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Experiment 1

Introduction to Semiconductors

Diode Characteristics

INTRODUCTION:

Semiconductors are the cornerstone of modern electronic devices, with diodes playing a critical role by allowing current to flow in one direction. This experiment investigates the voltage-current (V-I) characteristics of a silicon junction diode to understand its behavior under different biasing conditions. Utilizing Multisim software for circuit simulation and a bench setup for empirical measurement, the experiment aims to compare the forward bias region's theoretical expectations, where the diode conducts electricity after surpassing the silicon diode's characteristic turn-on voltage, with practical observations. This comparison is expected to demonstrate the practical application of semiconductor theory, as detailed in section 2-2 of the course textbook, and offer insight into the nuances of diode functionality through graphical analysis of the V-I relationship.

BENCH PARTS AND EQUIPMENT LIST:

1. **Diodes:**
   - Silicon Diode (1N4001)
2. **Resistors:**
   - 1 kΩ resistor

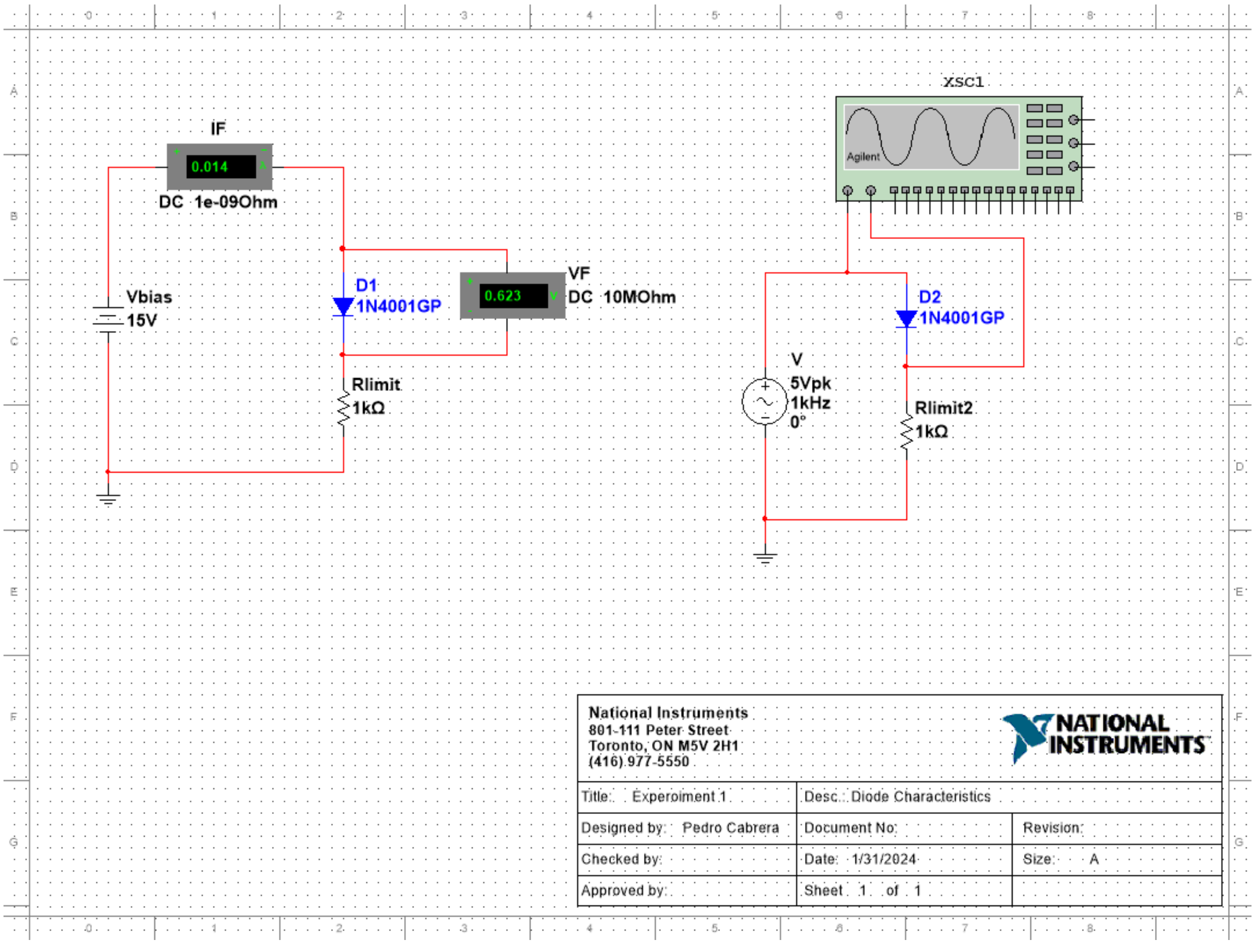
Bench Equipment:

1. **Power Supply:**
   - DC Voltage Source capable of supplying a variable voltage from 1V to 15V.
2. **Measurement Instruments:**
   - Multimeter (for measuring voltage across and current through the diode).
   - Oscilloscope (to observe and analyze the V-I characteristics of the diode under AC conditions).
3. **Signal Generators:**
   - Function Generator (capable of producing a sine wave signal, with an amplitude of 10 Vpp at a frequency of 1 kHz for AC analysis).

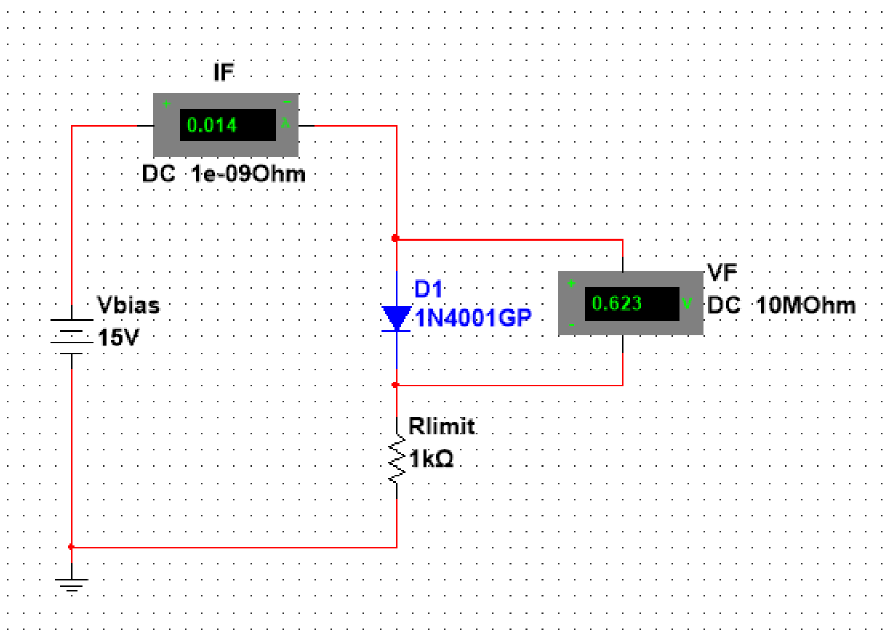
4. **Prototyping and Interconnect:**
    - Breadboard or other prototyping board (for assembling the circuit).
    - Connecting wires and/or jumper wires (for making electrical connections between components on the breadboard).

DISCUSSION:

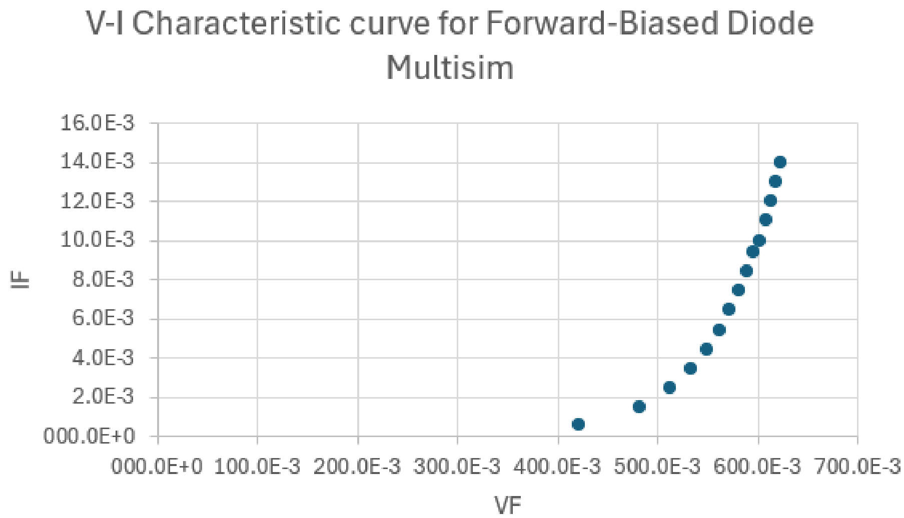
Part 1: Multisim DC Circuit Analysis



In the first part of the experiment, we built a DC circuit in Multisim to observe the V-I characteristics of a silicon diode. The bias voltage (V_bias) was varied in 1V increments from 1V to 15V, and the corresponding forward current (I_F) was measured. The diode's behavior agreed with semiconductor theory, exhibiting a threshold voltage near 0.7V, beyond which the current increased significantly, indicating the diode had entered its conducting state. Notably, the simulation allowed for an ideal environment where temperature and manufacturing variances were absent, thus presenting a more idealized diode characteristic curve compared to what one might expect in a physical setup.

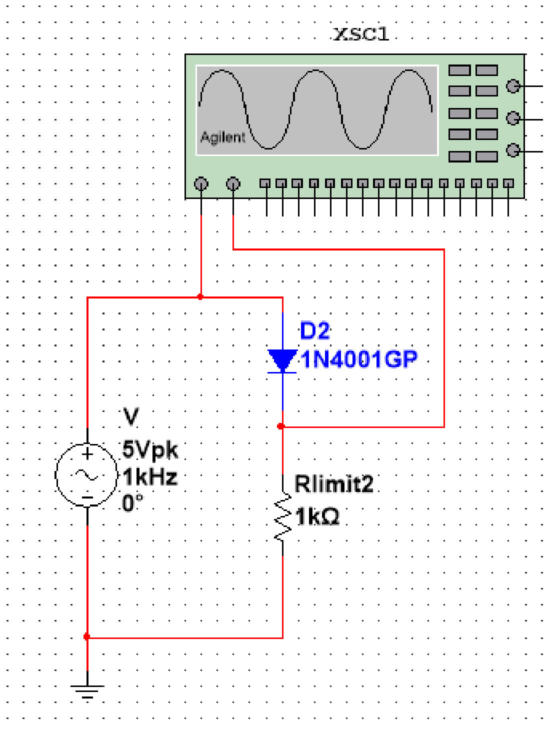


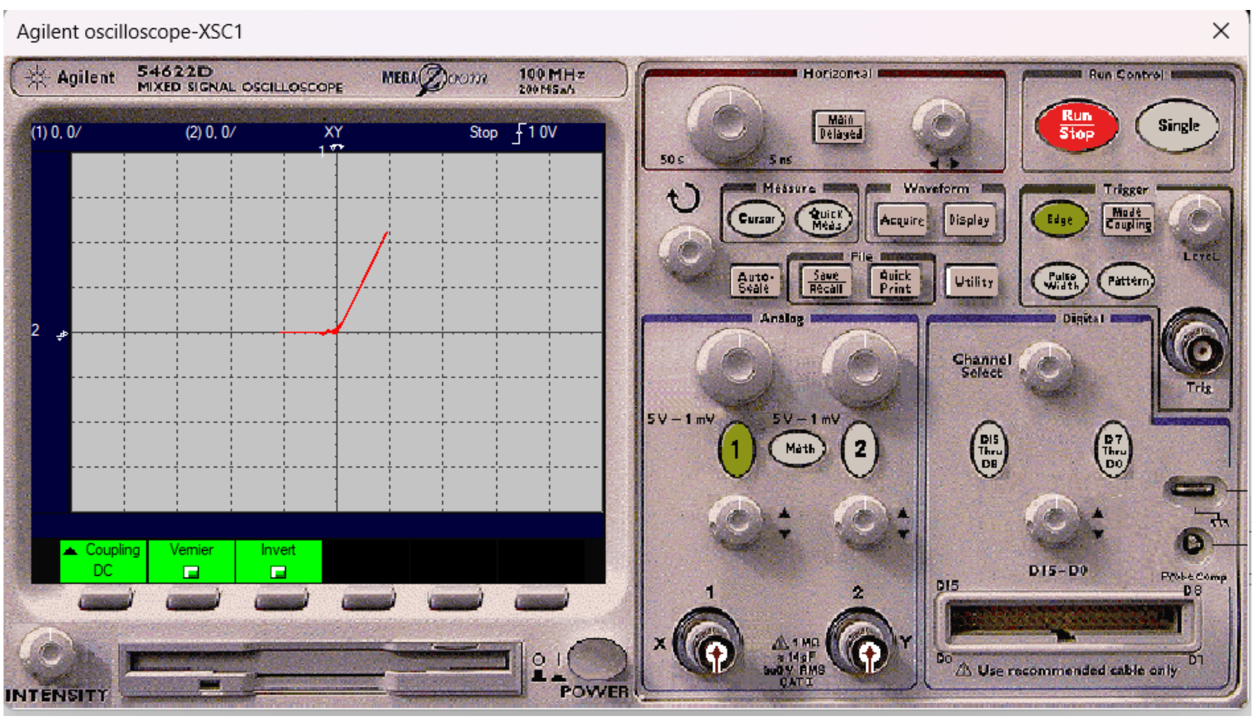
V_{bias} (V)	Simulated		Measured		Variance	
	V_F	i_F	V_F	i_F	V_F	i_F
1	422.0E-3	578.0E-6	5.57E-01	5.10E-04	24%	-13%
2	482.0E-3	1.518E-3	6.05E-01	1.45E-03	20%	-5%
3	513.0E-3	2.487E-3	6.28E-01	2.44E-03	18%	-2%
4	534.0E-3	3.467E-3	6.43E-01	3.40E-03	17%	-2%
5	549.0E-3	4.450E-3	6.55E-01	4.37E-03	16%	-2%
6	562.0E-3	5.438E-3	6.63E-01	5.38E-03	15%	-1%
7	572.0E-3	6.429E-3	6.70E-01	6.41E-03	15%	0%
8	581.0E-3	7.419E-3	6.76E-01	7.35E-03	14%	-1%
9	589.0E-3	8.409E-3	6.81E-01	8.42E-03	14%	0%
10	596.0E-3	9.404E-3	6.85E-01	9.43E-03	13%	0%
11	602.0E-3	10.0E-3	6.89E-01	1.04E-02	13%	4%
12	608.0E-3	11.0E-3	6.93E-01	1.14E-02	12%	4%
13	613.0E-3	12.0E-3	6.97E-01	1.24E-02	12%	3%
14	618.0E-3	13.0E-3	7.00E-01	1.34E-02	12%	3%
15	623.0E-3	14.0E-3	7.02E-01	1.44E-02	11%	3%



Part 2: Multisim AC Circuit Analysis

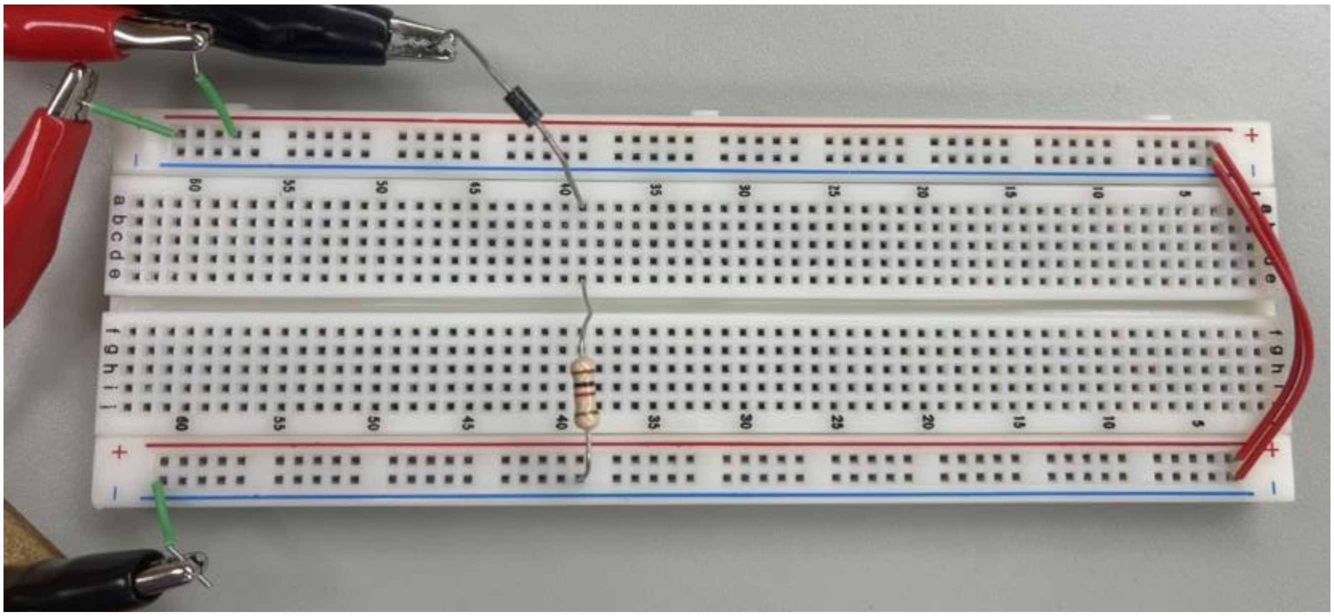
For the AC analysis in Multisim, the circuit used a sine wave from a function generator with a peak voltage of 10V at 1kHz. The oscilloscope displayed distinct half-wave rectification, as only the positive half of the sine wave was allowed to pass, a characteristic inherent to diodes. It was particularly interesting to observe the effect of the diode on the sine wave, confirming its rectifying nature in real-time. The virtual oscilloscope's clean signal display highlighted the advantage of simulation in analyzing ideal circuit behaviors without real-world interference.



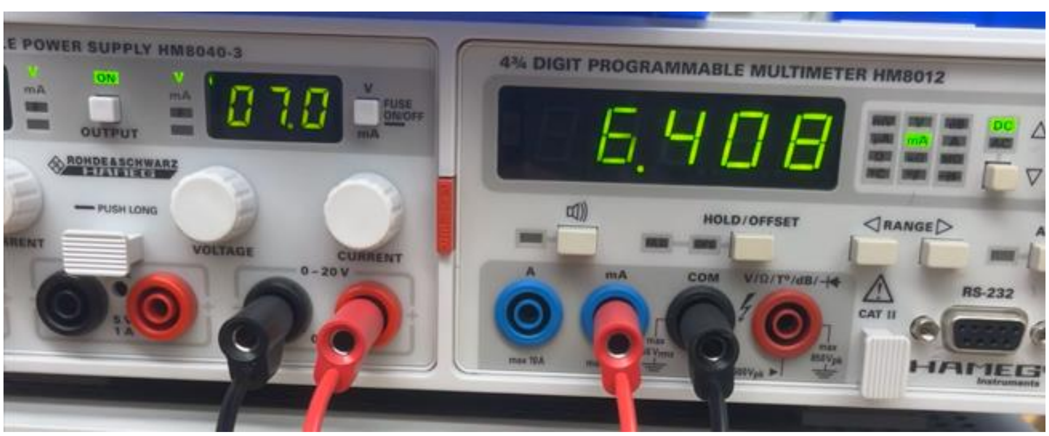


Part 3: Bench DC Circuit and Excel Graphing Analysis

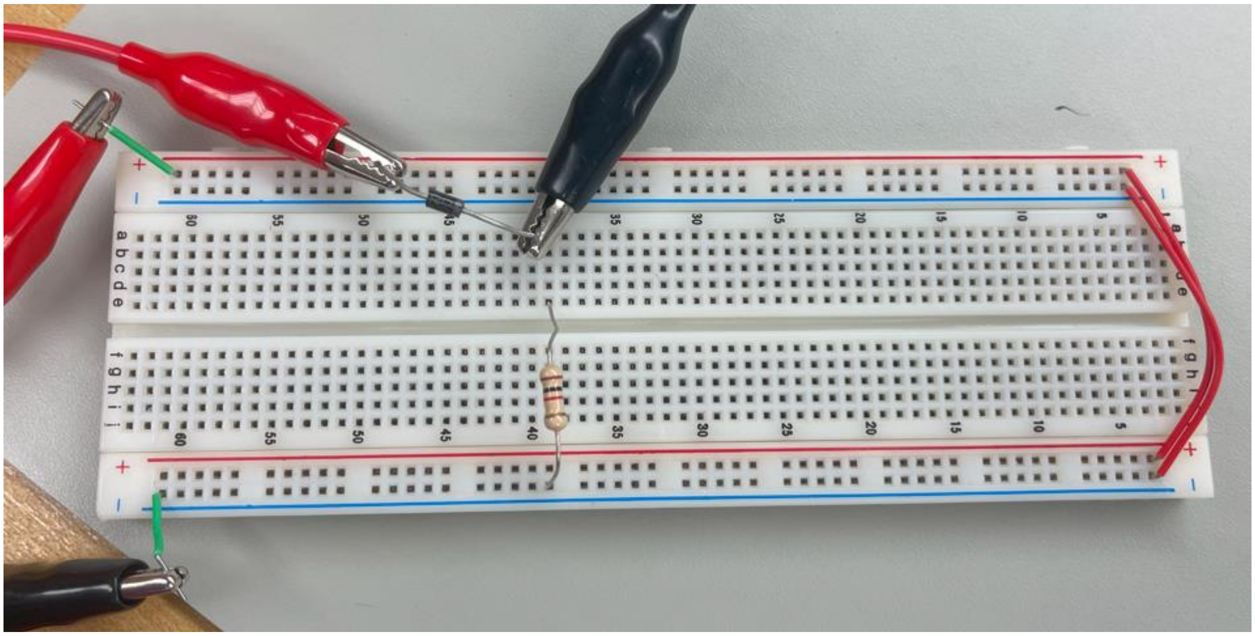
The bench DC circuit replicated the Multisim setup, using a physical diode and resistor. By varying V_bias manually and measuring the V_F (forward-bias voltage) and I_F with a multimeter, we plotted the V-I curve in Excel. The results showed a steeper curve after the threshold voltage, characteristic of real diodes. This activity underscored the influence of physical factors, such as the diode's temperature sensitivity and manufacturing imperfections, on its operational characteristics, which were not as apparent in the simulation.



** Using DMM to measure I_F @ 1V



** I_F @ 7V



** Getting ready to measure V_F

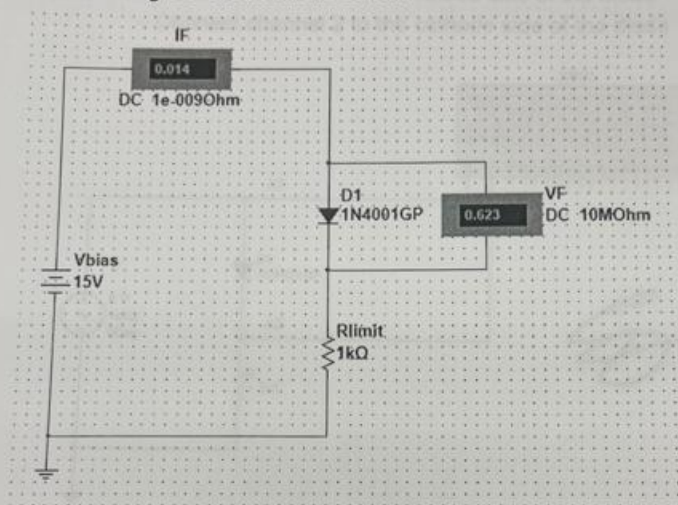
** V_F @ 9V measuring 680.6 mV

Part 3: Bench DC Circuit and Excel Graphing Analysis

Materials:

- Resistor (1 kΩ)
- Diode (1N4001)
- DC Voltage Source
- Multimeter

1. Build the following DC circuit on the bench:



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2. Vary Vbias from 1 V to 15 V in increments of 1 V
3. Create three columns in Excel: Vbias, VF, IF
4. Record Vbias, VF, and IF in Excel
5. Graph VF on x-axis and IF on y-axis in Excel by selecting the VF and IF data cells and then clicking on “Insert”/”Recommended Charts”/”Scatter” to obtain your “V-I Characteristics Curve for a Forward-Biased Diode”
6. Compare this curve to your Multisim DC Circuit analysis results in Part 1

V_{bias} (V)	Simulated		Measured		Variance	
	V_F	i_F	V_F	i_F	V_F	i_F
1	422.0E-3	578.0E-6	5.57E-01	5.10E-04	24%	-13%
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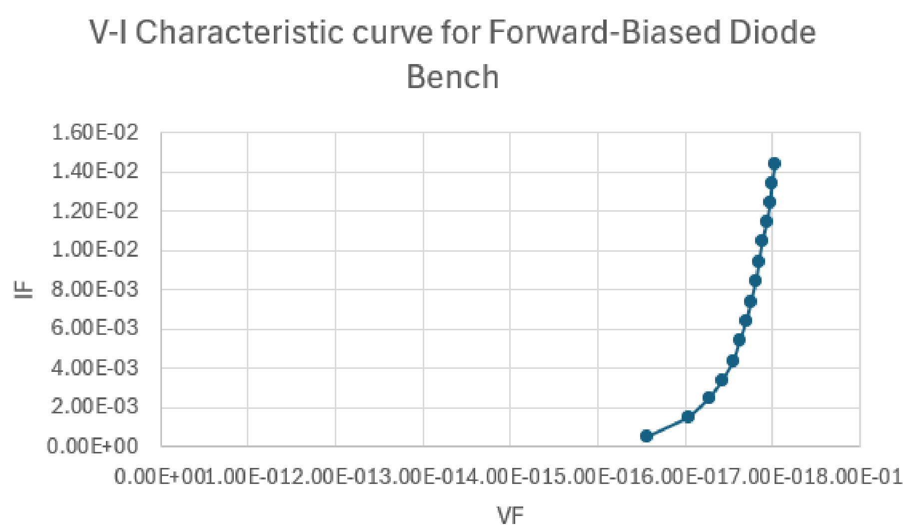
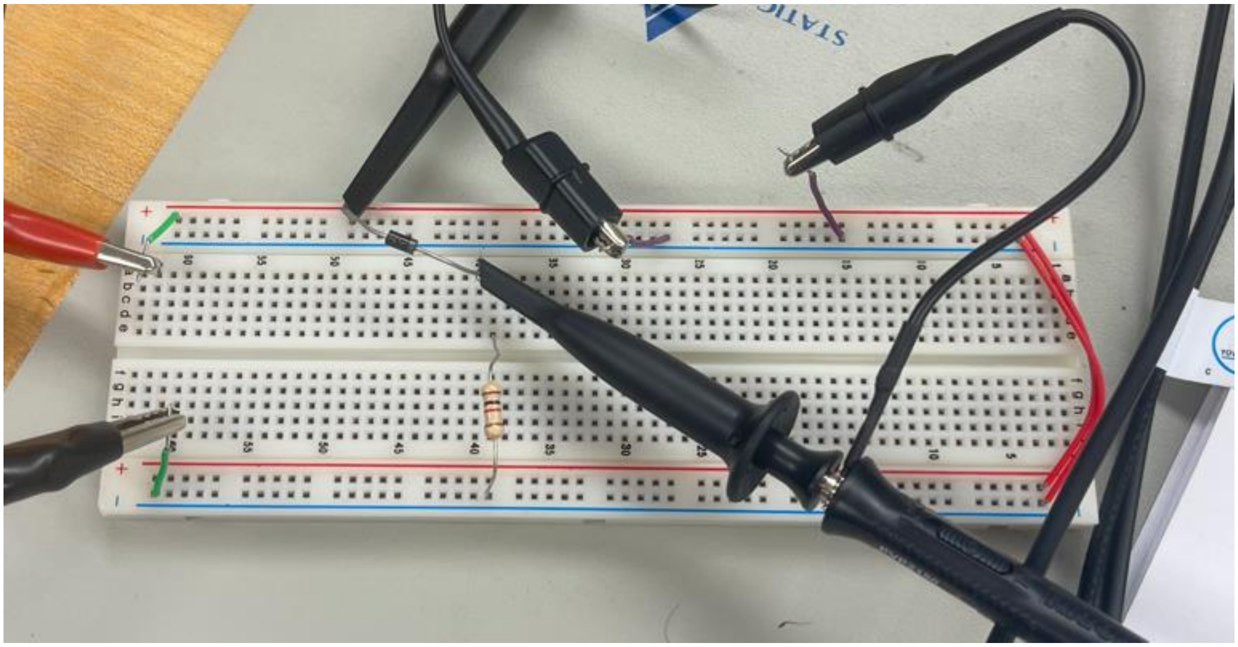
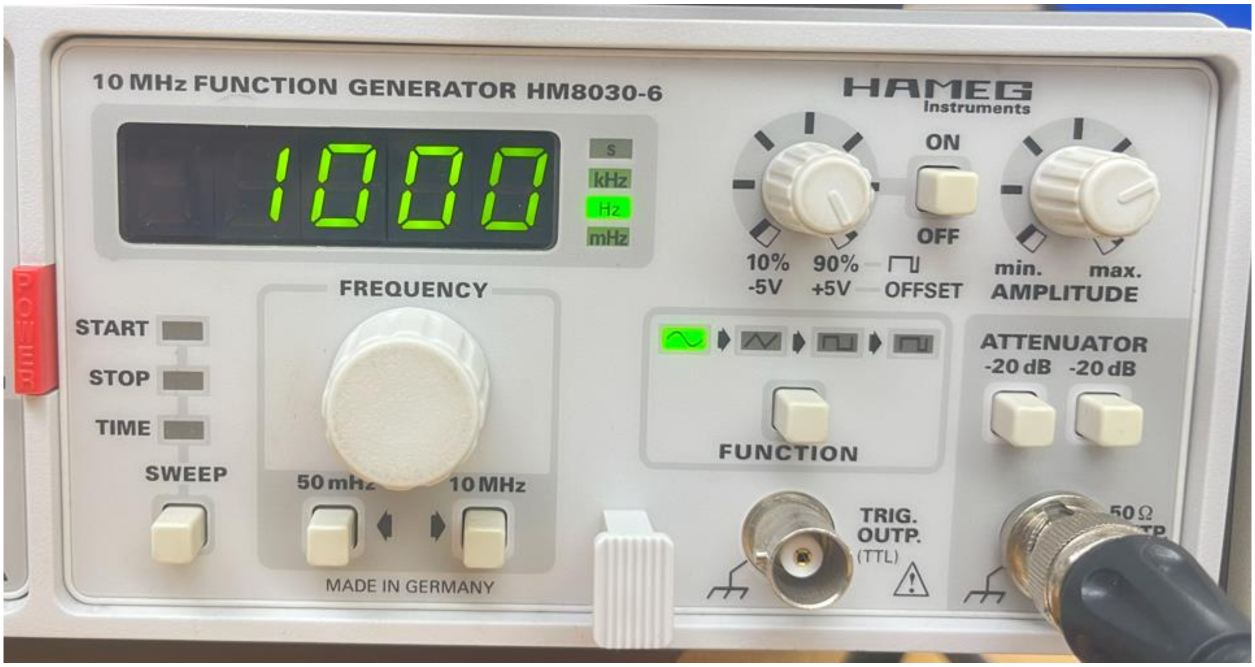


Part 4: Bench AC Circuit Analysis

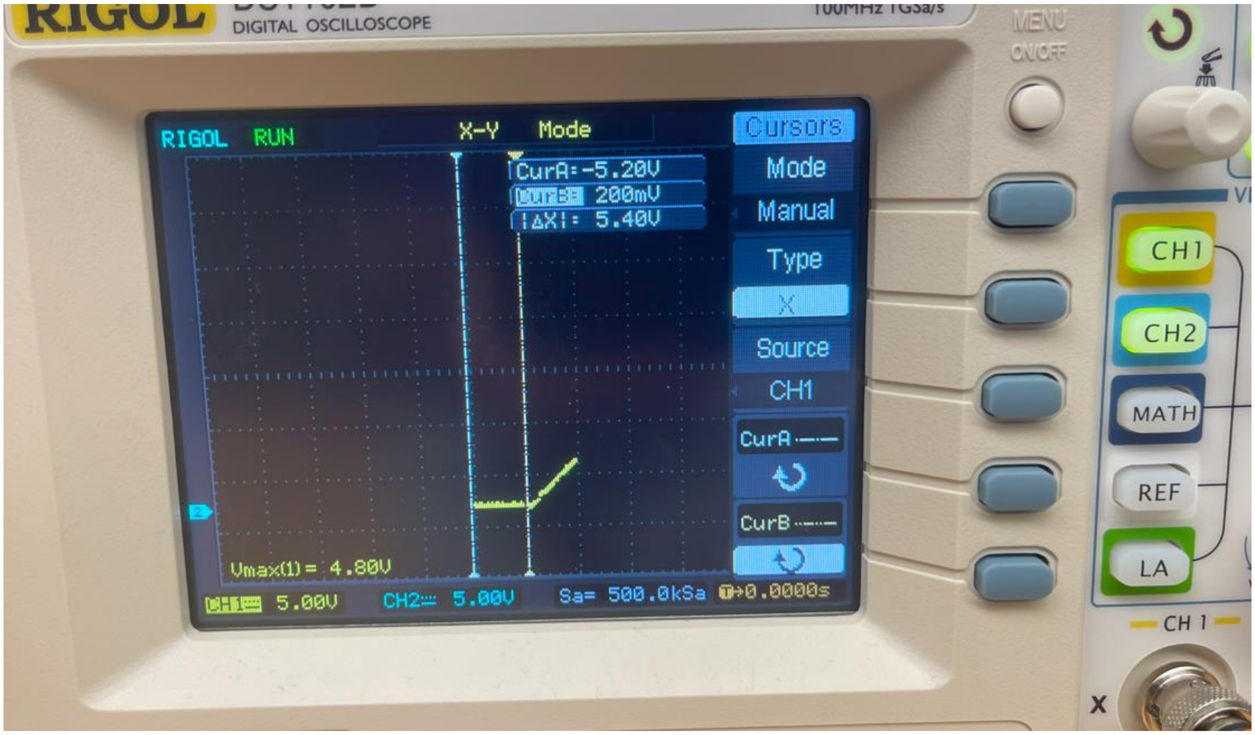
On the bench, the AC circuit used a function generator and an oscilloscope, similar to the simulation, but the real-world implementation provided insights into practical challenges, such as noise and signal integrity. The oscilloscope revealed a V-I characteristic curve with noticeable irregularities compared to the ideal curve seen in Multisim. This part of the experiment was crucial in illustrating the impact of real-world conditions on the diode's performance, offering a tangible contrast to the simulated environment.



** Setting up the circuit with the Signal Generator wires and Oscilloscope probes.



** Verification of the Frequency


RIGOL
DIGITAL OSCILLOSCOPE
RIGOL RUN X-Y Mode
CurA:-5.20V
CurB: 200mV
|ΔX|: 5.40V
Cursors
Mode
Manual
Type
X
Source
CH1
CurA
CurB
Vmax(1) = 4.80V
CH1 5.00V CH2 5.00V Sa= 500.0kSa 0.0000s
CH1
CH2
MATH
REF
LA

** Bench V-I

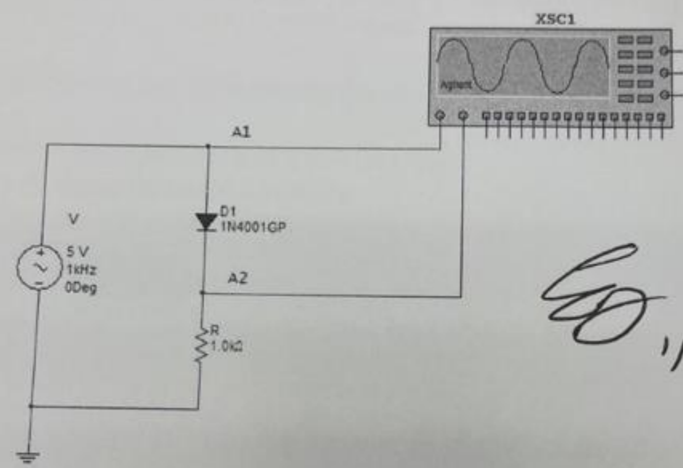
- Function Generator
- Oscilloscope
- Resistor (1 kΩ)
- Diode (1N4001)

1. Build the following AC circuit:

Input: Function Generator - Sine Wave, 10 V_{pp}, 1 kHz

Output: Oscilloscope – Connect channel 1 to the Anode side of the diode

– Connect channel 2 to the cathode side of the diode



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. To make sure that both oscilloscope probes are set on "1x" and on "DC" coupling, on the Rigol Oscilloscope:
1. Press "CH1"
2. Press top blue button
3. Dial in "DC"
4. Press "CH2"
5. Press top blue button
6. Dial in "DC"

To view the V-I characteristic of the diode curve on the Rigol Oscilloscope:
1. Look under Horizontal section and press "Menu"
2. Select Time Base
3. Use knob to turn to X-Y
4. Press in knob to make selection permanent

CONCLUSION:

This laboratory experiment provided a comprehensive examination of the voltage-current characteristics of a silicon diode, both through simulation and practical bench work. The exercise reinforced the theoretical principles of diode operation, with Multisim simulations offering an idealized view that closely matched textbook expectations, specifically demonstrating the diode's rectifying nature and its forward bias behavior. Bench experiments further solidified our understanding by introducing the complexities of real-world applications, such as the effects of temperature and component imperfections, which slightly altered the diode's V-I characteristics. The discrepancies observed between the simulated and actual results emphasize the necessity of hands-on experience in engineering education, as it highlights the nuances that can only be appreciated through physical experimentation. Overall, the experiment successfully bridged the gap between theoretical semiconductor diode behavior and its practical implementation, thereby enhancing our grasp of the fundamental electronic principles critical for the design and analysis of electronic circuits.