EEO352 Lab 2
RC Filters and Diodes

Pete Mills

September 18, 2023

Copy of Original Assignment

EEO 352 Fall 2023 - Assignment 2 – RC Filters and Diodes

Please document each step with snapshots of the built circuit, plots, pictures and your observations. Please include this page.

1a) Using the LTspice simulator, design an RC filter with R=1kΩ and C=4.7nF (**15pts**):

a) simulate and plot the response to a 1V 10kHz sinusoidal signal
b) simulate and plot the response to a 1V 100kHz sinusoidal signal and extract the phase shift
c) simulate and plot the frequency response (Bode plot: magnitude and phase)
d) extract the -3dB frequency and the corresponding phase shift

1b) Using the Analog Discovery 2 and the components, build and measure the RC filter at (1a) (**35 pts**):

a) measure and plot the response to a 1V 10kHz sinusoidal signal
b) measure and plot the response to a 1V 100kHz sinusoidal signal and the phase shift
c) measure (network function) and plot the frequency response (magnitude and phase)
d) extrapolate, from the measurement of the resistor and the -3dB frequency, the exact value of the total capacitance
e) remove the capacitor and extrapolate, from the measurement of the resistor and the -3dB frequency, the value of the residual capacitance from the oscilloscope input

2a) Using the LTspice simulator (**15pts**):

a) simulate and plot the diode 1N4148 current for a -1V to +1V diode voltage swing
b) place the marker at the 20mA current, report the corresponding voltage and the dynamic resistance (derivative)

2b) Using the Analog Discovery 2 and the diode 1N4001 (**35 pts**):

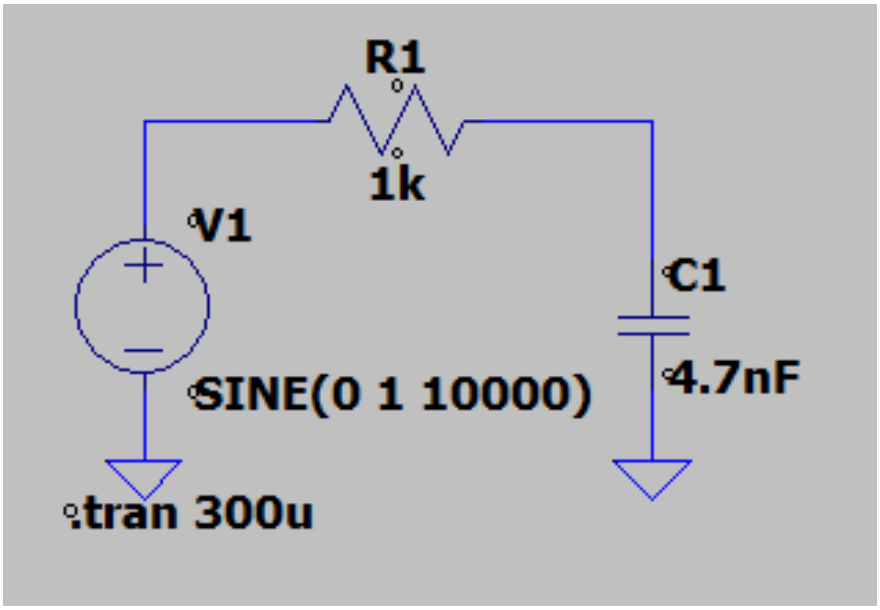
a) trace the diode current
- use a 100Ω series resistor
- use a +/- 4V 100Hz triangular waveform

b) zoom to the 20mA current, report the diode voltage, extrapolate the dynamic resistance

Hint: search for “Semiconductor Curve Tracer with the Analog Discovery 2”

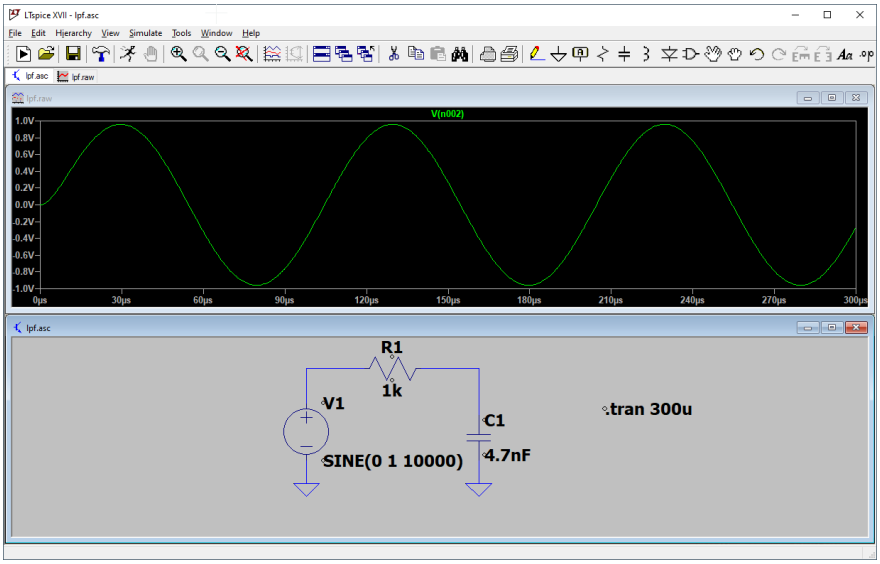
1a

Using the LTspice simulator, design an RC filter with R=1kΩ and C=4.7nF



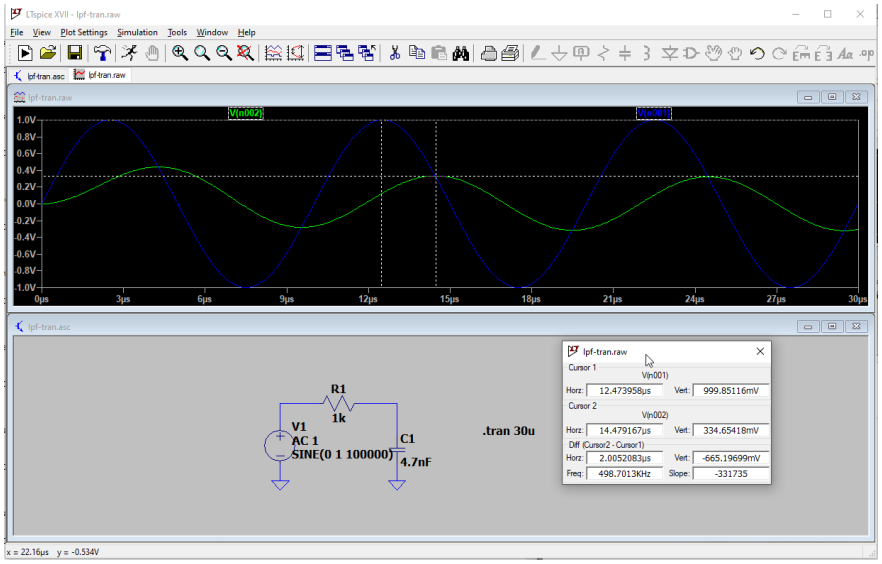
a

Simulate and plot the response to a 1V 10kHz sinusoidal signal



b

Simulate and plot the response to a 1V 100kHz sinusoidal signal and extract the phase shift



$$\theta = \frac{\Delta T}{T_0} 2\pi$$

Where:

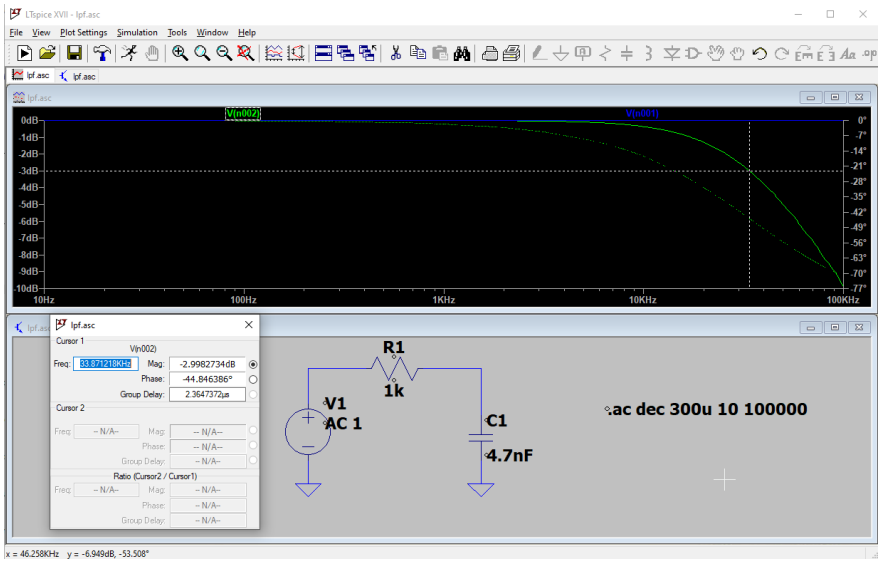
- θ is the phase shift angle in radians.
- ΔT is the time time difference.
- T_0 is the period of the periodic signal.
- 2π is the number of radians in one complete cycle.

Therefore, the phase shift is

$$\theta = \frac{2\mu s}{10\mu s} 2\pi = 0.4\pi \text{radians}$$

c

Simulate and plot the frequency response (Bode plot: magnitude and phase)



d

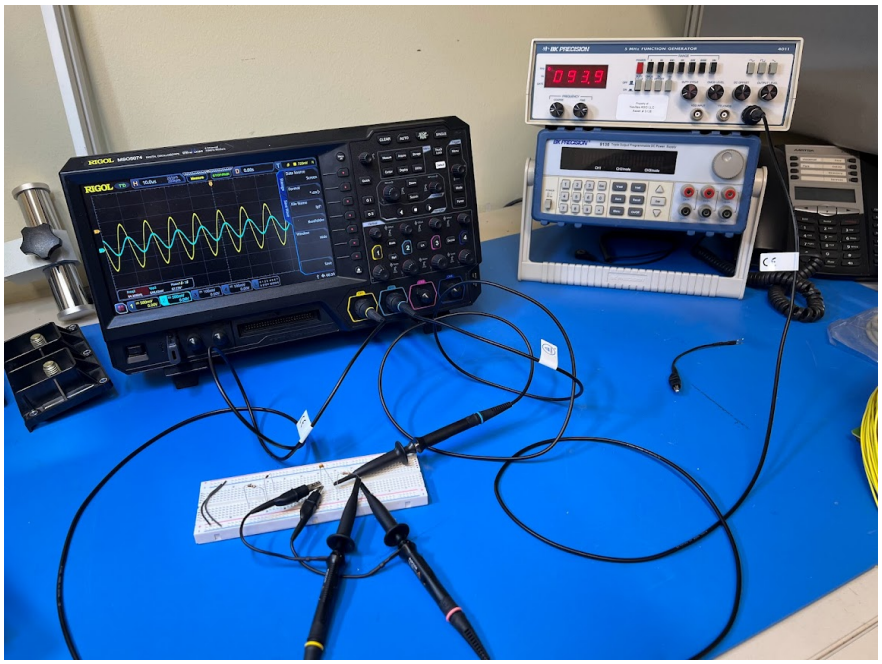
Extract the -3dB frequency and the corresponding phase shift

- From the plot in **c** above it can be seen the -3db point occurs at $\approx 34\,\text{kHz}$
- The phase shift is shown to be $\approx -45°$

As a point of interest, I placed the cursor at the $\approx 100\,\text{kHz}$ and found the phase shift to be $-71.3°$. This is very close to the 0.4πradians value extracted in section **b** above.

1b

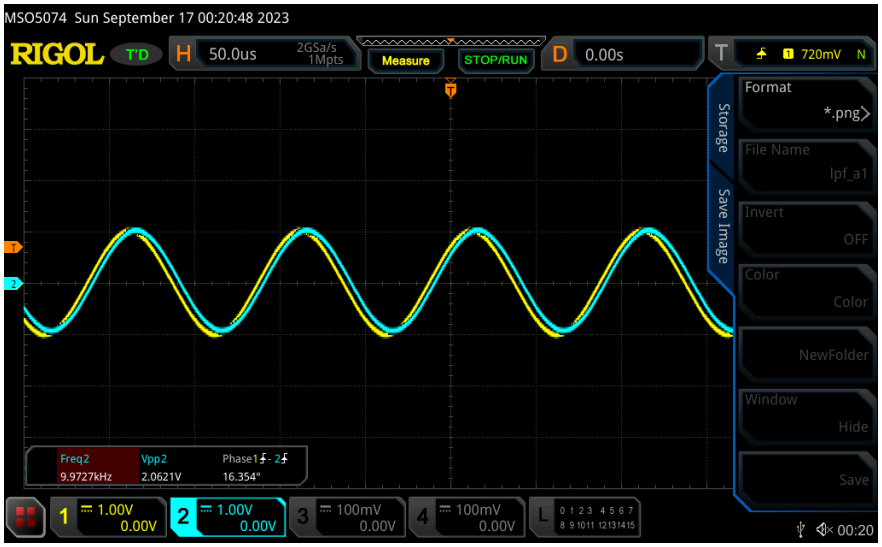
Using the Analog Discovery 2 and the components, build and measure the RC filter at (1a) (35 pts):



a

Measure and plot the response to a 1V 10kHz sinusoidal signal

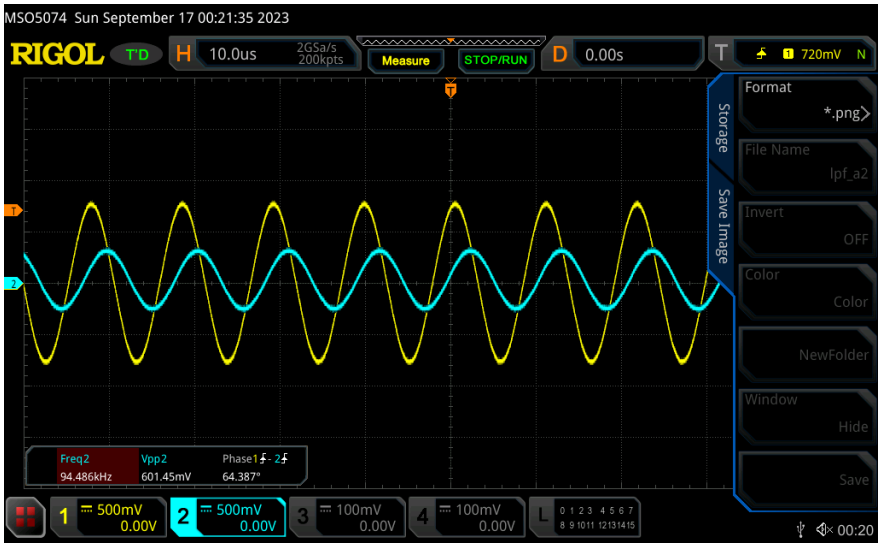
The signal is slightly affected by the LPF as can be seen in the oscilloscope screenshot. There is a 16.4° phase shift.



b

Measure and plot the response to a 1V 100kHz sinusoidal signal and the phase shift

The signal is significantly affected by the LPF as can be seen in the oscilloscope screenshot. There is a 64.4° phase shift and the amplitude is reduced to 601 mV p-p.

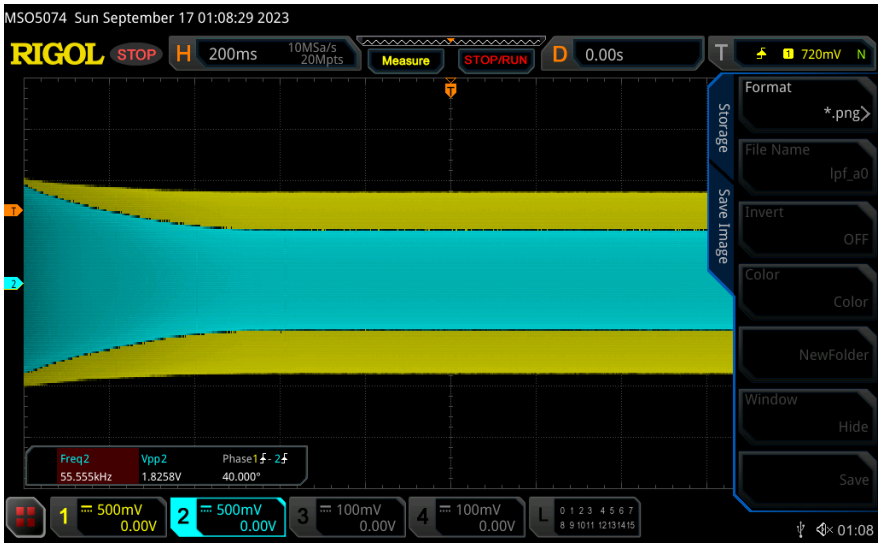


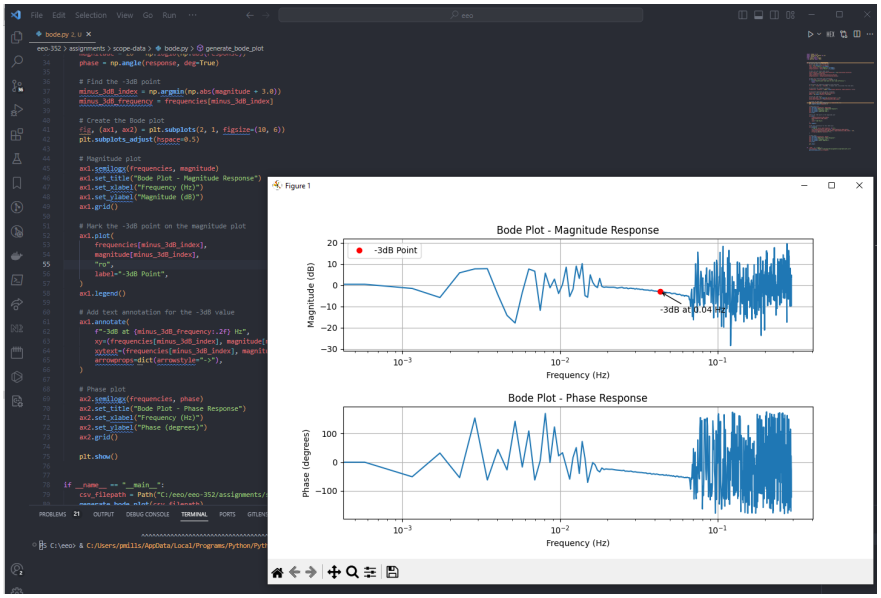
c

Measure (network function) and plot the frequency response (magnitude and phase)

Unfortunately I do not have the frequency analysis or function generator modules purchased for this scope.

Working withing the limitations of my setup, I attempted to perform a manual sweep with the function generator and capture the data on the scope. I exported the scope data to csv and wrote a python program to analyze the data. The program intent was to plot the frequency response of the filter in a semilog plot and mark the -3db filter knee. Unfortunately, this method did not produce results I understand at this time.





d

Extrapolate, from the measurement of the resistor and the -3dB frequency, the exact value of the total capacitance

e

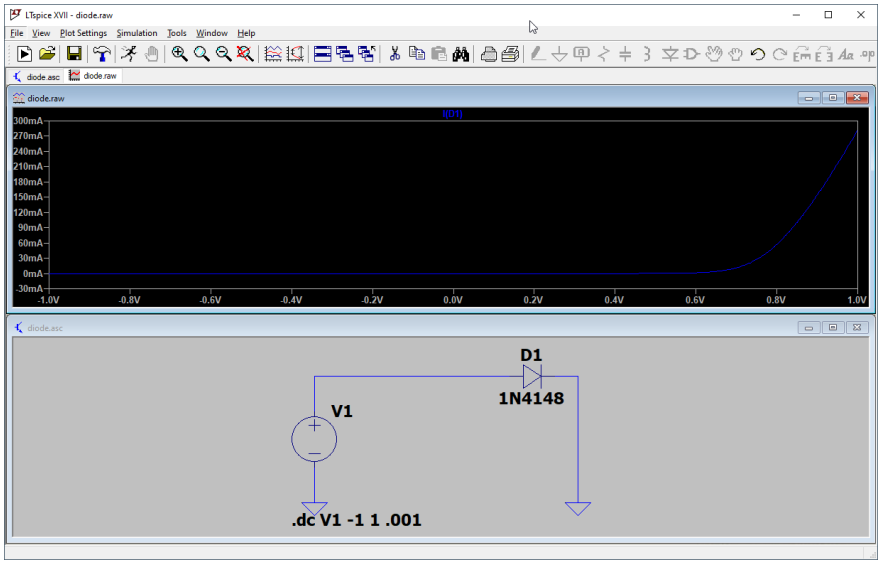
Remove the capacitor and extrapolate, from the measurement of the resistor and the -3dB frequency, the value of the residual capacitance from the oscilloscope input

2a

Using the LTspice simulator (15pts):

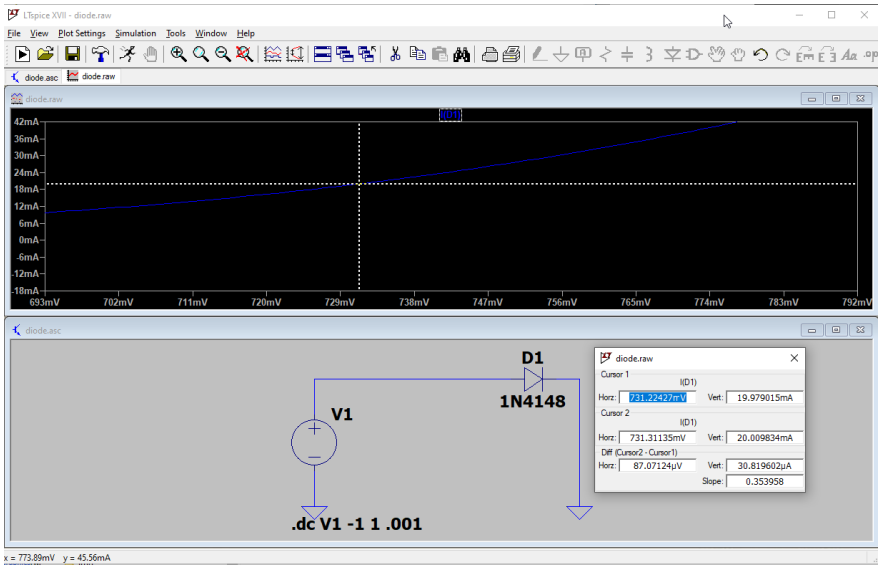
a

Simulate and plot the diode 1N4148 current for a -1V to +1V diode voltage swing



b

Place the marker at the 20mA current, report the corresponding voltage and the dynamic resistance (derivative)



To extract the dynamic resistance consider

$$R = \frac{\Delta V}{\Delta I}$$

Where:

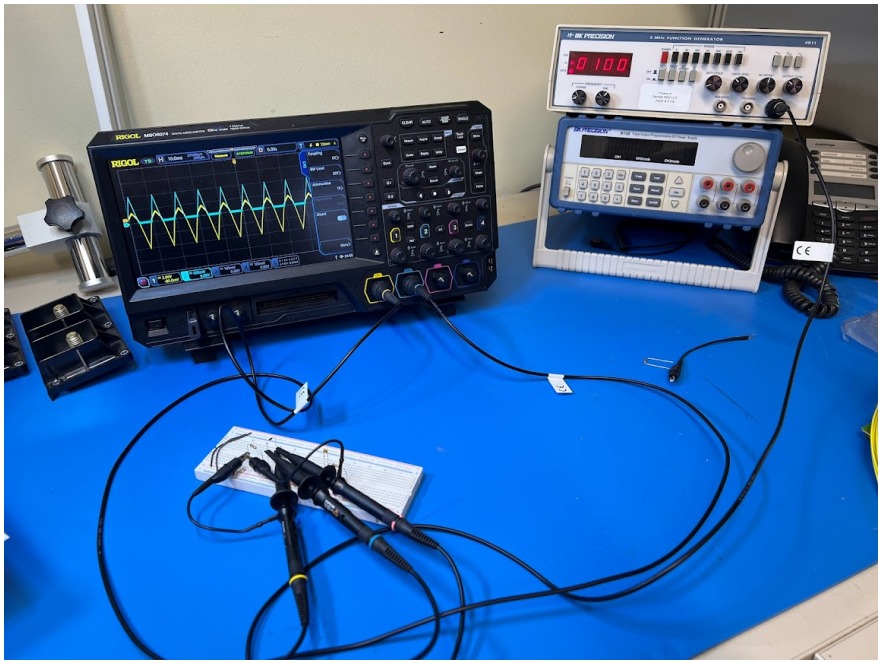
- ΔV is the change in voltage.
- ΔI is the change in current.

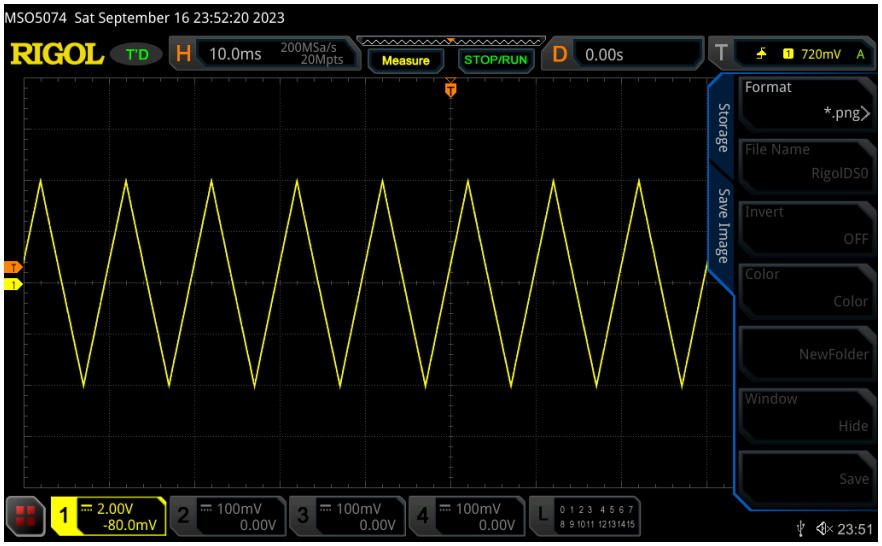
then the dynamic resistance of the diode under test is

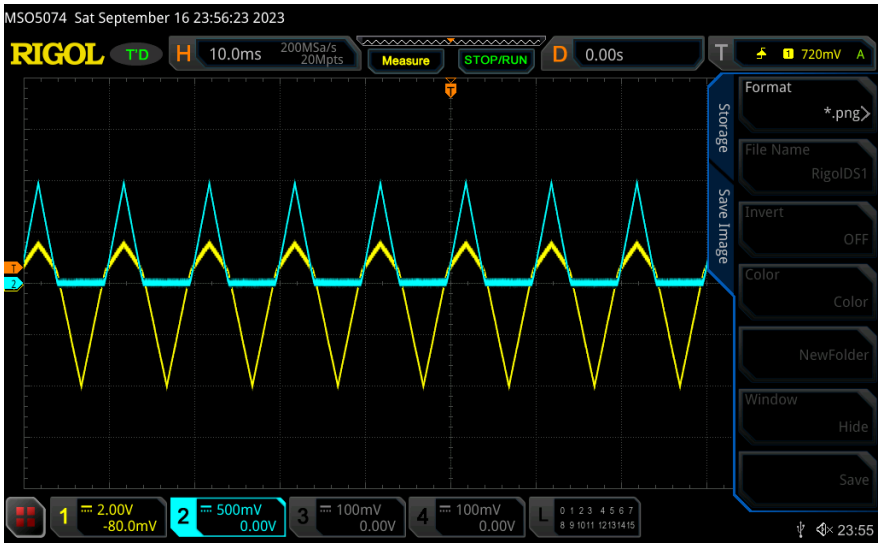
$$R = \frac{731.31 - 731.22}{20.01 - 19.98} \approx 3.0\,\Omega$$

2b

Using the Analog Discovery 2 and the diode 1N4001 (35 pts):





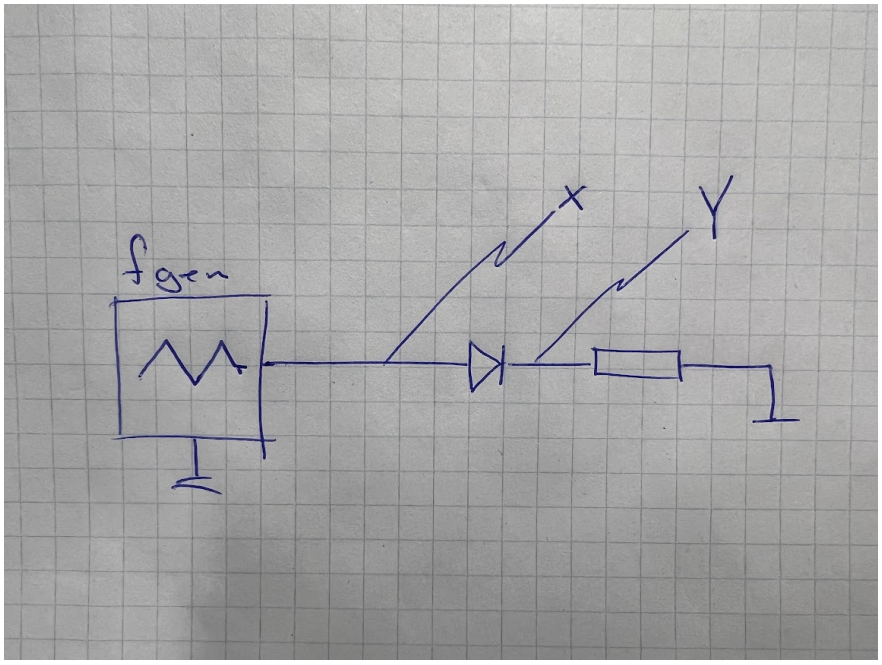


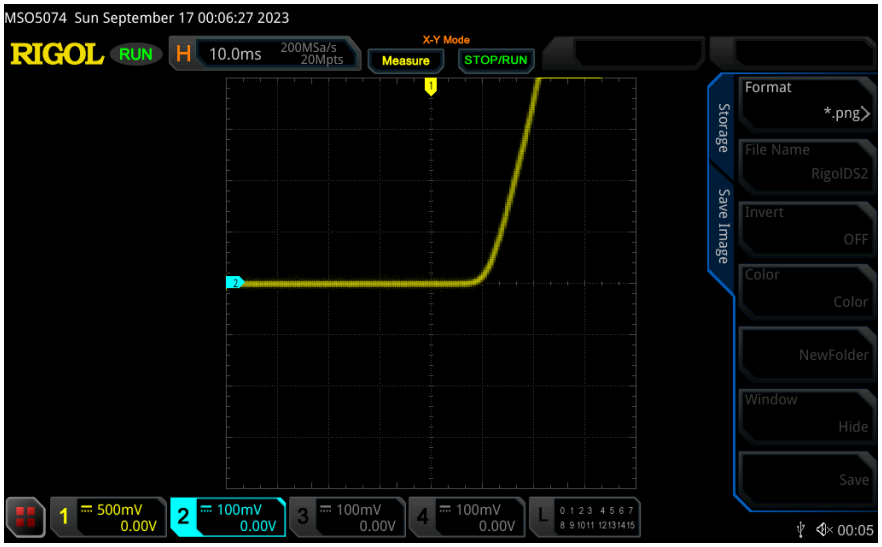
a

Trace the diode current

- Use a 100Ω series resistor
- Use a +/- 4V 100Hz triangular waveform

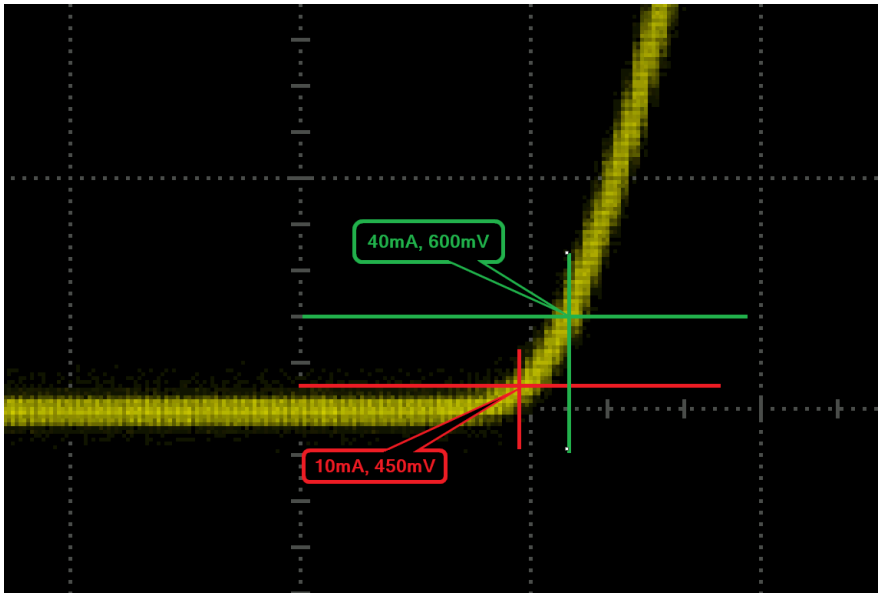
Using x-y mode on the scope I am able to plot the I-V curve of the diode. A schematic of the connections are shown below. I used diode 1N4148





b

Zoom to the 20mA current, report the diode voltage, extrapolate the dynamic resistance



The dynamic resistance $\frac{dV}{dI}$ of the diode under test is calculated as

$$R = \frac{580\,\mathrm{mV} - 475\,\mathrm{mV}}{40\,\mathrm{mA} - 10\,\mathrm{mA}} \approx 3.5\,\Omega$$