



Department of Electrical Engineering

Laboratory Manual

EE3115

Applied Optoelectronic Devices

Semester B 2023/24

EE3115 Lab 1 Diode and LED Characteristics

I. Objectives

1. To study the current-voltage characteristics of *pn* junction diode and light-emitting diodes;
2. To study the temperature effects on the *pn* junction diode and LEDs;
3. To realize the non-ideal effects of the *pn* junction diode and LEDs.

II. Equipment and Component

1. Low-power *pn* diode $\times 1$, red LED $\times 1$, yellow LED $\times 1$, green LED $\times 1$, 100 Ω resistor
2. Solderless breadboard
3. Digital DC power supply (up to 10 V and 10-mV resolution for 1-V output)
4. Digital multimeter $\times 2$
5. Thermistor $\times 1$

III. Background

Before the laboratory session, study carefully the theoretical background involved in this experiment and have a clear picture of the operation, biasing, and forward characteristics of *pn* junction diode and LED. These materials could be found in the references listed at the end of this section.

The ideal forward I-V characteristics of a *pn* junction are given by $I = I_o(e^{\frac{qV}{kT}} - 1)$. For a real diode including LED, the I-V characteristics are better to be described by:

$$I = I_o \left\{ \exp^{\frac{q(V-IR)}{nkT}} - 1 \right\} \quad (1)$$

where q is the elementary charge, k is Boltzmann's constant, T is the temperature, R is the parasitic series resistance, and n is the ideality factor which is equal to unity for an ideal diode and is usually greater than unity because of the involvement of different carrier recombination mechanisms. For $V \gg IR$, the ideality factor can be approximated as:

$$n = \frac{q}{kT} \frac{dV}{d(\ln I)} \quad (2)$$

The experiment involved the measurement of the current-voltage characteristics of LED and *pn* junction diode. The above formula can be used to extract the essential device parameters from the measured characteristics.

References:

1. B. G. Streetman, Solid-State Electronic Devices, Prentice-Hall, 1995.
2. S. M. Sze, Physics of Semiconductor Devices, 2nd Edn., Wiley, 1981.
3. P. Antognetti and G. Massobrio, Semiconductor Device Modeling with SPICE, McGraw-Hill, 1988.

IV. Procedures

1. Choose one *pn* junction diode or one color of LED together with the $100\ \Omega$ resistors to construct the circuit shown in Fig. 1 on the breadboard. Set the voltage of the power supply to zero volts before connecting it to the circuit. Set the multimeter to 10 V range for voltage measurement and 1 μA range for current measurement if the meters are not auto range changing model.
2. Increase the power supply gradually with a 0.1 V step increment for *pn* junction diode and a 0.5/0.2 V increment for LEDs. Measure and record the current value and voltage value on the meters. For the measurement of LED characteristics, note the voltage value when the LED starts to light up and also note the brightness change when further increasing the supply voltage. As the current increases, choose a suitable meter measurement range for the current measurement. When the current value reaches 30 mA or above, stop further voltage increment.

For the above measurements, please use the following tables for data collection.

Table of LED (each colour of LED uses one table)

Diode Voltage (V)	0	0.5	1	1.2	1.4	1.6		
Diode Current (mA)								

Increase the diode voltage until diode current reaches 30mA

Table of *pn* junction diode

Diode Voltage (V)	0	0.1	0.2	0.3	0.4	0.5		
Diode Current (mA)								

Increase the diode voltage until diode current reaches 30mA

3. Repeat steps 1 to 2 for different LEDs.

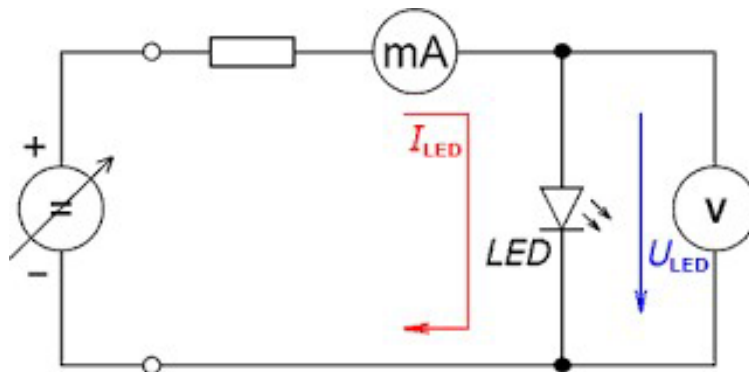


Fig.1 Circuit configuration for LED characteristic measurements.

4. Use the same configuration as given in Fig. 1, and set the supply voltage so that the voltage across the LED or *pn* junction diode to the value of “ON” voltage plus 0.2 V or the diode current is 30 mA. Keep the supply voltage unchanged. Attach the thermistor to the diode surface. Use a hair dryer (set the hair dryer to low-heat mode) to heat the LED for a few seconds. Record the current and voltage values across the *pn* diode or LED for the temperature at around 40, 60, and 80 $^{\circ}\text{C}$. For the measurement of LED, note the change in light intensity of the LED under testing. Repeat for different LEDs. The light intensity change in this work is notified by observation. You may record the light

intensity change by comparison. If the LED is lit up, register the light intensity as “1”, if it is brighter in the next voltage put it as “2”, and “3” if it is even brighter, and so on.

A table should be used for recording the data in the following format:

Temperature (°C)	25 (replace with the temperature you measured)	40	60	80
Diode Voltage (V)				
Diode Current (mA)				

V. Results and Discussion

1. For step 2, plot $\log(I)$ versus voltage across the diode, and determine the built-in/on voltage potential, ideality factor, reverse saturation current, and parasitic series resistance of the LEDs using (1) and (2) given in Section III. Explain why the values of the parameters are different for different LEDs. Discuss qualitatively the change of light intensity at different biasing voltages.
2. For step 4, plot the measured current and voltage versus the temperature (4 sets of data points, *i.e.*, temperatures at around 25, 40, 60, and 80 °C, for each plot, should be included.) Discuss the different temperature characteristics of these diodes (Hints: Note the different built-in voltages and then the bandgaps of the materials used for the diode/LEDs).