National University of Sciences and Technology (NUST)
School of Electrical Engineering and Computer Science

Department of Electrical Engineering

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Semester: 4th **Section:** D

EE215: ELECTRONIC DEVICES AND CIRCUITS

Lab 04: Small signal operation of pn-junction diodes

		PLO4/CLO4		PLO5/CLO5	PLO8/CLO6	PLO9/CLO7
Name	**Reg. No**	**Viva /Quiz / Lab Performance** **5 marks**	**Analysis of data in Lab Report** **5 marks**	**Modern Tool Usage** **5 marks**	**Ethics and Safety** **5 marks**	**Individual and Teamwork** **5 marks**
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Lab 04: Small signal operation of pn-junction diodes

Objective: To Study the small signal analysis of diode circuits

1. The aim of this experiment is to investigate the diode small-signal AC model that was developed in class.

EQUIPMENT REQUIRED

2. The following components and test equipment is required.
   - PN Diode (D1N4002 or any other diode of the same family)
   - Oscilloscope
   - Function Generator
   - Resistors
   - Capacitors
   - DC Power Supply

The Experiment:

3. The experiment is broken down into three exercises. It involves the calculation of required parameters in the circuit given. Second exercise involves the simulation of the circuit on PSpice using OrCAD-Capture module. The third one involves the practical setup of this circuit and making required measurements, tabulation, and its analysis.

Theory:

4. For a forward biased diode, the small-signal resistance is given by

$$r_d = \frac{nV_T}{I_{DQ}}$$

where V_T is the thermal voltage, n is the ideality factor, and I_{DQ} is the quiescent (DC) diode current.

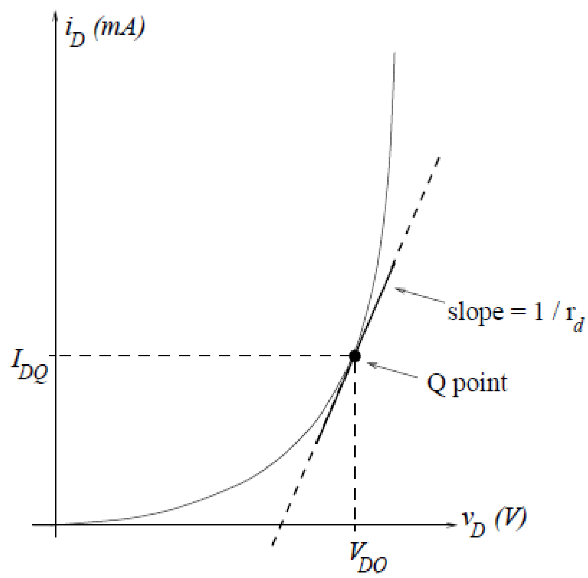
The theory behind this experiment is outlined The i-v characteristics of a pn junction diode is

$$i_D = I_s\left[e^{v_D/nV_T} - 1\right] ,$$

where the ideality factor n is a number between 1 and 2. By definition, the small-signal resistance is the inverse of the slope of this i-v curve evaluated at the Q-point. In other words,

$$\frac{1}{r_d} = \frac{d}{dv_D}\left[I_s\left[e^{v_D/nV_T} - 1\right]\right]\Big|_{v_D=V_{DQ}} = \frac{I_s e^{V_{DQ}/nV_T}}{nV_T} \simeq \frac{I_{DQ}}{nV_T} ,$$

since $I_{DQ} \simeq I_s e^{V_{DQ}/nV_T}$ for a forward biased diode.



The diode small-signal AC model is a linear approximation to the exponential diode i-v curve around a DC operating point in the forward-bias region. Consider a diode in a circuit. The presence of the diode with its nonlinear i–v relationship poses a problem in analyzing the circuit. In general, the diode voltage and current may have both DC and AC components. The small-signal AC model may be used if

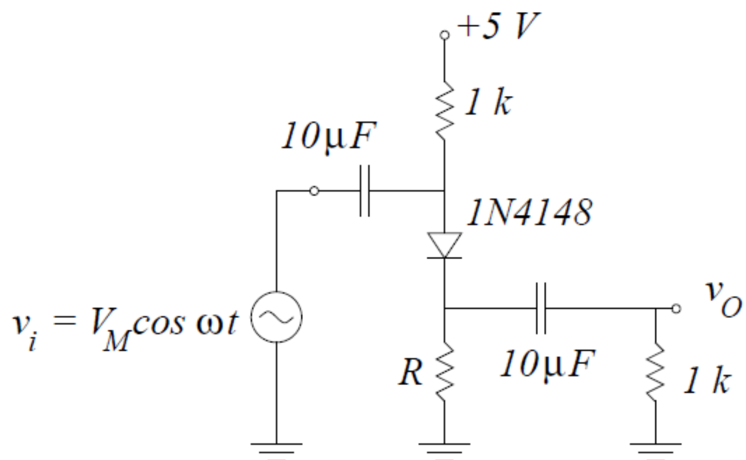
(i) the diode is biased to a DC Q-point in the forward-bias region and

(ii) the AC component of the diode voltage is small relative to nV_T.

The DC diode current and voltage (the Q-point) may be found using either a numerical method to solve the exponential i–v relationship or a simple piecewise linear model. Once the Q-point is found, AC variations around that Q-point can be considered to be approximately linear, provided they are small in amplitude. The AC diode current can then be considered to be linearly related to the AC diode voltage, and hence the diode can be modeled as a resistor with a resistance that is equal to the inverse of the slope of the i–v curve at the Q-point. The small-signal AC model begins to break down if the AC voltage across the diode exceeds nV_T. In this case distortions due to the diode nonlinearity become noticeable in the circuit.

Calculations:

In the laboratory, you will investigate the following circuit.



R= 4.7 kΩ, R= 68 kΩ

These R values will bias the diode at two different Q-points in the forward-bias region. The small-signal resistance r_d will therefore be different for different values of R.

For each value of R, perform the following steps. Assume that the coupling capacitors are short circuit at the frequency of operation. Also assume that the input voltage signal v_i is small enough so that $v_d \ll nV_T$. The ideality factor of 1N4148 diodes is 2.

1. Find the quiescent diode current I_{DQ} using a piecewise linear model with $V_\gamma = 0.6$ V.

2. Determine the small-signal resistance r_d and draw the small-signal AC model for the circuit.

Simulation:

Simulate the circuit using PSPICE. The diode is listed in PSPICE library as D1N4148. Use VSIN as the AC voltage source. First simulate using bias point analysis to find out all the DC voltages and currents and compare Q point with your calculations. Then use Time domain analysis to calculate small signal voltage gain using Vm= 50mV and f=5kHz. Comment on your simulation results and attach screenshots of the graph obtained.

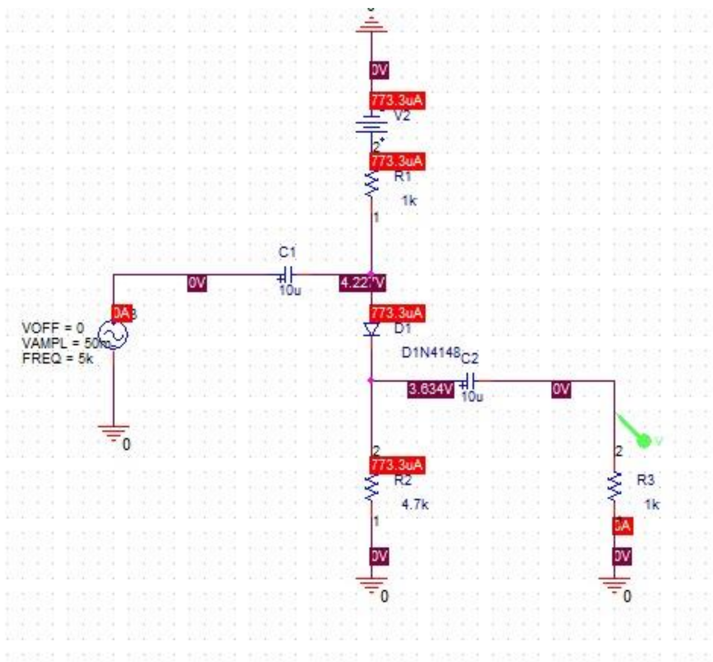


Figure 1: Hardware Simulation

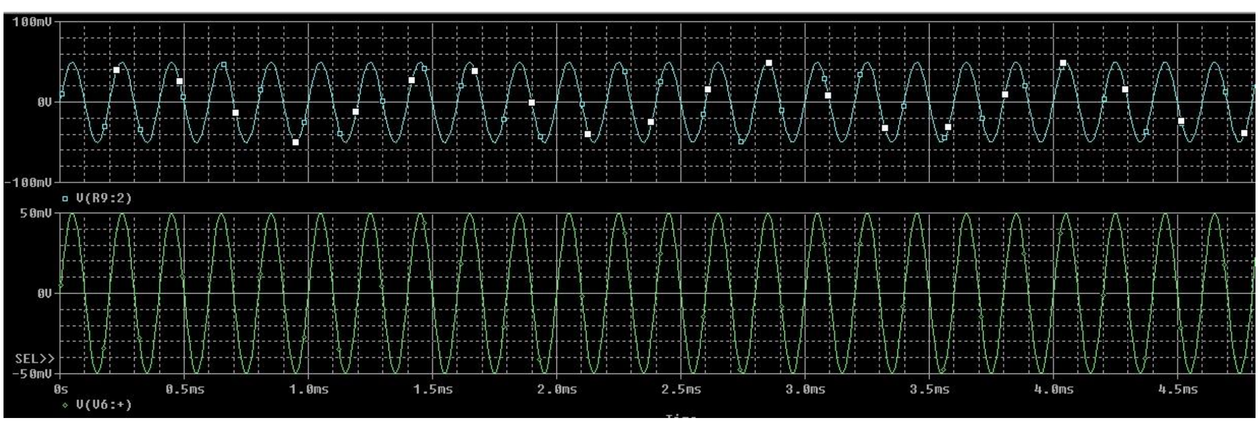


Figure 2: Voltage across input and Output using 4.7Kohm Resister

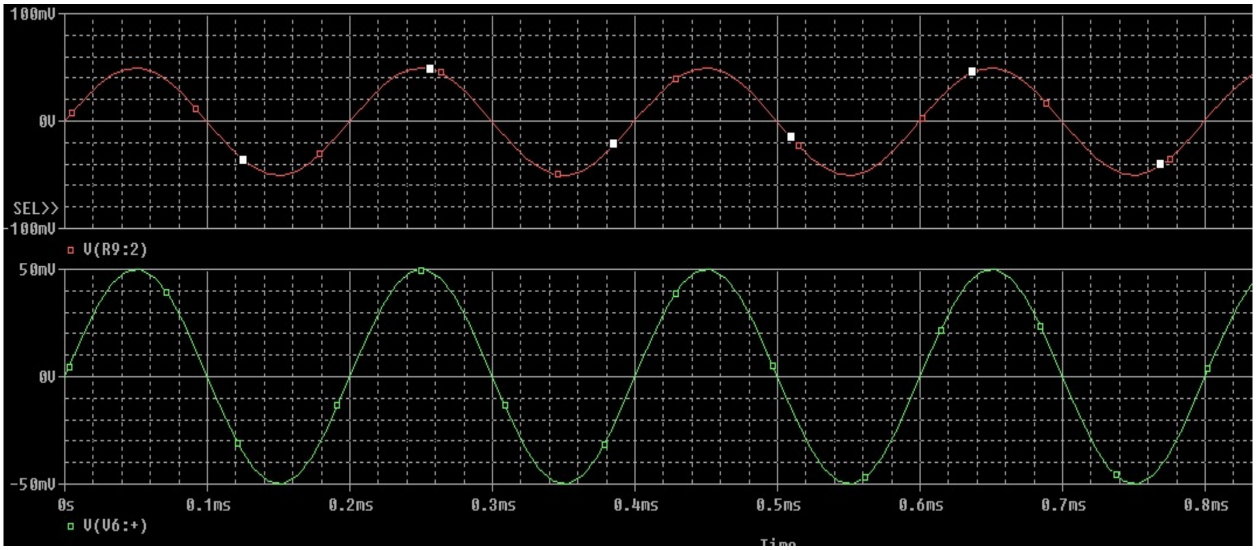


Figure 3: Voltage across Input and Output for 68KOhm Resistor

Implementation:

Construct the circuit using the value of R given in your lab .(Note that the capacitors that you use here are electrolytic capacitors. Make sure to connect positive terminal of the capacitor towards the dc power supply. Set the signal generator frequency to 5khz sinusoidal and amplitude to 100mV peak to peak.

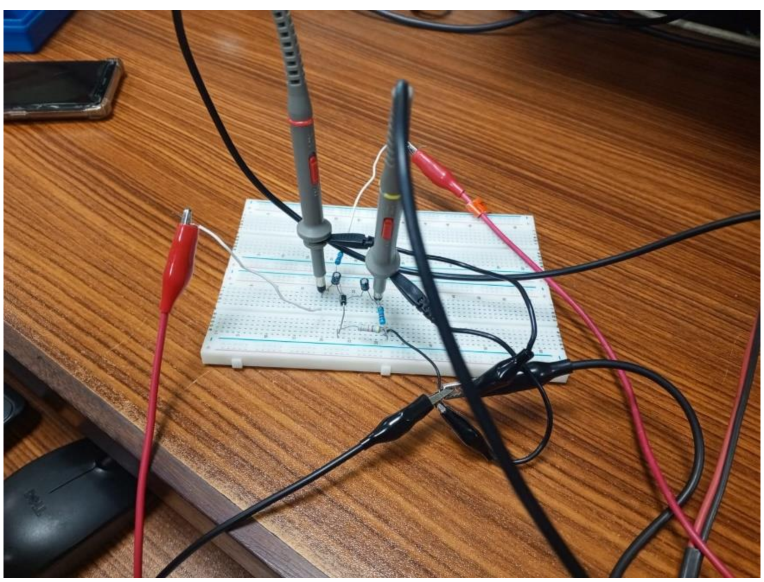


Figure 4: hardware Implementation

1. Turn off the signal generator. Measure the DC voltage drop (with a multimeter) across the 1 kΩ resistor that is connected to the DC supply. From your measurement, determine the quiescent diode current I_{DQ} and make sure that the diode is biased properly. Measure the DC voltage drop across the diode (V_{DQ}) as well.

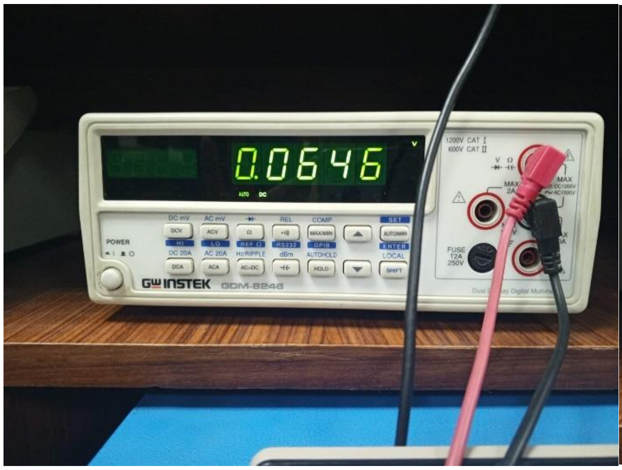


Figure 5: Voltage drop across 68kOhm

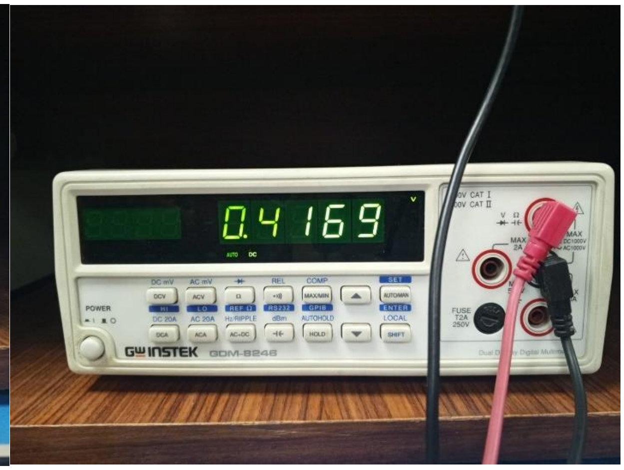


Figure 6: Voltage drop across Diode

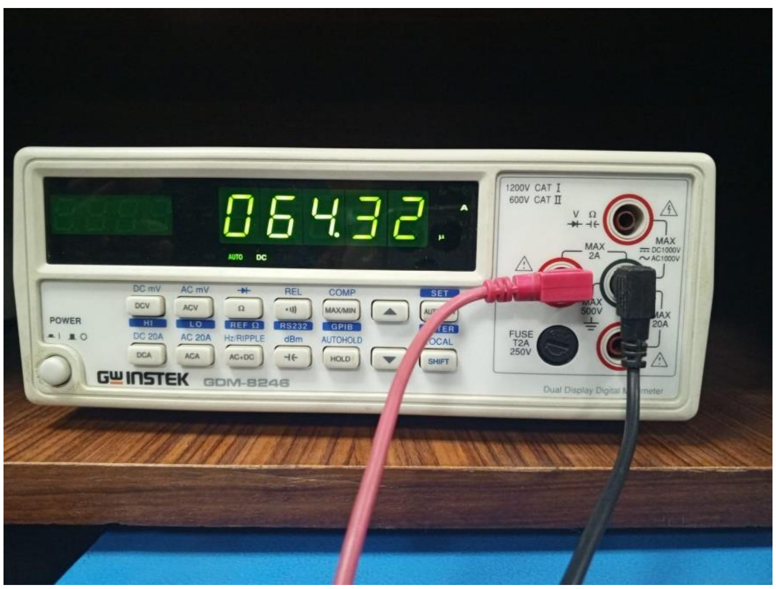
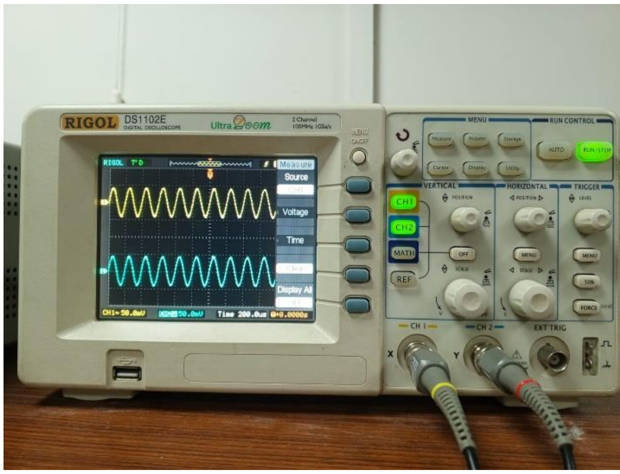


Figure 7: Current across Diode

2. Turn on the signal generator. Observe the input and output voltage waveforms on the oscilloscope on two separate channels. Measure the small-signal voltage gain A_v. Compare this with the value calculated in your preliminary work.



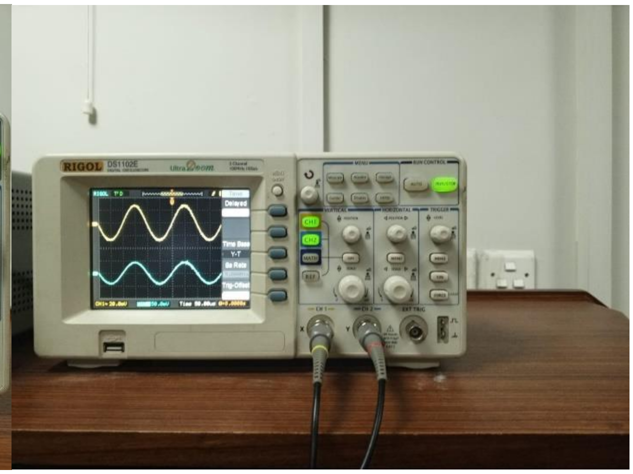


Figure 8: Sine Wave for 4.7kOhm Resistor

Figure 9: Sine Wave for 68kOhm Resistor

3. Increase the signal generator amplitude (V_M) until you begin to see distortion at the output (output no longer sinusoidal). Note the input voltage when this occurs.

Ans: The output starts to distort from Sinusoidal wave when the input voltage exceeds 310mV.

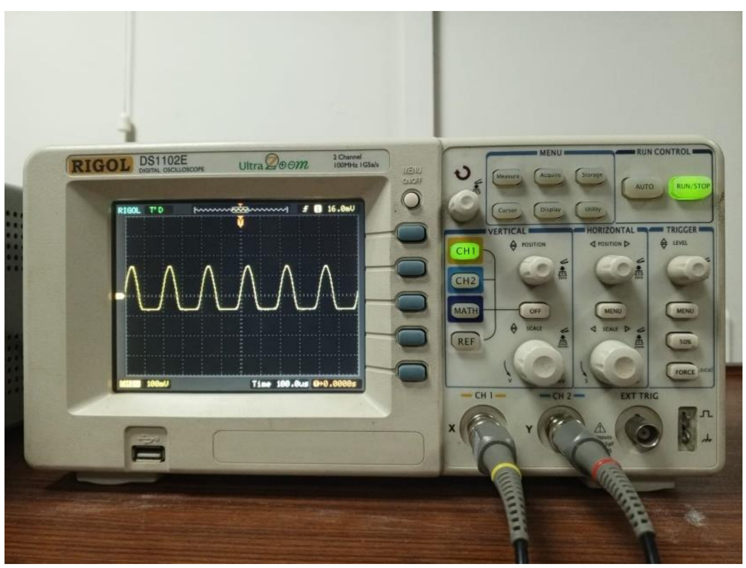


Figure 10: The Distorted Waveform

4. Put the oscilloscope into XY-mode to observe and record the input-output graph of this

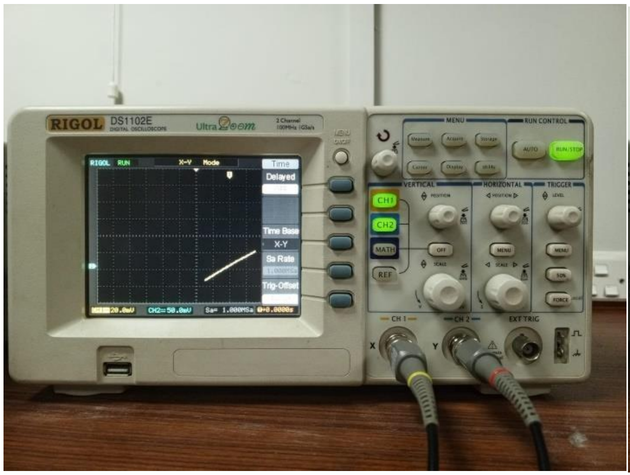


Figure 11: Output Graph for 4.7kOhm Resistor

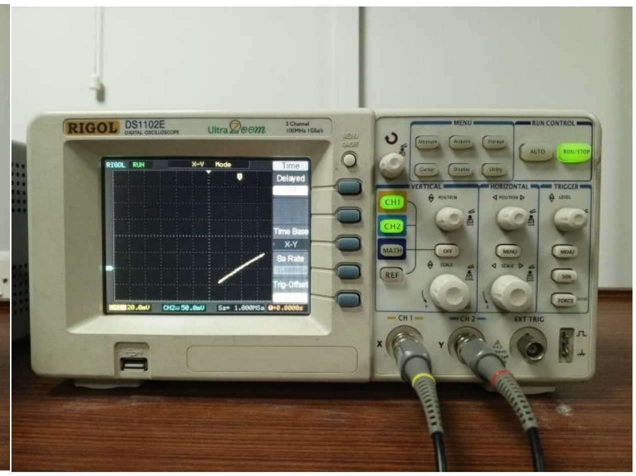


Figure 12: Output Graph for 68kOhm Resistor

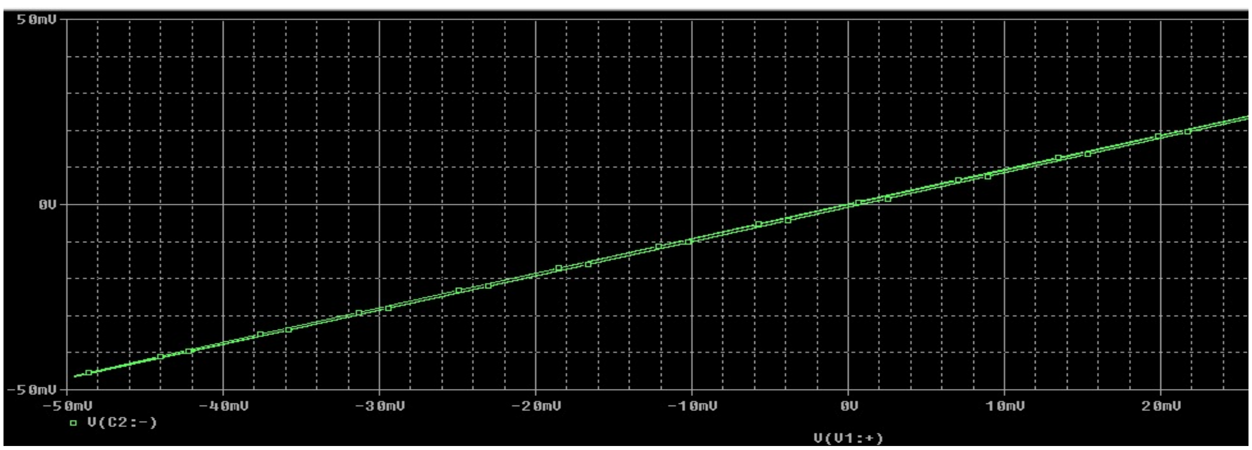


Figure 13: X-Y Graph for 4.7kOhm Resistor

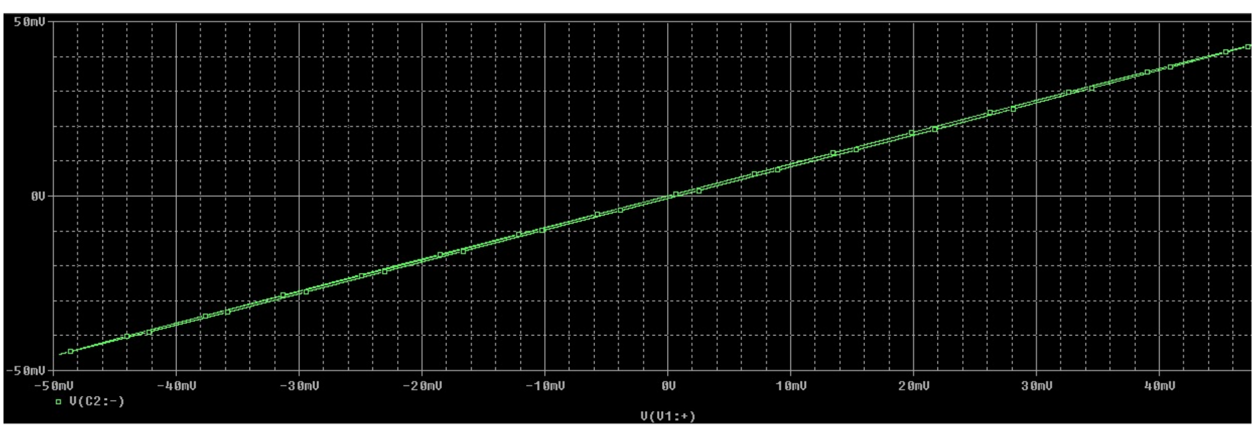


Figure 6: X-Y Graph for 68kOhm Resistor