Parallel Sinusoidal Circuits

Lab 008

Electrical Networks

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CET 3525 Section E213
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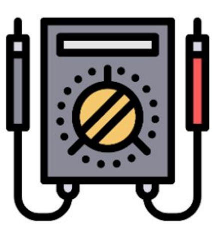
Objective

The objective of this laboratory exercise is to verify the validity of Kirchhoff's Voltage Law (also known as *Kirchhoff's Loop Rule*)when applied to AC circuits consisting of various electrical components placed in parallel configuration with respect to one another; and understand the underlying behavior of internal impedances interacting with the capacitive and inductive reactances of said components via experimentation. In addition, students will also learn to determine the phase angle (often denoted as ϕ) associated with the corresponding voltages using the dual trace method on the oscilloscope. Upon completion of this exercise students will learn to successfully analyze a network consisting of the three components: resistors, inductors, and capacitors - and apply the voltage divider rule via acquisition of experimental results.

Theory

RLC circuits are electrical circuits constructed with three main elements: a capacitor, a resistor and a inductor. The purpose of using these three components in a circuit is to form a harmonic oscillator for current or to creating what is also called "damping". The resistor helps reduce the resonant frequency. In an Ideal LC circuit, when the supply voltage is reduced, the charge in the capacitor is also diminished, hence, discharging the capacitor. But in an AC circuit the input signal is always changing from positive to negative and with a change rate controlled by the frequency of said supply. This implies that the capacitor receiving an AC signal is either being charged or discharged on a continuous basis at a rate regulated by the frequency of the supply. As the capacitor charges or discharges. There's a current flow being slowed down by the internal impedance of the capacitor. This is what we call as capacitive reactance or Xc, measured in Ohms. however, capacitive reactance does not behave as resistance because its based on the frequency; therefore, any variation in supply frequency will have a notable effect on the capacitive reactance measured value.

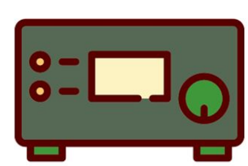
Instruments & Materials



Digital Multimeter

Oscilloscope

Function Generator



DC Power Supply

Resistors	Capacitors	Inductors
1 kΩ 10 Ω	0.01 μF	10 mH

Procedure

Part 1 Parallel R-L Circuit

The first step into this exercise is to construct the circuit shown below and assume that we have an ideal parallel R-L circuit. A function generator is provided to emulate an input AC voltage of 10KHz.By using the value of the inductor and the measured resistance, we calculated the currents of the network.

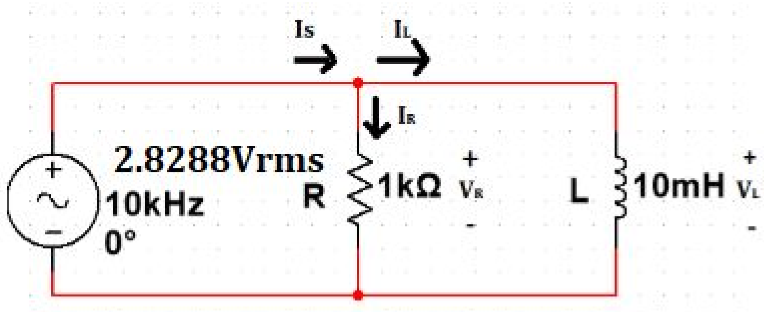


Fig.1

Then, the next step required us to insert a sensing resistor, Rs, in the circuit previously constructed and shown below. Depending on the positioning of this resistor, it allowed us to measure the various currents in the circuit ($I_{S(p-p}$, $I_{R(p-p)}$, $I_{L(p-p)}$). The resistance value of this resistor is considerably smaller than our parallel resistor; this is to ensure that there is no loss while measuring each of the currents. All of these values were then recorded in table 9.1.

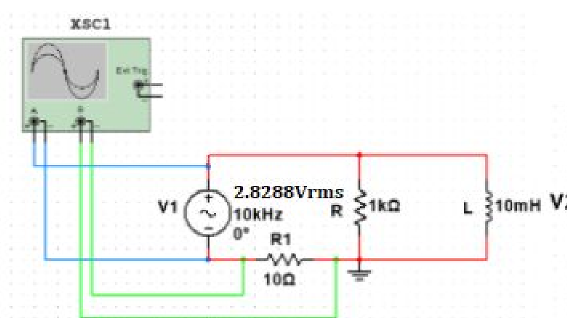


Fig.2

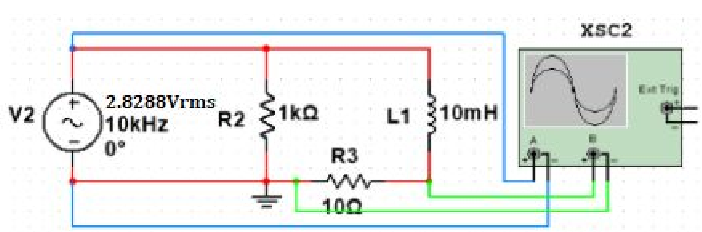


Fig.3

Next, we calculated the peak-to-peak value for the source current Is in Fig.2 by using the measurements for VRs from the previous part.

$$I_S = \frac{V_{Rs(p-p)}}{R_S} = \frac{166.0mV}{10.2} = 16.6mA$$

Determined the phase angle between E and Is using circuit labeled as fig.2. Since V_R is equal to E and also in phase with Is, the phase angle between them is the same. We recorded D1 and D2 in table 9.2 and calculated the resulting phase angle using the formula below.

$$\mathrm{T} = \frac{1}{10KHz} = 0.1ms \qquad \theta_S = \frac{\Delta t}{\mathrm{T}} = \frac{D_2}{\mathrm{T}} = \frac{16.8\mu s}{0.1ms} \times 360 = 60.48°$$

For this step, the sensing resistor Rs was moved to a location in series with the inductor(Refer to Fig.3). This would allow us to measure the current through the inductor by measuring the Voltage V_R and using ohm's law to calculate the current flowing through it.

$$I_L = I_{R_S} = \frac{V_{Rs(p-p)}}{R_S} = \frac{140.0mV}{10.2} = 13.73mA$$

Then calculated phase angle between E and I_L as previously done before. Since we know that the current flowing through V_R and the inductor is the same.

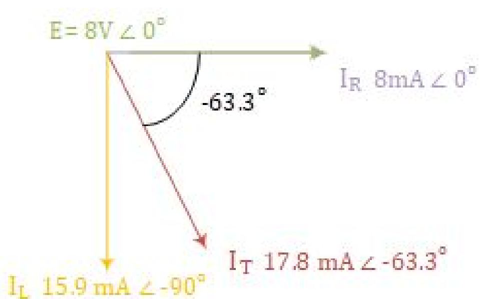
$$\mathrm{T} = \frac{1}{10KHz} = 0.1ms \qquad \theta_L = \frac{\Delta t}{\mathrm{T}} = \frac{D_2}{\mathrm{T}} = \frac{23.60\mu s}{0.1ms} \times 360 = 84.96°$$

A calculation to determine the value of the current I_R was performed by using the parallel voltage across R and E. The source current Is is larger in magnitude because there is a phase angle higher than zero in between the AC voltage E and the Source Current Is. in DC, however, currents should always add to the total that was introduced at the input; this is due to the phase angle always being equal to zero for direct currents and voltages. And last, we calculated the input impedance using the peak-to-peak values of E and Is. inductive reactance was also calculated at 10KHz as shown below.

$$Z_T = \frac{E}{I_S} = \frac{8V}{16.6mA} = 481\Omega$$

$$X_L = 2\pi f L = 2\pi(10KHz)(10mH) = 628.22\Omega$$

Phasor Diagram



Part 2 Parallel R-C Circuit

In part 2, the network shown in Fig.4 was constructed and the resistor labeled as R was measured. In contrast with Part 1, this is an R-C electrical circuit instead. By using the value of the capacitor and the measured resistance of R we calculated the peak-to-peak values of the current and recorded it in table 9.4.

Following the same reasoning as we did with our R-L Circuit, we implement a sensing resistor in order to measure the current Is flowing back through the 10Ω resistor branch. Then, using the measured voltage V_{Rs} we were able to calculate the peak-to-peak value for the source current Is and recorded it on table 9.5. The Phase angle $\boldsymbol{\theta}_S$ between E and Is was determined using the configuration shown in Fig. 5. In this configuration E = V_R and I_R is in phase with V_R

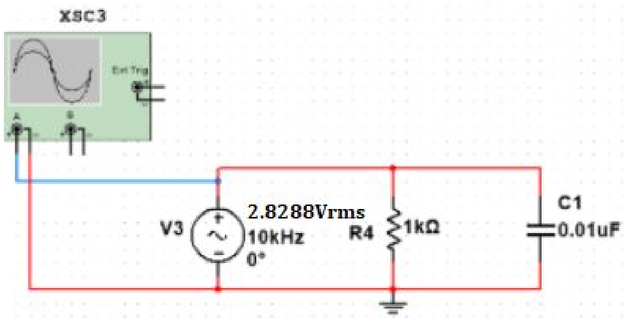


Fig.4

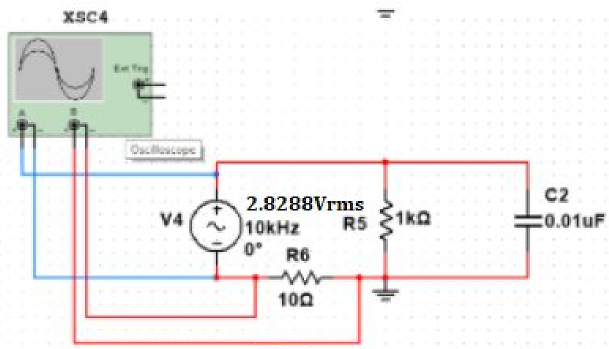


Fig.5

Next, we rearranged the previous configuration once more in order for us to read the current flowing through the capacitor by placing our sensor resistor in series with the 0.01uF capacitor. Thus, reading the voltage across that resistor, we would be able to find the current flowing in that circuit branch and record it in table 9.5. Then, determined the phase angle $\boldsymbol{\theta}_C$ between E and Ic using the connections in Fig.6. This can be done because V_R = E and I_R is in phase with V_R.

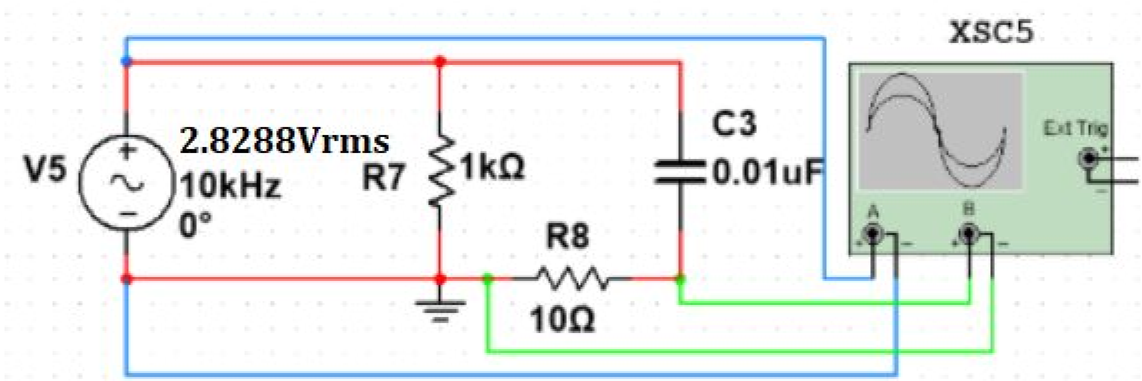


Fig.6

Since V_R = E, that means we can use ohm's law and the measured resistor value to determine the current flowing through that resistor, I_R. this was determined by using the equation below.

$$E = V_R \qquad\qquad I_R = \frac{V_{R(p-p)}}{R} = \frac{8V}{10.2} = 0.784A$$

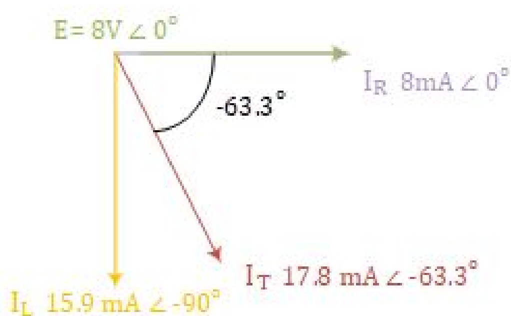
And last, we calculated the input impedance using the peak-to-peak values of E and Is. capacitive reactance was also calculated at 10KHz as shown below.

$$Z_T = \frac{E}{I_S} = \frac{8V}{6.27mA} = 1275.92\Omega$$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(10KHz)(.01\mu F)} = 1591.55\ \Omega$$

Using the input voltage as a reference and the measured values of the currents I_R & I_S , a phasor diagram was drawn to scale and also determined the current Is

Phasor Diagram



Part 3 Parallel R-L-C Circuit

For this RLC circuit, we constructed the network shown in Fig.7 and measured/calculated the peak to peak values of the currents of said network. [This portion of the experiment was simulated using MultiSim.]

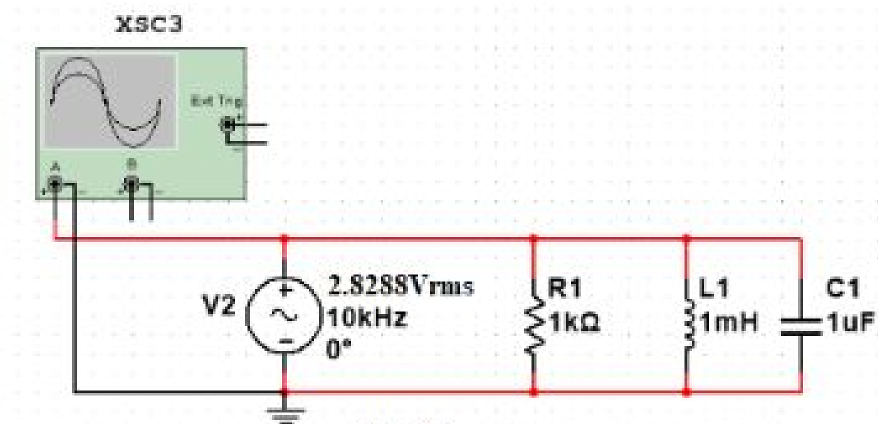
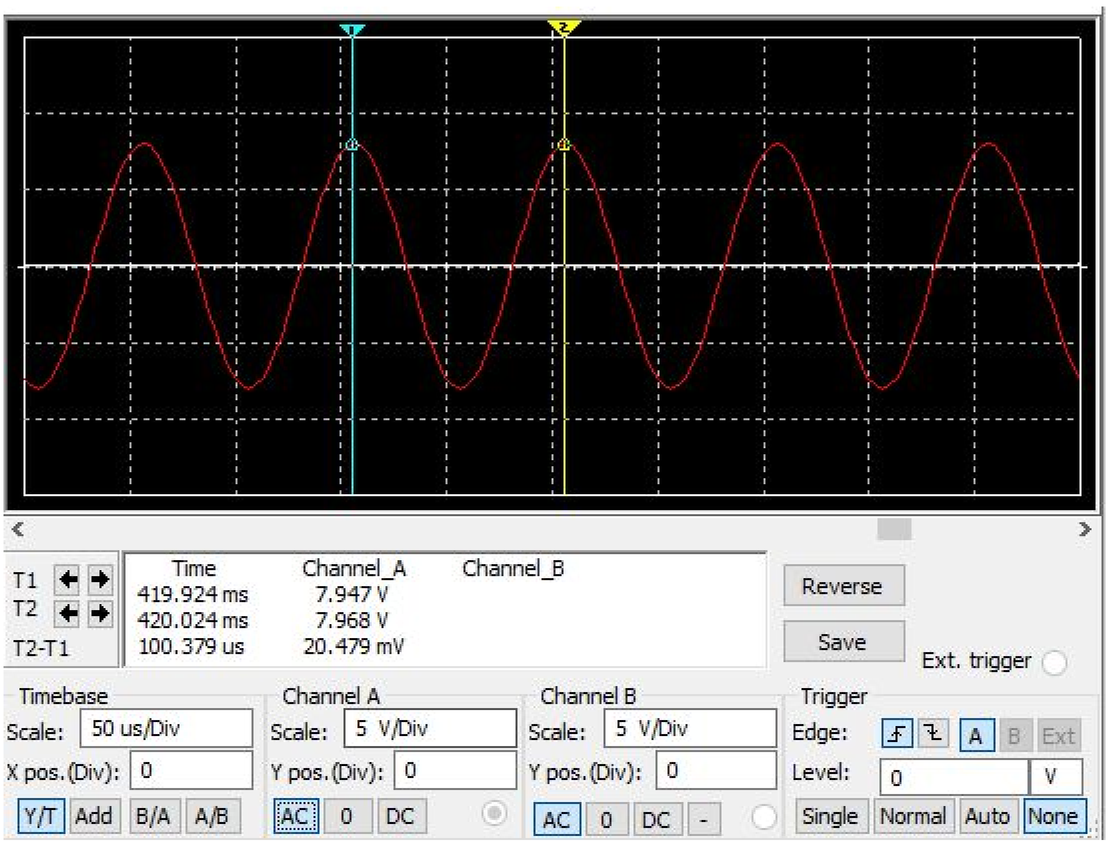


Fig.7



Results

Table 9.1

Quantity		Measured (Calculated from Measured Values)	Theoretical (Calculated)
$I_{S(p-p)}$		16.6mA	17.8 mA $\angle$-63.3°
$I_{L(p-p)}$		13.73mA	15.9 mA $\angle$-90°
$I_{R(p-p)}$		8mA	8 mA $\angle$0°
(for I_S)$V_{Rs(p-p)}$		166.0mV	.178 V $\angle$-63.30°
(for I_L)$V_{Rs(p-p)}$		140.0mV	.159 V $\angle$-90°

Table 9.2

		D_1	D_2	Angle in Degrees
θ_S		0.1ms	16.8µs	60.48°
θ_L		0.1ms	23.60µs	84.96°

Table 9.3

Z_T		X_L
481 Ω		628.32 Ω

Phasor Diagram

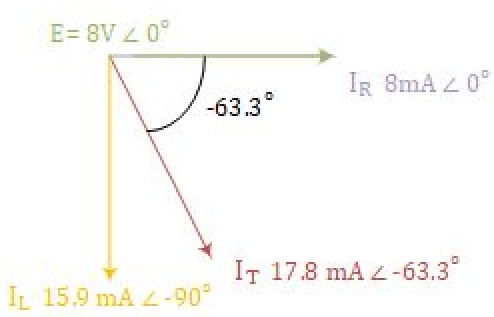


Table 9.4

I_S(Diagram)		I_S(Measured)	θ_S	θ_R	θ_L
17.8 mA∠-63.3°		16.6 mA	63.3°	26.7°	90°

Table 9.5

Quantity		Measured (Calculated from Measured Values)	Theoretical (Calculated)
$I_{S(p\text{-}p)}$		10mA	9.45 mA ∠32.14°
$I_{C(p\text{-}p)}$		6.27mA	5 mA ∠90°
$I_{R(p\text{-}p)}$		8mA	8 mA ∠0°
(for I_S)$V_{Rs(p\text{-}p)}$		102.0mV	
(for I_C)$V_{Rs(p\text{-}p)}$		64.0mV	

Table 9.6

		D_1	D_2	Angle in Degrees
θ_S		0.1ms	11.20μs	40.32°
θ_L		0.1ms	24.0μs	86.40°

Table 9.7

Z_T		X_L
1275.95 Ω		1591.55 Ω

Phasor Diagram

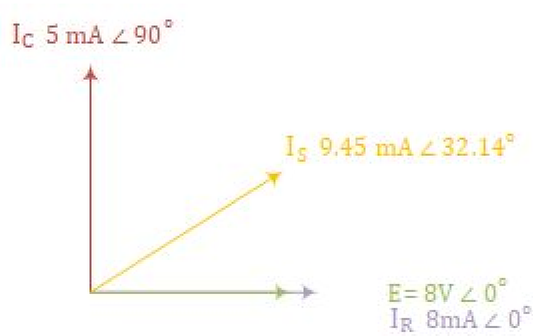


Table 9.8

I_S(Diagram)		I_S(Calculated)	θ_S	θ_C	θ_T
9.45 mA ∠ 32.14°		10 mA	40.32°	86.40°	126.72°

Table 9.9

Quantity		Measured (Calculated from Measured Values)	Theoretical (Calculated)
$I_{S(p\text{-}p)}$		11.10 mA	12.7 mA ∠-90°
$I_{L(p\text{-}p)}$		12.8 mA	12.7 mA ∠90°
$I_{C(p\text{-}p)}$		5.03 mA	.005 mA ∠90°
$I_{R(p\text{-}p)}$		8 mA	8 mA ∠0°

Conclusion

In this laboratory exercise we studied the effect of a parallel AC network consisting of inductive and capacitive components, used a sensing resistor to determine the current passing through said elements, and verified the validity of Kirchhoff's Current Law or Junction Rule via comparison of experimental and theoretical results.

References

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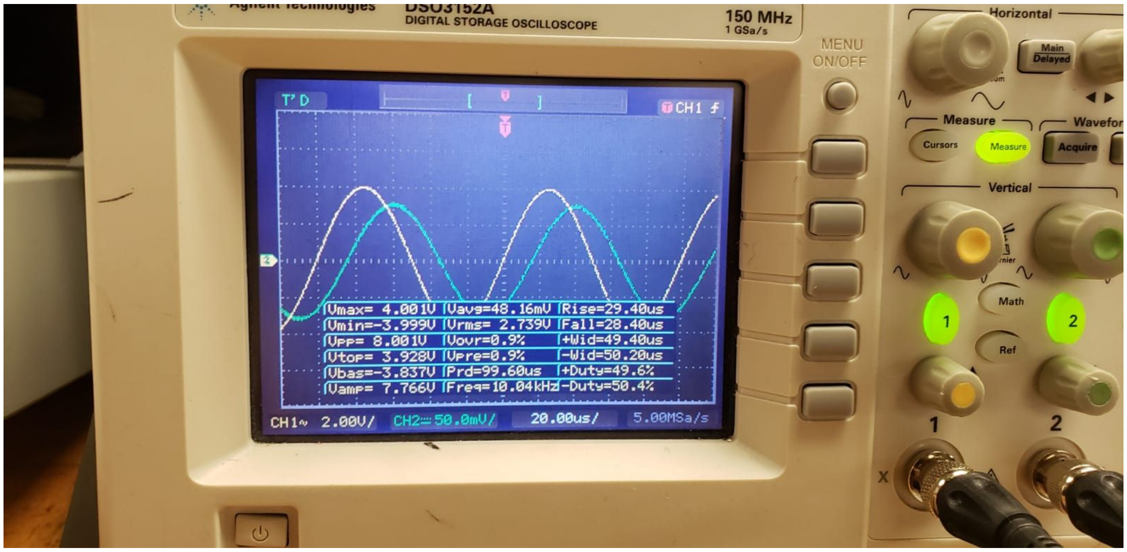
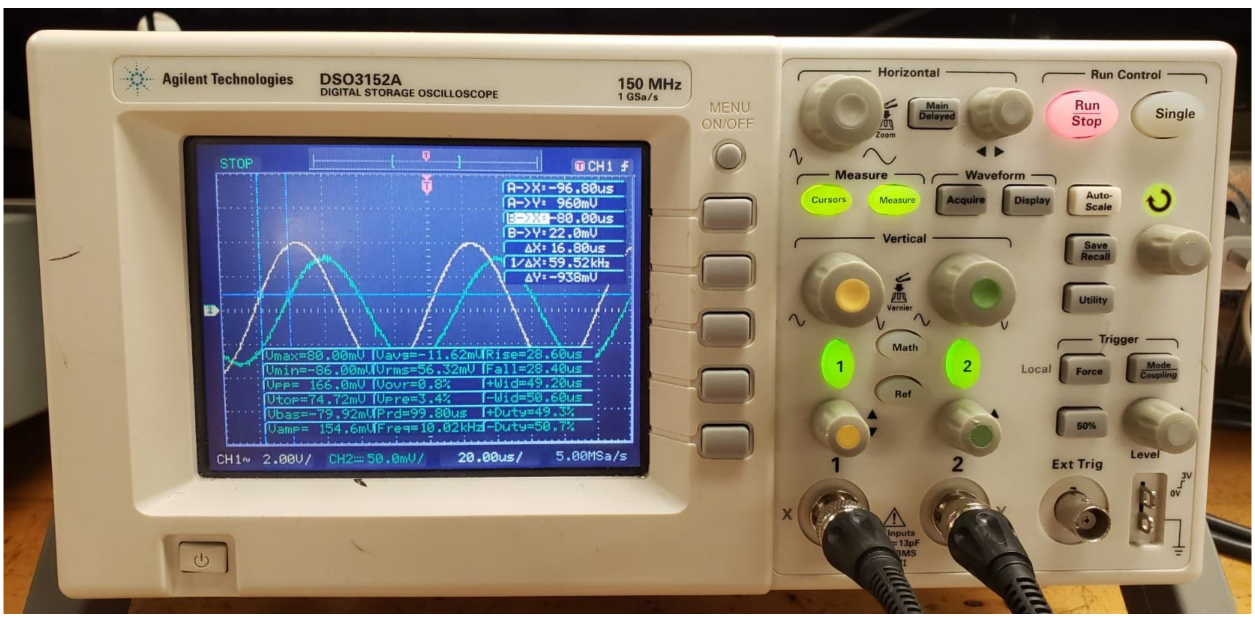
Experimental Photos

Part 1





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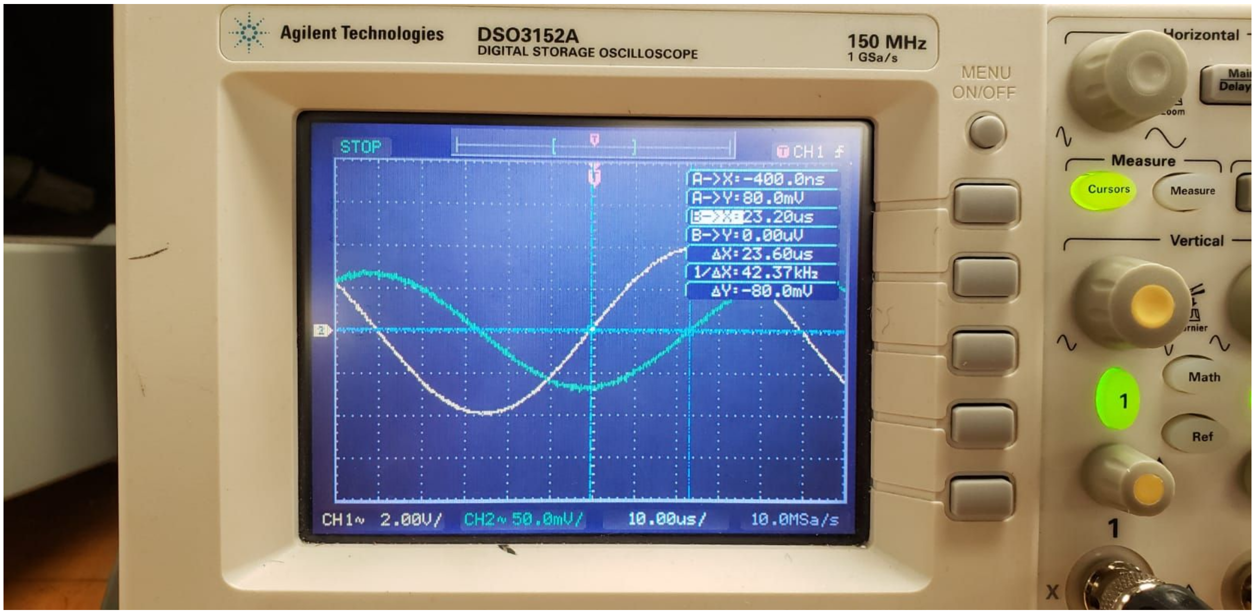
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Measure
Cursors
Measure
Vertical
Math
Ref
STOP
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A->Y:80.0mV
B->X:23.20us
B->Y:0.00uV
ΔX:23.60us
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ΔY:-80.0mV
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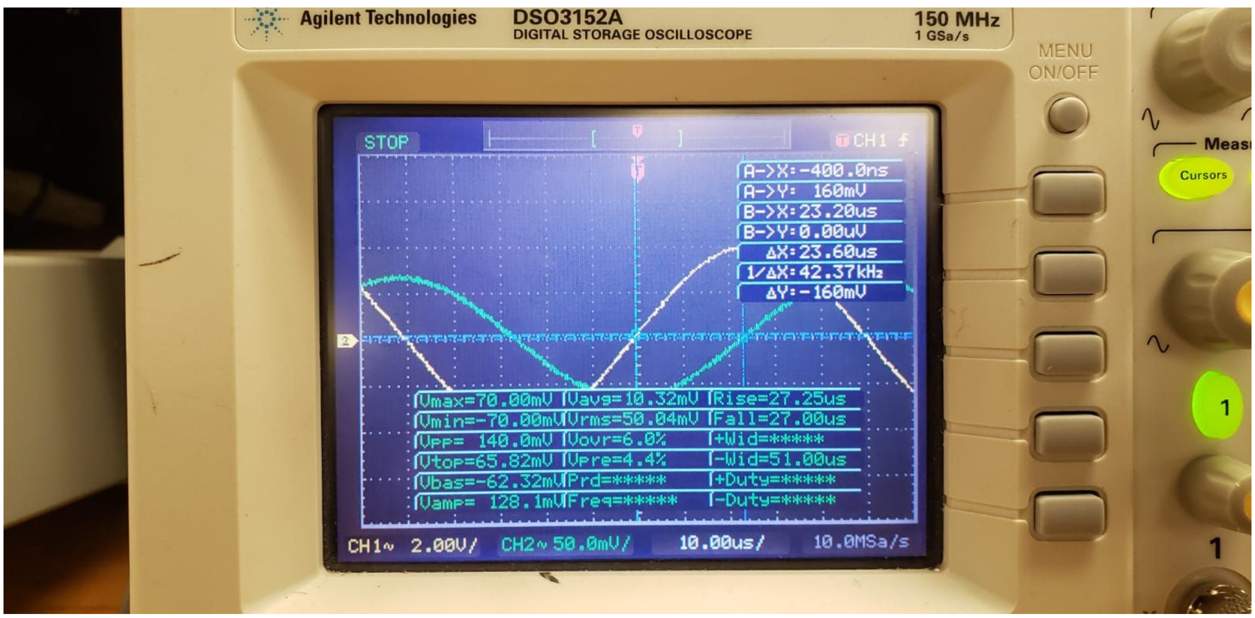
CH2~ 50.0mV/
10.00us/
10.0MSa/s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B->Y:0.00uV
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ΔY:-160mV
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Vpp= 140.0mV Vovr=6.0% +Wid=*****
Vtop=65.82mV Vpre=4.4% -Wid=51.00us
Vbas=-62.32mV Prd=***** +Duty=*****
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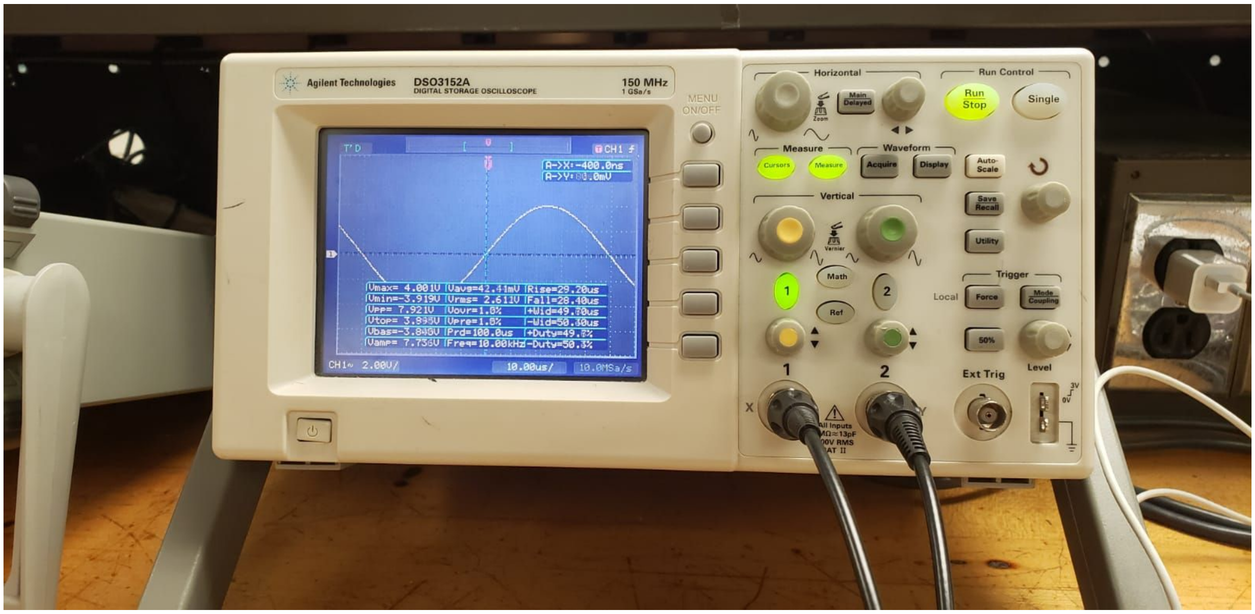
CH1~ 2.00V/
CH2~ 50.0mV/
10.00us/
10.0MSa/s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CH1 2.00V/
10.00us/
10.0MSa/s
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Run Stop
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Acquire
Display
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Ref
Trigger
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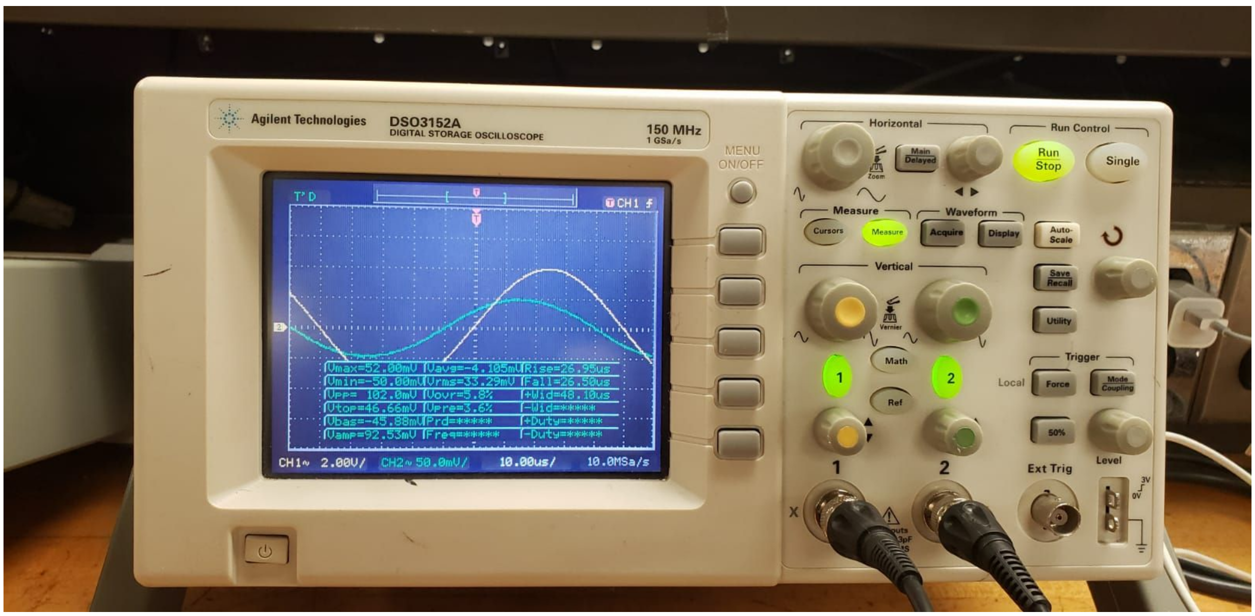
Ext Trig
Level

Part 2b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+Wid=48.10us
Vtop=46.66mV
Vpre=3.6%
Vbas=-45.88mV
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CH1 2.00V/
CH2 50.0mV/
10.00us/
10.0MSa/s
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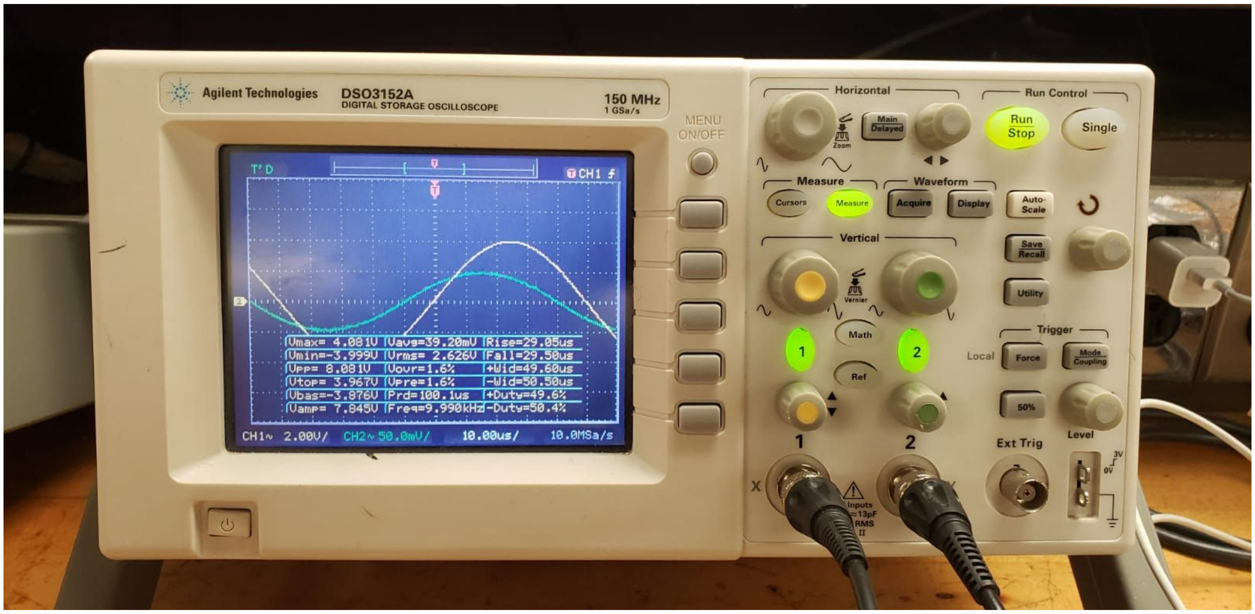
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Vpp= 8.081V |Vovr=1.6% |+Wid=49.60us
Vtop= 3.967V |Vpre=1.6% |-Wid=50.50us
Vbas=-3.876V |Prd=100.1us |+Duty=49.6%
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CH1~ 2.00V/ CH2~ 50.0mV/ 10.00us/ 10.0MSa/s
Horizontal
Main Delayed
Zoom
Run Control
Run Stop
Single
Measure
Cursors
Measure
Waveform
Acquire
Display
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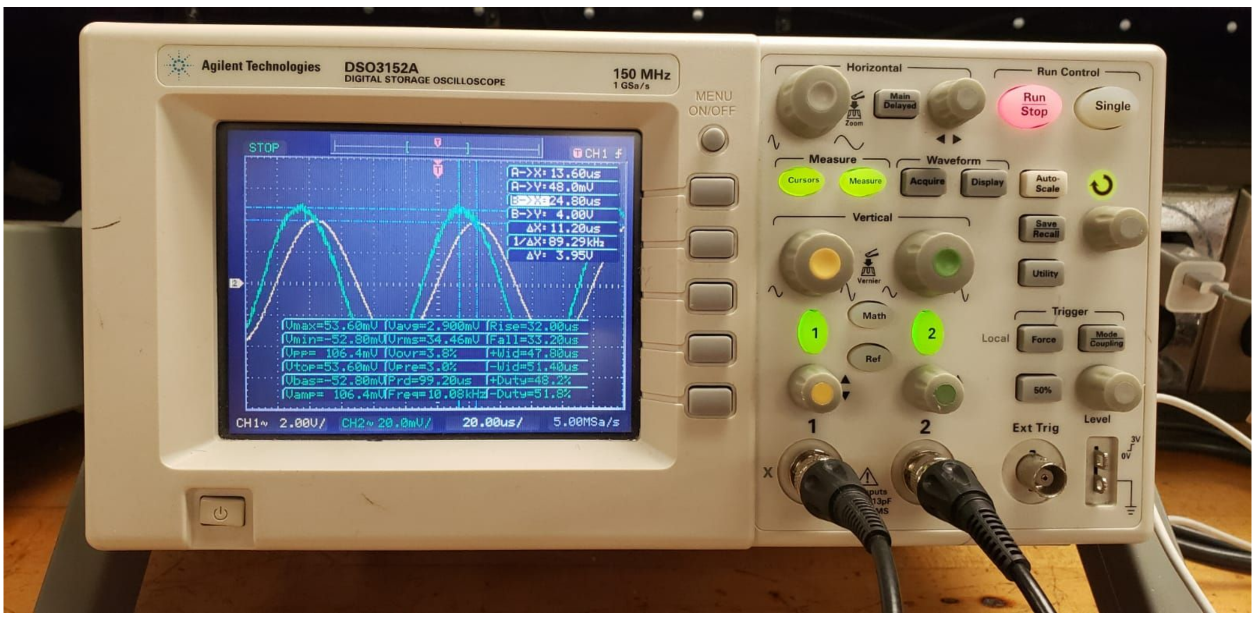
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Vpp= 106.4mV |Vovr=3.8% |+Wid=47.80us
Vtop=53.60mV |Vpre=3.8% |-Wid=51.40us
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CH1~ 2.00V/ CH2~ 20.0mV/ 20.00us/ 5.00MSa/s
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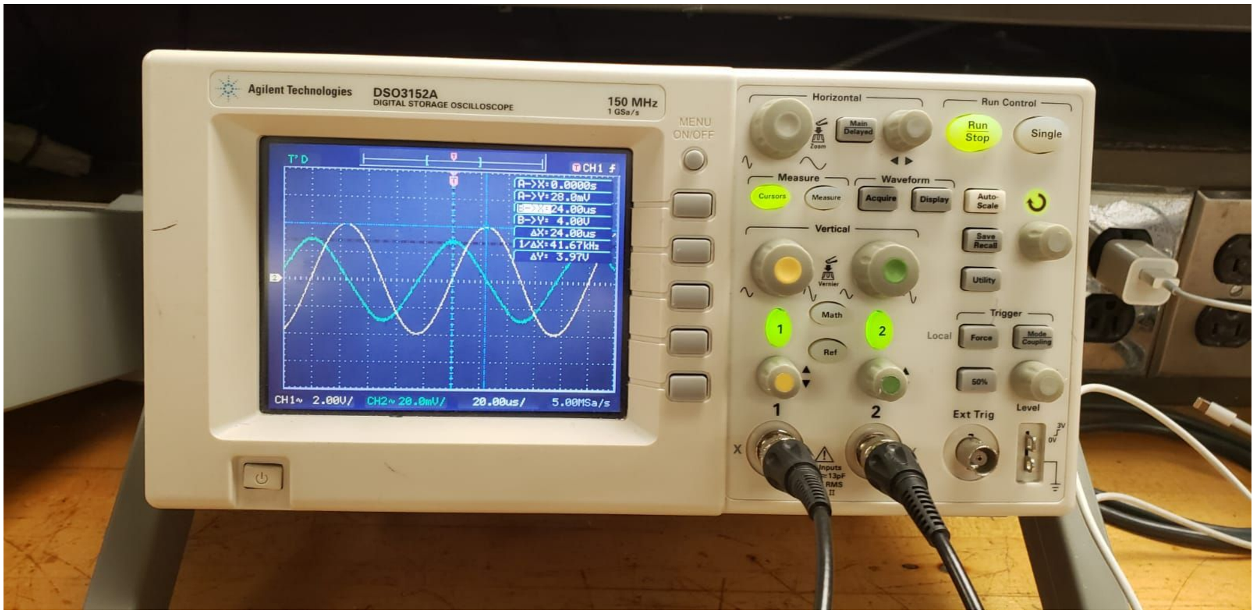
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B->Y: 4.00V
ΔX:24.00us
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ΔY: 3.97V
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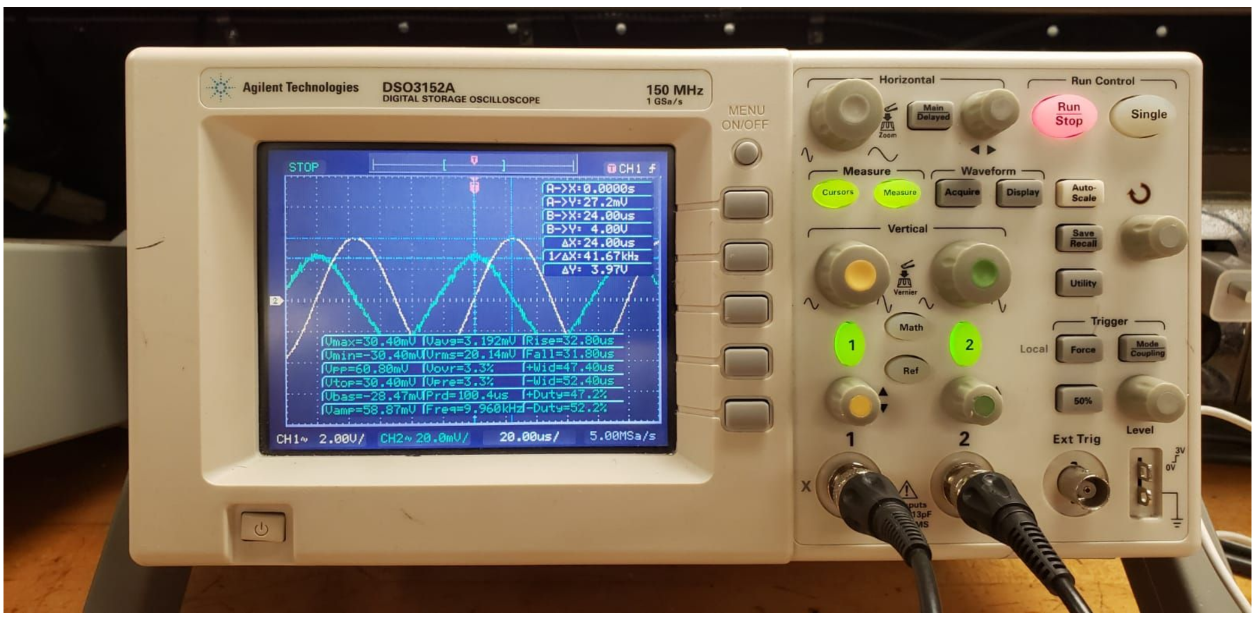
5.00MSa/s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ΔX:24.00us
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ΔY: 3.97V
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Vmin=-30.40mV Vrms=20.14mV Fall=31.80us
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CH1~ 2.00V/
CH2~ 20.0mV/
20.00us/
5.00MSa/s