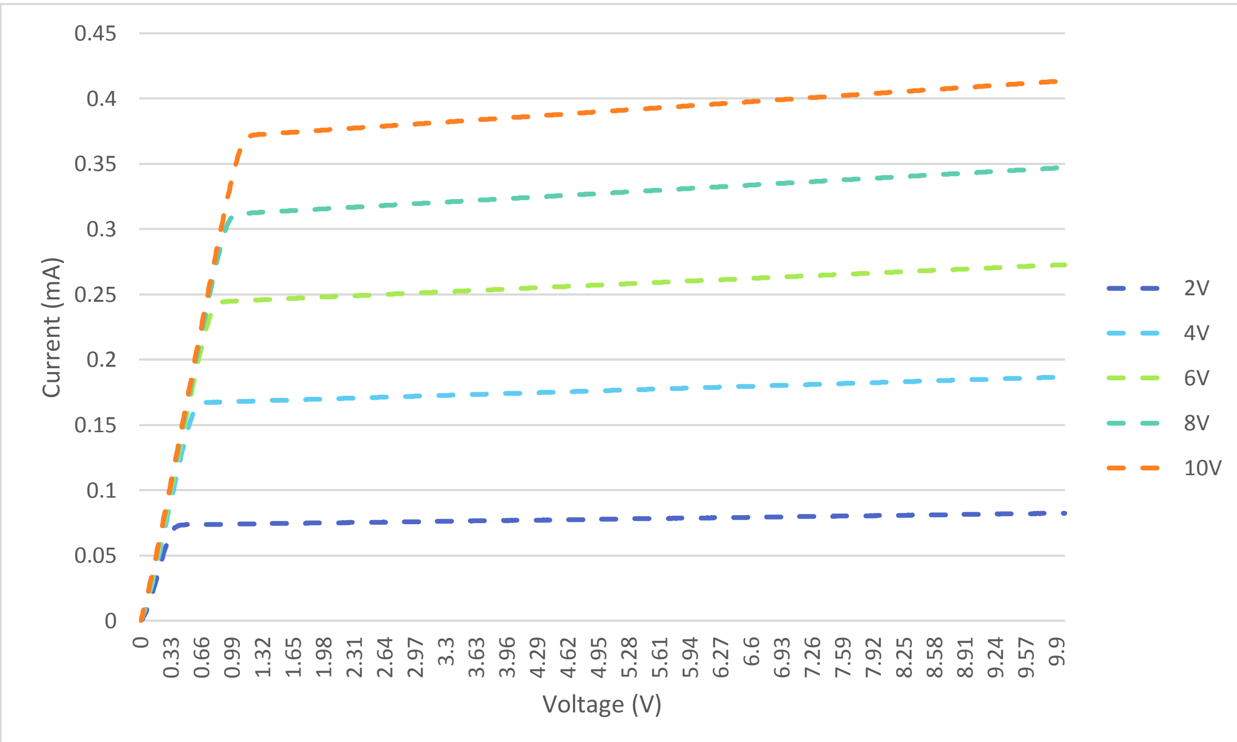


Figure 1: 2N2222A Bipolar Junction Transistor displayed the above curves at the supplied voltages.

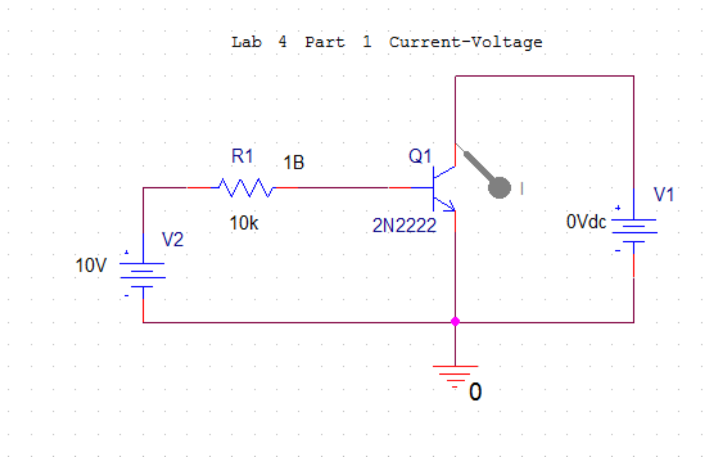


Figure 2: Screenshot of PSpice schematic.

The information displayed above in figure 1 could have been collected using either a Tecktronix 576 Curve Tracer or by the schematic shown in figure 2 in PSpice. Both options would generate the same solution, allowing for personal preference on how one would solve the problem.

Part 2: Current Gain

a) The current gain was calculated to be 474 A/A. We calculated ΔI_C by drawing a vertical line

At what value of Vce did you draw your straight line?

and see the y-component for different V_B. We chose our V_B to be 2V and 4V and calculated our ΔI_B to be 0.095A. To calculate our ΔI_B we used equation 2 from theoretical basis. Again used 2V and 4V as our V_B. We calculated our ΔV_B to be 2E-4V. Therefore we arrived to our current gain to be 474 A/A.

b) According to the 2N2222A. The gain is 300. We believe that the reason the values are off because we chose our V_B to be 2V and 4V, whereas they may have used a larger difference.

Part 3: Piece-wise model of the BJT

$$f(x) = \begin{cases} if\ 0 < x < 1.3\ then\ 0.0013x + 0.0405 \\ if\ 1.3 < x < 2.6\ then\ 2E - 5x + 0.1656 \\ if\ 2.6 < x < 5.2\ then\ 2E - 5x + 0.1657 \\ if\ 5.2 < x < 10\ then\ 2E - 5x + 0.1658 \end{cases}$$

For what value of Vb?

__**Part 4: BJT Variable Resistor**__

One of the uses for a BJT is to have it be used as a variable resistor. A variable resistor is a circuit created using a BJT that has a varying resistance dependent on the base input bias voltage.

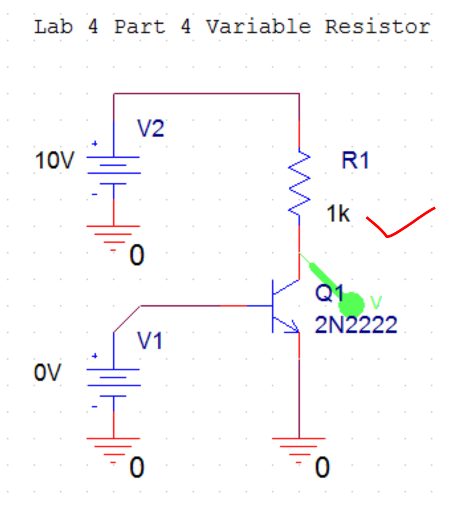


Figure 3: Spice schematic for the variable resistor.

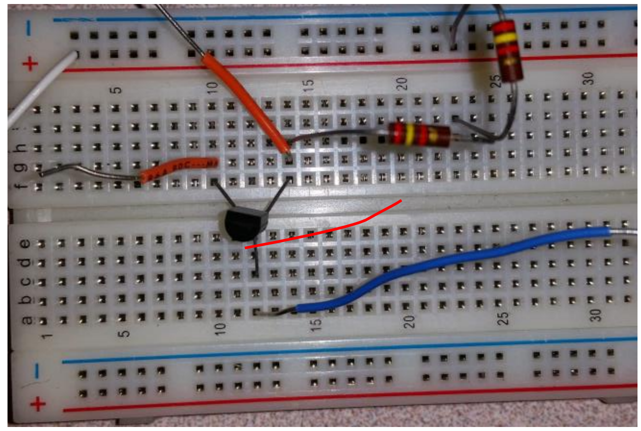


Figure 4: Hardware version of the variable resistor.

When the common and emitter terminals are reversed, the output of the variable resistor changes from what is shown in figure 5 to that shown in figure 6.

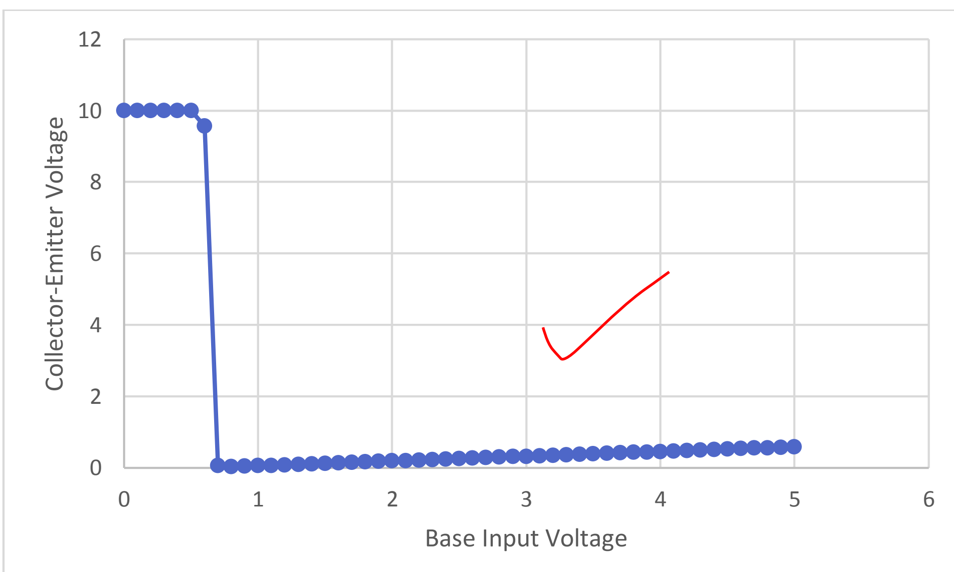


Figure 5: Simulated results for the variable resistor.

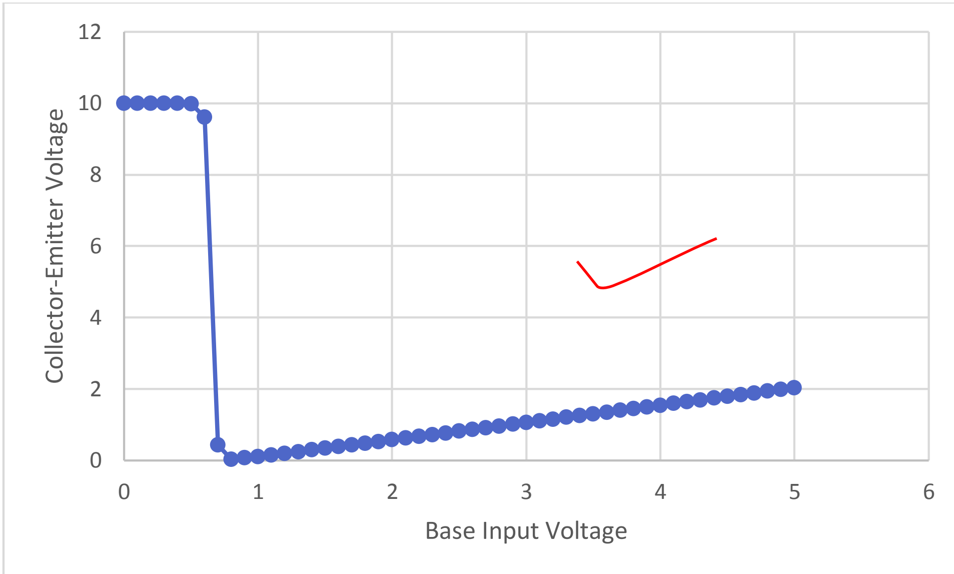


Figure 6: Simulated results for the variable resistor with the common and emitter terminals flipped.

Using equation 1, ic could be solved for using the known values of Vout and the value of the VCC. Using Ohm's law on the value of ic, a value of 11.6k Ohms is calculated as a usable value to be used between the drain and source terminals.

When the BJT has the common and the emitter terminals flipped, the collector-emitter voltage drops at a quicker rate and has a higher slope after the drop, increasing at a much higher rate.

In order to utilize the variable resistor, there must be two supplies of power, one that is constant and the other which is the base input bias voltage. In the variable resistor as the base input bias voltage is increased the emitter to collector resistance begins to drop until a threshold is reached. A variable resistor works the same as a BJT switch that is set by default to direct current to the ground. As a voltage is applied, the BJT slowly switches over to allow the current flow to the Vout.

Part 5: BJT Switch

A BJT switch works very similarly to that of a BJT variable resistor. The introduction of a second resistor before the actual BJT controls the amount of current that can flow into the BJT having it only switch when it reaches a specific threshold. In the circuit designed this threshold was about 1.3 volts.

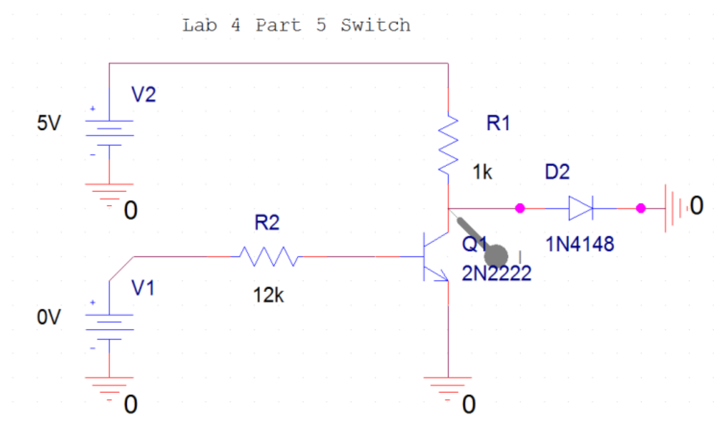


Figure 7: Schematic of a BJT switch that controls an LED.

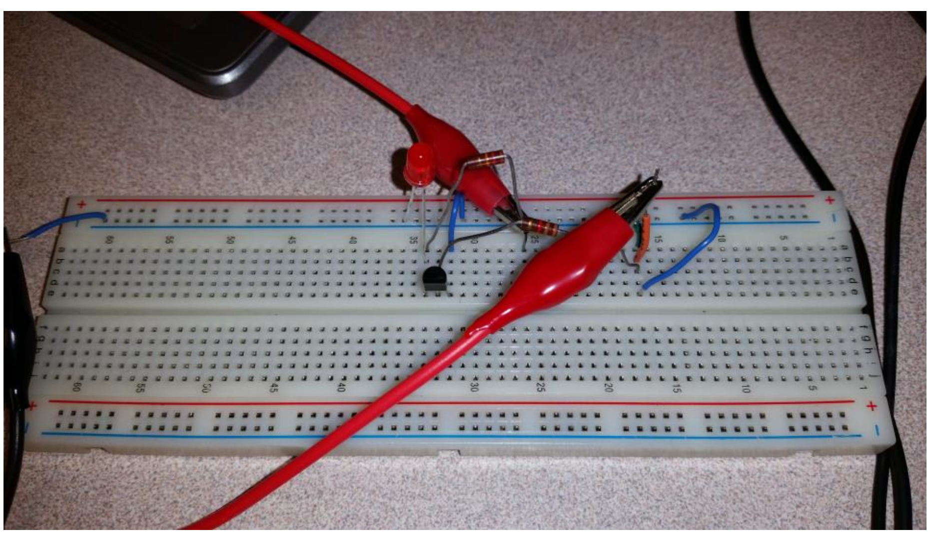


Figure 8: Hardware circuit of the schematic from figure 7.

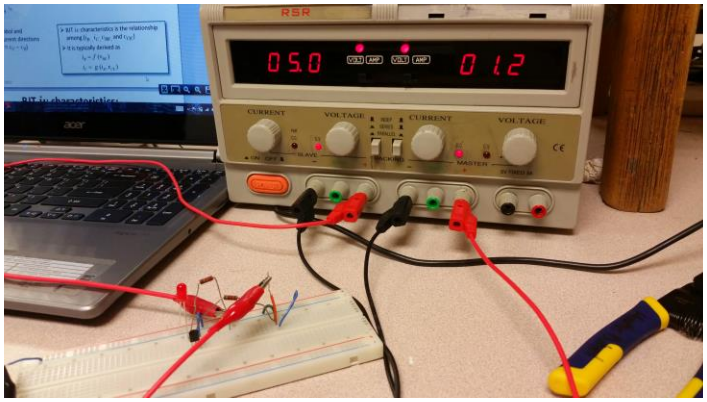


Figure 9: The circuit that displays the threshold voltage for the switch.

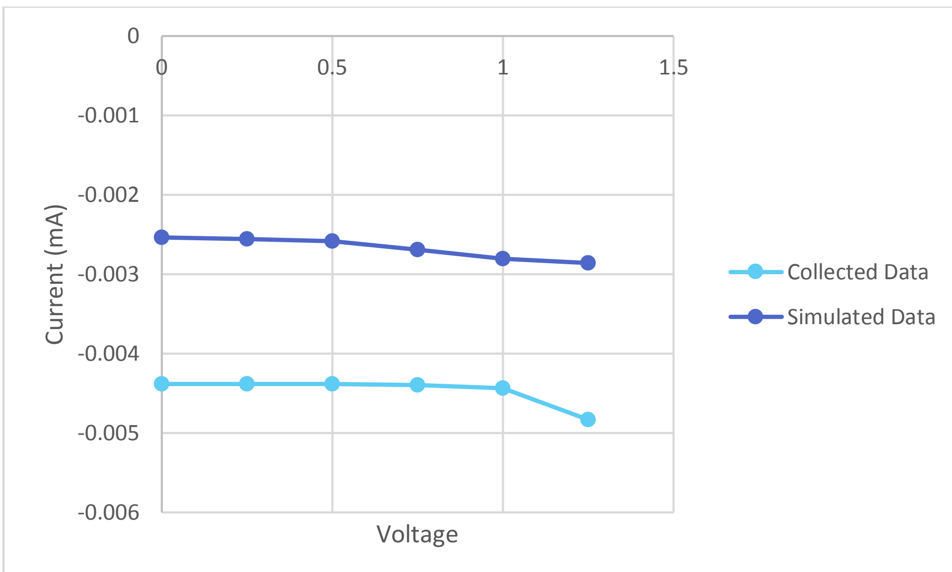


Figure 10: The collected and simulated data graphed for comparison.

In order to have the LED start to become lit, a minimum value of Ic is needed. This value was measured to be about 0.0595mA. The hardware was roughly double that of the data collected from the simulation. This could be due to natural variations in the components as well as the temperature of the room. Both forms of data show a similar pattern of regression as the voltage increases.

Part 6 BJT AND Gate

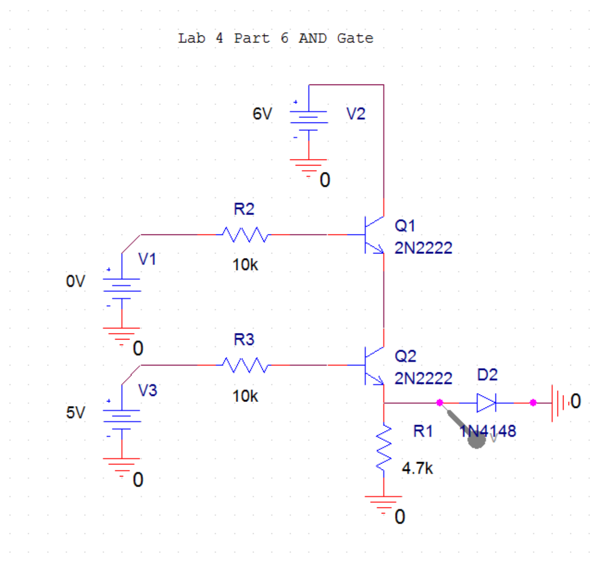
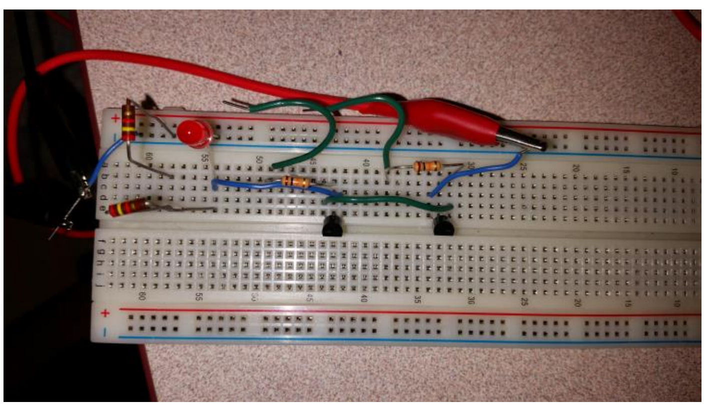


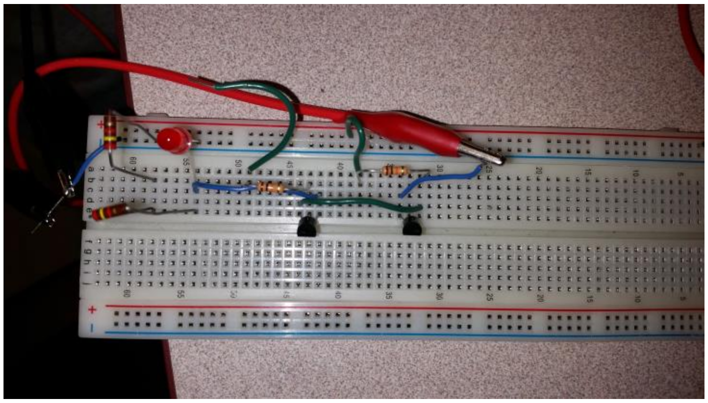
Figure 11: PSpice schematic for a BJT AND Gate.



Where V1 = 0V

Where V3 = 0V

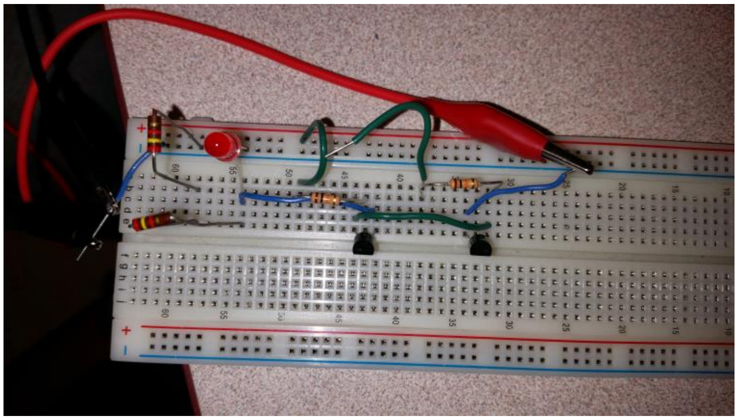
The LED is not lit.



Where V1 = 5V

Where V3 = 0V

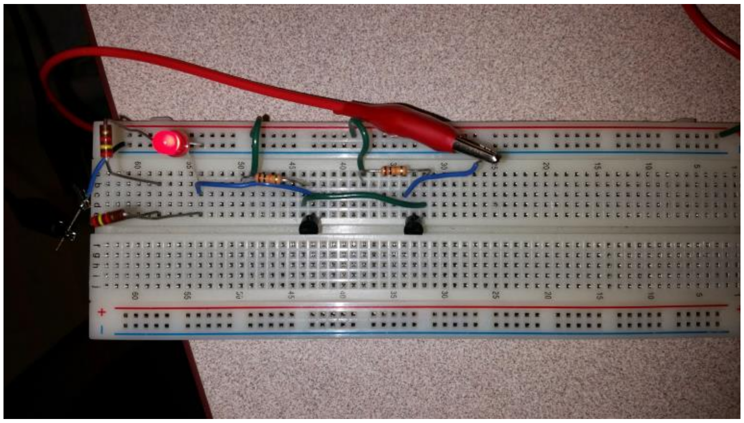
The LED is not lit.



Where V1 = 0V

Where V3 = 5V

The LED is not lit.



Where V1 = 5V

Where V3 = 5V

The LED is lit.

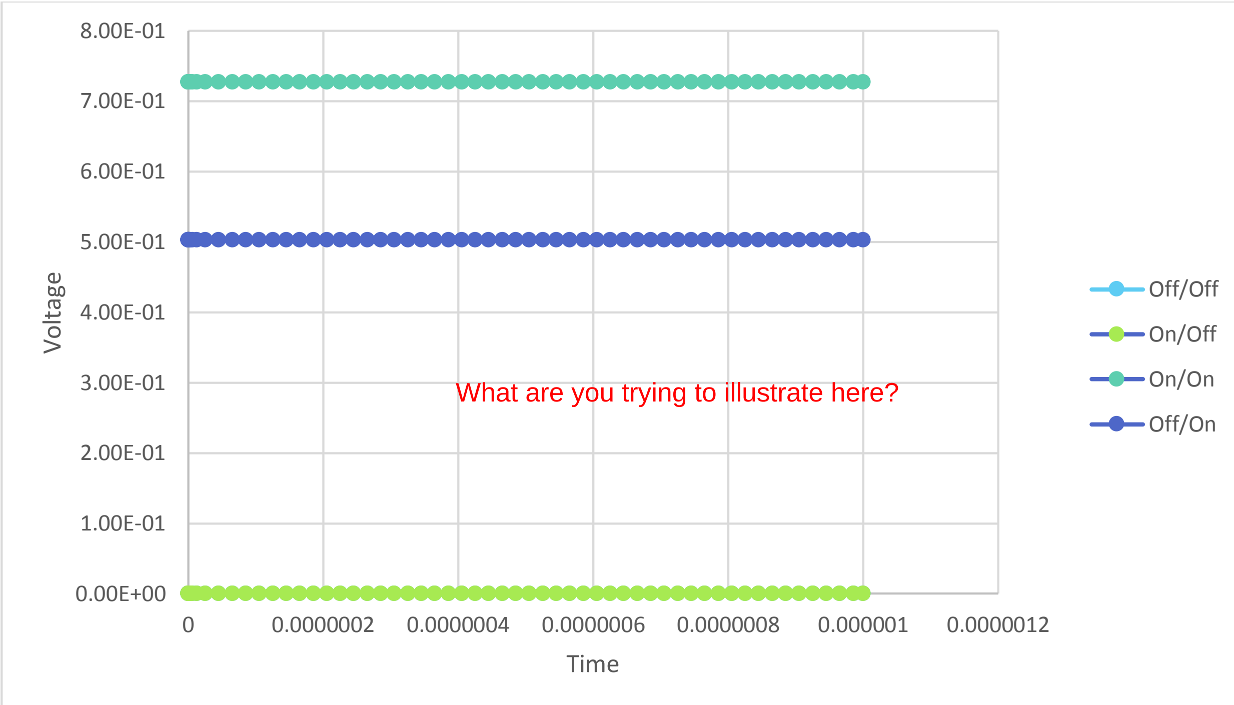


Figure 12: Simulated data for the BJT AND Gate. Only when both power supplies were active did the LED receive enough voltage to turn on.

The constructed BJT AND Gate functioned better than the simulated schematic did. This was due to the way how PSpice functions and not being able to easily and directly flip a switch to deliver either 5V or 0V. If PSpice was able to output a truthtable, the values received could be more easily understood.

Part 7 BJT OR Gate

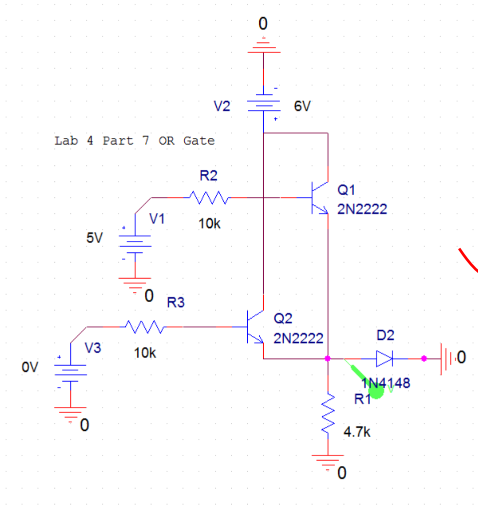
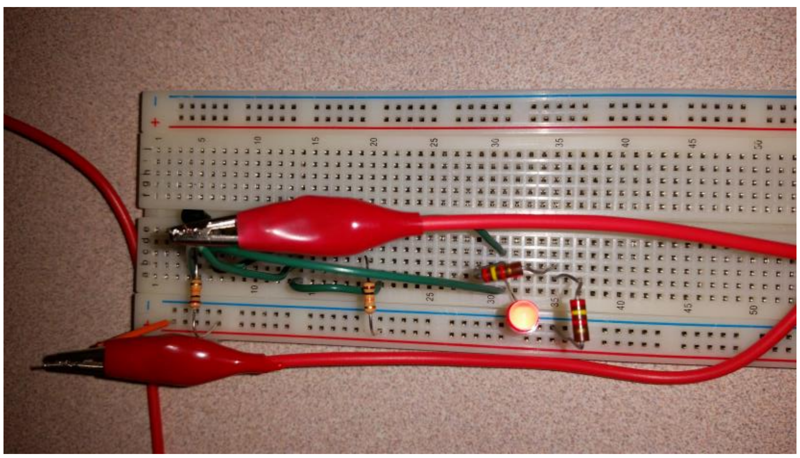


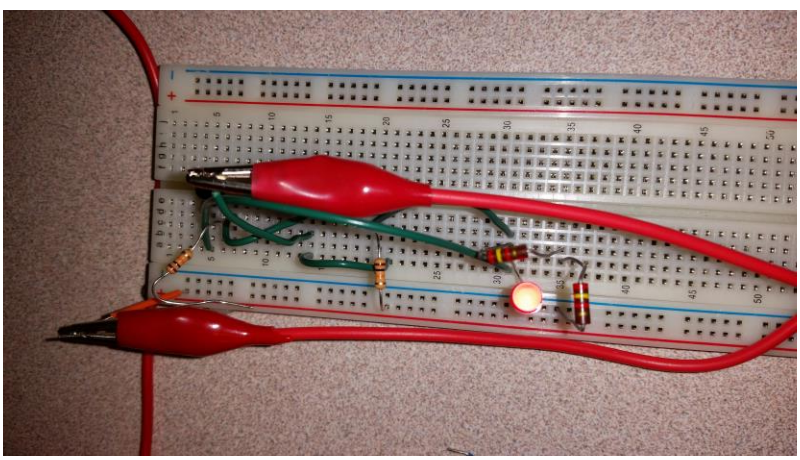
Figure 13: PSpice schematic for an AND Gate converted to an OR Gate.



Where V1 = 5V

Where V3 = 5V

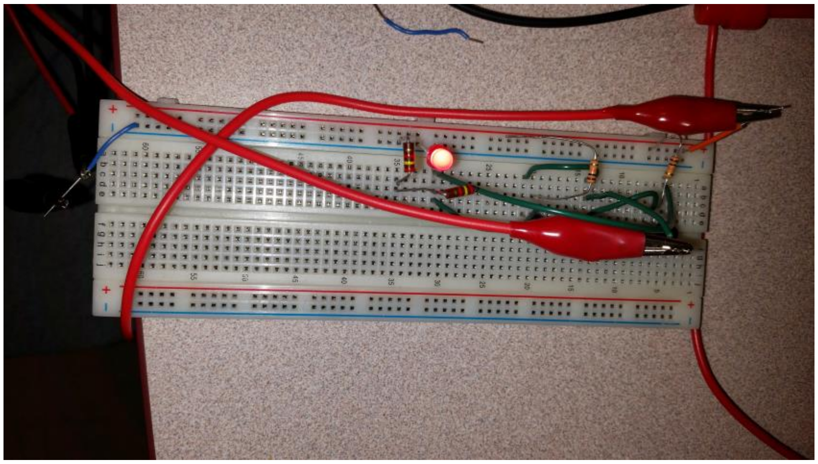
The LED is lit.



Where V1 = 5V

Where V3 = 0V

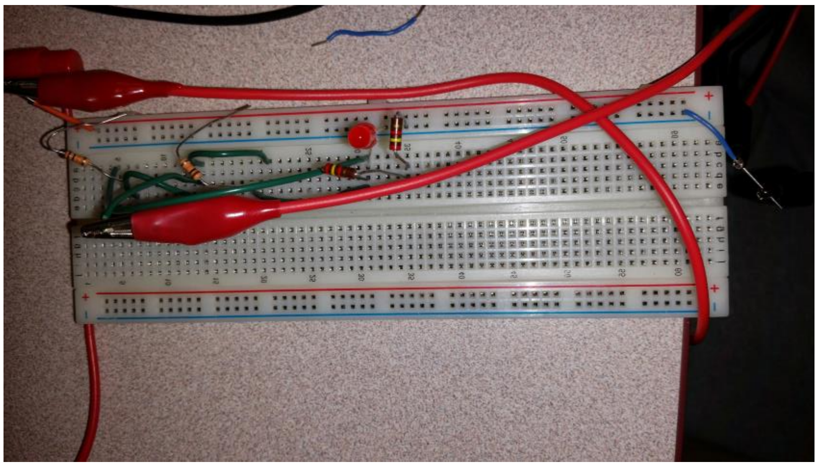
The LED is lit.



Where V1 = 0V

Where V3 = 5V

The LED is lit.



Where V1 = 0V

Where V3 = 0V

The LED is not lit.

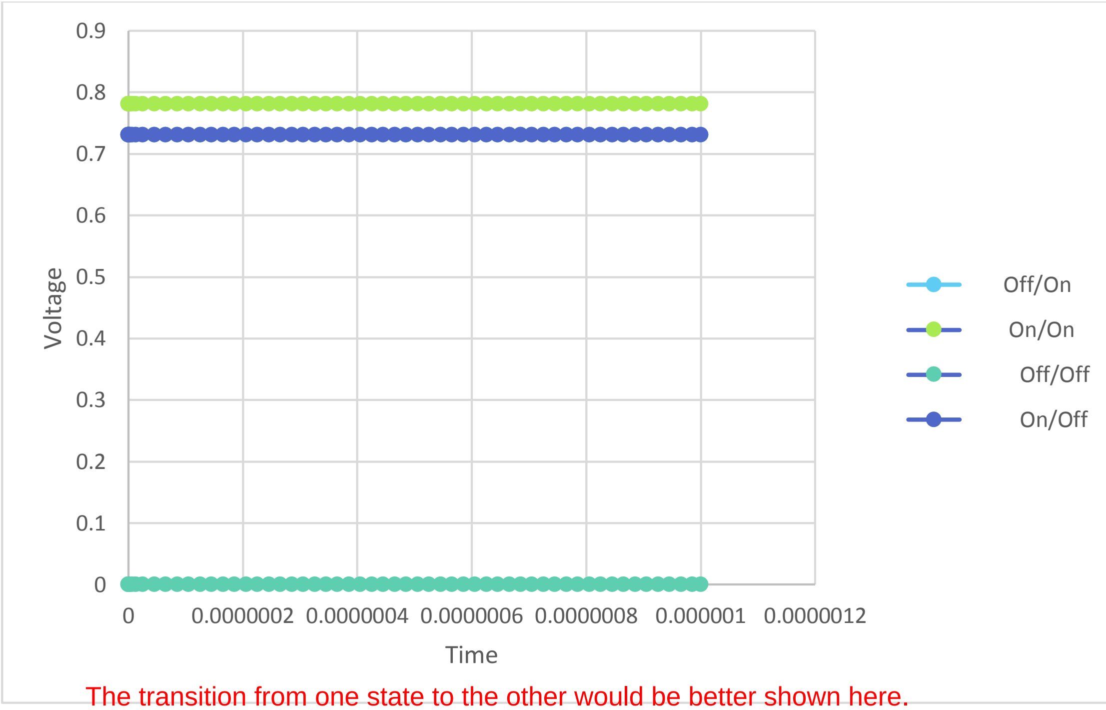


Figure 14: Collected data from PSpice showing the different values and their states.

Conclusion

The goal of laboratory experiment #4 was to introduce the purpose and uses of a bipolar junction transistor (BJTs). In addition, we learned how to be able to characterize the behavior of such transistors, how to design and construct a circuit where a BJT is used as a variable resistor, switch, AND gate and finally an OR gate. All of the circuits that were designed worked as expected. A few concerns that we had with the lab were that the required components needed to construct the circuits accurately were not available in the stock room, such as lack of resistors. We solved this issue by having 2 resistors in series to apply the resistance needed. Some additional difficulties experienced in this laboratory experiment was that we were not able to limit the amount of current going into the transistor which would result in the transistor to burn out. Various other transistors had to be researched and checked to see if they would be compatible with the constructed circuit. This laboratory experiment is very important to students who would want to pursue an electrical route because it introduces to students how BJTs operate and how they can experiment with these electrical components to use them as a logic gate, switch or a variable resistor like we did in this experiment.

Appendix

LT03XX-41 — 3.0MM ROUND LAMP (LONG LEADSWITH 2.54mm PITCH)

Features
* LOW CURRENT REQUIREMENTS
* HIGH LIGHT OUTPUT
* RELIABLE AND RUGGED
* IC COMPATIBLE

Absolute Maximum Ratings at T_A=25˚C

REVERSE VOLTAGE	GaAsP RED 3.0 V, OTHER 5.0 V
D.C. FORWARD CURRENT	30 mA
PULSE CURRENT (1/10 DUTY CYCLE, 0.1 ms PULSE WIDTH)	100 mA
OPERATING TEMPERATURE RANGE	-25˚C TO +85˚C
STORAGE TEMPERATURE RANGE	-25˚C TO +100˚C
LEAD SOLDERING TEMP. (1.6mm FROM BODY)	260˚C FOR 5 SEC

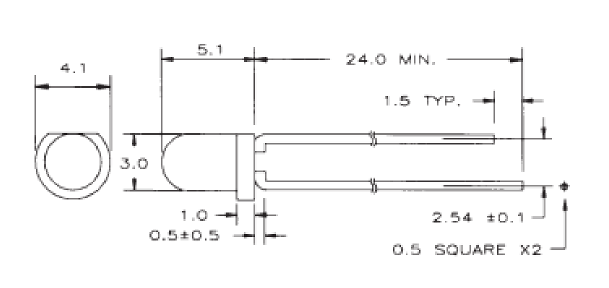
Electrical/Optical Characteristics at T_A=25˚C

PART	NUMBER	LED CHIP MATERIAL	LED CHIP EMITTING COLOR	LEN'S COLOR		PEAK WAVELENGTH @20mA(nm)	FORWARD VOLTAGE @20mA(V) TYP.	FORWARD VOLTAGE @20mA(V) MAX.	LUMINOUS INTENSITY @20mA(mcd) MIN.	LUMINOUS INTENSITY @20mA(mcd) TYP.	VIEW ANGLE $2\theta_{1/2}$ (deg)
LT0311-41	LT0312-41	GaAsP	RED	R.D.	W.D.	655	1.7	2.0	1.1	1.8	56
LT0311G-41	LT0312G-41	GaP	RED	R.D.	W.D.	700	2.1	3.0	1.6	2.7	56
LT0321-41	LT0322-41	GaP	GREEN	G.D.	W.D.	567	2.1	3.0	8.0	13.3	56
LT0331-41	LT0332-41	GaAsP ON GaP	YELLOW	Y.D.	W.D.	585	2.1	3.0	6.6	11.0	56
LT0341-41	LT0342-41	GaAsP ON GaP	ORANGE	O.D.	W.D.	635	2.1	3.0	9.3	15.5	56
LT0341R-41		GaAsP ON GaP	ORANGE	R.D.		635	2.1	3.0	9.3	15.5	56
LT0313-41	LT0314-41	GaAsP	RED	W.C.	R.C.	655	1.7	2.0	3.7	6.1	36
LT0313G-41	LT0314G-41	GaP	RED	W.C.	R.C.	700	2.1	3.0	5.5	9.2	36
LT0323-41	LT0324-41	GaP	GREEN	W.C.	G.C.	567	2.1	3.0	27.0	45.0	36
LT0333-41	LT0334-41	GaAsP ON GaP	YELLOW	W.C.	Y.C.	585	2.1	3.0	22.6	37.6	36
LT0343-41	LT0344-41	GaAsP ON GaP	ORANGE	W.C.	O.C.	635	2.1	3.0	31.7	52.9	36
	LT0344R-41	GaAsP ON GaP	ORANGE		R.C.	635	2.1	3.0	31.7	52.9	36

(1) LENS COLOR
R.D. RED DIFFUSED
Y.D. YELLOW DIFFUSED
W.D. WHITE DIFFUSED
G.D. GREEN DIFFUSED
O.D. ORANGE DIFFUSED
W.C. WATER CLEAR
R.C. RED CLEAR
Y.C. YELLOW CLEAR
G.C. GREEN CLEAR
O.C. ORANGE CLEAR

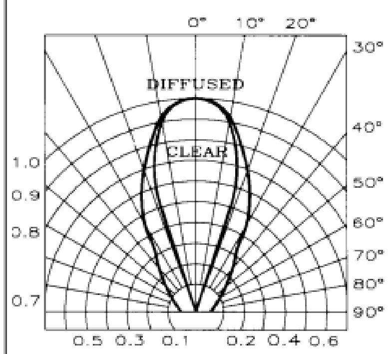
(2) SPECIFICATIONS ARE SUBJECT TO CHANGE WITHOUT NOTICE.
(3) ALL ABOVE COMPONENTS ARE CONSIDERED. DEVIATIONS FROM STATED SPECIFICATIONS WILL REQUIRE A NEW PART NUMBER BE ASSIGNED.

Package Dimensions



1. ALL DIMENSIONS ARE IN mm, TOLERANCE IS ±0.25mm UNLESS OTHERWISE NOTED
2. AN EPOXY MENISCUS MAY EXTEND ABOUT 1.0mm DOWN THE LEADS
3. BURR AROUND BOTTOM OF EPOXY BODY MAY BE 0.5mm MAX.

Radiation Pattern



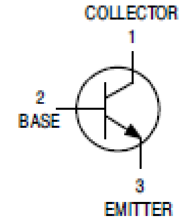
P2N2222A

Amplifier Transistors

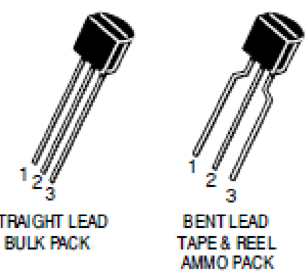
NPN Silicon

ON Semiconductor®

http://onsemi.com



TO−92
CASE 29
STYLE 17



Features

- These are Pb−Free Devices*

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

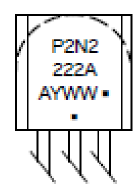
Characteristic	Symbol	Value	Unit
Collector−Emitter Voltage	V_{CEO}	40	Vdc
Collector−Base Voltage	V_{CBO}	75	Vdc
Emitter−Base Voltage	V_{EBO}	6.0	Vdc
Collector Current − Continuous	I_C	600	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	625 5.0	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.5 12	W mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	−55 to +150	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	$R_{\theta JA}$	200	°C/W
Thermal Resistance, Junction to Case	$R_{\theta JC}$	83.3	°C/W

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

MARKING DIAGRAM



A = Assembly Location
Y = Year
WW = Work Week
• = Pb−Free Package
(Note: Microdot may be in either location)

ORDERING INFORMATION

Device	Package	Shipping†
P2N2222AG	TO−92 (Pb−Free)	5000 Units/Bulk
P2N2222ARL1G	TO−92 (Pb−Free)	2000/Tape & Ammo

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specification Brochure, BRD8011/D.

*For additional information on our Pb−Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.