Lab Two
Fundamentals of Electronics
EECE2412/3

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Abstract

The goal of this laboratory experiment is to introduce the performer to several different types of pn-junction diodes, which include silicon/germanium junction diodes, light-emitting diodes (LEDs), and zener diodes. A custom circuit is then designed to turn on/off various LEDs at specified voltages.

KEYWORDS: pn-junction, diode, silicon/germanium, LED, zener

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1 Equipment

Available equipment included:

- Basic Circuit Components (Capacitors, Resistors, Inductors, etc.)
- Keysight EDU36311A Dual DC Power Supply
- Keysight EDU33212A Function Generator
- Keysight DSOX1204G Digital Oscilloscope
- BNC Cables
- A Variety of Diodes (1N914 Si Diode, 1N34A Ge Diode, 1N4735A Zener Diode, etc.)

2 Performing the Experiment

2.1 Basic Diode Test

We begin with the construction of a simple circuit to test a 1N914 Si Diode:

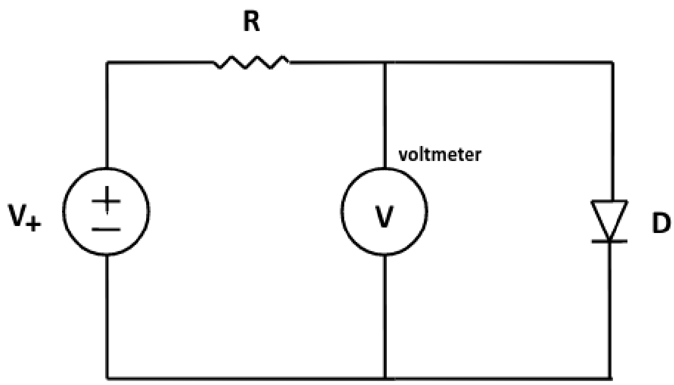

Figure 1: Circuit Schematic for Part 1

The physical construction is shown in Figure 2 below:

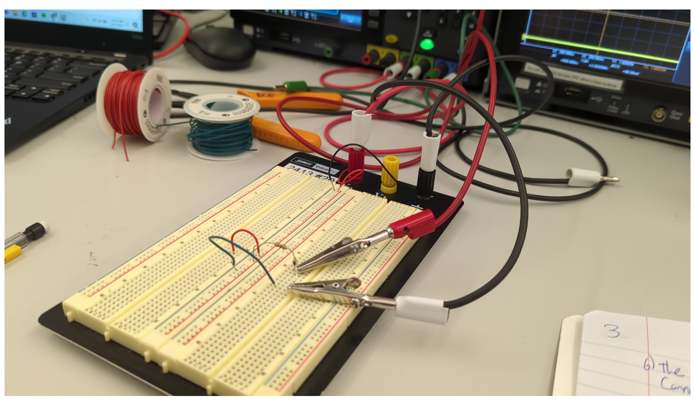

Figure 2: Physical Circuit Construction

Then testing this circuit, the **voltage across the forward-biased diode is measured as** .6[V], **and** 9.99[V] **for the reverse-biased diode.** We can then measure the value of the resistor to confirm it is within specification (the gold band indicates a ±5% tolerance. The **measured resistance is** 9.938[kΩ], which is within the tolerance. Finally, we **measure the voltage readout as** 10.007[V], which is close to the expected value of 10[V]. We may now proceed to calculate the reverse currents (I_s) from the taken measurements:

$$I_D = \frac{V_s - V_D}{R} \rightarrow \begin{cases} \frac{10.007 - .6}{9.938k}[\text{A}], & \text{in Forward-Bias} \\ \frac{10.007 - 9.99}{9.938k}[\text{A}], & \text{in Reverse-Bias} \end{cases}$$

$$\boxed{I_D = \frac{V_s - V_D}{R} \rightarrow \begin{cases} .9466[\text{mA}], & \text{in Forward-Bias} \\ 1.7106 \cdot 10^{-6}[\text{A}], & \text{in Reverse-Bias} \end{cases}}$$

We know that the current measurement is inaccurate, as it should be 0. Thus, the current that was calculated above must be the leakage current.

2.1.1 Calculating I_s and n

We can use the Shockley equation, or:

$$I_D = I_s e^{\frac{V_D}{nV_T}}$$

Note: the added 1 term can be dropped, as it does not make a significant difference to the large magnitudes we are dealing with. Thus, we can use our original measurement, as well as an additional one taken at 5[V] input. Thus, we obtain:

Input #	Input Voltage	Diode Voltage	Diode Current
Input 1	10.007[V]	.6[V]	.9466[m]
Input 2	5[V]	.577[V]	.4451[m]

We may now set up the equations:

$$\left(.9466 \cdot 10^{-3}\right) = I_s e^{\frac{.6}{(.025)n}}$$

$$\left(.4451 \cdot 10^{-3}\right) = I_s e^{\frac{.577}{(.025)n}}$$

Solving these, we find:

$$\boxed{n = 1.22 \quad \text{and} \quad I_s = 2.675 \cdot 10^{-12}[\text{A}]}$$

2.1.2 Temperature Dependence

We now proceed to spray the diode with an aerosol refrigerant. After spraying the diode, we found that the voltage became .76[V]. From our room temperature measurement, we know that the voltage is .6[V] at approximately 20[°C]. Thus, we may find the constant:

$$6 = -.002(20) + C$$

$$C = .64[\text{V}]$$

We can now calculate the temperature response, with V_r as the response voltage, using:

$$V_r = -.002T + .64$$

Therefore, with an output of .76[V], the **temperature must be**:

$$.76 = -.002(T) + .64$$
$$T = -(.12/.002)$$
$$\boxed{T = -60[°C]}$$

Applying heat by holding the diode, we **find the body temperature voltage to be** .595[V], which gives us:

$$.595 = -.002T + .64$$
$$T = .045/.002$$
$$\boxed{T = 22.5[°C]}$$

2.2 Using Different Diodes

2.2.1 Energy Band Gaps and Diodes

Using a 1N34A instead of the 1N914, we measure:

$$V_D = \begin{cases} .34[V], & \text{In Forward-Bias} \\ 9.912[V], & \text{In Reverse-Bias} \end{cases}$$

Repeating similar measurements with Green and Red LEDs, respectively, we see:

$$V_{D(grn)} = \begin{cases} 1.858[V], & \text{In Forward-Bias} \\ 9.992[V], & \text{In Reverse-Bias} \end{cases}$$

$$V_{D(red)} = \begin{cases} 1.626[V], & \text{In Forward-Bias} \\ 9.992[V], & \text{In Reverse-Bias} \end{cases}$$

Thus, we may conclude that the Red LED has less energy band gap, which results in less V_{drop} when in forward bias mode. Similarly, we can conclude that, for the germanium diode, the energy band gap is the least by far.

2.2.2 Implementing Zener Diodes

We now swap the LEDs with a 1N4735A Zener Diode. Measuring the Diode's voltage response, we get:

V^+[V]	0	1	2	3	4	5	6	7	8
V_D[V]	0	.999	1.999	2.999	3.999	4.969	5.671	5.927	6.017

9	10	11	12	13	14	15
6.06	6.084	6.1	6.111	6.119	6.128	6.131

We may see that the implementation of a zener diode can provide useful voltage limitation properties to a circuit, oftentimes for circuit protection.

2.2.3 The 1N4744A and 1N4735A

The breakdown voltage **was measured as roughly** 15.2[V]
Experimenting with the 1N4735A, we dissipated 5[W] of power; however, the maximum current of the diode can be found as:

$$\frac{1[\mathrm{W}]}{10[\mathrm{V}]} = .1[\mathrm{A}]$$

This is less than the passed .5[A], which caused the diode to break down. Adding a LED, we found that it began glowing once the current was greater than the .1[A], indicating that too much voltage is dissipated in the resistor, so the zener diode must go into breakdown to supply the needed current to the LED. Still, it was quite dim, meaning it most likely needs more current than it was receiving (it would need more than .1[A].

3 Conclusion