ECEN 204 **Laboratory 2**

Diode Characteristics

Equipment

Breadboard, power supply
Diode: A Si 1N4148 diode and a light emitting diode
Resistors: 470 Ω, 1 kΩ , 10 kΩ and decade resistance box

1. Background - Read before coming to the lab

Carefully read through **Section 2a in your class notes** (Diodes and p-n junctions) as well as the introductory paragraphs below.

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.

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

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

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.

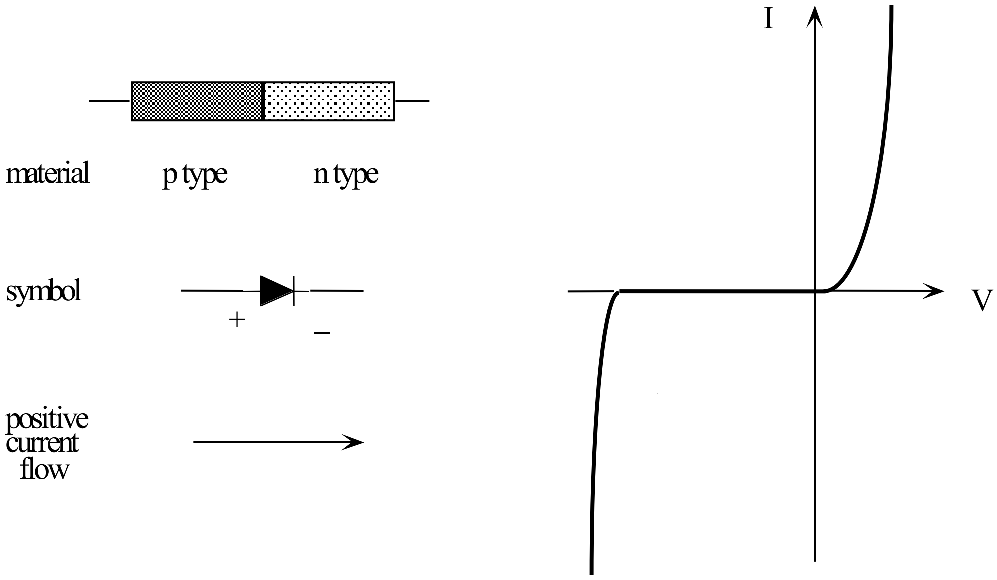

Figure 1: The current-voltage (I-V) curve of a diode

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.

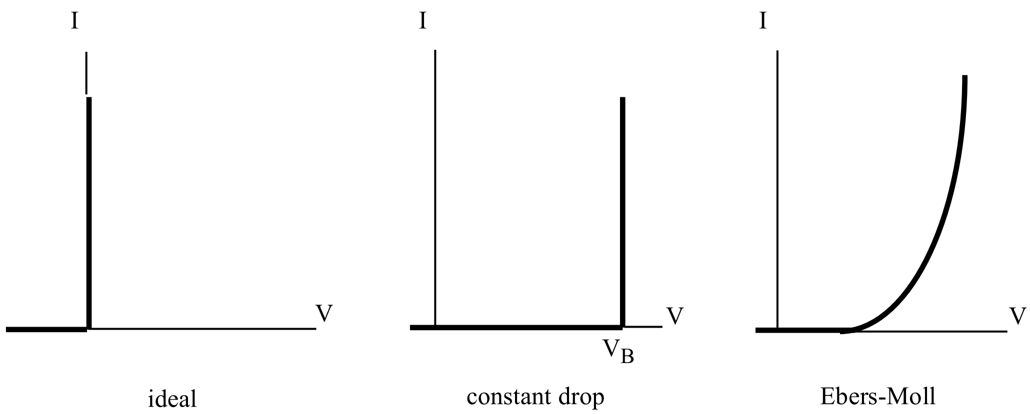

fig. 2

Figure 2: Some different diode models

The polarity of a diode is typically indicated by the presence of a ring (line) around the package. This line corresponds to the vertical line in the diode symbol and thus indicated the negative lead (cathode) of the diode.

Light Emitting Diodes

LED's are made from alloys of such as GaP and GaAs which have their band-gap energy in the visible optical region. Under forward bias conditions, injected electrons and holes recombine in the region of the p-n junction, releasing their energy in the form of light (see later lectures for theory). The photon energy of emitted light corresponds closely to the band-gap energy. Of course the package must now consist of a transparent material to allow the light to be observed.

In LEDs the polarity cannot be indicated by a line on the package and two methods would be used:
(i) The package would have a flat side that indicated the negative terminal
(ii) The lead of the positive terminal will be longer than that of the negative terminal.

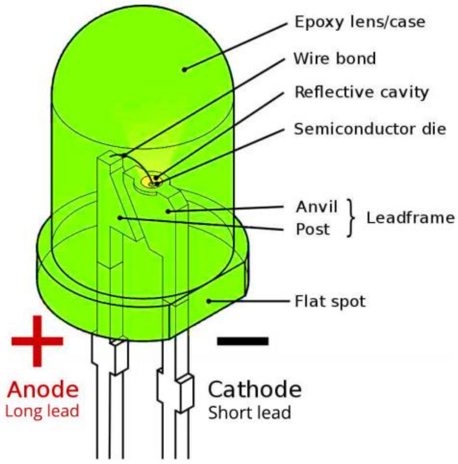

Figure 3: Internal structure and polarity of an LED

Loadlines

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

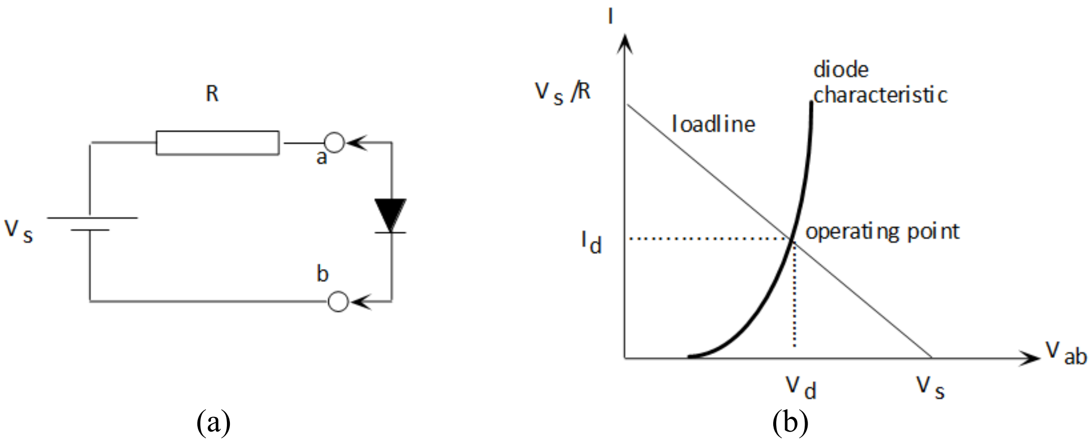

Figure 4: A diode circuit (a) and the load line that can be constructed to determine the operating point.

For the circuit of Fig. 4a, 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

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

This equation may also be shown on an *I-V* plot, as a *loadline* in Figure 4b. 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 loadline 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.

2. Pre-lab tasks

Search on the internet for a datasheet for a 1N4148 diode from the Vishay manufacturer and answer the questions below.

In the Section "Absolute Maximum Ratings" find the maximum value for:

- The constant (DC) forward current
- The peak forward current surge lasting no more than 1 second.
- The operating temperature range of the device.
- The maximum power dissipation of the diode assuming a 25 ºC environment.

From the Section "Electrical Characteristics" determine:

- The reverse breakdown voltage with a reverse current of 5 µA.
- The worst case recovery time of the diode

3. Experimental

3.1 Measuring the characteristics of a conventional diode (1N4148)

(a) Set up the circuit shown in Fig. 5.

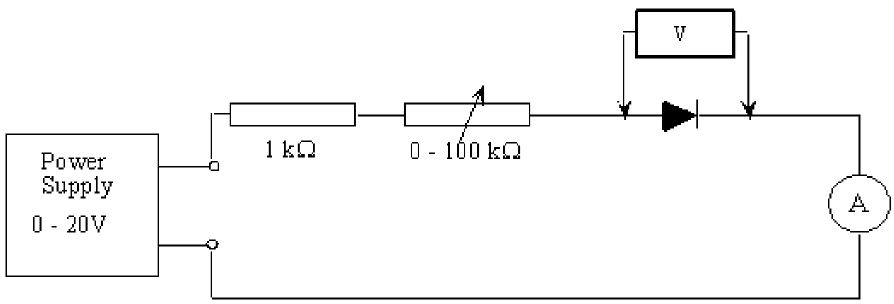

Figure 5: Circuit for I-V measurements on diode.

Important: In all these experiments we want to measure small currents. It is then essential that we use the most sensitive multimeter of the two available for this task. Carefully check the current sentivity of your two multimeters. You should also ensure that both your multimeter are measuring DC and not AC.

(b) Using the two Fluke 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) 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 record room temperature.

3.2 Light Emitting Diode Characteristics

Replace the 1N4148 silicon diode with an LED and repeat the above procedure. Note the (approximate) current at which clearly visible light emission begins and also note the colour of the emitted light.

3.3 Determining the operating point of the diode

(a) In the circuit of Fig. 4, set the power supply to 1.5 V (simulating a battery) and remove the decade resistance box but keep the 1kΩ resistor in place.

(b) For this circuit use equation (3.2) with R = 1 kΩ and V_S = 1.5 V to plot the loadline on your graph of the forward bias diode characteristic (as you have determined in Section 3.1(b)). 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 to the graphically deduced operating point.

4. Report

Complete the associated report for the lab by filling in the report form