TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI
VICTORIA
UNIVERSITY OF WELLINGTON

Laboratory Instructions

Course Number:	XMUT204
Laboratory Number:	2
Laboratory Title:	Diode Characteristics

1. Measuring the characteristics of a conventional diode.
2. Determining the operating point of the diode.
3. Working with basic diode circuit.

Name: ______________________________

Student Number: _________________________

Objectives:

- Measuring the characteristics of a conventional diode
- Determining the operating point of the diode
- Working with basic diode circuits

Part A: Theory

Introduction

Semiconductor diodes consist of p-type and n-type material in contact. The diode conducts when forward biased (i.e. the p-type material is made more positive than the n-type) if the bias exceeds a characteristic value (V_B: typically ~0.6 V to 0.8 V for silicon diodes at room temperature).

When the diode is reverse biased (i.e. the n-type material is made more positive than the p-type) effectively no current flows. If the reverse voltage exceeds an upper limit the diode will "breakdown" and become highly conducting which may lead to permanent damage. Some special purpose diodes called Zener diodes are designed to operate in this breakdown region). The I - V characteristic of a conventional diode is shown in Fig. 1; clearly, diodes are non-linear circuit elements.

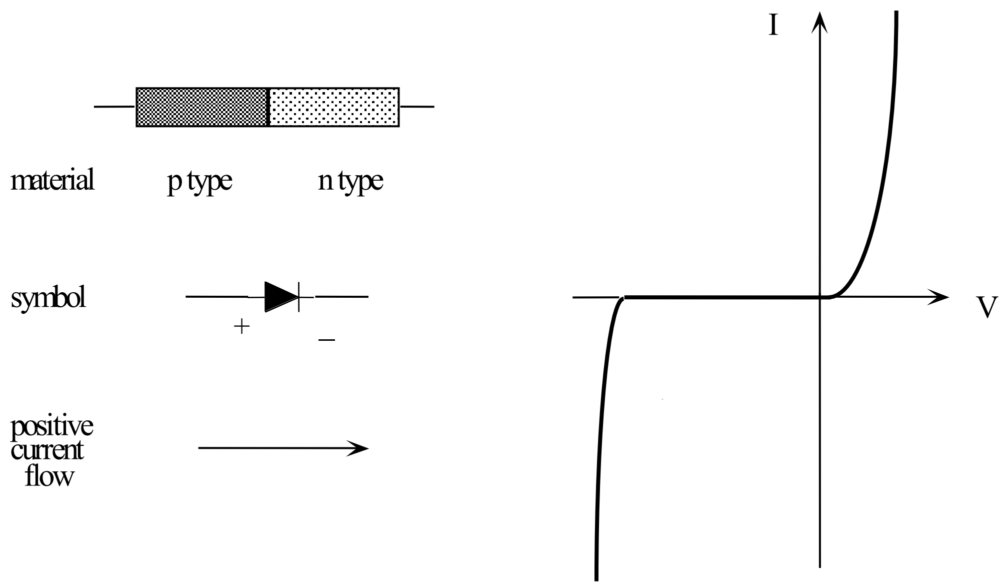

Fig. 1: The I-V characteristic of a conventional diode

The forward I - V relationship is most closely represented by the *Ebers-Moll* equation:

$$I = I_S \left(\exp \frac{V}{nV_T} - 1 \right) \qquad \text{(Eq. 3.1)}$$

where I_S is a constant for a given diode at fixed temperature T, $V_T = kT/q$ (where k is the Boltzmann constant and q the electronic charge), with a value ~25 mV at room temperature, and n is in the range $1 \rightarrow 2$. In practice the second term in the brackets in (3.1) is negligible. Both I_S and V_T are temperature dependent.

There is a series of models which may be used to represent diodes in circuit analysis. The two most common, in order of increasing complexity, are shown in Fig. 2 and compared to the Ebers-Moll curve. The *ideal model* treats the diode as a perfect switch - open circuit (zero current) when reverse biased, short circuit (zero voltage drop) when forward biased. The *constant drop* model assumes that the forward bias voltage drop is V_B.

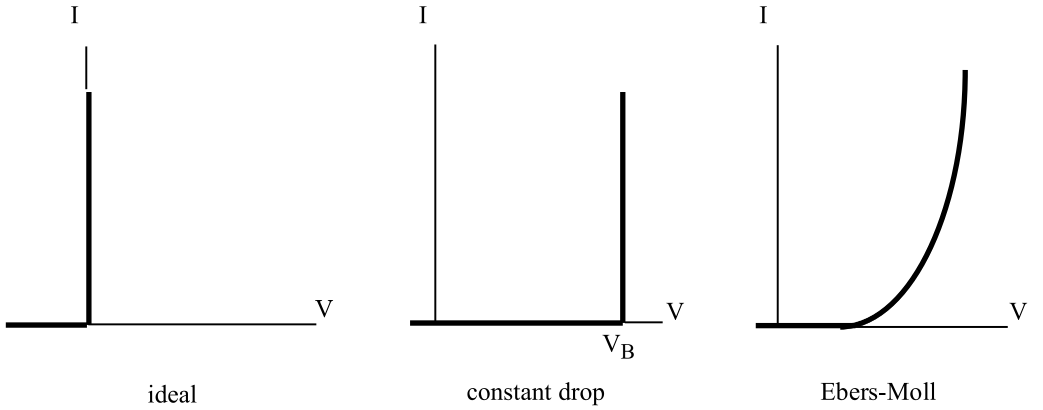

Fig. 2: V-I graphs of diode

Load lines

Circuits containing non-linear elements can be analysed graphically using a *load line.*

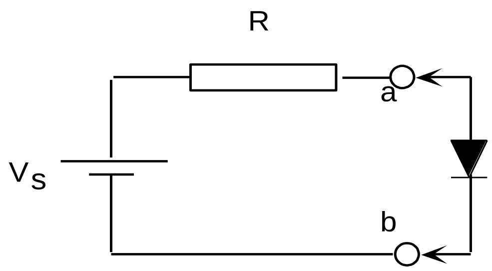

Fig. 3a

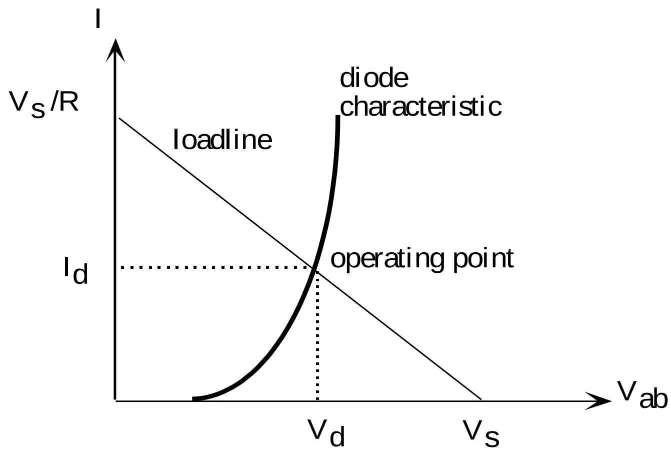

Fig. 3b

For the circuit of Fig. 3a, each part of the circuit defines a relationship between I and V_{ab}. If we plot the characteristic curve for the diode then I and V_{ab} must lie somewhere on it. On the other hand the entire circuit must obey Kirchhoff's loop rule, which gives

$$V_s - IR - V_{ab} = 0 \qquad \text{(Eq. 3.2)}$$

This equation may also be shown on an *I-V* plot, as a *load line* in Fig.3b. It cuts the axes at the open circuit voltage ($I = 0$), $V_{ab} = V_s$ and the short circuit current ($V_{ab} = 0$), $I = V_s/R$. Because the actual current and value of V_{ab} must lie on both the load line and the diode characteristic, the intersection of the two lines determines the values of V_{ab} and I (the operating point) for the diode with an applied voltage V_s and a series resistor R.

Part B: Experiment

1. Measuring the Characteristics of a Conventional Diode (1N4148)

a. Set up the circuit shown in Fig. 4.

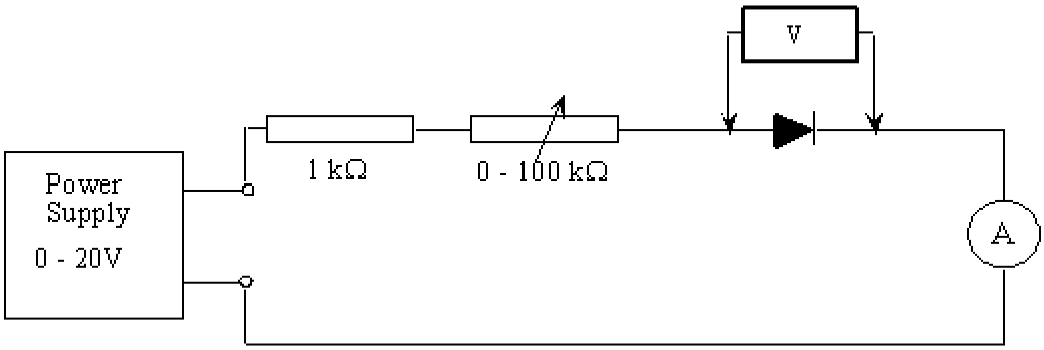

Fig. 4: Circuit for measuring characteristics of a diode

b. Using the two multimeters as DVMs record values of V_d (forward bias) for the following values of I_d (approximately): 3 µA, 10 µA, 30 µA, 60 µA, 100 µA, 0.3 mA, 1 mA, 2 mA, 3 mA, 6 mA.

c. Rearrange the circuit for reverse bias. Record I_d for V_d values of -1, -5, -10 and -20 V. Remember I_d will be very small.

d. In a piece of paper initially (because of different scales), plot the data for both forward and reverse bias (I on the vertical axis, V on the horizontal axis). As the range of currents and voltages are so different for forward and reverse bias you will need to think carefully about the scales to use: suitable values will be 0 to 1.5 volt, 0 to 10 mA for the forward biased data, and 0 to -20 V, 0 to -2 μA for the reverse biased data. Also produce a plot on the computer of the forward bias part of the characteristic.

2. Determining the Operating Point of the Diode

a. In the circuit of Fig. 4, replace the 20 V power supply with a 1.5 V battery and remove the 0 - 100 kΩ resistor.

b. For this circuit use equation (3.2) with R = 1 kΩ and V_S = 1.5 V to plot the load line on your graph of the forward bias diode characteristic. From the intersection of the two lines determine the theoretical operating point for the diode.

c. Measure I_d and V_d for the circuit. Compare the measured values with the graphically deduced operating point.

3. Working with Basic Diode Circuits

a. Construct the following half-wave rectifier circuit.

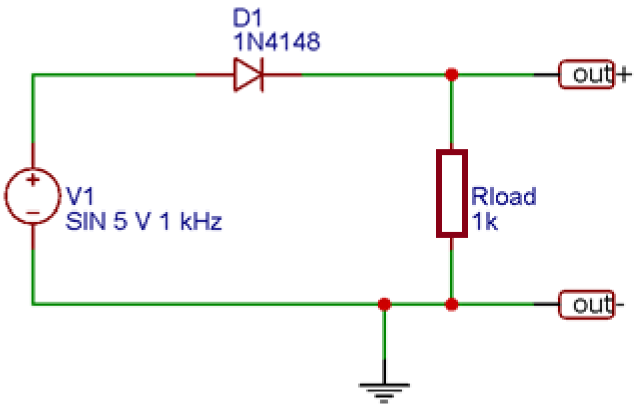

Fig. 5: Half-wave rectifier diode circuit

For the above circuit:

i. Sketch the waveforms in the input and output.

ii. Measure the voltage and current across the diode.

iii. Measure the voltage across the load.

b. Construct the following bridge rectifier circuit.

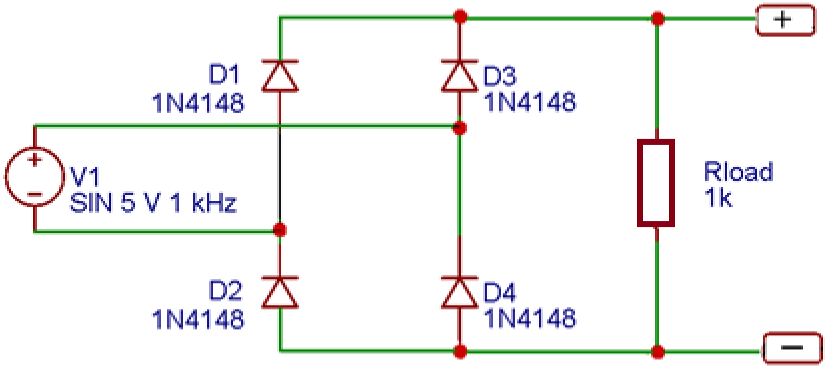

Fig. 6: Full-wave diode rectifier circuit

For the above circuit:

i. Sketch the waveforms in the input and output.

ii. Measure the voltage and current across the diode.

iii. Measure the voltage across the load.

Part C: Report

Now complete a short report by answering the questions from the associated question sheet.

Equipment

Resistor:	1kΩ
Variable resistor:	100kΩ
Diode:	1N4148 (4 pieces)
Battery:	1.5 V

- End of laboratory -