Basic Course on Diodes and Transistors

Day 1: Diodes, Basic Circuits, Polarization Curve, and Rectification

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Course Registration

Please register for the course using the following link:

`http://gmarx.itmorelia.com/form-diodes`

This form will be used to collect participant information and follow up on course activities.

Course Context

Day 1 objective:

The objective of this session is to introduce the diode as a basic semiconductor device and analyze its behavior using elementary circuit laws and experimental measurements.

Topics:

1. Diode fundamentals.
2. Kirchhoff laws in simple diode circuits.
3. Diode polarization curve.
4. Basic half-wave rectifier.

Learning Outcomes

At the end of this session, the student should be able to:

- Identify the terminals of a diode: anode (A) and cathode (K).
- Explain forward and reverse polarization.
- Apply Kirchhoff's Voltage Law to a diode-resistor circuit.
- Measure voltage and current to build a diode polarization curve.
- Explain the operation of a basic half-wave rectifier.

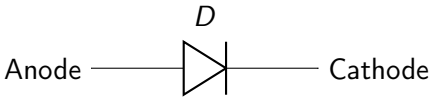
What Is a Diode?

A diode is a semiconductor device that, ideally, allows current to flow in only one direction.

Main terminals:

- Anode: positive terminal.
- Cathode: negative terminal.

Current flows from anode to cathode when the diode is forward-biased.



Ideal Diode Approximation

In the ideal approximation, the diode behaves as:

Forward bias

- The diode behaves like a closed switch.
- Current can flow.
- Ideally, $V_D = 0$.

Reverse bias

- The diode behaves like an open switch.
- Current does not flow.
- Ideally, $I_D = 0$.

Important: the ideal model is useful for initial analysis, but real diodes require a forward voltage drop V_D.

Practical Diode Approximation

A practical silicon diode usually requires a forward voltage of approximately:

$$V_D \approx 0.7 \text{ V}$$

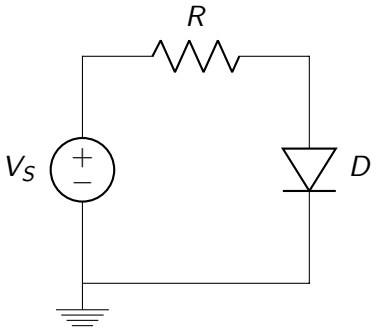
Therefore, for a conducting silicon diode:

$$V_S = V_R + V_D$$

If V_S is not large enough to overcome the diode forward voltage(V_D), the current is very small.

Basic Diode-Resistor Circuit

The simplest circuit for studying a diode uses a DC source, a resistor R, and the diode in series D.



Kirchhoff's Voltage Law

For the diode-resistor circuit:

$$V_S = V_R + V_D$$

Since the resistor voltage is:

$$V_R = I_D R$$

then:

$$V_S = I_D R + V_D$$

Therefore, the diode current can be estimated as:

$$I_D = \frac{V_S - V_D}{R}$$

This equation is valid when the diode is forward-biased and conducting.

Example Calculation

Consider:

$$V_S = 5 \text{ V}, \qquad R = 1 \text{ k}\Omega, \qquad V_D = 0.7 \text{ V}$$

The current is:

$$I_D = \frac{5 - 0.7}{1000}$$

$$I_D = 4.3 \text{ mA}$$

Interpretation: most of the source voltage appears across the resistor, while the diode maintains an approximately constant forward voltage.

Diode Polarization Curve

The diode polarization curve describes the relationship between diode voltage and diode current.

The measured variables are:

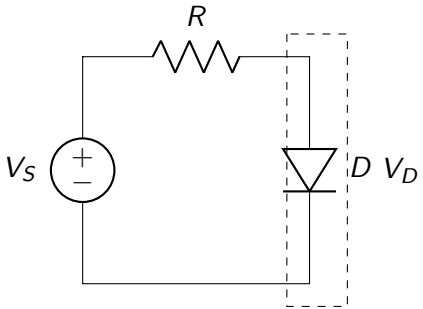
$$V_D \quad \text{and} \quad I_D$$

The typical curve has three regions:

1. Reverse bias region.
2. Low-current forward region.
3. Forward conduction region.

Experimental Circuit for Measuring the Curve

A series resistor is required to limit the diode current.



The current can be calculated using:

$$I_D = \frac{V_R}{R}$$

Measurement Procedure

1. Connect the diode in series with a resistor.
2. Start with a low value of V_S.
3. Increase V_S gradually.
4. Measure the voltage across the diode, V_D.
5. Measure the voltage across the resistor, V_R.
6. Calculate the diode current using:
$$I_D = \frac{V_R}{R}$$
7. Fill the measurement table.
8. Plot I_D versus V_D.

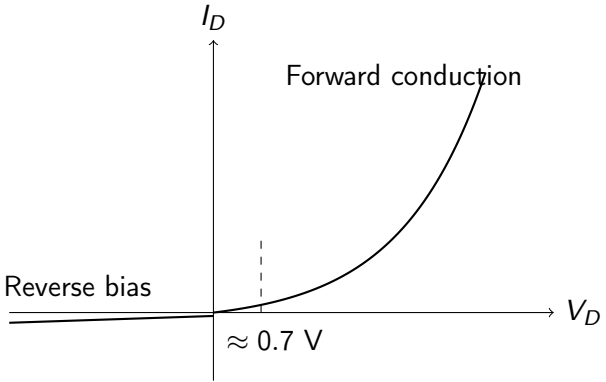
Measurement Table

Example table for a silicon diode using $R = 1$ kΩ.

V_S [V]	V_D [V]	V_R [V]	$I_D = V_R/R$ [mA]
0.0	0.00	0.00	0.00
0.2	0.20	0.00	0.00
0.4	0.38	0.02	0.02
0.6	0.55	0.05	0.05
0.8	0.65	0.15	0.15
1.0	0.68	0.32	0.32
2.0	0.72	1.28	1.28
3.0	0.74	2.26	2.26
5.0	0.76	4.24	4.24

The values are illustrative. Students should replace them with experimental measurements.

Expected Shape of the Diode Curve



The current increases rapidly once the diode enters the forward conduction region.

What Is Rectification?

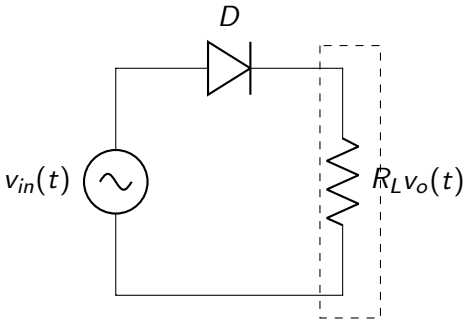
Rectification is the process of converting an alternating voltage into a single-polarity voltage.

A diode can be used as a rectifier because it conducts mainly in one direction.

The simplest rectifier circuit is the:

Half-wave rectifier

Half-Wave Rectifier Circuit



During the positive half-cycle, the diode conducts.
During the negative half-cycle, the diode blocks the current.

Half-Wave Rectifier Operation

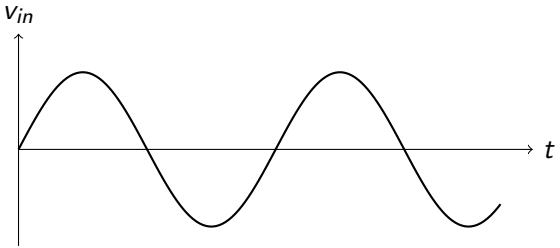
Positive half-cycle:

- The diode is forward-biased.
- Current flows through the load resistor.
- The output voltage follows the positive part of the input.

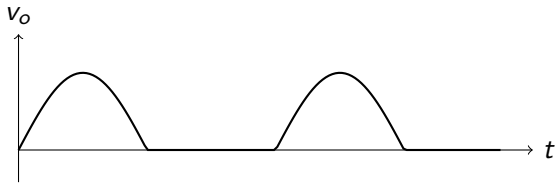
Negative half-cycle:

- The diode is reverse-biased.
- Current is approximately zero.
- The output voltage is approximately zero.

Input and Output Waveforms



Input sinusoidal voltage



Half-wave rectified output

Practical Consideration: Diode Voltage Drop

For a real silicon diode, the output voltage is not exactly equal to the input voltage.

When the diode conducts:

$$v_o(t) \approx v_{in}(t) - V_D$$

where:

$$V_D \approx 0.7 \text{ V}$$

Therefore, the peak output voltage is approximately:

$$V_{o,peak} \approx V_{in,peak} - 0.7$$

Activity 1: Diode Polarization Curve

Objective:
Build the diode-resistor circuit and obtain the experimental polarization curve.

Required material:

- 1 silicon diode, for example 1N4001 or 1N4148.
- 1 resistor of 1 kΩ.
- DC power supply.
- Digital multimeter.
- Breadboard and wires.

Activity 1: Student Tasks

Students must:

1. Assemble the diode-resistor circuit.
2. Vary the source voltage.
3. Measure V_D and V_R.
4. Calculate I_D.
5. Complete the measurement table.
6. Plot I_D versus V_D.
7. Identify the approximate conduction voltage.

Activity 2: Half-Wave Rectifier

Objective:
Observe the rectification effect of a diode using a sinusoidal input signal.

Required material:

- 1 silicon diode.
- 1 load resistor.
- Function generator.
- Oscilloscope.
- Breadboard and wires.

Suggested input signal:

$$v_{in}(t): \quad 5\ V_{pp}, \quad 1\ kHz$$

Activity 2: Student Tasks

Students must:

1. Assemble the half-wave rectifier circuit.
2. Apply a sinusoidal input signal.
3. Measure the input voltage with the oscilloscope.
4. Measure the output voltage across the load resistor.
5. Compare input and output waveforms.
6. Explain why the negative half-cycle disappears.
7. Estimate the effect of the diode voltage drop.

Day 1 Summary

In this session, we studied:

- The diode as a unidirectional semiconductor device.
- Forward and reverse bias.
- Kirchhoff's Voltage Law applied to a diode-resistor circuit.
- Measurement of the diode polarization curve.
- The operation of a basic half-wave rectifier.

Main idea:
The diode is a nonlinear device whose behavior depends strongly on its polarization condition.

Questions for Discussion

1. Why is a resistor required when measuring the diode polarization curve?
2. What happens if the diode is connected in reverse bias?
3. Why does the diode current increase rapidly after a certain voltage?
4. Why does a half-wave rectifier remove one half-cycle of the input signal?
5. How does the diode voltage drop affect the rectified output?

Homework / Report

Students should prepare a short report including:

1. Objective of the experiment.
2. Circuit diagrams.
3. Measurement table.
4. Plot of I_D versus V_D.
5. Oscilloscope evidence for the rectifier circuit.
6. Discussion of the diode voltage drop.
7. Conclusions.

Thank you

Questions?