Lab 01 – 1N4148 Diode Characterization

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ELE404 – Electronics I

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Date Published: Feb 4, 2025

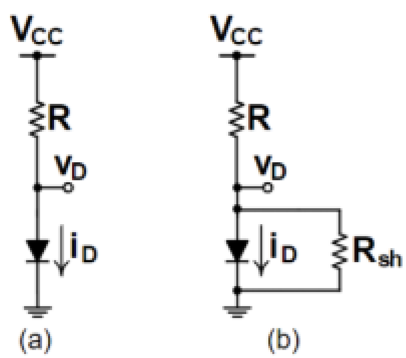
Introduction:

The voltage-current (v-i) characteristics and small-signal behavior of the 1N4148 silicon diode, specifically in its forward-bias region, are investigated in this lab report. The purpose of this experiment is to learn how a diode works in electronic applications by examining how it reacts to different electrical circumstances. We have a better understanding of the 1N4148 diode's uses in electronic circuits thanks to this experiment.

Objective:

The purpose of this lab is to examine the 1N4148 silicon diode's forward-bias region's voltage-current (v-i) characteristics and small-signal behavior. In order to do this, the voltage source must be adjusted to produce particular current values across the diode. The voltage across the diode must then be recorded, and variations must be seen when a resistor is connected in parallel at different resistance values.

Circuit Under Test:



A series circuit comprising a diode, a resistor, and a voltage source (Vcc) is depicted in Figure (a). By adding an additional resistor in parallel with the diode, Figure (b) alters this configuration and enables us to see how the diode behaves in various circuit scenarios.

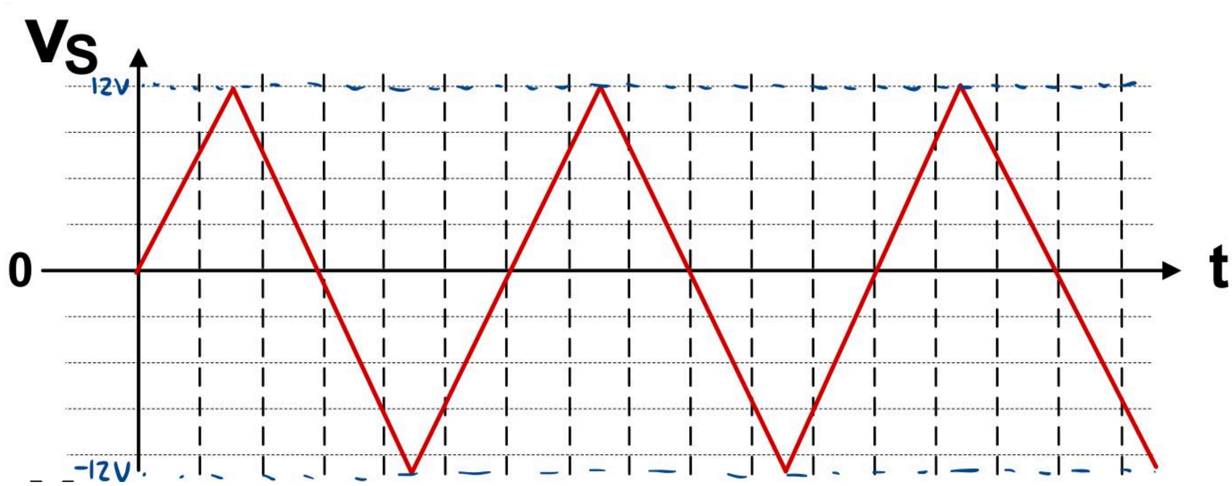
Experimental Results:

My partner and I used Figures (a) and (b) on the breadboard to construct the circuits in this lab. Next, in order to fit the current input into the diode for figure (a), we utilize the power supply and multimeter to supply a specific amount of voltage input into the circuit. This allowed us to determine the voltage flowing through the diode. Then, using the same procedures as for Figure (a), we measured the voltage across the diode after adding a particular resistor to the circuit that was parallel to the diode for Figure (b). We computed the variation in the diode's resistance, voltage, and current after gathering all the data.

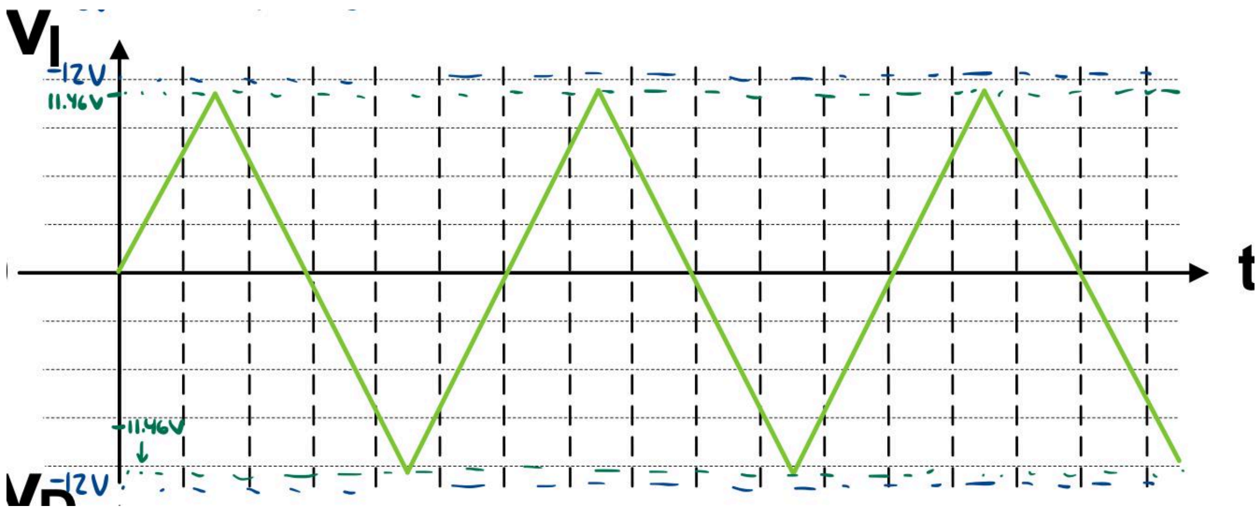
Table E1. Test results for the circuit of Figure 2(a) and Figure 2(b)

I_{D1} [mA}	V_{cc} [V]	V_{D1} [V]	R_{sh} [kΩ]	V_{D2} [V]	$\Delta V_D[V] = V_{D2} - V_{D1}$	$\Delta i_D[mA] = -\frac{V_{D2}}{R_{sh}}$	$R_d = [\Omega]$ $\frac{\Delta V_D}{\Delta i_D}$ x 1000
10	10.55	0.73464	1.5	0.72952	-5.12×10^{-3}	-0.4863	10.528
7	7.60	0.71365	2.2	0.71060	-3.05×10^{-3}	-0.3230	9.443
5	5.61	0.69642	2.7	0.69238	-4.04×10^{-3}	-0.2564	15.757
2	2.62	0.64867	6.8	0.64663	-2.04×10^{-3}	-0.0951	21.451
1	1.64	0.61609	12	0.61307	-3.02×10^{-3}	-0.0511	59.010

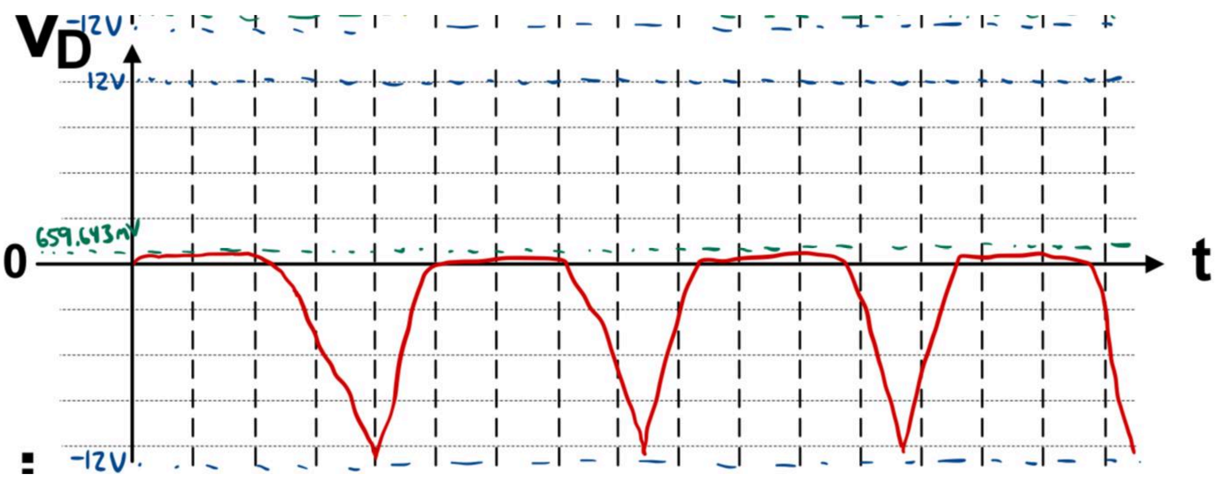
Conclusion & Remark:



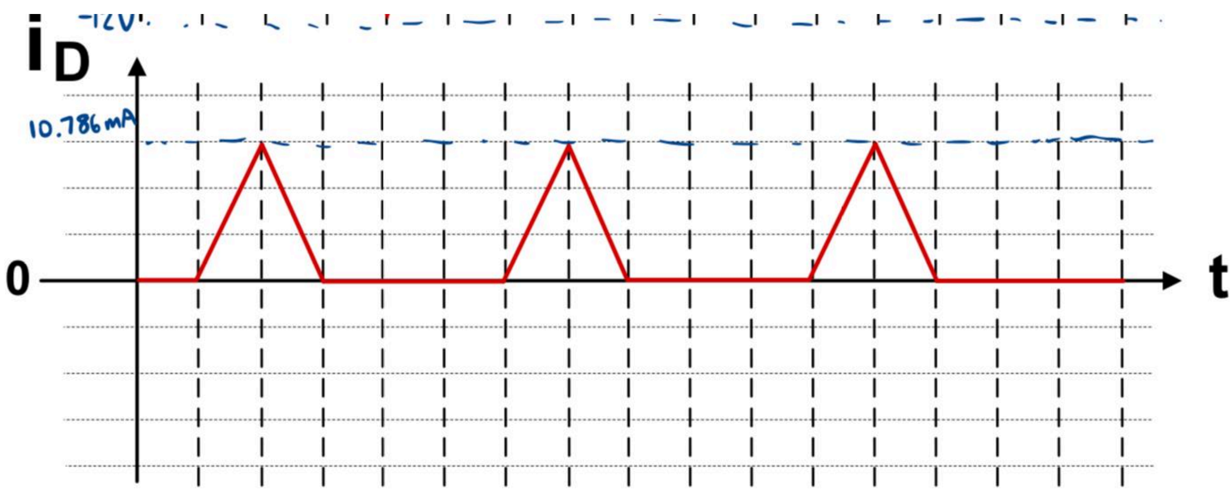
The first graph, a 1 kHz triangle waveform with a peak-to-peak amplitude of 24 volts, displays the source voltage's Vs vs time (Vs-t) relationship. Since there are no diodes or resistors in this configuration, we can anticipate a triangle waveform with peak amplitudes of +12V and -12V.



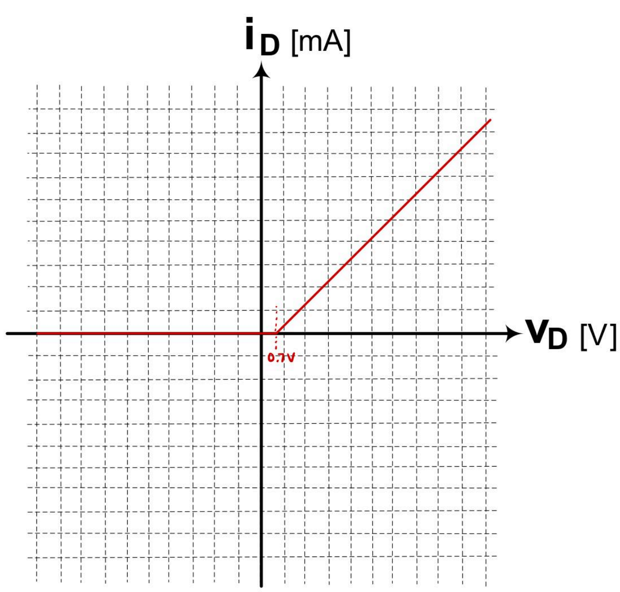
The plot of input voltage (Vi) against time is shown in the second graph. The inclusion of a 50 Ω resistor, Rs, makes this graph different from the first. Because of this resistor, the amplitude of Vi is marginally less than 12 volts. The graph shows that the amplitude is approximately 11.461 V.



The third graph illustrates the behavior of the 1N4148 silicon diode by plotting the voltage across the diode (Vd) over time. The diode functions as a constant voltage source when forward-biased and as an open circuit when reverse-biased, according to the ideal diode voltage drop model. In its conducting condition, the 1N4148 diode normally has a 0.7-volt drop. This is seen in the graph, where a non-conducting diode is indicated when Vs is less than 0.7 volts and Vd equals the source voltage Vs. The diode behaves as a constant voltage drop source in its conducting state when Vs exceeds 0.7 volts, and Vd stays close to 0.7. This graph illustrates how the diode works and reacts to various voltage levels.



Id, or current flowing through the diode, is plotted over time in the fourth graph. The diode acts as an open circuit, which means it does not conduct and the current is zero, when the source voltage (Vs) is less than 0.7 volts, as the preceding graph illustrates. Stated differently, for voltages lower than 0.7 volts, the current is zero. But when the voltage rises above 0.7 volts, the diode begins to conduct, and the voltage across it and the current have an exponential connection. When Vs peaks at 12 volts, the maximum current happens. The following formula can be used to determine this maximum current: ID = 12/(1000 + 50) = 10.76 mA. This graph illustrates the variation in the diode's conduction with varying voltage levels.



As mentioned before, a diode acts as an open circuit and produces zero current flow when the voltage across it is less than 0.7 volts. Furthermore, when the voltage rises above 0.7 volts, the diode becomes conductive, permitting current to pass through it. Equation $I_D = I_s \cdot e^{\frac{vD}{vT}}$ describes the diode's current-voltage relationship, showing that the voltage across the diode and its current have an exponential relationship. The equation ($e^{\frac{vD}{vT}}$) nearly equals 1 + ($\frac{vD}{vT}$) and can be used to approximate this exponential term for tiny values of vD (that is, when vD is substantially lower than vT, (vT >> vD)). This makes it useful. $I_d = I_s \cdot (1 + (\frac{vD}{vT}))$ is equivalent to $I_d = I_s + I_s \cdot \frac{vD}{vT}$

The I_s term in this equation is frequently negligible in comparison to the $I_s \cdot \frac{vD}{vT}$ term, especially when vD is not tiny, because (I_s) is usually very small (normally in nanometers). Consequently, the current can be roughly calculated using the formula ($I_d = I_s \cdot \frac{vD}{vT}$). In the end, the relationship between the voltage across the diode and the current flowing through it is linear for small values of vD.

CONCLUSIONS

C2:

$V_T = 25\,mV = 0.025\,V$

$i_{D_1} = 1\,mA = 0.001\,A$

$V_{D_1} = 0.61609\,V$

$i_{D_2} = 10\,mA = 0.002\,A$

$V_{D_2} = 0.73464\,V$

$\underline{n:}$

$$i_D = I_S\left(e^{\frac{V_D}{n \cdot V_T}} - 1\right) \approx I_S\left(e^{\frac{V_D}{n \cdot V_T}}\right)$$

$$i_{D_2} = 10\, i_{D_1}$$

$$\cancel{I_S}\left(e^{\frac{V_{D_2}}{n \cdot V_T}}\right) = 10\, \cancel{I_S}\left(e^{\frac{V_{D_1}}{n \cdot V_T}}\right)$$

$$10 = \frac{\left(e^{\frac{V_{D_2}}{n \cdot V_T}}\right)}{\left(e^{\frac{V_{D_1}}{n \cdot V_T}}\right)} = e^{\frac{V_{D_2} - V_{D_1}}{n \cdot V_T}}$$

$$\ln 10 = \frac{V_{D_2} - V_{D_1}}{n \cdot V_T}$$

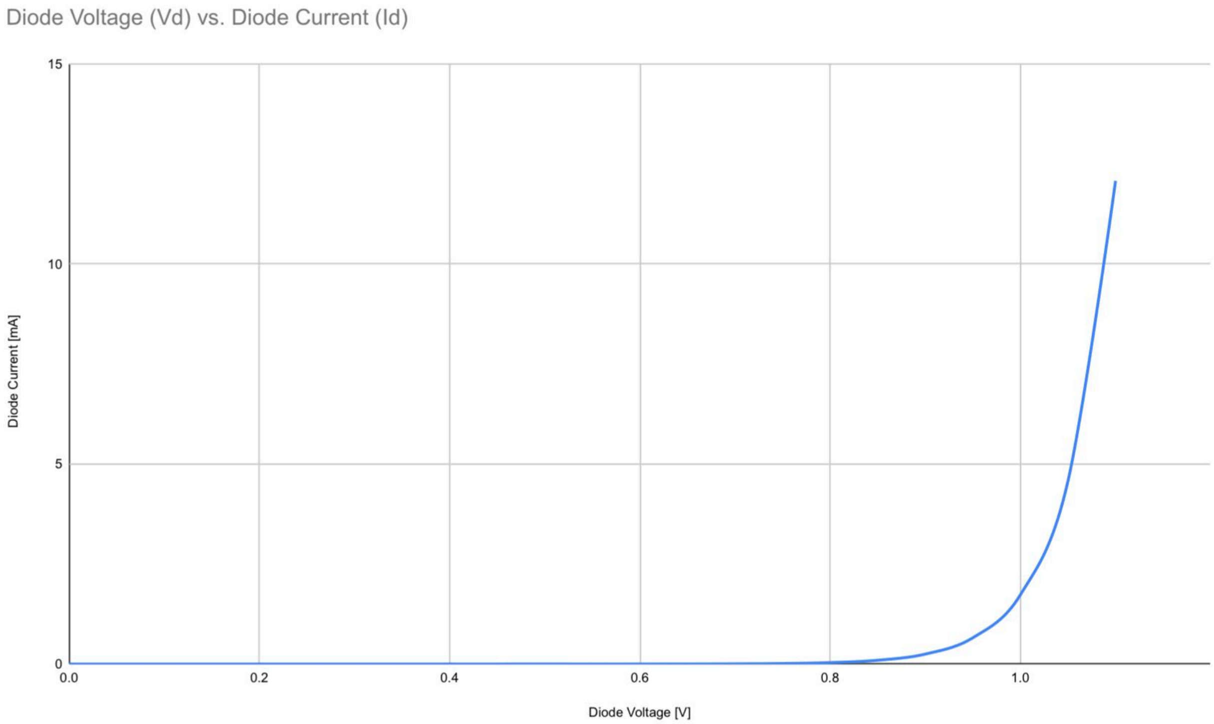
$$n = \frac{V_{D_2} - V_{D_1}}{\ln 10 \cdot V_T} = \frac{0.73464\,V - 0.61609\,V}{\ln 10 \cdot 0.025\,V} = 2.05942$$

$\underline{I_S:}$

$$i_D = I_S\left(e^{\frac{V_D}{n \cdot V_T}} - 1\right)$$

$$I_S = \frac{i_{D_1}}{e^{\frac{V_{D_1}}{n \cdot V_T}} - 1} = \frac{0.001\,A}{e^{\frac{0.61609\,V}{2.05942 \cdot 0.025}} - 1} = 6.35495 \times 10^{-9}\,A$$

Diode V-I Characteristic:



C3:

Quiescent Current, I_D [mA]	10	7	5	2	1
Theoretical value of r_d (from $r_d = nV_T/I_D$)	5.14855	7.35507	10.2971	25.74275	51.4855
Measured value of r_d (Table E1)	10.528	9.443	15.757	21.451	59.010
Percent error, $e\%$	51.09%	22.11%	34.65%	20.00%	12.75%

percent error (example):

$$\frac{10.528 - 5.14855}{10.528} = 51.09\%$$

$I_D = 10\text{ mA}$

$$r_D = \frac{nV_T}{I_D} = \frac{2.05942 \cdot 25}{10} = 5.14855$$

$I_D = 7\text{ mA}$

$$r_D = \frac{nV_T}{I_D} = \frac{2.05942 \cdot 25}{7} = 7.35507$$

$I_D = 5\text{ mA}$

$$r_D = \frac{nV_T}{I_D} = \frac{2.05942 \cdot 25}{5} = 10.2971$$

$I_D = 2\text{ mA}$

$$r_D = \frac{nV_T}{I_D} = \frac{2.05942 \cdot 25}{2} = 25.74275$$

$I_D = 1\text{ mA}$

$$r_D = \frac{nV_T}{I_D} = \frac{2.05942 \cdot 25}{1} = 51.4855$$

C4:

From Table E1, we can see the Vd value at 1mA is 0.61609V and the Vd value at 10mA is 0.73464V. To check if the Table E1 values agree with the fact the diode voltage increases by 60n mV every decade, we can find the theoretical calculation for Vd at 10mA:

Vd (at 10mA) = Vd (at 1mA) + 60 * n mV = 0.61609V + 60 * 2.05942 * 10^-3 = 0.7396552V

The percent error is 0.68%, suggesting that the table E1 values are accurate.