Introduction

In this lab you will examine the v-i characteristic of the 1N4148 silicon diode. You will also study the small-signal behaviour 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 $R = 1k\Omega$. Also, assume that v_s is a 1-kHz symmetrical triangular voltage whose peak-to-peak swing is $24V$. Further, assume the source resistance, R_S to be 50Ω. Present the waveforms of v_s, v_I, i_D, and v_D, for three cycles (periods) as Graph P1(a). Also, present the plot of i_D versus v_D, as Graph P1(b).

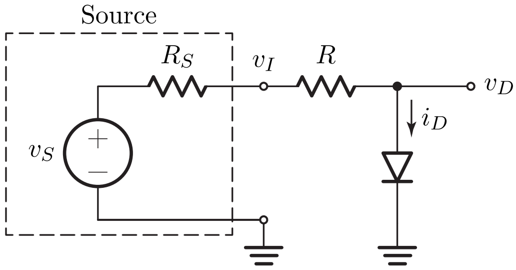

Figure 1: A voltage source driving a diode through a series resistance.

Experiment and Results

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

Tip: After setting v_R, connect your multimeter probes across the diodes 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.

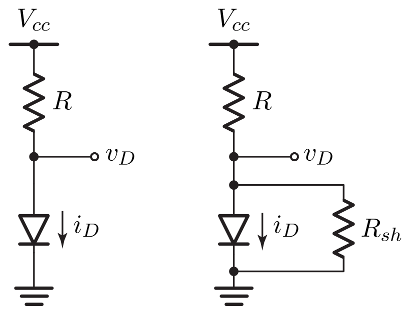

Figure 2: (a) A diode biased with a DC power supply, and (b), the same circuit but with a shunt resistor connected across the diode.

Table 1: Test results for the circuits of Figure 2(a) and Figure 2(b).

Rsh before after (+)

$i_{D1}(mA)$	$V_{cc}(V)$	$v_{D1}(V)$	$R_{sh}(k\Omega)$	$v_{D2}(V)$	$\Delta v_D(V) = v_{D2} - v_{D1}$	$\Delta i_D(mA) = -\frac{v_{D2}}{R_{sh}}$	$r_d(\Omega) = \frac{\Delta v_D}{\Delta i_D} \times 1000$
10	10.64	0.7252	1.5	0.7230	−0.0022	−1.467	1.499
7	7.71	0.7072	2.2	0.7050	−0.0022	−1	2.2
5	5.71	0.6895	2.7	0.6875	−0.0020	-7.407×10^{-1}	2.677
2	2.63	0.6444	6.8	0.6405	−0.0039	-5.735×10^{-1}	6.800
1	1.67	0.6138	12	0.4989	−0.1149	-0.0169×10^{3}	6.7988

$\sim 10\ \Omega$

increase

$\frac{V}{\times 10^{-3}} \cdot 10^{3}$

Conclusion

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 $25mV$ at room temperature), and n is an ideality factory whose value is between 1 and 2, depending on the material, structure, etc., of the diode. In our course, we 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 1, for example those corresponding to $10mA$ and $1mA$ (i.e., the two current extremes in your test cases), calculate I_S and n for your diode. Then, plot the $v - i$ characteristic of your diode using a program such as MATLAB or Microsoft Excel for the voltage range $0 \leq v_D \leq 1.1V$. If, however, the diode current corresponding to $v_D = 1.1V$ turns out to be larger than $20mA$, limit the vertical axis range of the plot to $20mA$ (hence, also limit the horizontal axis range to the value of v_D that corresponds to $i_D = 20mA$). Include the resultant curve in your post-lab report.

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 1) for each of the quiescent currents listed in Table 1 ($10mA, 7mA, ...$), and complete Table 2. Calculate the percent error using the following expression:

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

Table 2: 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					
Measured value of r_d					
Percent error, $e_{\%}$					

C4. Do the results of Table 1 agree with the common understanding that the diode voltage rises by about $60n$ mV for a one decade increase in current? Support your answer using specific examples. If it does not, comment on any discrepancies that may cause this behaviour.

TA Copy of Results

Table 3: Test results for the circuits of Figure 2(a) and Figure 2(b).

$i_{D1}(mA)$	$V_{cc}(V)$	$v_{D1}(V)$	$R_{sh}(k\Omega)$	$v_{D2}(V)$	$\Delta v_D(V)$ $= v_{D2} - v_{D1}$	Δi_D $= -\frac{v_{D2}}{R_{sh}}$	$r_d(\Omega)$ $= \frac{\Delta v_D}{\Delta i_D} \times 1000$
10			1.5				
7			2.2				
5			2.7				
2			6.8				
1			12				

Student Name	Pre-lab (/20)	Set-up (/10)	Data Collection (/10)	Participation (/5)