Toronto Metropolitan University

Department of Electrical, Computer and Biomedical Engineering

ELE 404: Electronics I
Lab 1: Diodes

Introduction

In this lab you will examine the v-i characteristic of the 1N4148 silicon diode. You will also study the small-signal behavior of the diode in the forward-bias region.

Pre-lab Assignment

P1. Simulate the circuit of **Figure 1**, assuming that the diode is the **1N4148** and $R = 1\ k\Omega$. Also assume that v_s is a 1-kHz symmetrical triangular voltage whose peak-to-peak swing is 24 volts. Further, assume the source resistance R_S to be 50 Ω. Present the waveforms of v_S, v_I, i_D, and v_D, for three cycles (periods) as **Graph P1(a)**. Also, present a plot of i_D versus v_D, as **Graph P1(b)**.

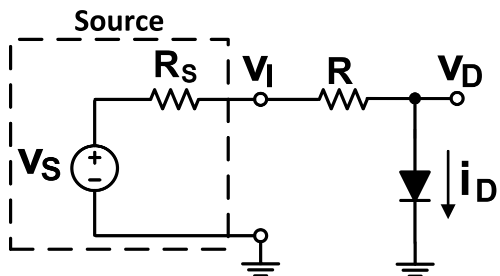
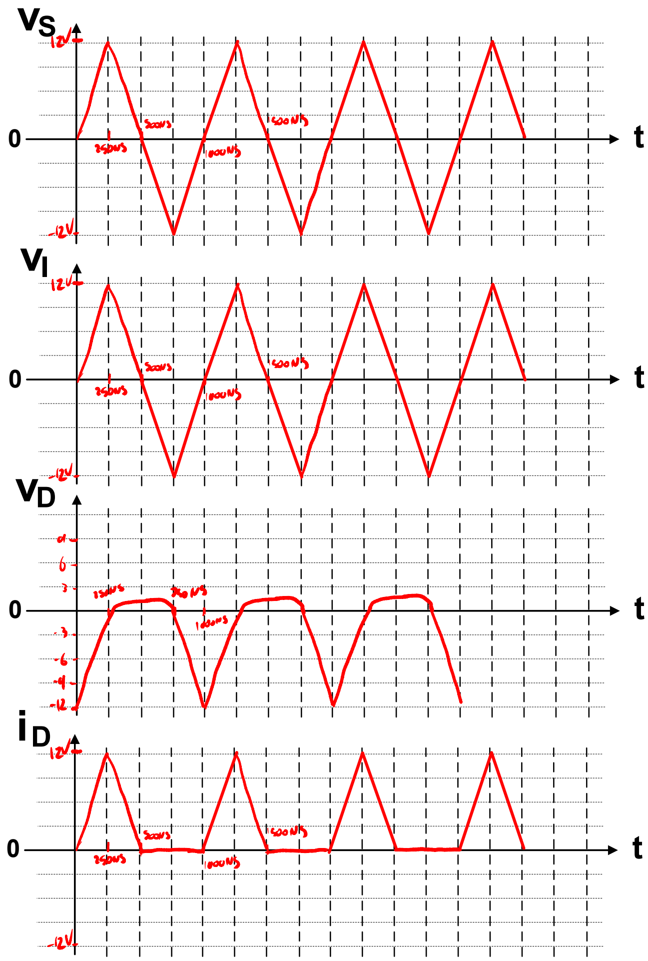
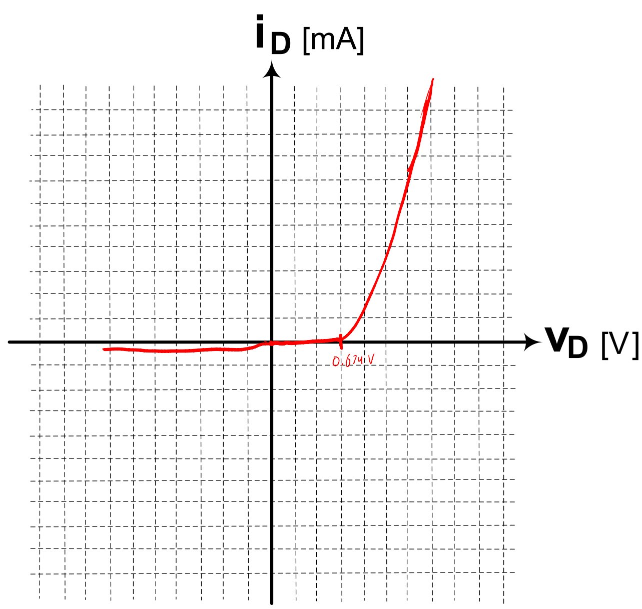


Figure 1. A voltage source driving a diode through a series resistance.



Graph P1(a). Simulated waveforms of the circuit of Figure 1.



Graph P1(b). Voltage-current characteristic of the diode.

Experiment and Results

E1. The main objective of this experiment is to understand the small-signal behavior of a diode, and to calculate its small-signal (AC) resistance at different quiescent current values. To that end, construct the circuit of **Figure 2(a)** with a 1N4148 as the diode, and a 1-$k\Omega$ resistor as resistor R. Set the multimeter to the DC voltage measurement mode and have it handy. Then, turn on the power supply and raise V_{CC} in such a way that the voltage across the resistor, v_R (that indeed is $V_{CC} - v_D$) becomes equal to 10 volts; this corresponds to a diode current of about $i_D = 10\ mA$ (assume that R is precisely 1 $k\Omega$). Record the diode voltage as v_{D1}. Also, record the corresponding value of V_{CC}. Next, connect a 1.5-$k\Omega$ resistor, R_{sh}, across the diode as **Figure 2(b)** illustrates, and record the diode voltage as v_{D2}. The function of the *shunt* resistance R_{sh} is to change the diode current by the small amount $\Delta i_D = -v_{D2}/R_{sh}$ (the negative sign shows that i_D becomes smaller after the connection of R_{sh}), amounting to about 5% to 7% of the initial value of i_D. Complete the first row of **Table E1** with the recorded values. Then, repeat the test for the other values of v_R and R_{sh} as listed in **Table E1**.

Tip: After setting v_R, connect your multimeter probes across the diode and hold them there waiting for the reading to stabilize. Record the stable voltage as v_{D1}. Then, while still holding the probes, connect the resistor R_{sh} and quickly record the new voltage as v_{D2}. Record v_{D1} and v_{D2} with the maximum number of digits displayed by the multimeter.

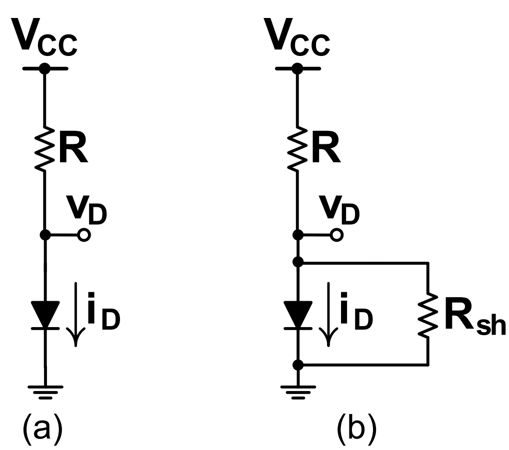


Figure 2. (a) A diode biased with a DC power supply and (b) the same circuit but with a shunt resistor connected across the diode.

Table E1. Test results for the circuits of **Figure 2(a)** and **Figure 2(b)**.

$i_{D1} [mA]$	$V_{CC} [V]$	$v_{D1} [V]$	$R_{sh} [k\Omega]$	$v_{D2} [V]$	$\Delta v_D [V] = v_{D2} - v_{D1}$	$\Delta i_D [mA] = -\frac{v_{D2}}{R_{sh}}$	$r_d [\Omega] = \frac{\Delta v_D}{\Delta i_D} \times 1000$
10	10.79	0.7332	**1.5**	0.7270	-.0062	-0.4846	12.79
7	7.76	0.7142	**2.2**	0.7079	-0.0063	-0.3217	19.58
5	5.71	0.6969	**2.7**	0.6877	-0.0092	-0.2547	36.12
2	2.66	0.6521	**6.8**	0.6444	-0.0077	-0.09476	81.25
1	1.60	0.6186	**12**	0.6096	-0.009	-0.0508	177.16

Conclusions and Remarks

C1. Describe the waveforms of **Graph P1(a)**, and explain what is happening. Also, comment on the v-i characteristic of **Graph P1(b)**. Did you expect this characteristic curve? Explain.

C2. As discussed in the lectures, the diode characteristic in the forward region is described by

$$i_D = I_S \left(e^{\left(\frac{v_D}{nV_T}\right)} - 1 \right)$$

where I_S is the *saturation current*, V_T is the *thermal voltage* (approximately 25 mV at room temperature), and n is an *ideality factor* whose value is between 1 and 2, depending on the material, structure, etc., of the diode. In our course, we often assume n to be unity, for the sake of simplicity. However, as the following exercise shows, this is not necessarily the case.

Using the data of **Table E1**, for example those corresponding to 10 mA and 1 mA (i.e., the two current extremes in your test), **calculate I_S and n for your diode**. Then, **write a program code (e.g., in Matlab) and plot the v-i characteristic of your diode** for the voltage range $0 \leq v_D \leq 1.1\,V$. If, however, the diode current corresponding to $v_D = 1.1\,V$ turns out to be larger than 20 mA, limit the vertical axis range of the plot to 20 mA (hence; also limit the horizontal axis range to the value of v_D that corresponds to $i_D = 20\,mA$). Present the curve as **Graph C2**.

C3. As also discussed in the lectures, the small-signal resistance of a forward-biased diode is theoretically given by $r_d = nV_T/I_D$, where I_D is the quiescent current (or the operating-point current) of the diode. Thus, r_d will be in ohms if V_T and I_D are expressed in mV and mA, respectively.

Using the ideality factor that you calculated in **Part C2**, compare the theoretical values of r_d (based on $r_d = nV_T/I_D$) and the measured values of r_d (listed in **Table E1**) for each of the quiescent currents listed in **Table E1** (10 mA, 7 mA, …), and complete **Table C2.** Calculate the percent error from the following expression:

$$e\% = \frac{theoretical\ value - measured\ value}{measured\ value} \times 100$$

Table C2. Theoretical and measured values of the small-signal resistance of the diode.

Quiescent Current, I_D [mA]	**10**	**7**	**5**	**2**	**1**
Theoretical value of r_d (from $r_d = nV_T/I_D$)					
Measured value of r_d (Table E1)					
Percent error, $e\%$					

C4. Do the results of **Table E1** agree with the common understanding that the diode voltage rises by about $\boldsymbol{60n\ mV}$ for an increase in current of one decade (support your answer by numbers)? If not, what could be the reason(s)?

TA Copy of Results

Table E1. Test results for the circuits of **Figure 2(a)** and **Figure 2(b)**.

$i_{D1} [mA]$	V_{CC} $[V]$	v_{D1} $[V]$	R_{sh} $[k\Omega]$	v_{D2} $[V]$	Δv_D $[V]$ $= v_{D2} - v_{D1}$	Δi_D $[mA]$ $= -\frac{v_{D2}}{R_{sh}}$	r_d $[\Omega]$ $= \frac{\Delta v_D}{\Delta i_D} \times 1000$
10	10.79	0.7332	**1.5**	0.7270	-.0062	-0.4846	12.79
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	Partner's Name	Set-Up (out of 10)	Data Collection (out of 10)	Participation (out of 5)
1	Brian Xu			
2	Lathika			