characteristics of PN junction diode

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Abstract

In this particular experiment, we have two main goals. The first is to find the forward voltage V_f and measure the saturation current I_f.

1 AIM

1. To find the forward voltage V_f.
2. To measure the saturation current I_f.

2 APPRATUS

1. diode (1N4148)
2. Resistor (1k Ω and 100 Ω)
3. breadboard
4. picoscope
5. And other basic electronic components.

3 THREORY:

1. Ideal Diode Characteristics
   An **ideal diode** behaves as follows:

   - **Forward Bias**: Conducts current freely when forward biased ($V > 0$). No voltage drop is assumed in the ideal case.
   - **Reverse Bias**: Blocks current completely when reverse biased ($V < 0$).

   Graphically:

   - For $V > 0$: $I \to \infty$ (or large)
   - For $V < 0$: $I = 0$

2. Real Diode Characteristics (Practical Diode)

A real diode deviates from the ideal case due to physical limitations.

Forward Bias Region

A **threshold voltage (cut-in voltage)** must be reached before significant current flows.

- Silicon diode: approximately $0.7\,\mathrm{V}$
- Germanium diode: approximately $0.3\,\mathrm{V}$

After the threshold, current increases **exponentially** with voltage.
Shockley Diode Equation:

$$I = I_s \left(e^{\frac{qV}{nkt}} - 1 \right)$$

Where:

- I: diode current
- I_s: reverse saturation current (very small, typically nanoamperes)
- V: voltage across the diode
- V_T: thermal voltage (approximately $26\,\mathrm{mV}$ at room temperature)
- n: ideality factor (typically between 1 and 2)

Reverse Bias Region

- A small **reverse saturation current** I_s flows due to minority carriers.
- If the reverse voltage increases too much, the diode may undergo **breakdown** (Zener or avalanche), and current increases rapidly.

3. Breakdown Region

- For **Zener diodes**, this region is used intentionally for voltage regulation.
- Breakdown does not destroy the diode if the current is properly limited.

4. Summary of I-V Characteristics

- **Forward region**: Exponential rise in current after threshold voltage.
- **Reverse region**: Almost zero current until breakdown.
- **Breakdown region**: Sharp rise in reverse current.

4 RESULTS

4.1 graphs

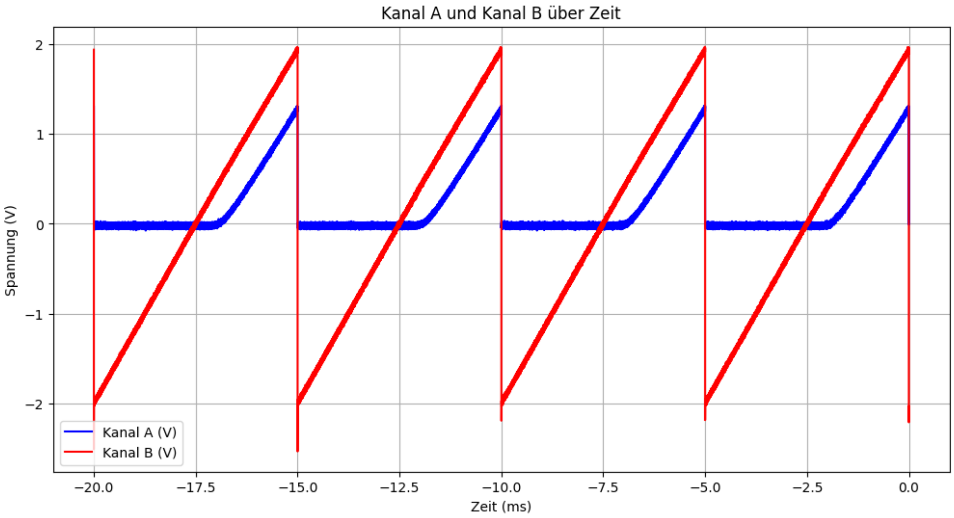


Figure 1: Graph of first 3000 data points taken from the picoscope.

Picoscope results:
the following screenshots are taken from the picoscope at different resistor values.

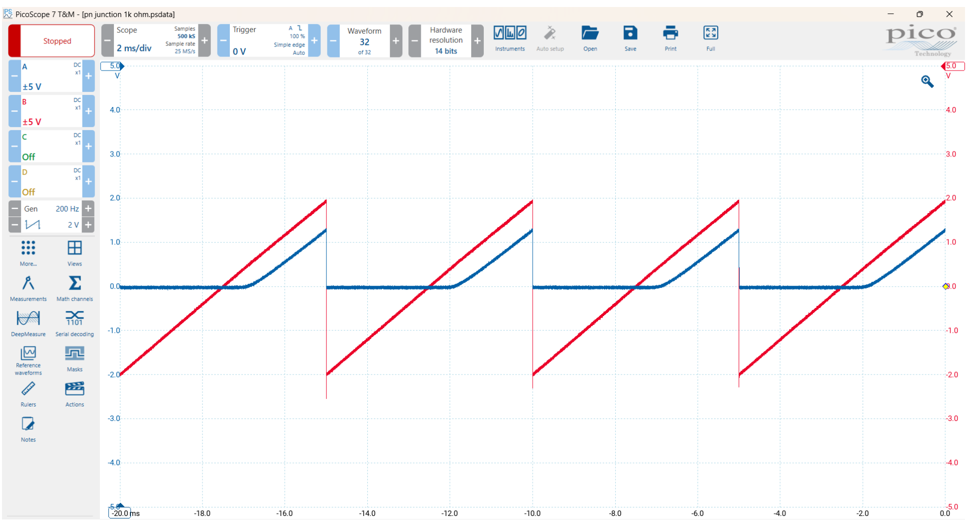


Figure 2: Graph of 1k ohm resistor.

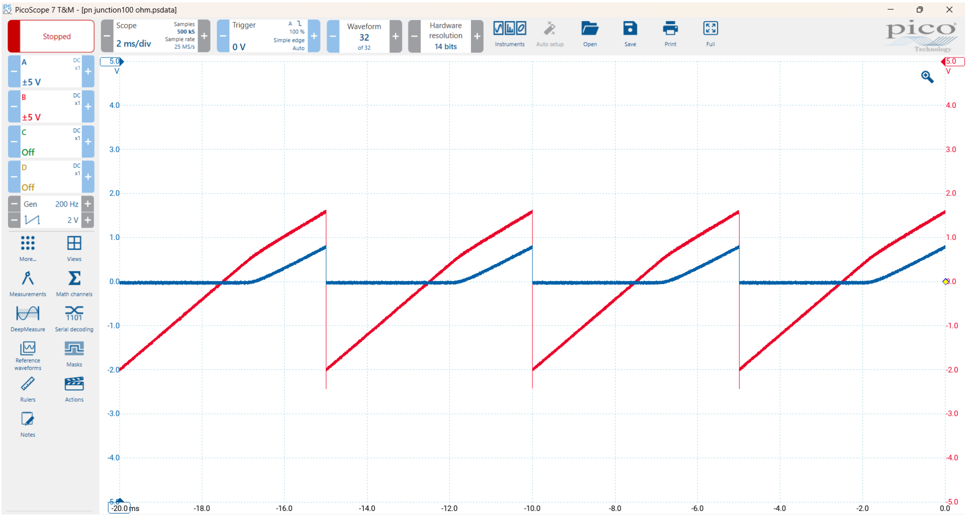


Figure 3: Graph of 100 ohm resistor.

4.2 Calculation

1.

$$V_Tot = V_D + V_R$$

here:
V_D is the voltage across the diode
V_R is the voltage across the resistor.

2. For saturation Current I_f

$$I = I_s \left(e^{\frac{qV}{nkt}} - 1 \right)$$

where
I is the current through the diode
I_s is the saturation current
V is the voltage across the diode
q is the charge of an electron
n is the ideality factor
k is the Boltzmann constant
t is the temperature in Kelvin

To find the saturation current I_s we can rearrange the equation to get

$$I_s = \frac{I}{e^{\frac{qV}{nkt}} - 1}$$

From the 5 we can see that thee V_f is around 0.6V.
from ohm law we can find the current through the diode.
which is around 0.6V/100 ohm = 0.006A
Now we can plug in the values to find the saturation current.

$$I_s = \frac{0.006}{e^{\frac{1.6*10^{-19}*0.6}{1*1.38*10^{-23}*300}} - 1}$$

$$I_s = \frac{0.006}{e^{\frac{9.6*10^{-20}}{4.14*10^{-21}}} - 1}$$

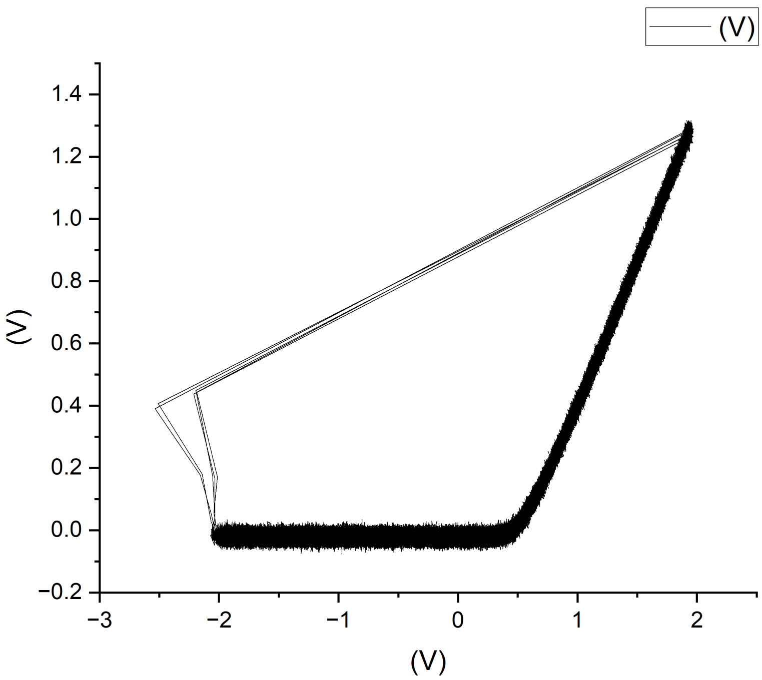
$$I_s = \frac{0.006}{e^{23.2} - 1}$$

$$I_s = \frac{0.006}{9.8 * 10^{10} - 1}$$

$$I_s = 6.12 * 10^{-14} A$$

5 Conclusion

1. The forward voltage V_f is approximately 0.6V .



2. The saturation current I_f is I_s=$6.12 * 10^{-14}$
3. We can also see from 2 and 3 that there is a drop in voltage when the resistance is decreased. This is because decreasing the resistance increases the current flow, hence the drop in the graph.
4. Here is the graph of diode voltage and diode current.

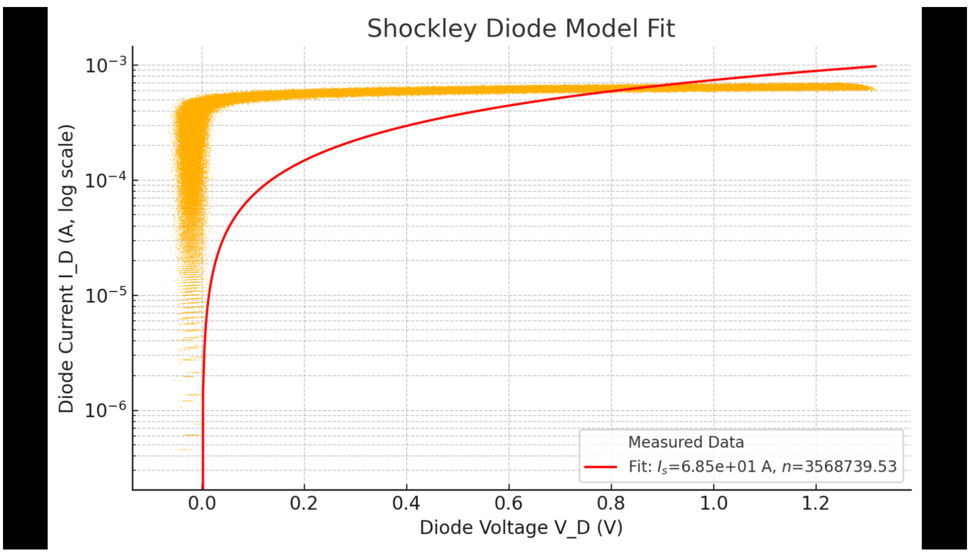


Figure 4: IV curve of the diode.

NOTE: THESE GRAPHS CONTAIN 3000 DATA POINTS AS THERE ARE MORE THAN 500K DATA POINTS WHICH IS NOT POSSIBLE TO SHOW IN THE REPORT, AS IT TAKE A LOTS OF TIME TO PROCESS. HENCE I HAVE TAKEN THE FIRST 3000 DATA POINTS.