ELEC-237
ELECTRONICS LABORATORY-I

EXPERIMENT 3

Junction Diode Basics

Prepared By:
Selen Erdoğan - 1901022038
Berk Hakan Öge - 200102002005

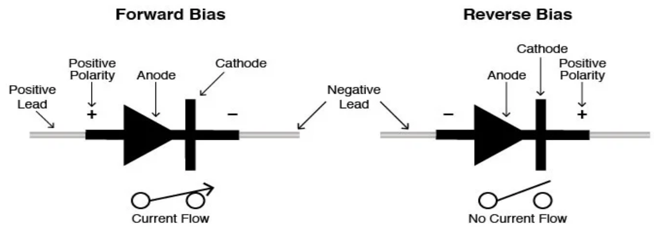


Figure 1

What is the Diode?

Diodes can be used as **rectifiers, signal limiters, voltage regulators, switches, signal modulators, signal mixers, signal demodulators, and oscillators**. The fundamental property of a diode is its tendency to conduct electric current in only one direction.

1.1 Ideal Rectification:

One of the most common uses for the diode is to rectify the AC voltage into a DC power supply. Since, a diode can only conduct current one way, when the input signal goes negative, there will be no current.

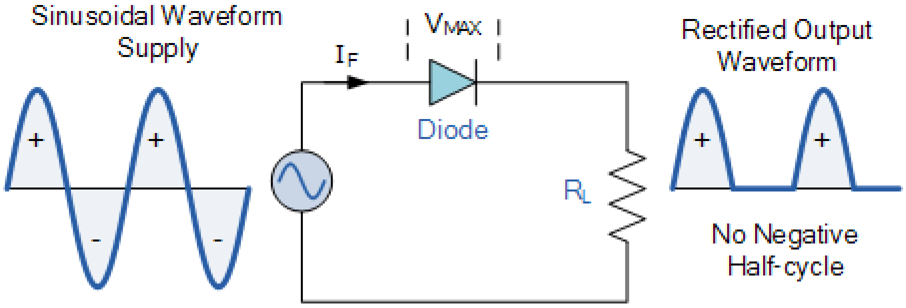
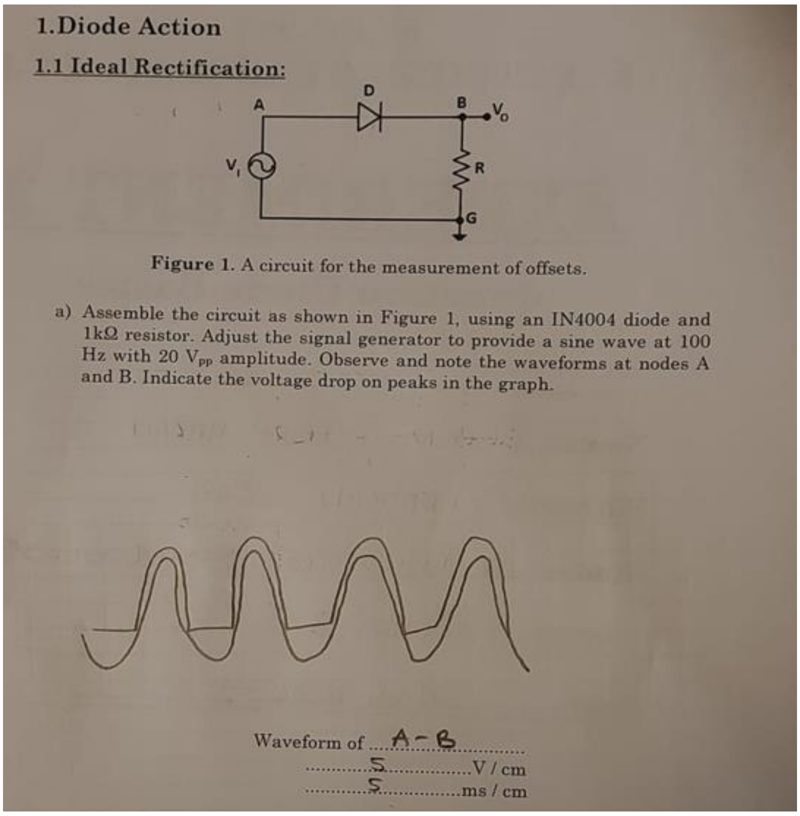


Figure 2



1.Diode Action

1.1 Ideal Rectification:

Figure 1. A circuit for the measurement of offsets.

a) Assemble the circuit as shown in Figure 1, using an IN4004 diode and 1kΩ resistor. Adjust the signal generator to provide a sine wave at 100 Hz with 20 V_{pp} amplitude. Observe and note the waveforms at nodes A and B. Indicate the voltage drop on peaks in the graph.

Waveform of A-B

5 V / cm

5 ms / cm

This is called a half-wave rectifier.

According to the theoretical information written above and the circuit observed and drawn during the experiment, it has been observed that the diode is to rectify the AC voltage to a DC power source. Since a diode can only conduct current one way, there will be no current when the input signal is negative. In this part of the experiment, it has been observed that the diode is a half-wave rectifier.

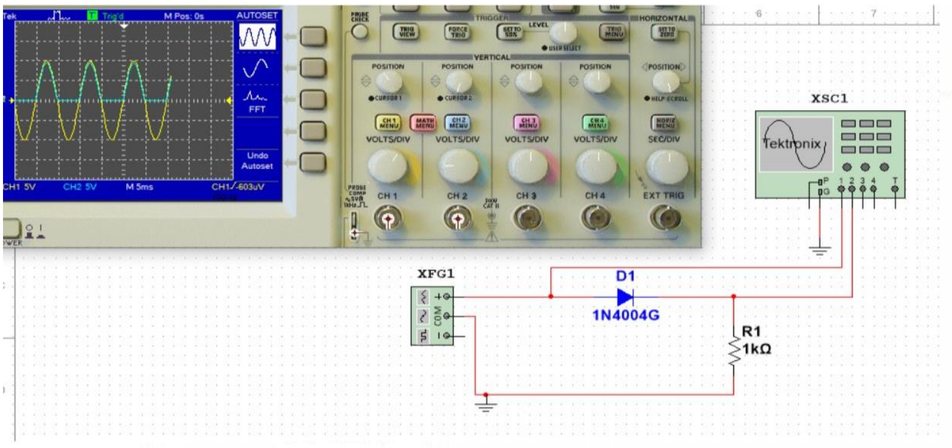
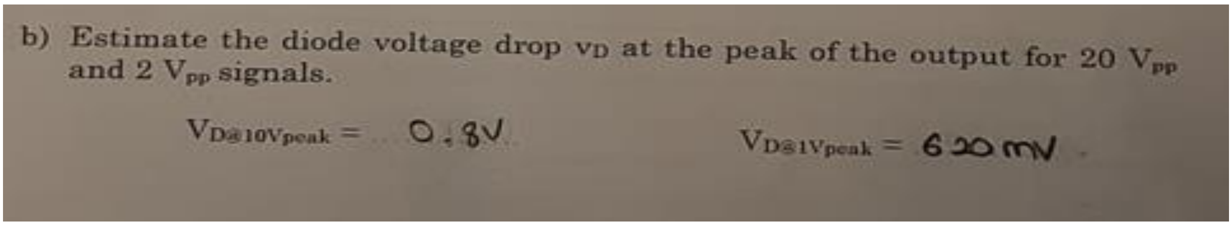


Figure 3 multisim

➔ When we tried the same circuit in the electronic environment, we observed that we got the same waveforms. Thus, we observed that we analyzed this part of the experiment correctly.



b) Estimate the diode voltage drop v_D at the peak of the output for 20 V_{pp} and 2 V_{pp} signals.

$V_{D@10Vpeak}$ = 0.8V $V_{D@1Vpeak}$ = 620 mV

Figure 4 experiment results

The result obtained from the experiment in the electronic environment:

Vd 10Vpeak = 0.63V
Vd 1Vpeak = 476mV

It has been observed that the results are the same in the experimental environment and in the electronic environment.

We examined the relationship between vA and vB near where vB starts to become positive. We estimated the time the output voltage was ½ of the peak diode drop. We noted your measurements in Table 1.

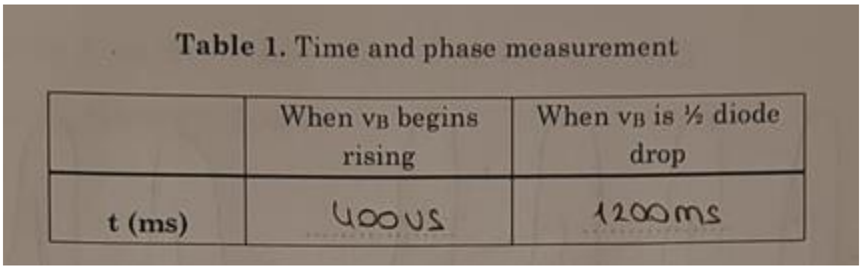


Table 1. Time and phase measurement

	When v_B begins rising	When v_B is ½ diode drop
t (ms)	400us	1200ms

Figure 5 experiment results

The results obtained with the circuit established in the MULTISIM environment above are observed as follows.

When Vb begins rising: 140us
When Vb is ½ diode drop: 1.22ms

➔ When the two cases are examined, it is seen that the results are quite close to each other. This indicates that this part of the experiment went well. It can be said that the slight differences are due to the fact that the type of diode used in the experimental environment and the type of circuit established in the electronic environment are not the same.

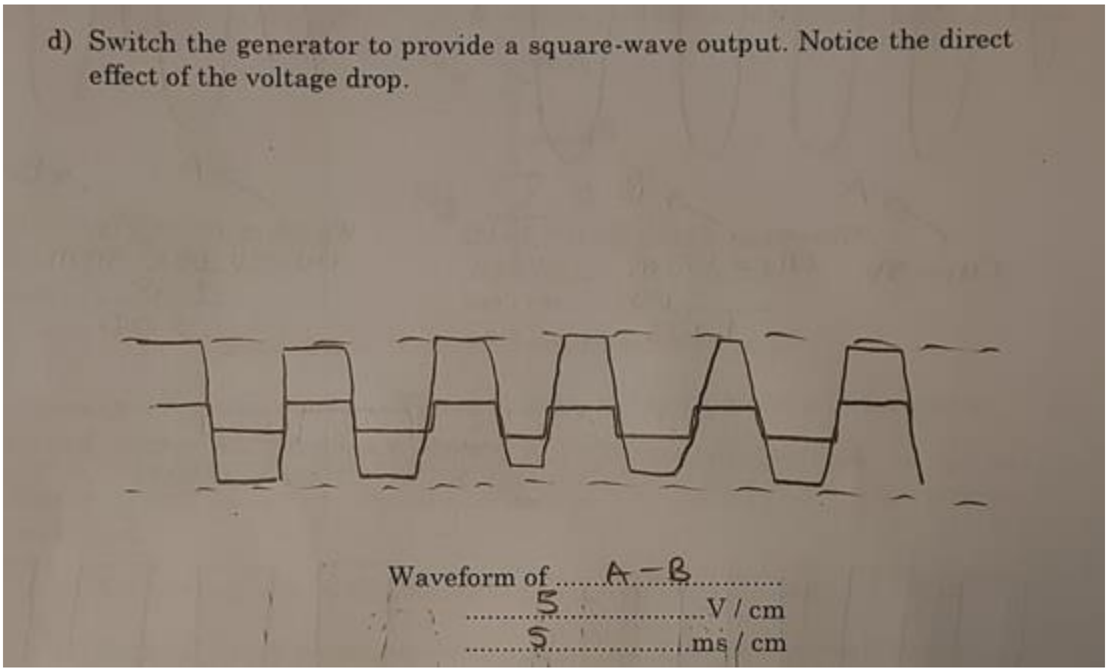


Figure 6 experiment results

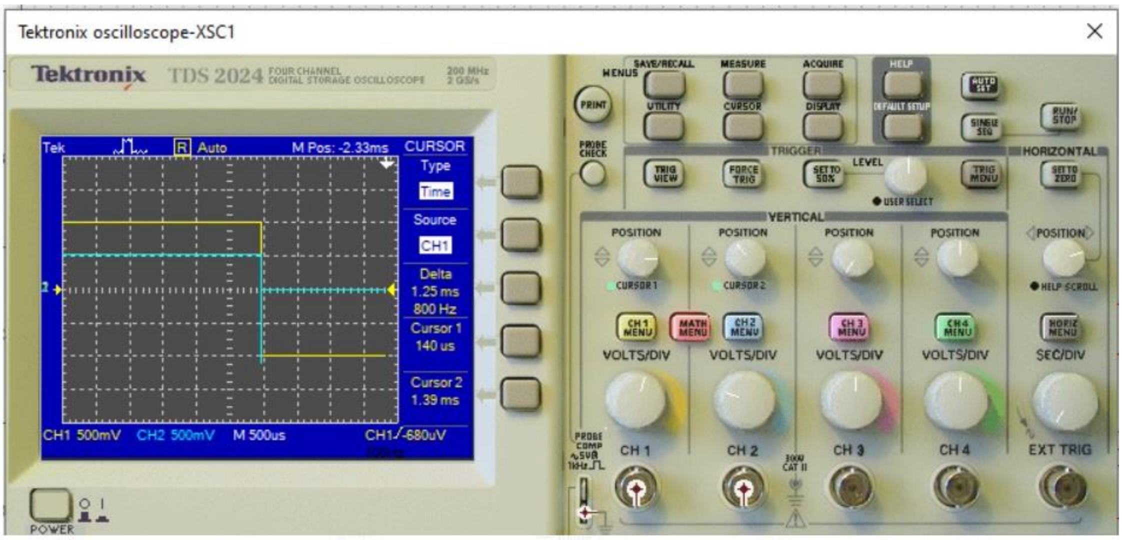


Figure 7 multisim results

➔ We modified the generator to provide a square wave output. Attention had to be paid to the direct effect of the voltage drop. It is observed that we receive the same waveforms, only the oscilloscope settings are different.

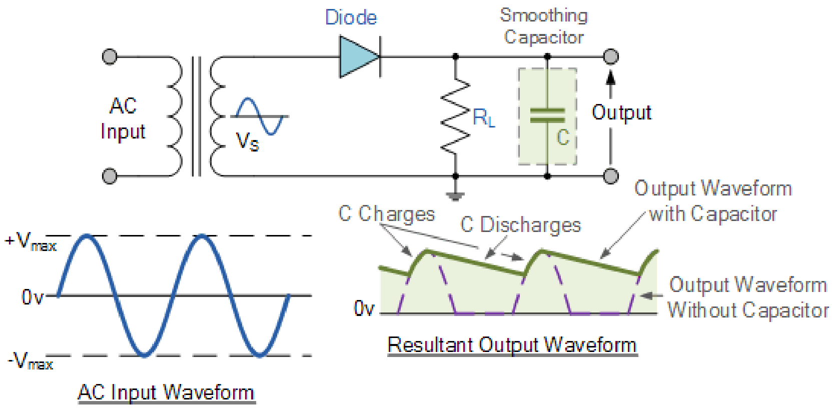


Figure 8

1.2 Rectifier Filtering

A rectifier is a special type of diode that converts alternating current (AC) into direct current (DC). This is an important process, as alternating current is able to reverse direction periodically, while direct current consistently flows in a single direction, making it simple to control.

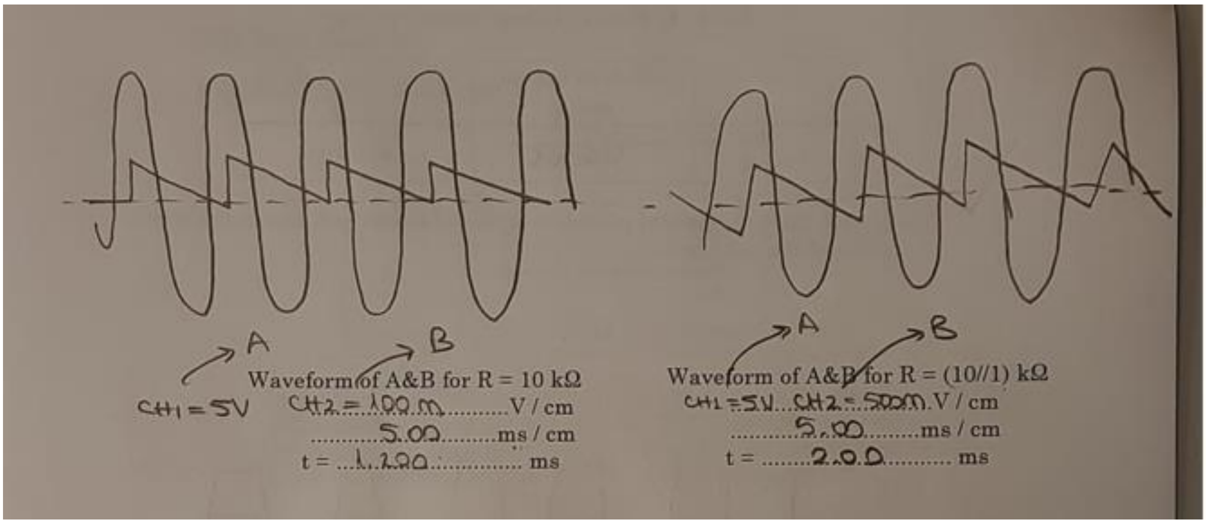


Figure 9 experiment results

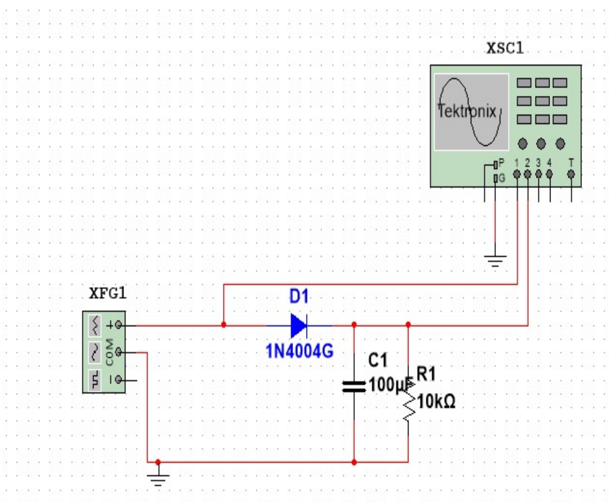


Figure 10 circuit in multisim

➔Here, the rectifier, that is, the diode model that converts alternating current to direct current, is examined. The effect of the diode on the capacitor has been studied from the east. The wave outputs that occur when there is a capacitor and when there is no capacitor match exactly with the circuit established in the electronic environment and the results we obtained during the experiment.The same situation is observed when a 1k resistor is connected to a 10k resistor.

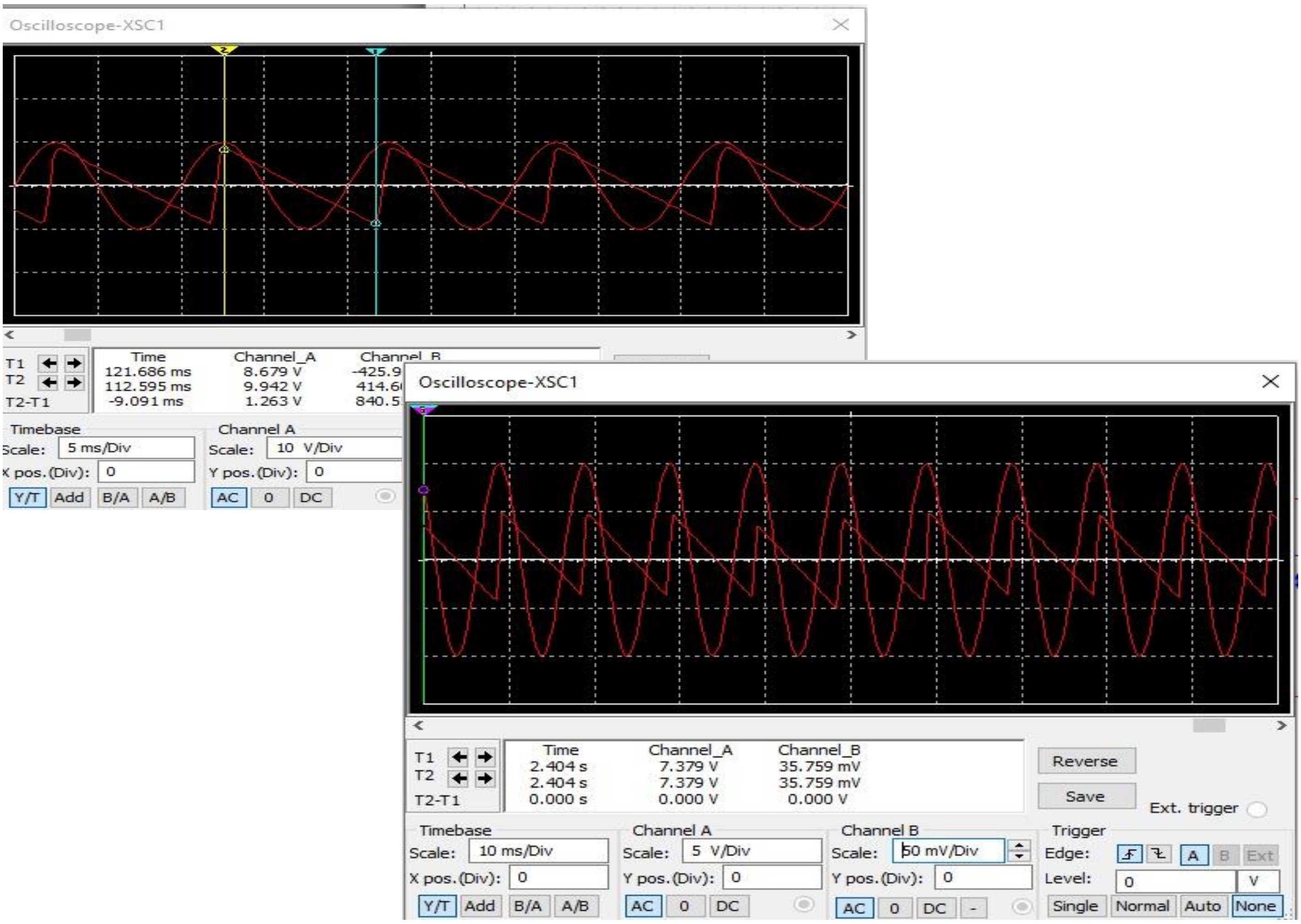
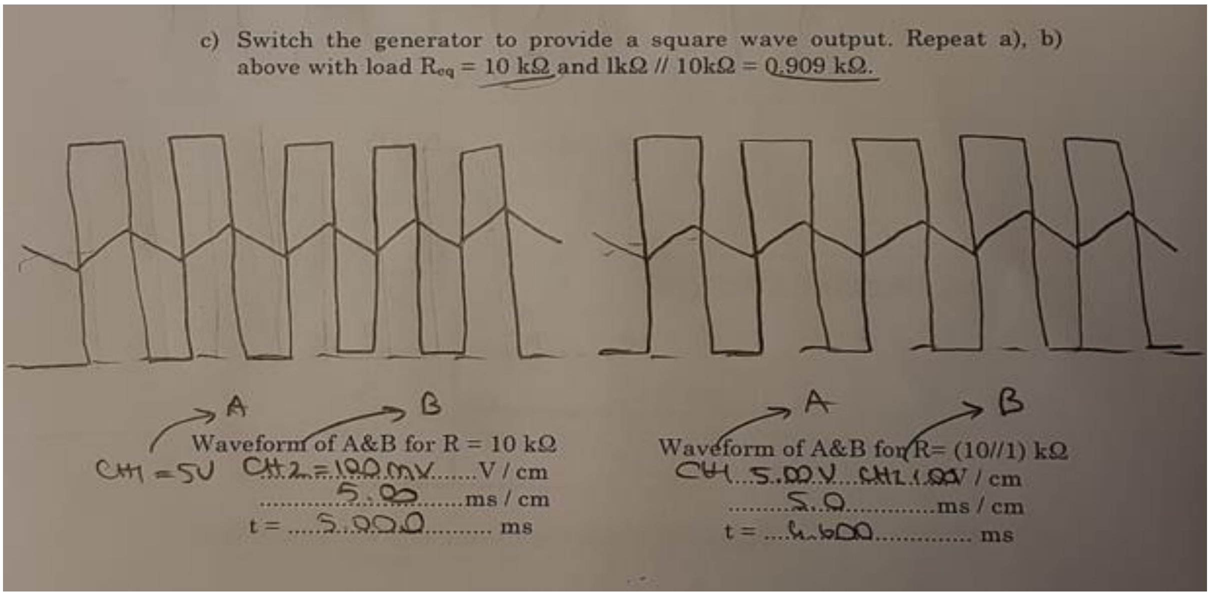


Figure 11 waveforms

We modified the
generator to provide a square wave output.



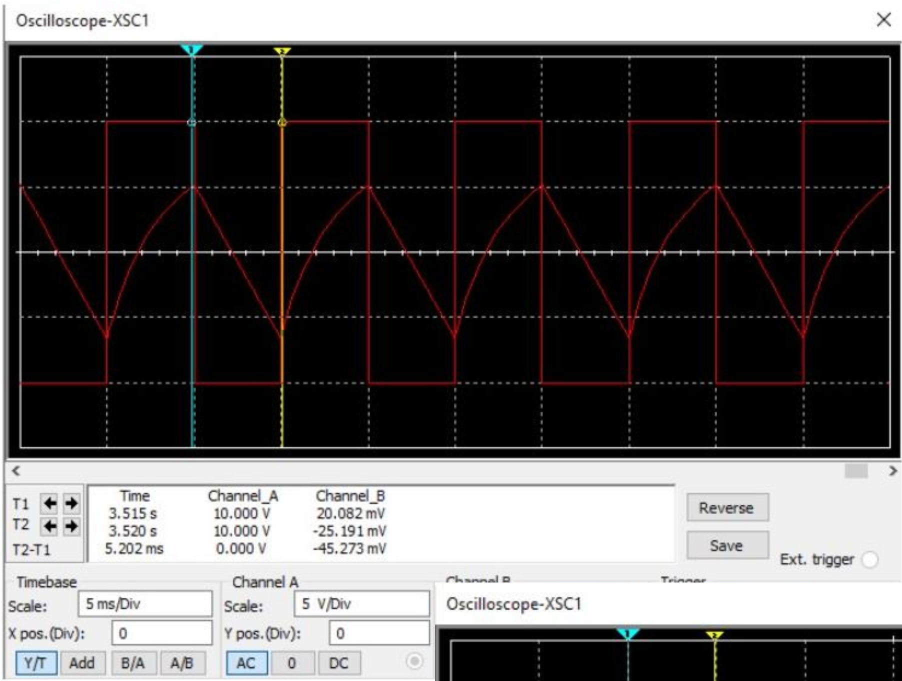
c) Switch the generator to provide a square wave output. Repeat a), b) above with load R_{eq} = 10 kΩ and 1kΩ // 10kΩ = 0.909 kΩ.

A B

Waveform of A&B for R = 10 kΩ
CH1 = 5V CH2 = 100 mV......V / cm
5.00 ......ms / cm
t = ...5.000......... ms

A B

Waveform of A&B for R= (10//1) kΩ
CH1 5.00V CH2 1.00V / cm
.........5.0............ms / cm
t = ...4.600.............. ms



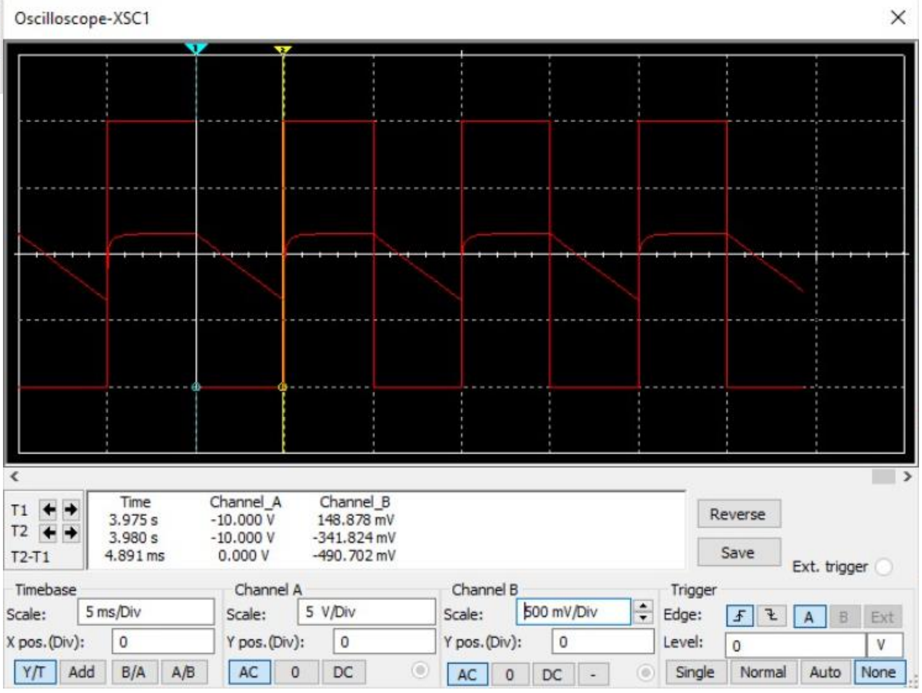


Figure 12 waveforms

- ➔ In the square wave output, we have observed the logic of operation with and without capacitors, which is suitable for the purpose of the diode. When the results obtained in the experimental environment and the results obtained in the electronic environment are compared, it has been observed that the situations are quite similar.

2. Diode Conduction- The Forward Drop

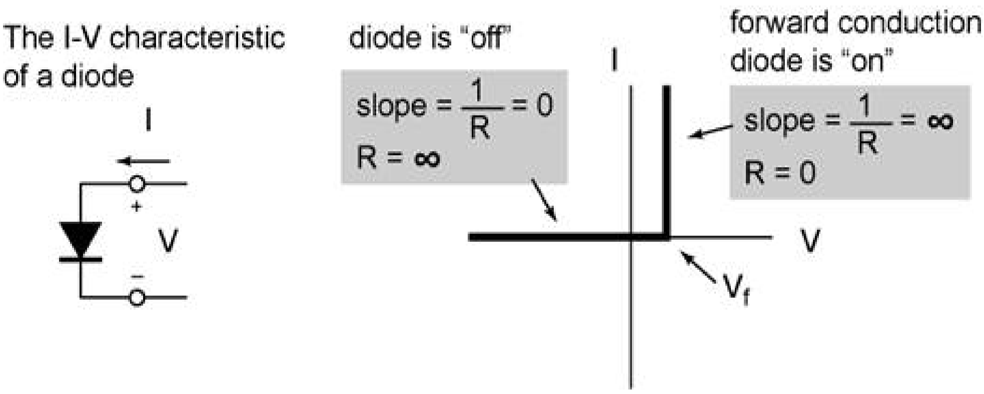
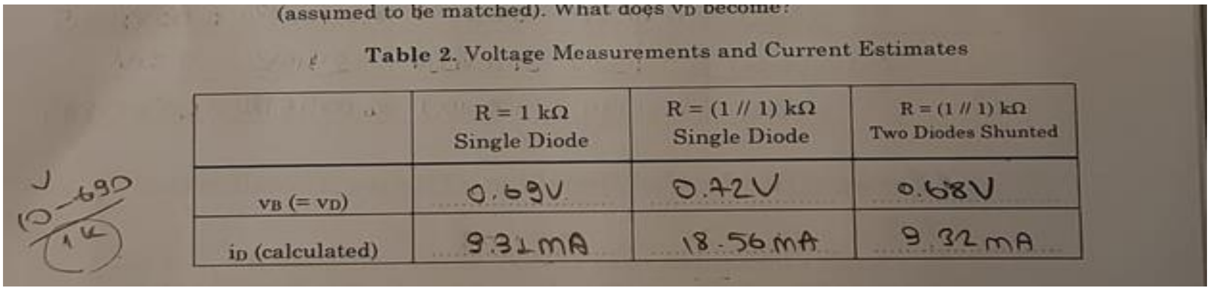


Figure 13

When the diode is in forward conduction, the voltage drop across the diode is constant. The forward voltage drop is an intrinsic property of the semiconductor material used to make the pn junction and is related to the band gap. Thus Vf is the same for all silicon diodes.



(assumed to be matched). What does v_D become?

Table 2. Voltage Measurements and Current Estimates

	R = 1 kΩ Single Diode	R = (1 // 1) kΩ Single Diode	R = (1 // 1) kΩ Two Diodes Shunted
v_B (= v_D)	0.69V	0.42V	0.68V
i_D (calculated)	9.31mA	18.56mA	9.32mA

Figure 14 experiment results

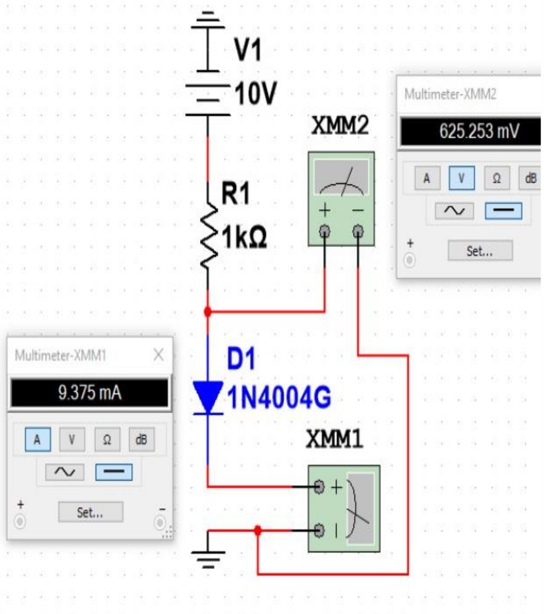


Figure 15 circuit in multisim

	Single Diode	(1//1) Single Diode	(1//1) Two Diodes Shunted
Va = Vd	625.253 mV	661.274mV	625.253mV
id-simulation results	9.375 mA	18.677mA	18.749mA

➔ When the diode is forward conducting, the voltage drop across the diode is constant. This is an intrinsic property of the material and is related to the band gap. We have observed that all of the Vd voltages resulting from this situation are the same both in the experimental environment and in the electronic environment. That is, the voltage Vd remained unchanged in parallel connection or double diode situations.

We used four widely-ranging values for the resistor R. These values are: 1 kΩ, 10 kΩ, 100 kΩ and l MΩ and an IN4004 diode.
we grounded the cathode of the diode to be tested and connected all four resistors to the anode, each one open at one end and to which the 10 V supply will be connected in sequence. For a supply voltage of 10 V, we measured VD as each resistor is connected to the source in turn. We tried to determine the corresponding current by calculation. We tried the same conditions for the other diode.

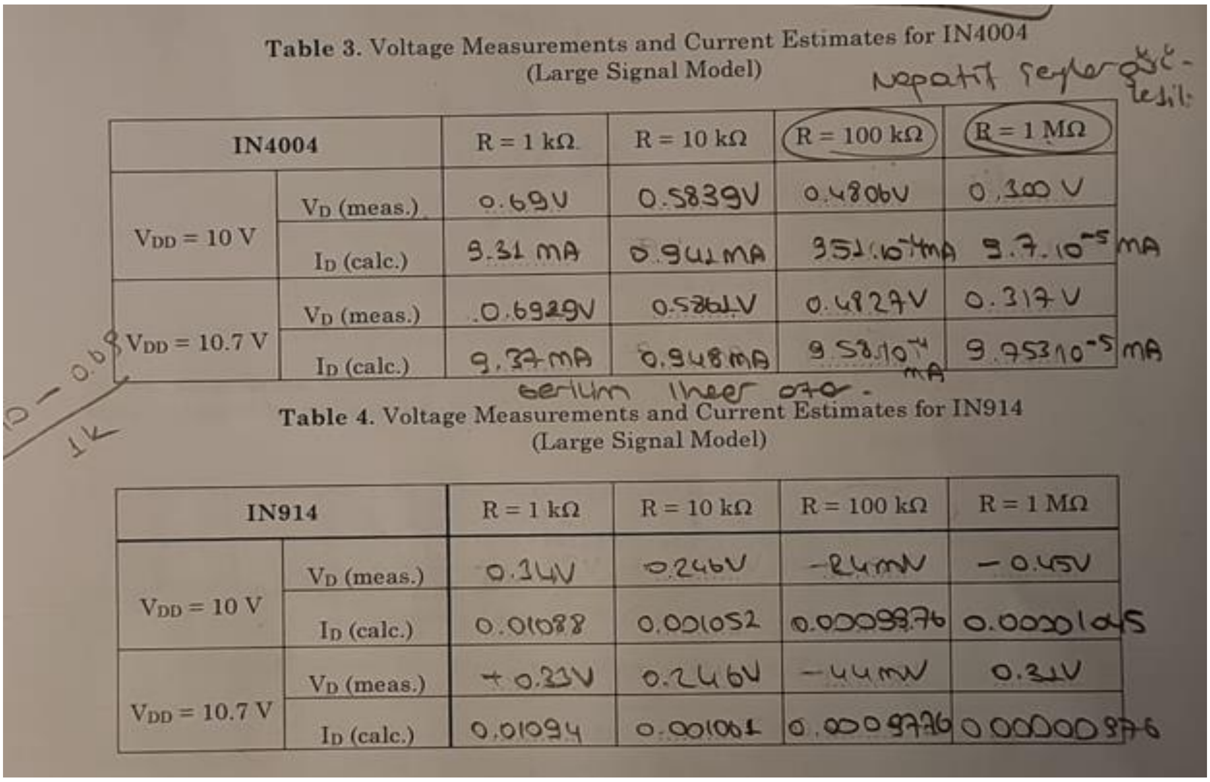


Table 3. Voltage Measurements and Current Estimates for IN4004 (Large Signal Model)

IN4004		R = 1 kΩ	R = 10 kΩ	R = 100 kΩ	R = 1 MΩ
V_{DD} = 10 V	V_D (meas.)	0.69V	0.5839V	0.4806V	0.300 V
	I_D (calc.)	9.31 mA	0.941 mA	351.10^{-4} mA	$9.7.10^{-5}$ mA
V_{DD} = 10.7 V	V_D (meas.)	0.6929V	0.5861V	0.4827V	0.317 V
	I_D (calc.)	9.37 mA	0.948 mA	$9.58.10^{-4}$ mA	$9.953.10^{-5}$ mA

Table 4. Voltage Measurements and Current Estimates for IN914 (Large Signal Model)

IN914		R = 1 kΩ	R = 10 kΩ	R = 100 kΩ	R = 1 MΩ
V_{DD} = 10 V	V_D (meas.)	0.34V	0.246V	−24mV	−0.45V
	I_D (calc.)	0.01088	0.001052	0.0009876	0.0000105
V_{DD} = 10.7 V	V_D (meas.)	+0.33V	0.246V	−44mV	0.31V
	I_D (calc.)	0.01094	0.001061	0.0009776	0.00000976

Figure 16 experiment results

When calculating current:

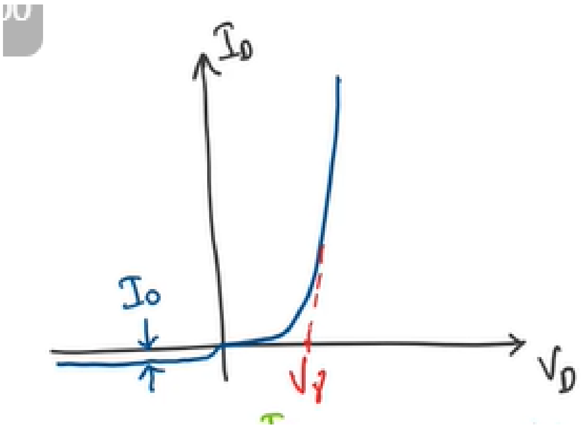
$$\frac{Vdd - Vd}{r}$$

		1k	10k	100k	1M
Vdd = 10 V	Vd	604.74mV	506.467mV	387.992mV	269.764mV
Vdd = 10 V	Id	932.851uA	949.353uA	96.12uA	9.73uA
Vdd = 10.7V	Vd	628.986mV	510.131mV	391.608mV	273.321mV
Vdd =10.7V	Id	10.071mA	1.019mA	103.084uA	10.426uA

Other diode (IN914):

		1k	10k	100k	1M
Vdd = 10 V	Vd	668.241mV	595.462mV	534.72mV	475.191mV
Vdd = 10 V	Id	9.332mA	940.453uA	94.652uA	9.524uA
Vdd = 10.7V	Vd	671.22mV	597.425mV	536.572mV	477.021mV
Vdd =10.7V	Id	10.029mA	1.01mA	101.634uA	10.223uA

We performed the experiments in two different environments and added the results as output above. When the results were compared, we saw that almost similar situations were reached. This shows us that the experiment went well. We tried the same situations for different diodes and tried to extract the graphical characteristic of a diode in a large signal state. In this case, the figure we get is as follows.



2.3 Small Signal Diode

Saying a model for an electronic component is a “small-signal” model means something very specific. In particular, we mean that the voltage drop across the component is only a small fraction above or below some desired operating voltage. Developing a small-signal model is all about approximating the voltage drop across the diode and the diode current using a derivative. The goal is to describe how the output (the diode current) changes when there is a small change in the input (the voltage drop).

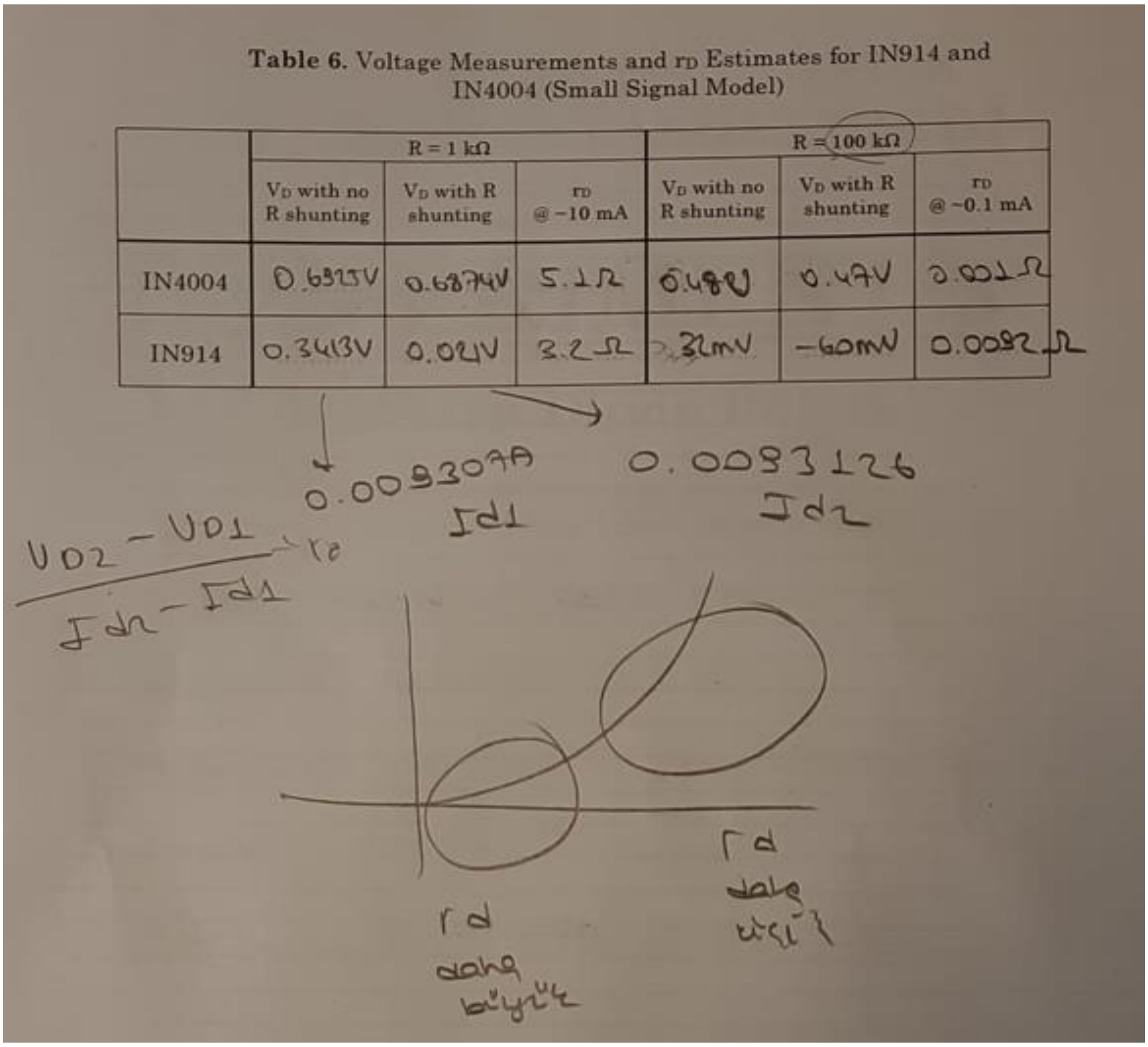


Table 6. Voltage Measurements and r_D Estimates for IN914 and IN4004 (Small Signal Model)

	R = 1 kΩ			R = 100 kΩ		
	V_D with no R shunting	V_D with R shunting	r_D @ ~10 mA	V_D with no R shunting	V_D with R shunting	r_D @ ~0.1 mA
IN4004	0.6925V	0.6874V	5.1Ω	0.48V	0.47V	0.001Ω
IN914	0.3413V	0.021V	3.2Ω	32mV	−60mV	0.0082Ω

Figure 17 experiment results

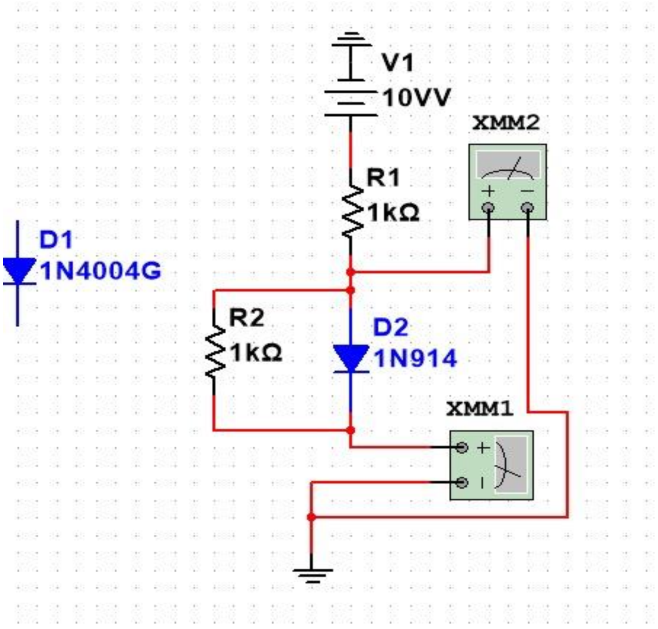


Figure 18 circuit in multisim

➔ This part of the experiment was also examined electronically and the results were obtained. It has been observed that the results are in accordance with the values we obtained. The change in Rd values was observed.

REFERENCES:

https://resources.pcb.cadence.com/blog/2020-small-signal-model-for-a-diode-in-dc-and-ac-circuits
https://www.youtube.com/watch?v=7iDSwixWESA
https://en.wikipedia.org/wiki/Large-signal_model
https://www.alborzelectronic.com/types-of-diodes-small-signal-led-schottky-zener-2/