GEBZE TECHNICAL UNIVERSITY

ELECTRONICS ENGINEERING DEPARTMENT

ELEC 237

EXPERIMENT – 3 REPORT

PREPARED BY

IREM CAN	1901022006
MERVE TUTAR	1901022050

INGREDIENTS

1. Introduction

Diode rectifier circuits are one of the key circuits used in electronic equipment. They can be used in switch mode power supplies and linear power supplies, RF signal demodulation, RF power sensing and very much more.

There are several different types of diode rectifier circuit, each with its own advantages and disadvantages. Decisions about which type of diode circuit to use depend upon the given situation.

Diode rectifier circuit basics

The key component in any rectifier circuit is naturally the diode or diodes used. These devices are unique in only allowing current through in one direction.

The semiconductor diode has a characteristic something like that shown below. In the forward direction, a small voltage is required across the diode before it conducts - this is known as the turn on voltage. The actual voltage depends on the type of diode rectifier and the material used. For a standard silicon diode rectifier this turn on voltage is around 0.6 volts. Germanium diodes have a turn on voltage of around 0.2 - 0.3V, and silicon Schottky diodes have a similar turn on voltage in the region of 0.2 - 0.3V

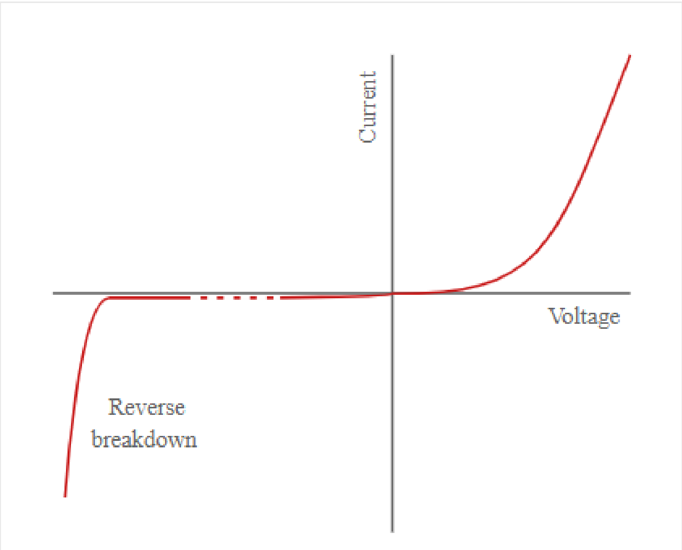


Figure 1. PN diode VI characteristic

In the reverse direction, the diode rectifier will ultimately break down. The breakdown voltage is normally well in excess of the turn on voltage - the scales on the diagram have been altered (compressed) in the reverse direction to illustrate that reverse breakdown occurs.

For power rectification applications, power diodes or Schottky diodes are normally used. For signal rectification small point contact diodes, signal diodes, or Schottky diodes may be used. The Schottky diode has the advantage that it only requires a forward voltage of around 0.2 - 0.3volts for forward conduction. This is particularly useful when detecting small radio signals, and when used as a power rectifier the power losses are reduced. However the reverse leakage characteristics are not as good as normal silicon diodes.

Diode symbol and packages

The diode circuit symbol is widely known. Diodes also come in a variety of packages, although some of the more usual formats are shown in the Figure 2.

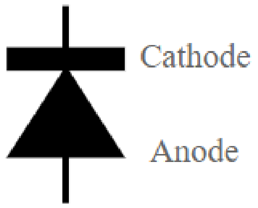


Figure 2. Diode circuit symbol

Diode rectifier action

The action of the diode is to allow current to flow in only one direction. Therefor is an alternating waveform is applied to a diode, then it will only allow conduction over half the waveform. The remaining half is blocked.

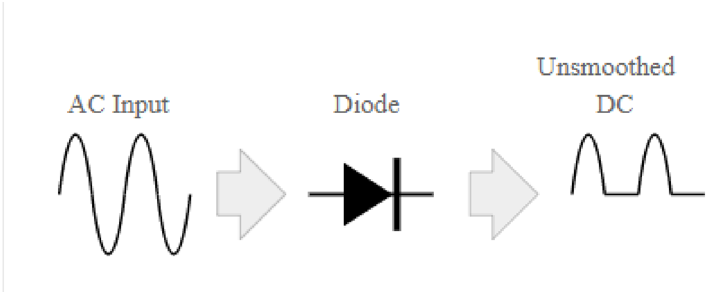


Figure 3. The rectifying action of a diode

Diode rectifier circuit configurations

There are a number of different configurations of diode rectifier circuit that can be used. These different configurations each have their own advantages and disadvantages, and are therefore applicable to different applications.

- ***Half wave rectifier circuit:*** This is the simplest form of rectifier. Often using only a single diode is blocks half the cycle and allows through the other. As such only half of the waveform is used.
- ***Full wave rectifier circuit:*** This form of rectifier circuit uses both halves of the waveform. This makes this form of rectifier more effective, and as there is conduction over both halves of the cycle, smoothing becomes much easier and more effective. There are two types of full ave rectifier.
- ***Bridge full rectifier circuit:*** This is a specific form of full wave rectifier that utilises four diodes in a bridge topology. Bridge rectifiers are widely used, especially for power rectification, and they can be obtained as a single component contain the four diodes connected in the bridge format.
- ***Synchronous rectifier circuit:*** Synchronous or active rectifiers use active elements instead of diodes to provide the switching. This overcomes the diode losses and significantly improves the efficiency levels.

2. Experiment

2.1. Diode Action

2.1.1. Ideal Rectification

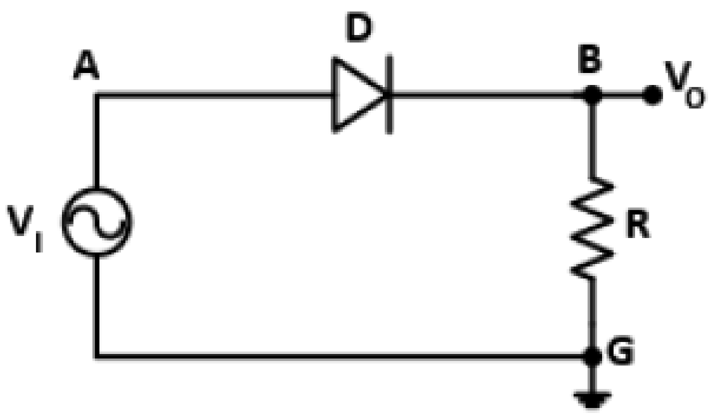


Figure 4. A circuit for the measurement of offsets

a) The circuit is assembled as shown in Figure 4 using an IN4004 diode and 1kΩ resistor. The signal generator is tuned to provide a sine wave at 100 Hz with 20 Vpp amplitude. Observing and noting the waveforms at A nodes and B. The graph shows the voltage drop at the peaks.

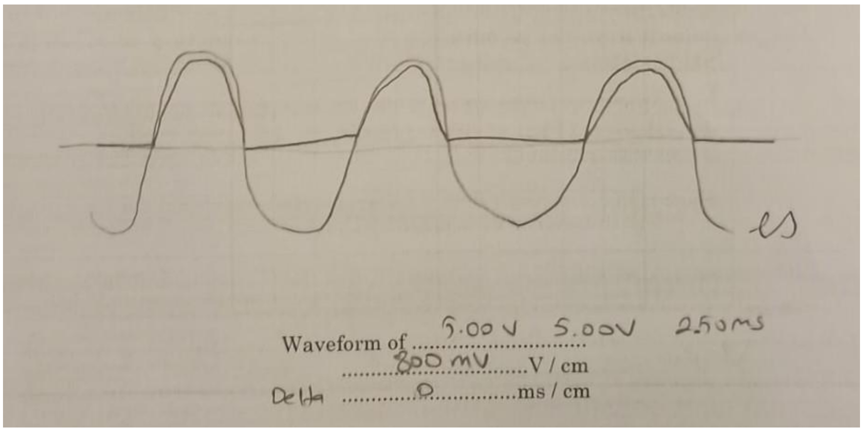


Figure 5. The sinusoidal waveform at nodes A and B

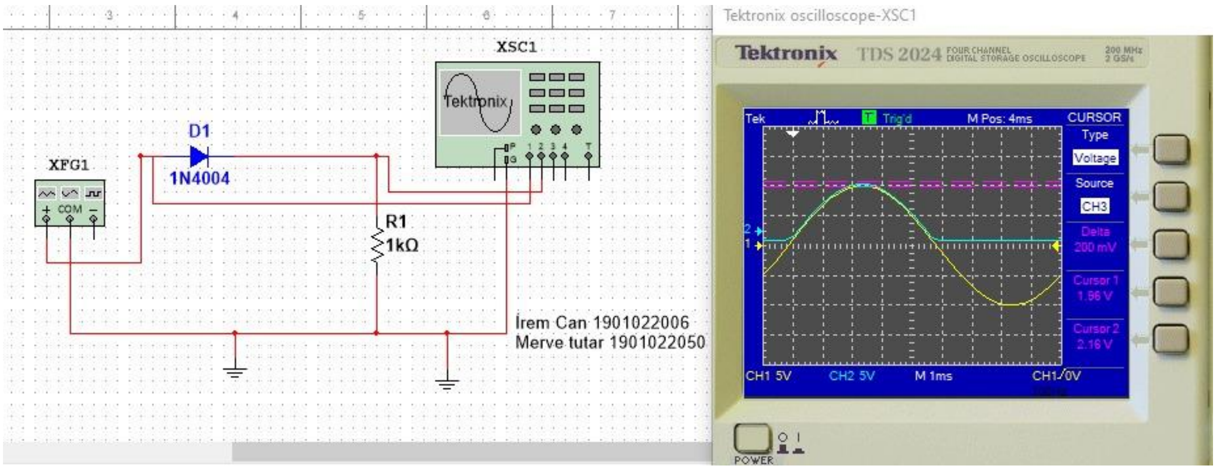


Figure 6. Simulation output the sinusoidal waveform at nodes A and B

b) The diode V_D voltage drop at the peak of the output is estimated for the 20 Vpp and 2 Vpp signals.

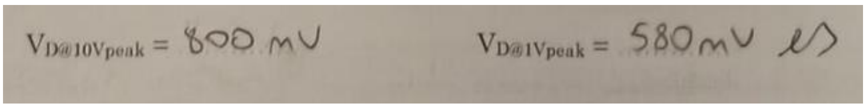


Figure 7. Measurement values

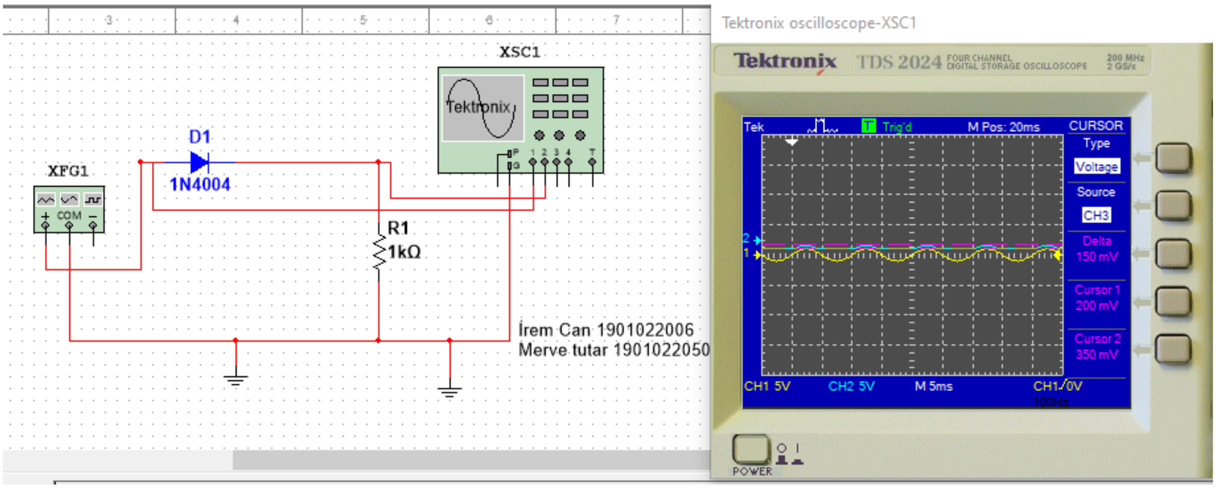


Figure 8. Simulation output

c) Examined the relationship between V_A and V_B near where V_B starts to go positive. By estimating the time that the output voltage is ½ of the diode decline at the peak. The measurements are noted in Table 1.

Table 1. Time and phase measurement

	When v_B begins rising	When v_B is ½ diode drop
t (ms)	1.20 us	1.200 ms

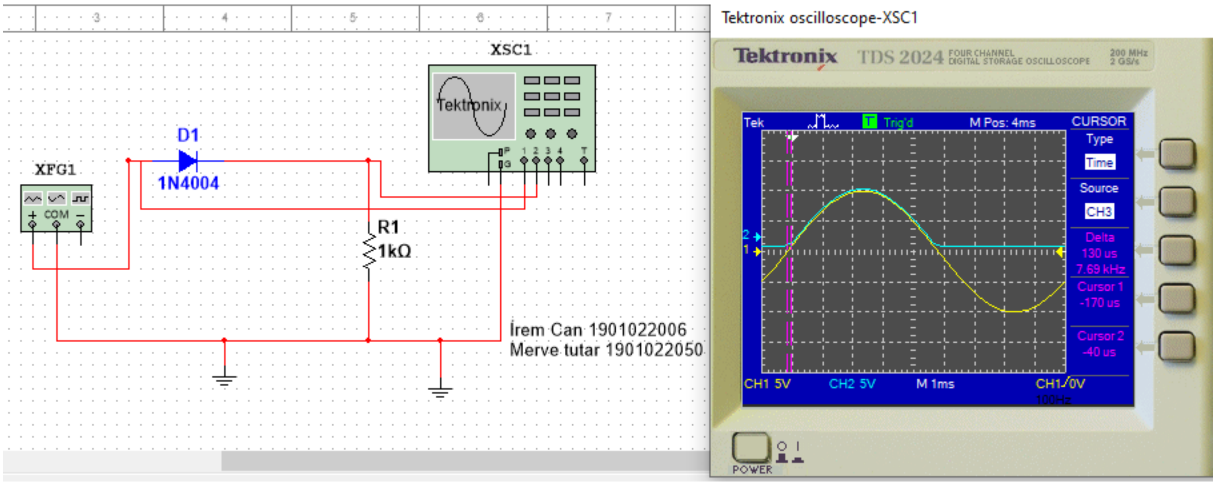


Figure 9. Simulation output when V_B begin rising

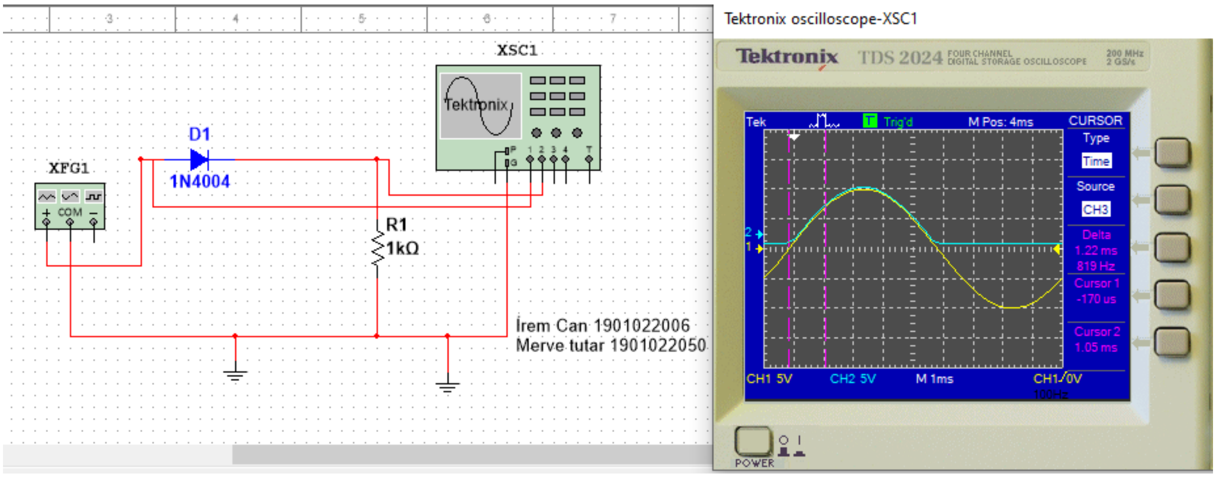


Figure 10. Simulation output when V_B is ½ diode drop

Table 2. Time and phase measurement in Multsim

	When V_B begins rising	When V_B is ½ diode drop
t (ms)	130 µs	1.22 ms

d) The generator was modified to provide a square wave output. Direct attention was paid effect of voltage drop.

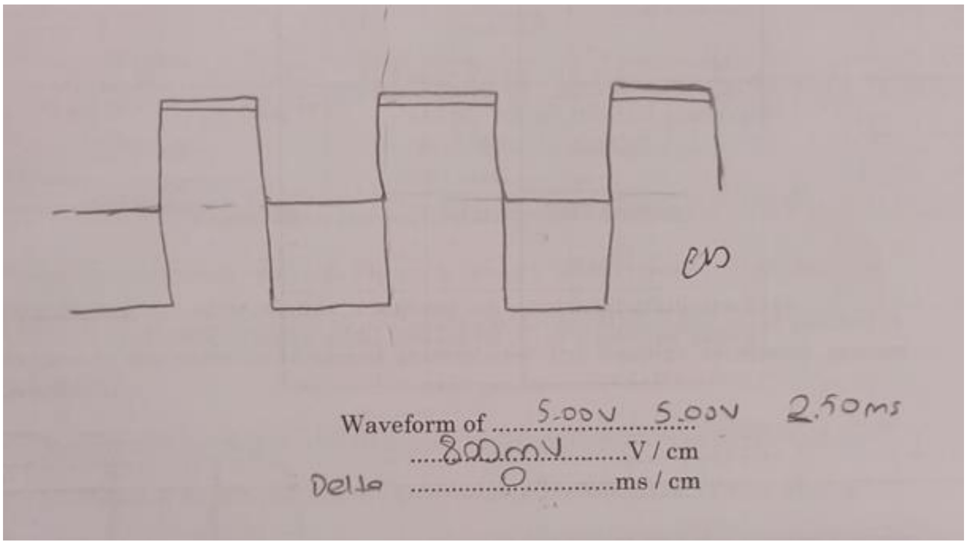


Figure 11. The square waveform at nodes A and B

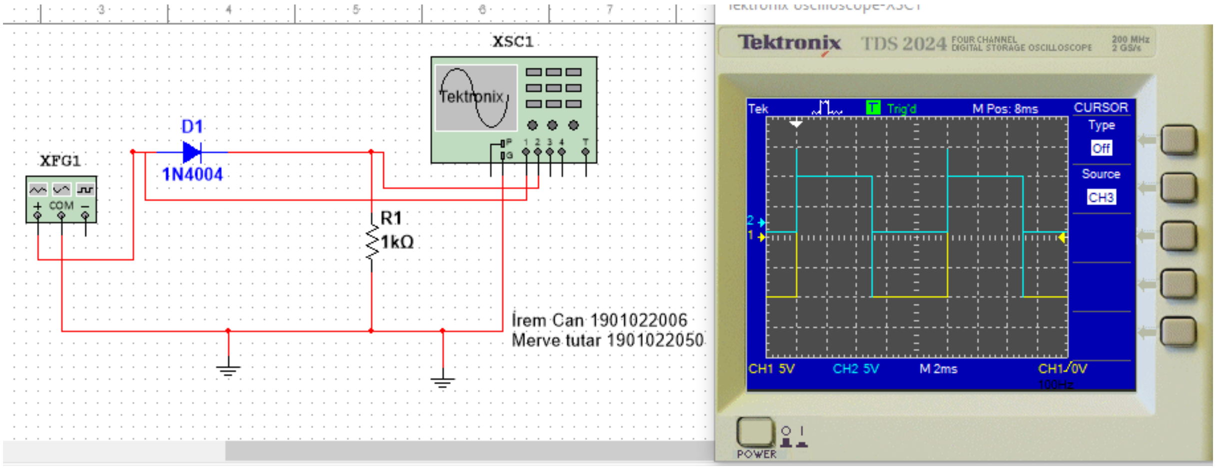


Figure 12. Simulation output the square waveform at nodes A and B

2.1.2. Rectifier Filtering

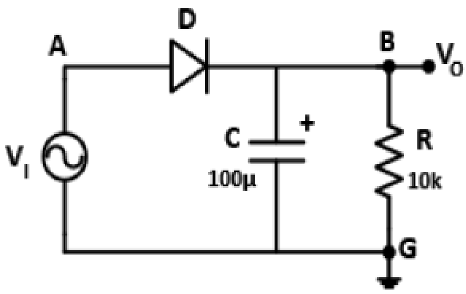


Figure 13. A Rectifier Circuit with Capacitor Filter

a) Using an IN4004 diode, the circuit is assembled as shown in Figure 13. Tuned the signal generator to provide a sine wave at 20 Vpp at 100 Hz amplitude. Observe and note the waveforms at nodes A and B. voltage drop at the peaks in the graph. estimated time interval for where the diode is forward conducting.

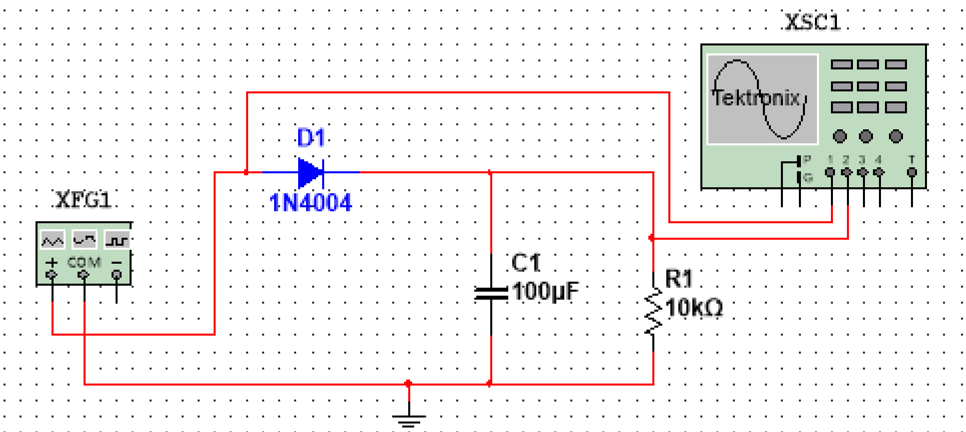


Figure 14. A Rectifier Circuit with Capacitor Filter in Multisim

b) R_L is shunted with a resistor $R_2 = 1\ k\Omega$. Measured V_A and V_B as in a).

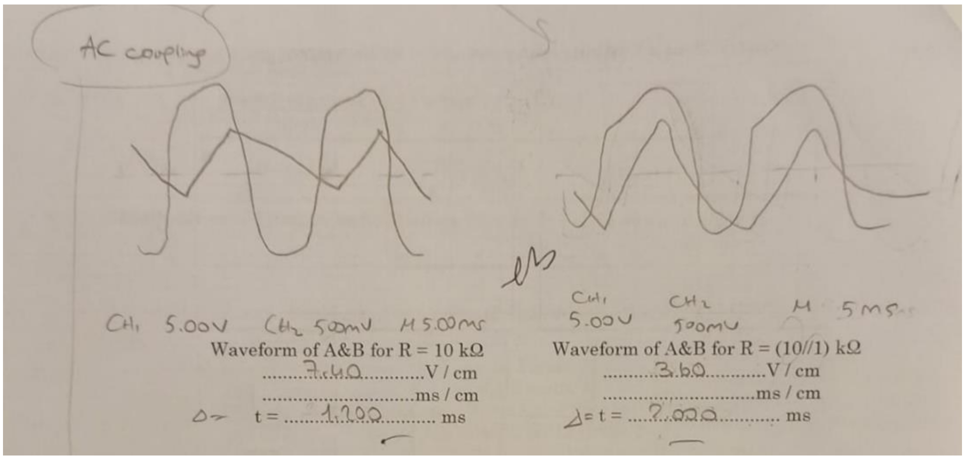


Figure 15. When R_2 = 0 and 1 kΩ measuring V_A and V_B

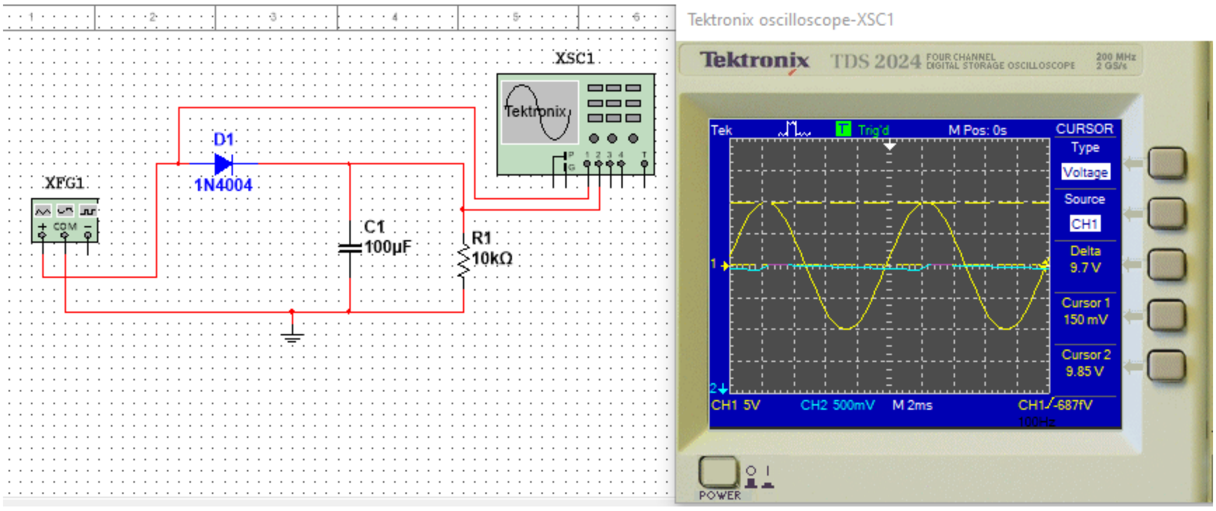


Figure 16. When R_2 = 0 measuring V_A and V_B in Multisim

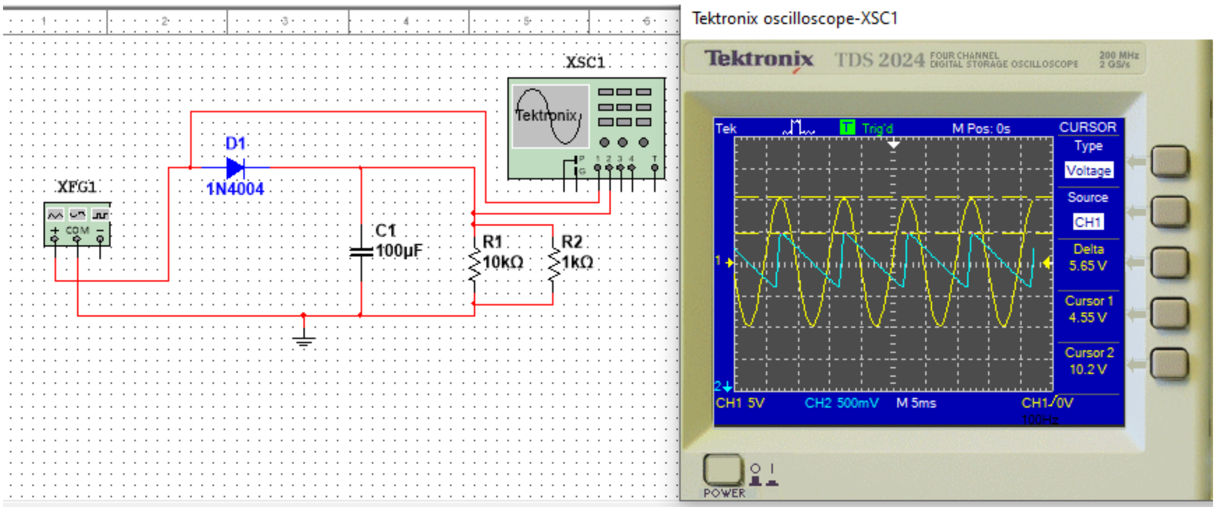


Figure 17. When R_2 = 1 kΩ measuring V_A and V_B in Multisim

c) The generator has been modified to provide a square wave output. **a), b)** repeated with the above load Req = 10 kΩ and lkΩ // 10kΩ = 0.909 kΩ.

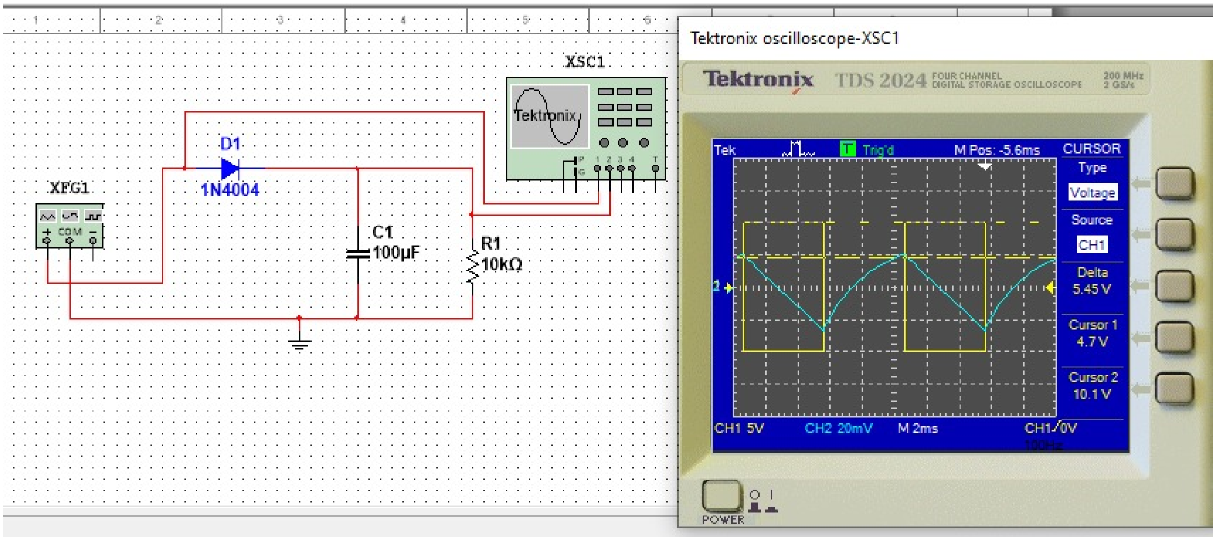


Figure 18. When $R_2 = 0$ measuring V_A and V_B in Multisim

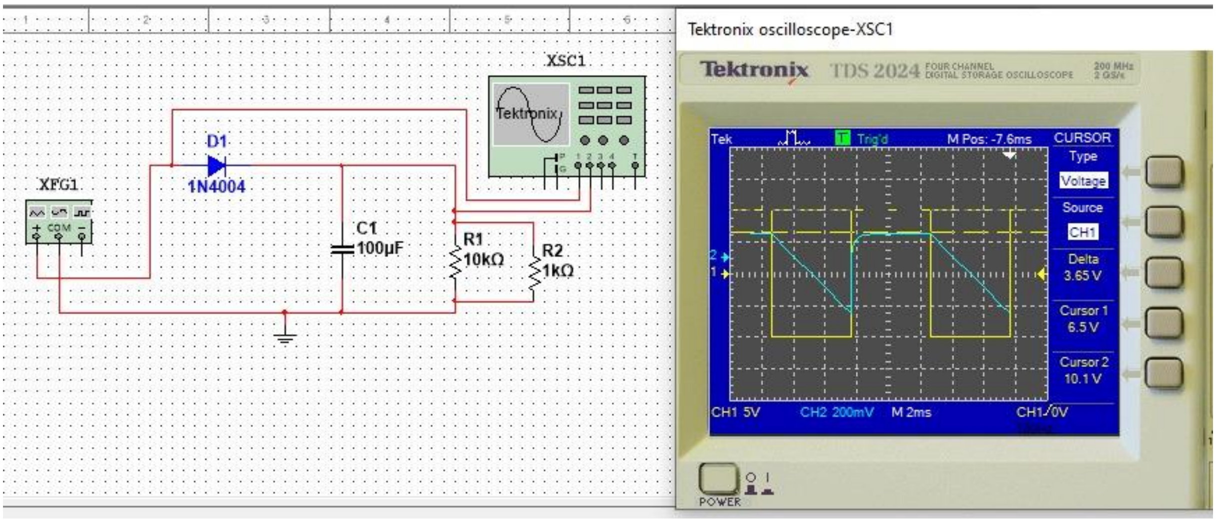


Figure 19. When $R_2 = 1$ kΩ measuring V_A and V_B in Multisim

2.2 Diode Conduction –The Forward Drop

2.2.1 Basic Measurement

Using the IN4004 diode, a 1 kΩ resistor, and a 10 V supply, the circuit shown in Figure 3 was assembled.

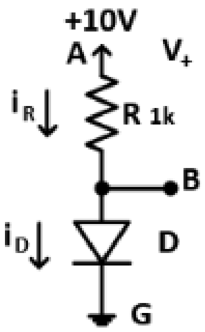


Figure 20. A Diode Forward-Drop Test Circuit

a) Measured V_B. The supply is set to 10.0V. (for convenience). i_D found.

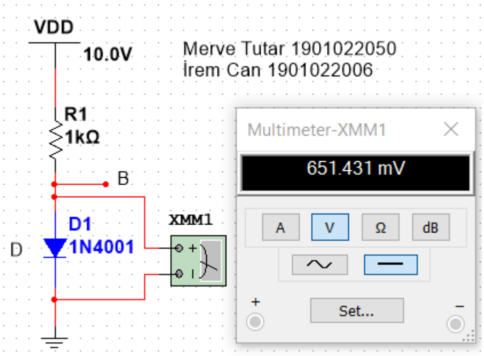


Figure 21. Simulation output for 10V supply

V_B=V_D=0.651 V $İ_D$=$İ_R$=((10-0.651)/1k)=9.349 mA

b) Shunted R with a 1 kΩ resistor. vB=vD measured. Found i_D.

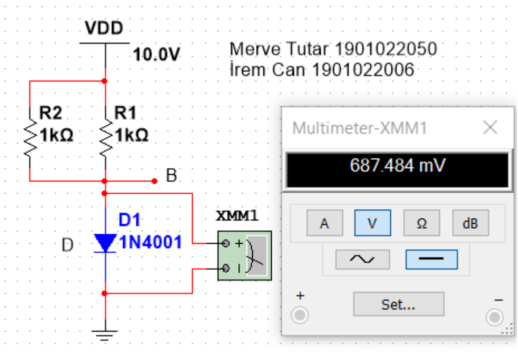


Figure 22. Simulation output for R=(1//1) kΩ

V_B=V_D=0.687 V $İ_D$=$İ_R$=((10-0.687)/1k)=9.313 mA

c) With two 1 kΩ resistors connected, a second diode IN4004 was shunted D .

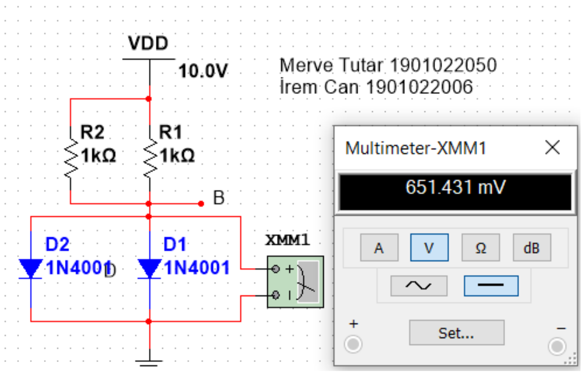


Figure 23. R = (1 // 1) kΩ Two Diodes Shunted

V_B=V_D=0.651 V $İ_D$=$İ_R$=((10-0.651)/1k)=9.349 mA

The voltage and current are the same in the initial state of the circuit and in the case of adding a parallel resistor and diode.

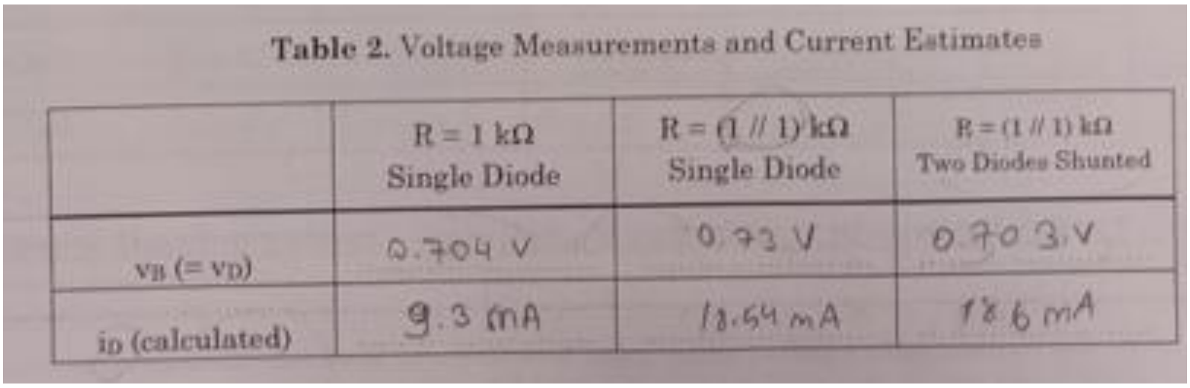


Table 2. Voltage Measurements and Current Estimates

	R = 1 kΩ Single Diode	R = (1 // 1) kΩ Single Diode	R = (1 // 1) kΩ Two Diodes Shunted
v_B (= v_D)	0.704 V	0.73 V	0.703 V
i_D (calculated)	9.3 mA	13.64 mA	18.6 mA

Figure 24. Experimental Results for Current and Voltage

Table 3. 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)	0.651 V	0.687 V	0.651 V
$İ_D$ (calculated)	9.349 mA	9.313 mA	9.349 mA

2.2.2 Forward Conduction Modelling –Finding a Large Signal Model:

a) Returning to the circuit in Figure 20, but using four widely-ranging values for R, namely 1 kΩ, 10 kΩ, 100 kΩ and l MΩ and an IN4004 diode. Experimentally, the cathode of the diode to be tested was grounded and connected all four resistors to the anode, each with one end open and 10 V supply connected in sequence.

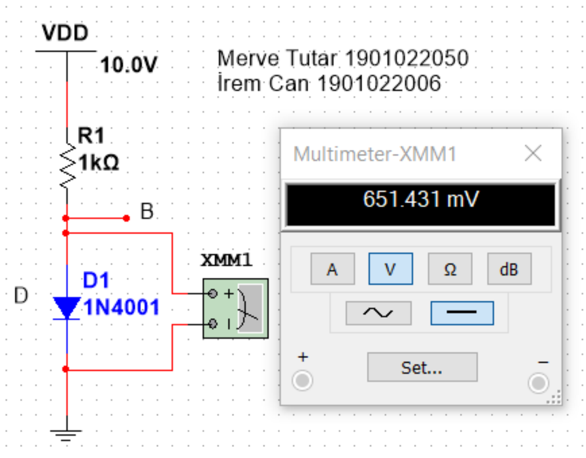


Figure 25. Simulation output for R = 1 kΩ

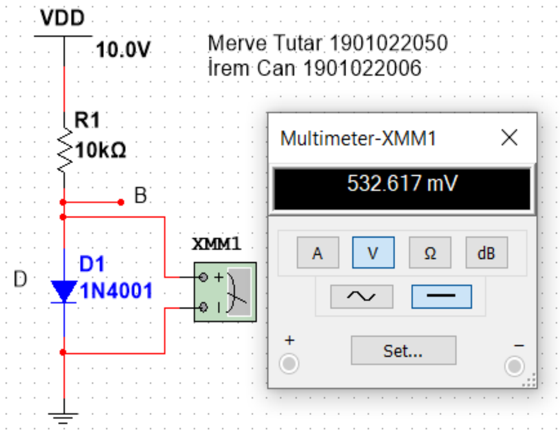


Figure 26. Simulation output for R = 10 kΩ

V_D=0.651 V $İ_D$ =((10-0.651)/1k)=9.349 mA

V_D=0.532 V $İ_D$=((10-0.532)/10k)=0.95 mA

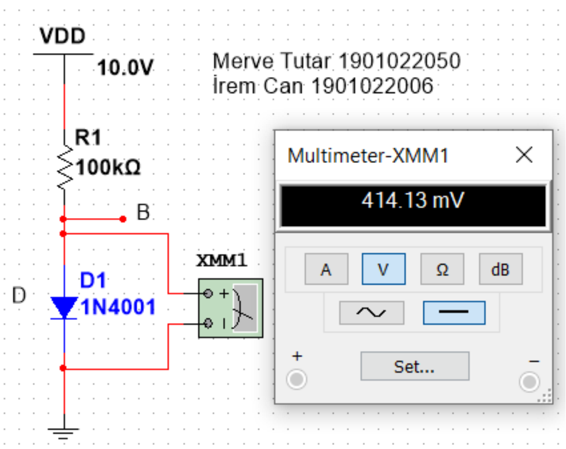


Figure 27. Simulation output for R = 100 kΩ

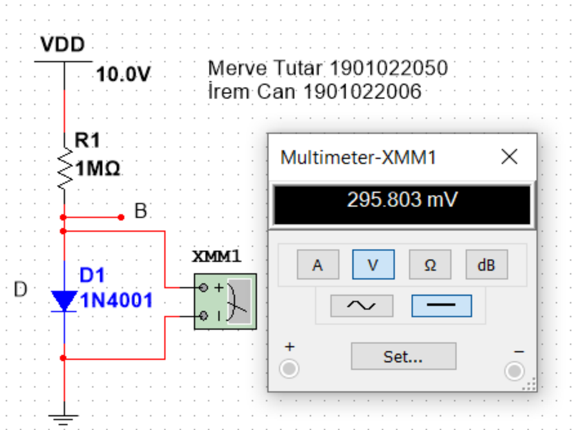


Figure 28. Simulation output for R = 1 MΩ

V_D=0.414 V $İ_D$=((10-0.414)/100k)=0.096 mA

V_D=0.295 V

$İ_D$= ((10-0.295)/1M)=9.705×10^{-6} A

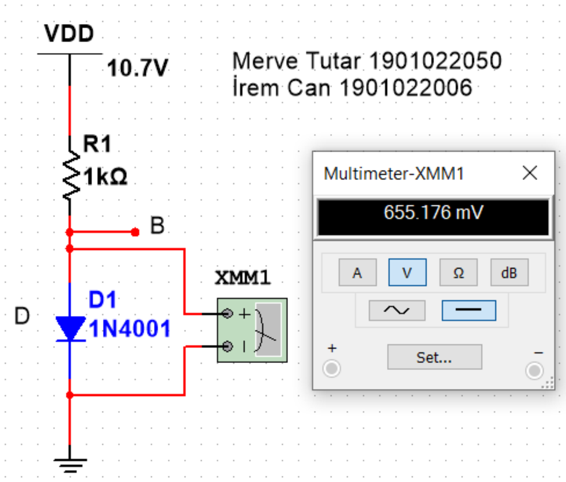


Figure 29. Simulation output for 10.7 supply and R=1k

V_D=0.655 V $İ_D$=((10-0.655)/1k)=9.345 mA

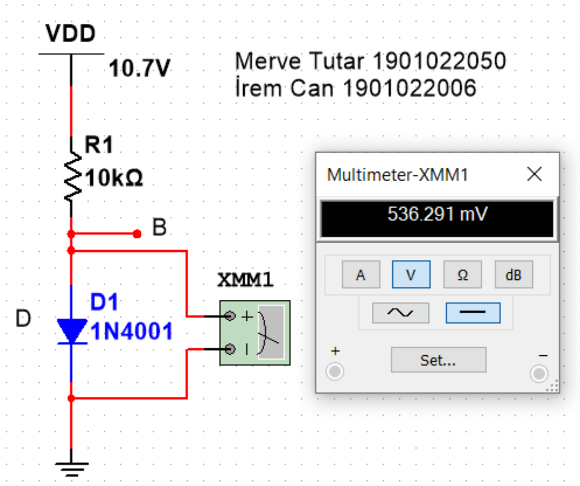


Figure 30. Simulation output for 10.7 supply and R=10k

V_D=0.536 V $İ_D$=((10-0.536)/10k)=0.946 mA

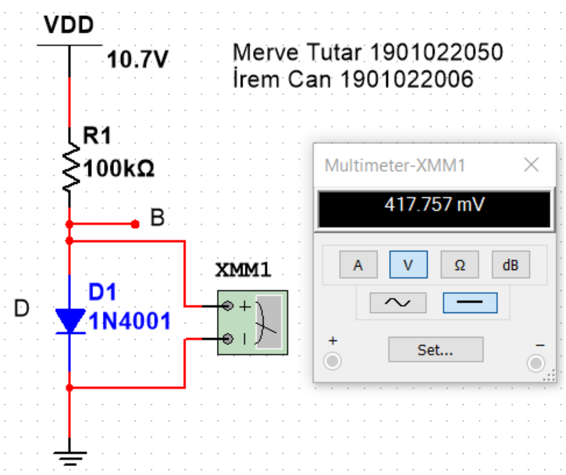


Figure 31. Simulation output for 10.7 supply and R=100k

V_D=0.417 V $İ_D$=((10-0.417)/100k)=0.096 mA

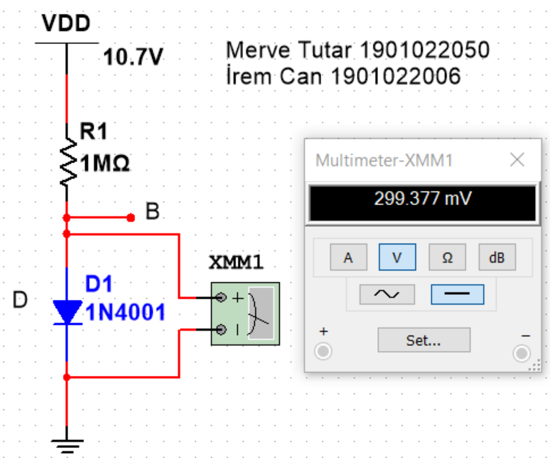


Figure 32. Simulation output for 10.7 supply and R=1M

V_D=0.299 V

$İ_D$=((10-0.299)/1M)=9.701×10^{-6} A

Table 4. Voltage Measurements and Current Estimates for IN4004 (Large Signal Model)

1N4001		R = 1 kΩ	R = 10 kΩ	R = 100 kΩ	R = 1 MΩ
VDD = 10 V	VD(meas.)	0.651 V	0.532 V	0.414 V	0.295 V
	ID(calc.)	9.349 mA	0.95 mA	0.096 mA	9.705×10^{-6} A
VDD=10.7V	VD(meas.)	0.655 V	0.536 V	0.417 V	0.299 V
	ID(calc.)	9.345 mA	0.946 mA	0.096 mA	9.701×10^{-6} A

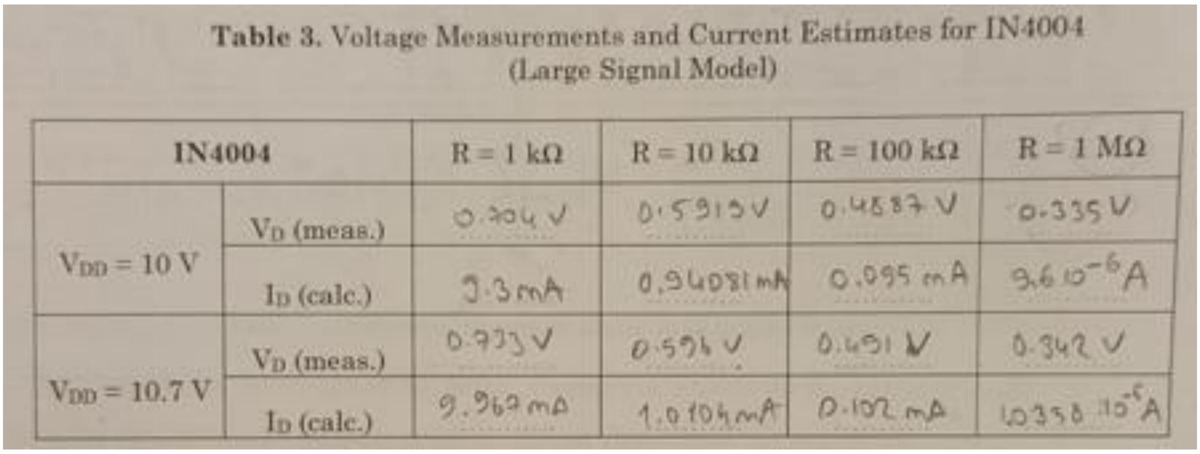


Table 3. Voltage Measurements and Current Estimates for IN4004 (Large Signal Model)

IN4004		R = 1 kΩ	R = 10 kΩ	R = 100 kΩ	R = 1 MΩ
V_{DD} = 10 V	V_D (meas.)	0.704 V	0.5915 V	0.4587 V	0.335 V
	I_D (calc.)	9.3 mA	0.94081 mA	0.095 mA	$9.6\ 10^{-6}$ A
V_{DD} = 10.7 V	V_D (meas.)	0.733 V	0.594 V	0.451 V	0.342 V
	I_D (calc.)	9.969 mA	1.0104 mA	0.102 mA	$1.0338\ 10^{-5}$ A

Figure 33. Voltage Measurements and Current Estimates for IN4004

b) Repeated for a second diode type a **IN914.**

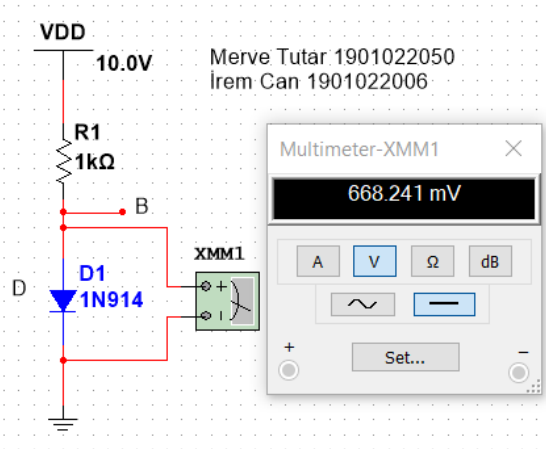


Figure 34. Simulation output for 10.0 supply and R=1k

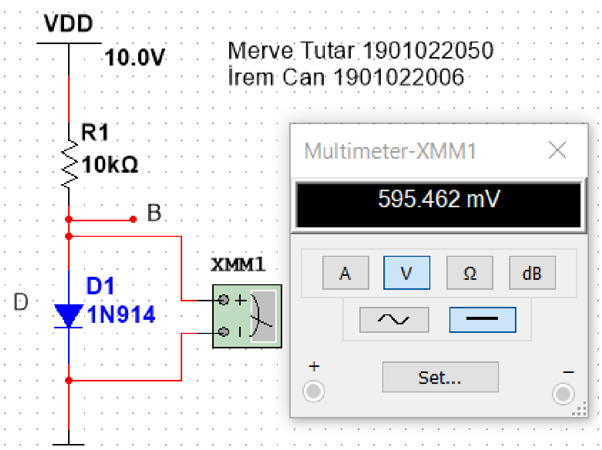


Figure 35. Simulation output for 10.0 supply and R=10k

V_D=0.668 V İ$_D$=((10-0.668)/1k)=9.332 mA V_D=0.595 V İ$_D$=((10-0.595)/10k)=0.941 mA

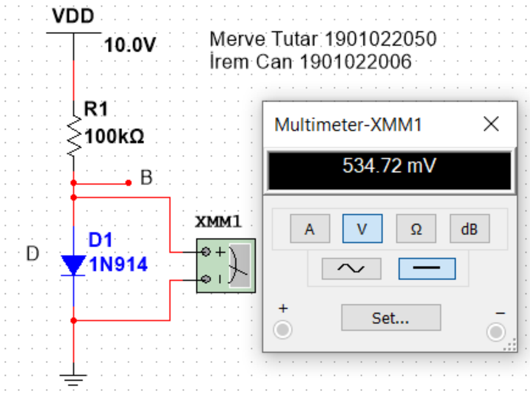


Figure 36. Simulation output for 10.0 supply and R=100k

V_D=0.534 V   İ$_D$=((10-0.534)/100k)=0.095 mA

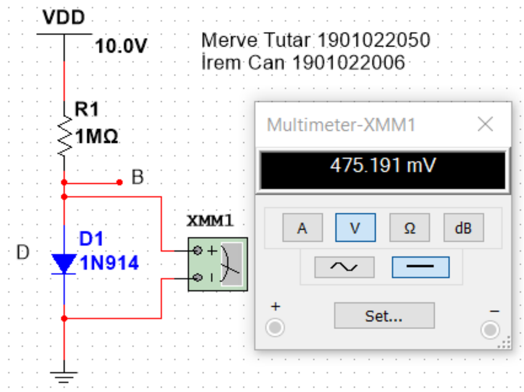


Figure 37. Simulation output for 10.0 supply and R=1M

V_D=0.475 V

İ$_D$=((10-0.475)/1M)=9.525×10^{-6} A

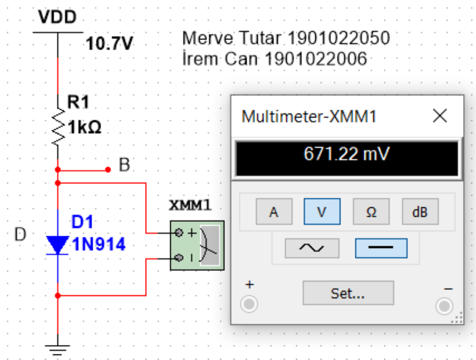


Figure 38. Simulation output for 10.7 supply and R=1k

V_D=0.671 V   İ$_D$=((10-0.671)/1k)=9.329 mA

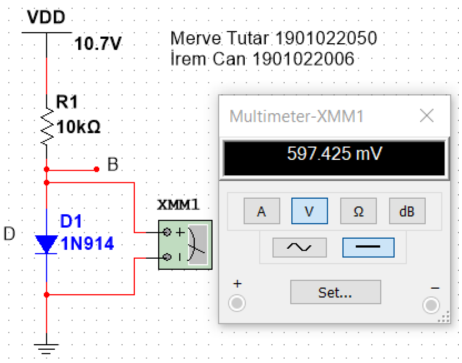


Figure 39. Simulation output for 10.7 supply and R=10k

V_D=0.597 V   İ$_D$=((10-0.597)/10k)=0.940 mA

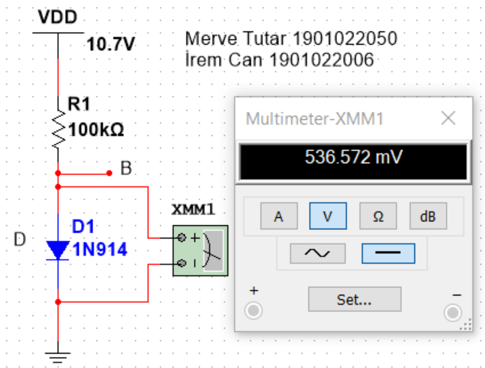


Figure 40. Simulation output for 10.7 supply and R=100k

V_D=0.536 V   İ$_D$=((10-0.536)/100k)=0.095 mA

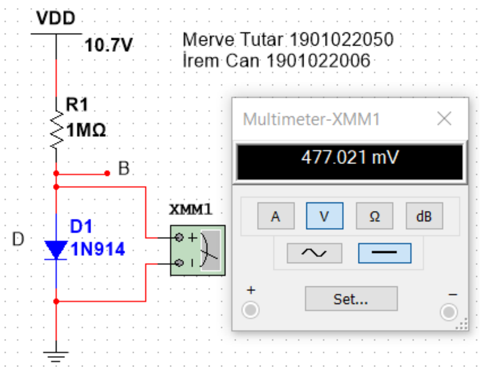


Figure 41. Simulation output for 10.7 supply and R=1M

V_D=0.477 V

İ$_D$= ((10-0.477)/1M)=9.523×10^{-6} A

Table 5. Voltage Measurements and Current Estimates for IN914 (Large Signal Model)

IN914		R = 1 kΩ	R = 10 kΩ	R = 100 kΩ	R = 1 MΩ
VDD= 10 V	VD(meas.)	0.668 V	0.595 V	0.534 V	0.475 V
	ID(calc.)	9.332 mA	0.941 mA	0.095 mA	9.525×10^{-6} A
VDD=10.7 V	VD(meas.)	0.671 V	0.597 V	0.536 V	0.477 V
	ID(calc.)	9.329 mA	0.940 mA	0.095 mA	9.523×10^{-6} A

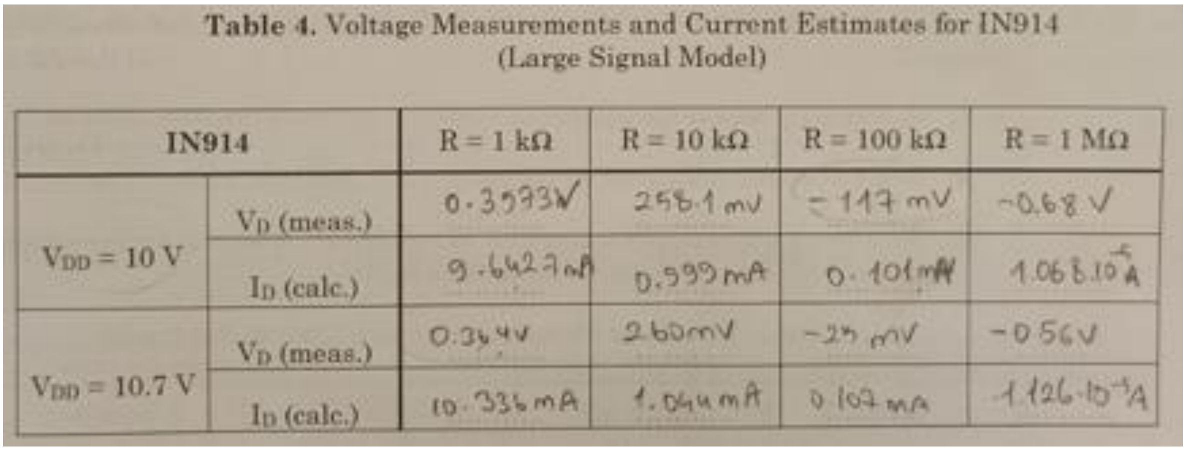
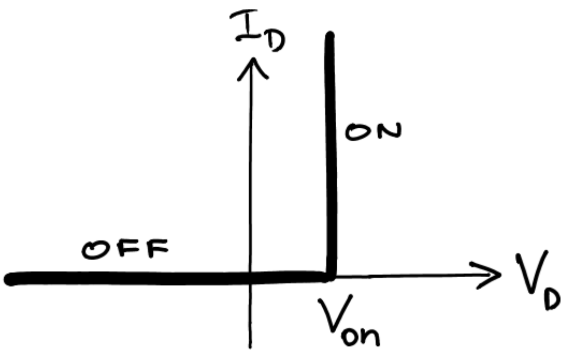


Table 4. Voltage Measurements and Current Estimates for IN914 (Large Signal Model)

IN914		R = 1 kΩ	R = 10 kΩ	R = 100 kΩ	R = 1 MΩ
V_{DD} = 10 V	V_D (meas.)	0.3593V	258.1 mV	-117 mV	-0.68 V
	I_D (calc.)	9.6427mA	0.599 mA	0.101mA	$1.068\cdot10^{-5}$ A
V_{DD} = 10.7 V	V_D (meas.)	0.364V	260mV	-25 mV	-0.56V
	I_D (calc.)	10.336 mA	1.044 mA	0.107 mA	$1.126\cdot10^{-5}$ A

Figure 42. Voltage Measurements and Current Estimates for IN914 (Large Signal Model)

A large-signal model is a representation used in the analysis of electric circuits using voltages and currents that are considered above the low-signal category. The main reason for having a low- and large-signal model is that the behavior circuits, specifically the semiconductors, depend on the relative amplitudes of the signals involved.



If VD<Von, we approximate ID=0. Otherwise, if ID>0, we approximate VD=Von. These two regions define two diode states, called OFF and ON.

Figure 43. Large signal model I-V characteristic of a diode

2.2.3 Forward Conduction Modelling –Finding a Small Signal Model:

a) Using V+=10 V and R =1 kΩ, an IN914 diode was connected and VD was measured.

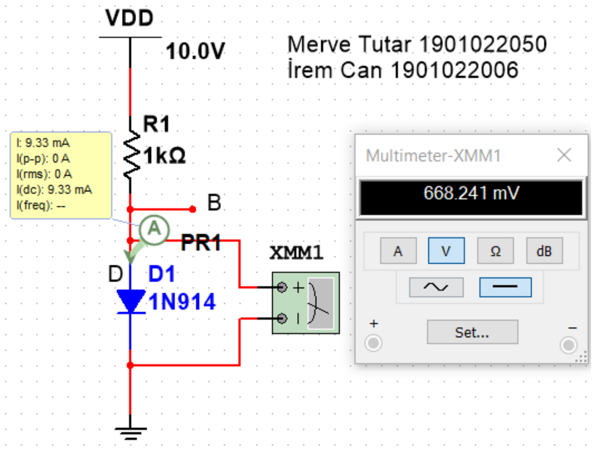


Figure 44. Simulation output for 10.0V and R=1k

b) The diode is shunted with a resistor that reduces the diode current by 5% to 10%. In particular, 1kΩ was used here. VD was measured.

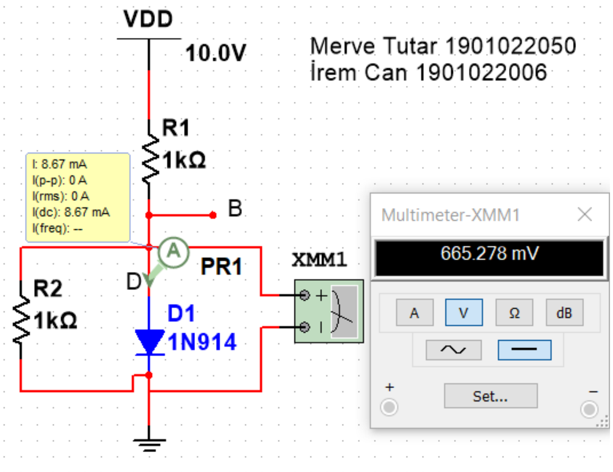


Figure 45. Simulation output for 10.0V and IN914//1k

$$rD = \frac{VD - VDR}{ID - IDR} = \frac{0.668 - 0.665}{9.33 - 8.67} = \frac{0.003}{0.66} = 4{,}55\Omega$$

c) The above procedure was repeated for R =100 kΩ and approximately 100 µA rd at was found.

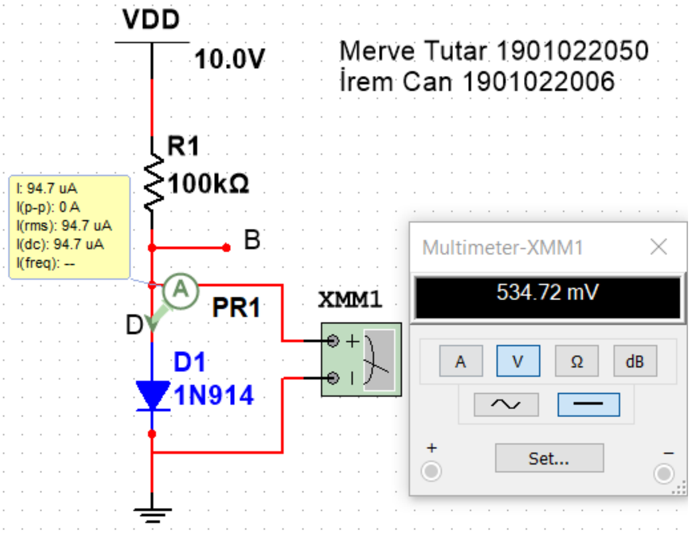


Figure 46. Simulation output for 10.0V and R=100k

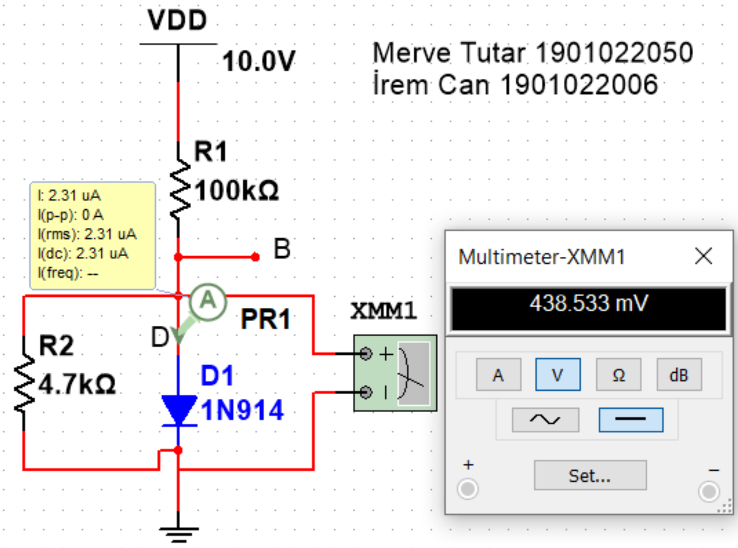


Figure 47. Simulation output for 10.0V and IN914//4.7k

$$rD = \frac{VD - VDR}{ID - IDR} = \frac{0.534 - 0.438}{(94.7 - 2.31)\mu A} = \frac{0.096}{92.39 \times 10^{-6}} = 1039\Omega$$

d) All of the above was repeated for the IN4004 diode.

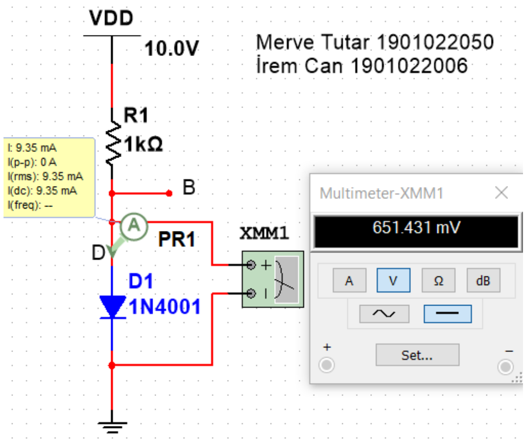


Figure 48. Simulation output for IN4001 and R=1k

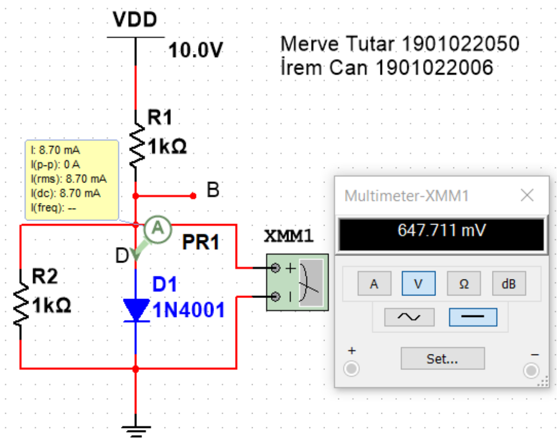


Figure 49. Simulation output for IN4001// R=1k

$$rD = \frac{VD - VDR}{ID - IDR} = \frac{0.651 - 0.647}{9.35 - 8.70} = \frac{0.004}{0.65} = 6.15\Omega$$

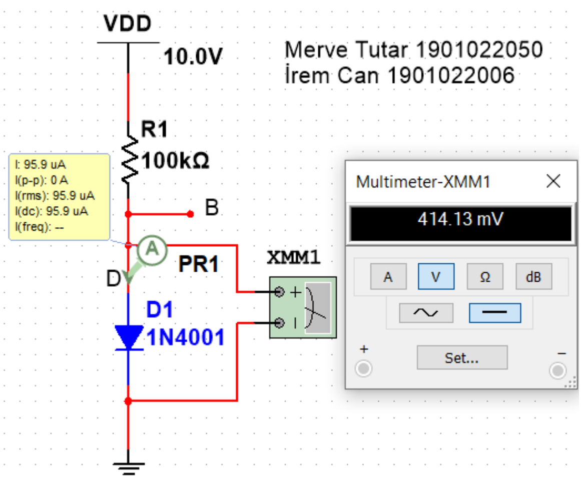


Figure 50. Simulation output for IN4001 and R=100k

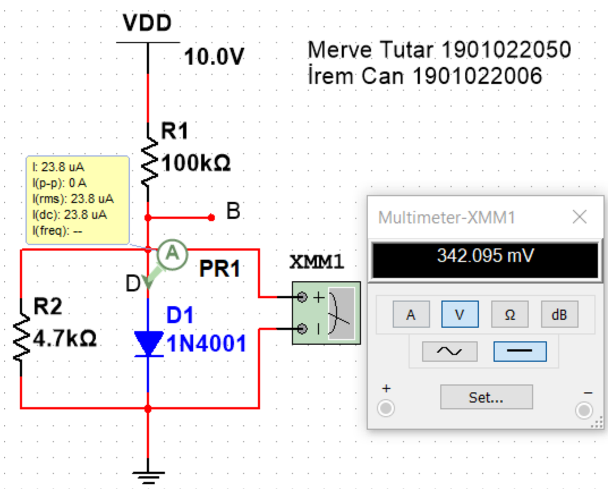


Figure 51. Simulation output for IN4001 // R=4.7k

$$rD = \frac{VD - VDR}{ID - IDR} = \frac{0.414 - 0.342}{(95.9 - 23.8)\mu A} = \frac{0.072}{72.9 \times 10^{-6}} = 987\Omega$$

Table 6. Voltage Measurements and r_D Estimates for IN914 and IN4001 (Small Signal Model)

	R=1kΩ			R=100k Ω		
	VD with no R shunting	VD with R shunting	r_D @ ~10 mA	VD with no R shunting	VD with R shunting	r_D @ ~0.1 mA
IN4004	0.651 V	0.647 V	6.15Ω	0.414 V	0.342 V	987Ω
IN914	0.668 V	0.665 V	4,55Ω	0.534 V	0.438 V	1039Ω

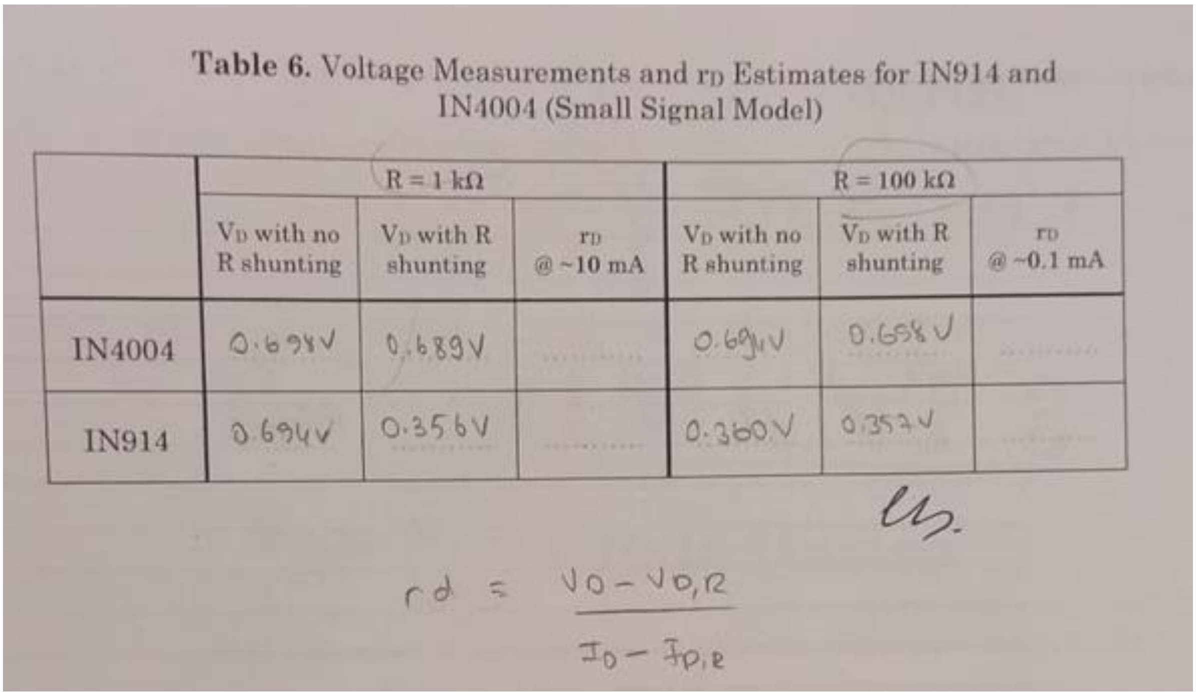


Table 6. Voltage Measurements and r_D Estimates for IN914 and IN4004 (Small Signal Model)

	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	0.698V	0.689V		0.694V	0.658V	
IN914	0.694V	0.356V		0.360V	0.357V	

$$rd = \frac{VD - VD,R}{ID - ID,R}$$

Figure 52. Voltage Measurements and rD Estimates for IN914 and IN4004 (Small Signal Model)

The large-signal model is a model that is acceptably accurate over a large range on input signals. For transistors and diodes, this model is polynomial or exponential, which makes it difficult to work with. But if you restrict the signals to small variations, then over the range of those variations the response can be approximated very well as being linear, which is very easy to work with.

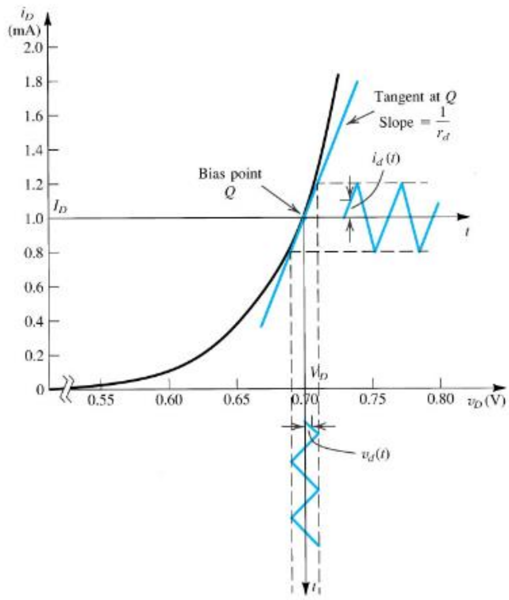


Figure 53. Bias point

Basically the idea is that you have a circuit in which the transistor is biased at a particular quiescent point and the signal is causing to move about that point. So you break the total response into two pieces -- the DC bias, or operating, point and the variation due to the signal. Usually the bias point is large compared to the signal, so the circuit model used to calculate the DC operating point and the circuit that is used to model the changes about that point due to the signal. The first is called the large signal model and the second is called the small signal model.

3. Conclusion

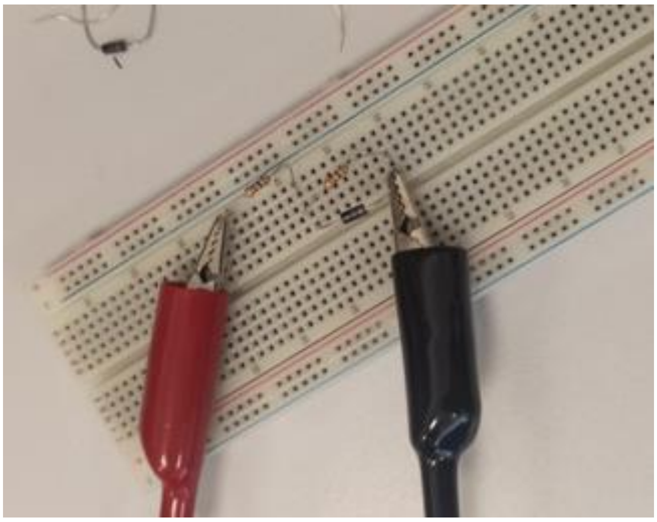


Figure 54. One of the circuits set up in the experiment

In this experiment Junction Diode Basics is used. We used concepts such as Rectification, The Forward Drop, and Large Signal Model, Small Signal Model and Rectifier Filtering.

It was learned that the actual voltage depends on the type of diode rectifier and the material used. Diode rectifier circuit configurations were examined. In the Rectifier Filtering, the voltage drop at the peaks was observed in the graph. The time interval during which the diode was forward conducting was estimated.

Diode conduction in the circuits were investigated by using different resistance values and different diodes. Voltage values were measured and currents were calculated. Forward Transmission Modeling was used. Since the ideal diode has a voltage of 0.7, the measurements were repeated at both 10.0 V and 10.7 V. At the same time, the measurements were repeated using a different diode. Different values were measured in different diodes due to the different diode characteristics in the large signal model.

The resistance was calculated by measuring the voltages and currents in the small signal model. The measurements were repeated for two different diodes.

There are some differences between the measurements we made during the experiment and the measurements made in the multism program. We think that these may be due to the diode characteristics, calculation errors or the sensitivity of the device in the measurement of very small values.

4. References

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