Analogue Electronics
Experiment 1 - Diode Cricuit
ENG221

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1 Objective

Explore the basic device parameters and properties of diodes using large and small signal analysis.

1.1 Background

Forward Bias of a Diode A diode that is in the forward bias region of operation is modelled by the following equation:

$$i = I_S(e^{v/nV_T} - 1) \tag{1}$$

where

i = current through the diode

I_S = saturation current

v = voltage across the diode

n = parameter relating to device material

V_T = thermal voltage $\approx$ 25mV

Incremental Resistance The incremental resistance of a diode is given by the following formula:

$$r_d = \frac{V_T}{I_D} \tag{2}$$

where

r_d = incremental resistance
I_D = bias current
V_T = thermal voltage $\approx$ 25mV

2 Experimental Data

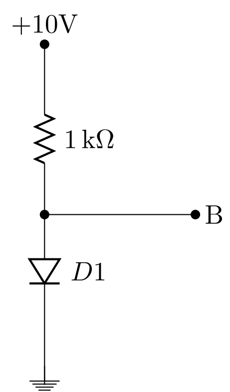


Figure 1: Resistor in series with diode

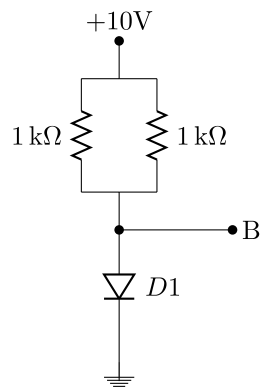
Voltage across resistor	9.37 V
Current through resistor	9.37 mA

Table 1: Experimental Data

Using the circuit set up from figure 1, experimental data for the voltage across the diode and the current was obtained for the different resistor types.

Resistor	Voltage	Current
1 kΩ	0.68 V	9.34 mA
10 kΩ	0.60 V	0.9 mA
100 kΩ	0.5 V	0.1 mA
1 MΩ	0.48 V	0 mA

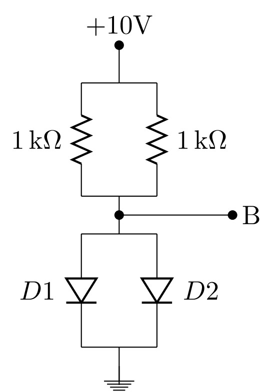
Table 2: Experimental Data



Voltage across diode	0.76 V
Current through diode	0.02 A

Table 3: Experimental Data

Figure 2: Parallel resistors and diode in series



Voltage across D1	0.7 V
Current through D1	9.51 mA
Voltage across D2	0.68 V
Current through D2	9.68 mA

Table 4: Experimental Data

Figure 3: Parallel resistors and parallel diodes in series

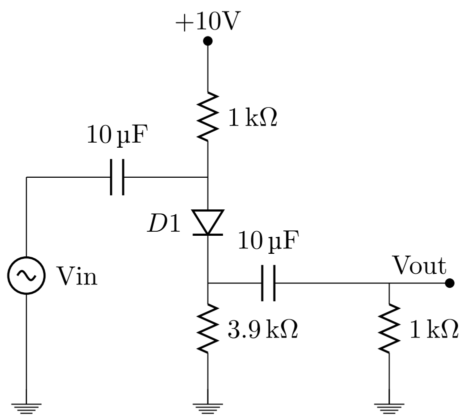


Figure 4: Small signal analysis circuit

3 Calculations

3.1 Device Parameters

In the first task we are asked to find the saturation current I_S and also the diode device parameter n. Consider the diode under operation in figure 2, modelled by equation (1) as follows:

$$i_1 = I_S(e^{v_1/nV_T} - 1) \approx I_S(e^{v_1/nV_T}) \tag{3}$$

Similarly the one of the diodes under operation in figure 3 is modelled by:

$$i_2 = I_S(e^{v_2/nV_T} - 1) \approx I_S(e^{v_2/nV_T}) \tag{4}$$

Dividing equation (2) by equation (3) yields:

$$\frac{i_1}{i_2} = \frac{I_S(e^{v_1/nV_T})}{I_S(e^{v_2/nV_T})}$$

Cancelling out the saturation current and simplifying the exponential gives:

$$\frac{i_1}{i_2} = e^{\frac{v_1 - v_2}{nV_T}}$$

$$\ln(\frac{i_1}{i_2}) = \frac{v_1 - v_2}{nV_T}$$

$$n = \frac{v_1 - v_2}{V_T \ln(\frac{i_1}{i_2})}$$

Hence,

$$n = \frac{0.76 - 0.68}{0.025 \ln(\frac{20}{9.68})}$$

$$n = 4.41$$

Further, the saturation current is:

$$I_S = ie^{\frac{-v}{nV_T}} = 0.02\text{mA}$$

Finally, according to the model parameters that have been calculated, if the voltage drop is 0.7V then the current level is:

$$\begin{aligned} i &= I_S(e^{v/nV_T} - 1) \approx I_S e^{v/nV_T} \\ &= 0.02\text{mA} \times e^{\frac{0.7}{4.41 \times 0.025}} \\ &= 11.44\text{mA} \end{aligned}$$

Note, all experimental data was taken from table 3 and table 4 from the experimental data section of the report.

3.2 Large Signal Analysis of Diodes

Using the linear regression model (5) we can find the bias current for estimates of the normal operating current at 0.5V and 0.48volt. If the voltage is 0.5V then:

$$i_D = 2.25\text{E-}8 \times e^{29.18 \times 0.5} = 48.8\text{mA}$$

Hence assuming that $V_T = 25$mV we get that:

$$r_d = \frac{25\text{E-}3}{0.0488} = 0.512\Omega$$

If the voltage is 0.48V then:

$$i_D = 2.25\text{E-}8 \times e^{29.18 \times 0.5} = 27.2\text{mA}$$

Hence assuming that $V_T = 25$mV we get that:

$$r_d = \frac{25\text{E-}3}{0.0272} = 0.918\Omega$$

3.3 Small Signal Analysis

Results not obtained.

4 Results and Conclusions

4.1 Large Signal Analysis of Diodes

Figure 6 shows the forward drop characteristic of the diode. Matlab was used to fit a an exponential model to the 4 data points using linear regression. The model is as follows:

$$i_D = 2.25\text{E-}8 \times e^{29.18 v_D} \tag{5}$$

We are told that the normal operating current, or dc operating point, of the diode is 10mA, which puts the dc operating voltage at approximately 0.7V according to experimental data in table 2. Further, the junction voltage at 1 % and 0.1 % of the normal operating current is 0.5V and 0.48V respectively, according to experimental data in table 2.

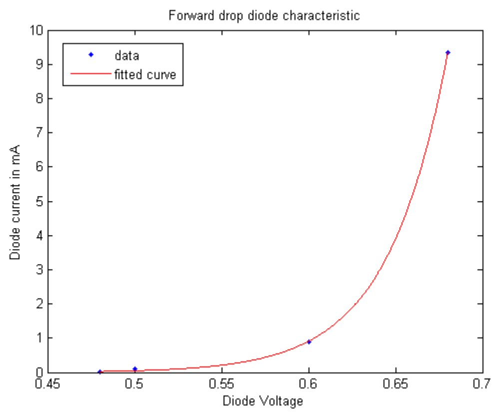


Figure 5: Forward drop characteristic of diode from circuit configuration in figure 1

The estimate for the incremental resistance for operating current values of 0.1mA and 10µA are 0.512Ω and 0.918Ω, respectively. Using the same method of calculation, the incremental resistance of the diode at operating currents 5mA and 0.5mA are 4.81Ω and 0.512Ω, respectively.

4.2 Small Signal Analysis

Results not obtained.