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Lab 3 & 4: Oscilloscope

EEE 117 Lab – Section 4: Tuesday, 4:30pm – 7:10pm

Abstract:

The objective of this lab is to provide an introduction to the oscilloscope and build on the skills of using the function generator and Digital Multimeter (DMM). The oscilloscope is the most used and important instrument used in the electrical engineering laboratory. It allows the user to view waveforms, but also their shape and position of several waveforms. There are four main control on the front panel of the oscilloscope; input (vertical) section, time base (horizontal), trigger section, measurement section. When testing circuits it is crucial to know what these four controls do, and where they are located at on the oscilloscope.

Introduction:

The four main control sections on the oscilloscope are on the front panel. The input (vertical section) is found on the bottom left of the control section. Time base (horizontal) section is found in the middle left of the control panel, and controls the time displayed on the horizontal axis. Third is the trigger section which synchronizes the horizontal sweep time with the input signals, and is located on the upper right of the control panel. Lastly the measurement section is found on the upper left of the control panel, and provides voltage and time measurements.

This lab is broken up into three parts; vertical controls, trigger controls, and measurements. In the first part the probes will be used along with the circuit diagram found in Figure 1 (below). A resistance value would be need to be known before setting up the circuit. The calculations made can be found in Figure 2. The second part use the same wave found in section one but will be exploring the trigger controls, by changing it from *Auto* to *Norm*, changing trigger level, and the slope. The last part considers the measurement section of the oscilloscope, while also explaining the voltage settings on the function generator.

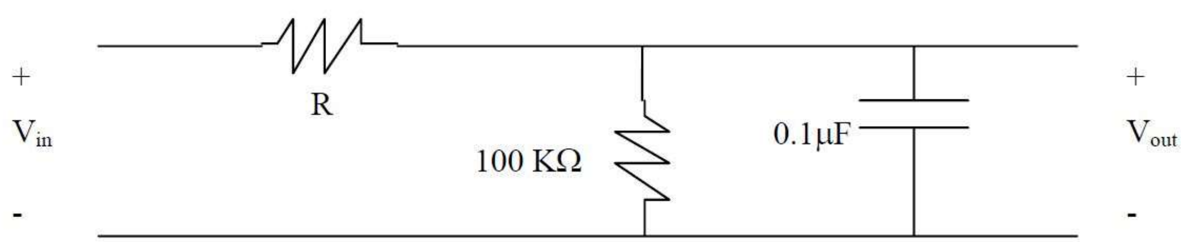


Figure 1. RC Circuit

Simulations and Data Collection:

In the Vertical Controls section there will be two voltage measurements made on the calibrator voltage. To begin on the Vertical (input) Controls section select Channel 2, then on the menu labeled *COUPLING* select DC. There will be a trace on the screen with a caret on the right vertical axis. Adjust the vertical position so that ground is in the center of the screen. Use the x10 probe to connect the calibrator voltage (metal loop below the screen) to the Chanel #2 input. Adjust the *TIME BASE* control so that are about 4 cycles seen on the screen, and repeat these steps for the x1 probe.

With Channel #1 on DC, and the probe set to x10 use the probe to connect the function generator to Channel #1, while also setting the trigger source to Channel #1 on the oscilloscope. Set the oscilloscope which has a function generator in it, to a 1 KHz sinusoid with a 1 volt peak to peak amplitude, and 0 volts DC offset. Adjust the oscilloscope's time base control for 4 cycles of the sine wave. Then add a DC offset of 1 volt, observe the changes (Figure 3). Change the channel coupling from DC to AC and observe the changes (Figure 4).

Connect the circuit shown in Figure 1, use the R value found in the calculations (Figure 2) so that there is a 45° phase shift from V_{in} to V_{out} for a 1 KHz sine wave. Connect V_{in} to the function generator, Channel #1 to V_{in}, and Channel #2 to V_{out}, then observe the waveforms. Adjust the vertical position of Channel #2 until the signal is off the screen. There will be an arrow with a 2 pointing up indicating the signal is off of the top of the screen.

Capacitor Value	Resistor Given Value	Resistor Measured Value	% Error
0.1 µF	100k Ω	100, 100 Ω	0.1 %
0.1 µF	1.6k Ω	1,573.9 Ω	1.63 %

Table 1. Measured Values from the R-C Circuits

The Triggering Controls section, use the same 1 Volt peak-peak sine wave that was used in the previous section. On the triggering controls select *SOURCE* and from the menu select *CHANNEL #1*. Next select on *MODE* and from the menu select *NORM*, if there is no trace turn the level control in the triggering control. The trigger level should intersect the signal voltage, turn the level control until a trace is observed. The time reference can be changed by selecting

MAIN/DELAYED in the horizontal control section and *TIME REFERENCE* from the menu. Observe the changes as the triggering point changes as the trigger level changes (Figure 5).

Select *SLOPE/COUPLING* and from the menu select rise/fall and observe the slope when it going from rise to fall (Figure 6). Lastly observe when triggering mode is toggled from *NORM* to *AUTO*. Move the triggering level from inside the voltage signal to outside the signal voltage range (Figure 7).

In the last section, set up the function generator for a 1 volt peak-peak 1 KHz sine wave with 0 volts offset. Connect the function generator to the DMM and to Channel #2 of the oscilloscope. From the measurement section of the oscilloscope select *VOLTAGE*, then on the on-screen menu select Channel #2 and measure Volt peak-peak and Vrms for the waveform. Then use the DMM to measure the AC rms value, and see if they are consistent. Connect a 51Ω resistor across the function generator and repeat for the readings.

	Oscilloscope	DMM
RMS Voltage of Waveform 1	0.35875	0.3545
RMS Voltage of Waveform 2	0.18	0.1782

Table 2. RMS Voltage Readings With and Without 51Ω Resistor

Vrms Channel #1	0.36 Vrms
Vrms Channel #2	0.2526 Vrms
Frequency Measurement	1 kHz
Frequency Measurement Channel #2	1 kHz
Period Measurements	1 ms
Timedelay	142 μs

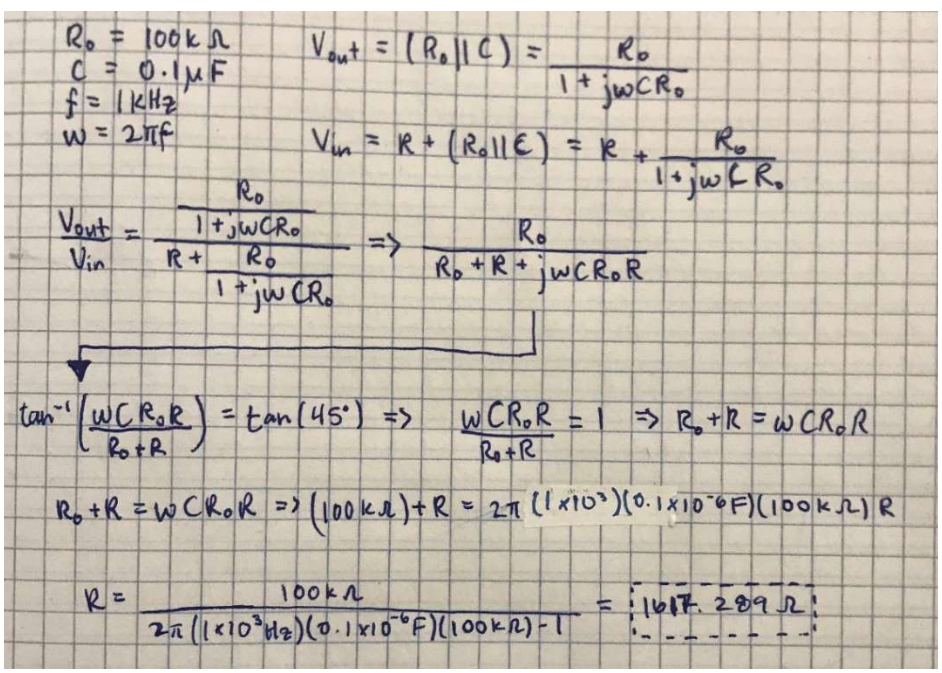
Table 3. Measurements for Determining Phaseshift

Connect the R-C circuit (Figure 1), and measure the RMS voltages of both waveforms. Clear the voltage measurements and use the *FREQUENCY* to measure the frequency of the waveform. Clear the frequency measurement and select *TIME*, use the cursors to measure the time delay and period from both waveforms. Us the sinusoidal steady state techniques to calculate the magnitude and phase between input and output voltages.

Results and Calculations:

The vertical position moves the trace up and down on the screen, and allows the operator to set their zero/origin. When trying to see the voltage going through a probe, it is important to put them in series with the oscilloscope. As a result when both the X1 and X10 probe were hooked up with the oscilloscope the peak to peak voltage was at 5 volts. When changing the DC offset to 1 volt is moves the sine wave up by one volt for both channels (Figure 3). However when changing the coupling from DC to AC and keeping the 1 volt peak-peak, it displays as if there is no offset (Figure 4). Examining the input and output on the oscilloscope there seems to be a notable phase difference between V_{in} and V_{out} where V_{out} is about 45° ahead. In order to have done this part of calculations of the resistance value would have need to be done, as seen on Figure 2.

Trigger notes where the caret lines up on the trace. Wherever the trigger line intercepts the race it will line up with the caret, but this also is dependent on the time reference. When changing the slope on the oscilloscope rise will make the positive slope of the trace will start at the trigger level (Figure 5). While fall will make the negative slope of the trace start at the trigger level (Figure 6). Having the trigger mode at *NORM* and outside range the trace stays stable (Figure 7), while having it on *AUTO* the trace becomes unstable (Figure 8).



$R_o = 100k\Omega$
$C = 0.1\mu F$
$f = 1kHz$
$w = 2\pi f$

$$V_{out} = (R_o \| C) = \frac{R_o}{1 + jwCR_o}$$

$$V_{in} = R + (R_o \| C) = R + \frac{R_o}{1 + jwCR_o}$$

$$\frac{V_{out}}{V_{in}} = \frac{\frac{R_o}{1+jwCR_o}}{R + \frac{R_o}{1+jwCR_o}} \Rightarrow \frac{R_o}{R_o + R + jwCR_oR}$$

$$\tan^{-1}\left(\frac{wCR_oR}{R_o+R}\right) = \tan(45°) \Rightarrow \frac{wCR_oR}{R_o+R} = 1 \Rightarrow R_o + R = wCR_oR$$

$$R_o + R = wCR_oR \Rightarrow (100k\Omega) + R = 2\pi(1\times10^3)(0.1\times10^{-6}F)(100k\Omega)R$$

$$R = \frac{100k\Omega}{2\pi(1\times10^3 Hz)(0.1\times10^{-6}F)(100k\Omega) - 1} = \boxed{1617.289\,\Omega}$$

Figure 2. Calculations for R Value in the R-C Circuit

Working on the last section of the lab when measuring the Vrms on the oscilloscope and DMM the measurements were consistent with each other. Then by putting the 51Ω resistor in series with the function generator halves the peak-to-peak voltage, the difference can be seen on Figures 9 and 10. The measurements of the R-C circuit in Figure 1, can be seen on Table 3. Calculating phaseshift was determined by the formula below:

$$Phaseshift = 360 * timedelay / period$$

The measured phaseshift was at 51.12°, while the calculated was at 45°, for a 13.2% percent error.

Conclusion:

In conclusion oscilloscope operation is an important skill to learn, and this ranges from reading the graphs and maneuvering the controls. Overall the difference between DC and AC coupling is that the offset does not apply to the AC waveform. Using the probes on the oscilloscope, it is better to use the X1 probe because you do not need to multiply it by anything and it gives you the raw number. The difference between *AUTO* and *NORM* is that the waveform being displayed is updating when on auto, making it become distorted when the trigger level goes out of range. However when in norm the waveform displayed is a snapshot of it and this is why the waveform stays stabilized when the trigger level is out of range, since the sine wave is during a set time. Overall our calculations were not as off as to what the theoretical values being presented to us.

Appendix:

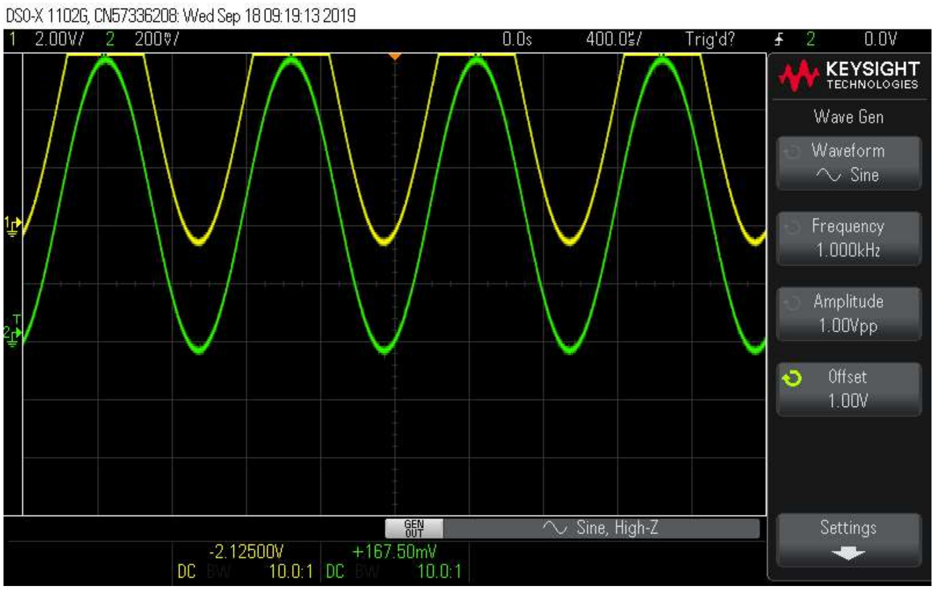


Figure 3. DC Offset Changed to 1 Volt peak-peak

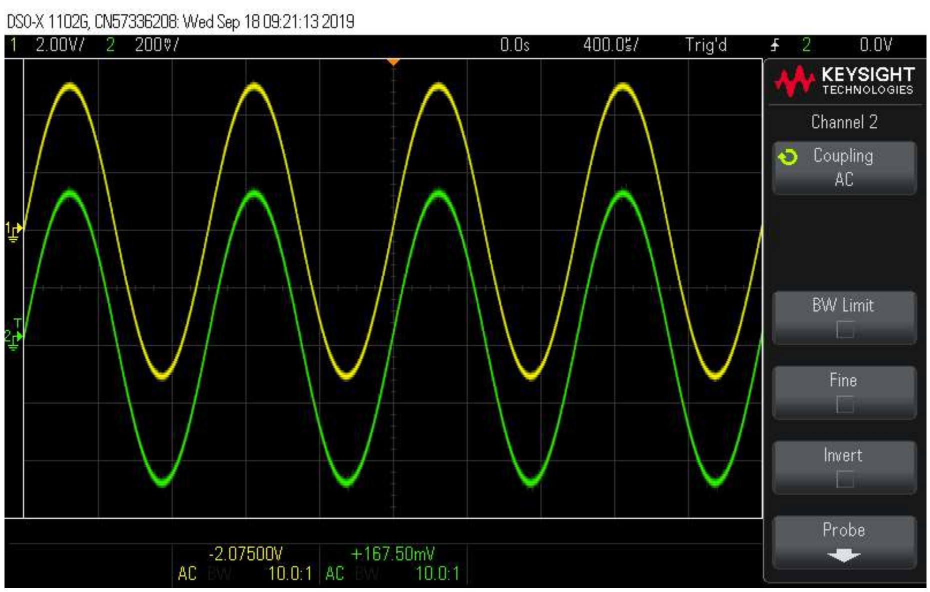


Figure 4. DC Coupling Changed to AC Coupling

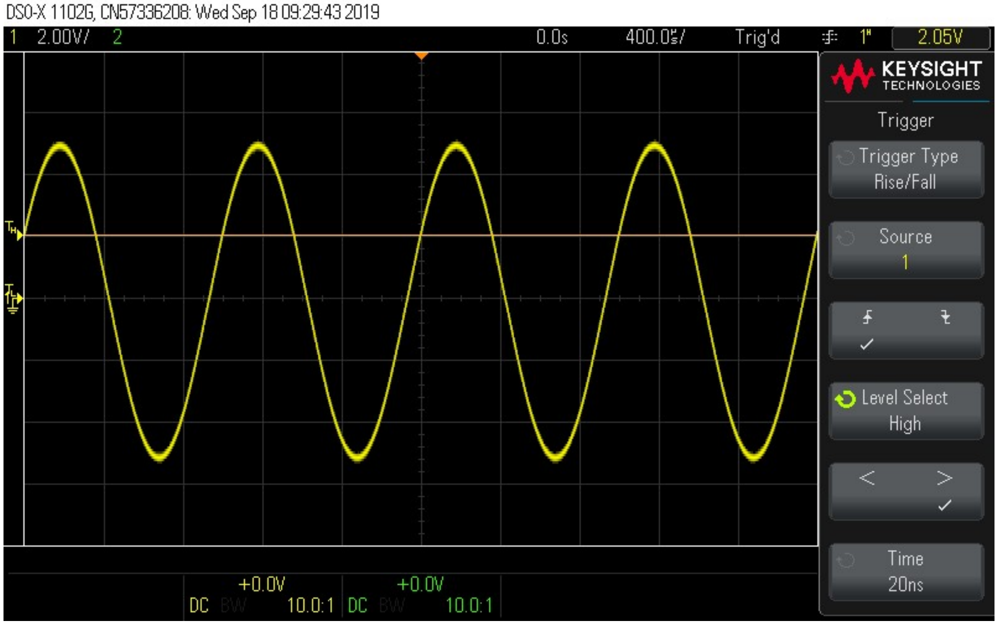


Figure 5. Trace When Trigger Type is Changed to Rise

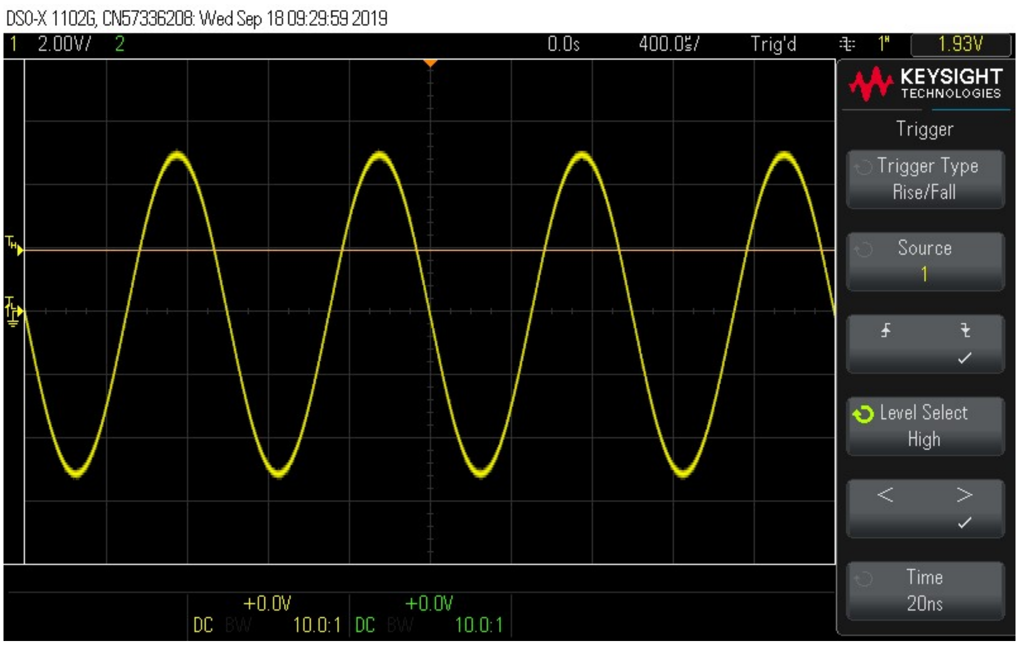


Figure 6. Trace When Trigger Type is changed to Fall

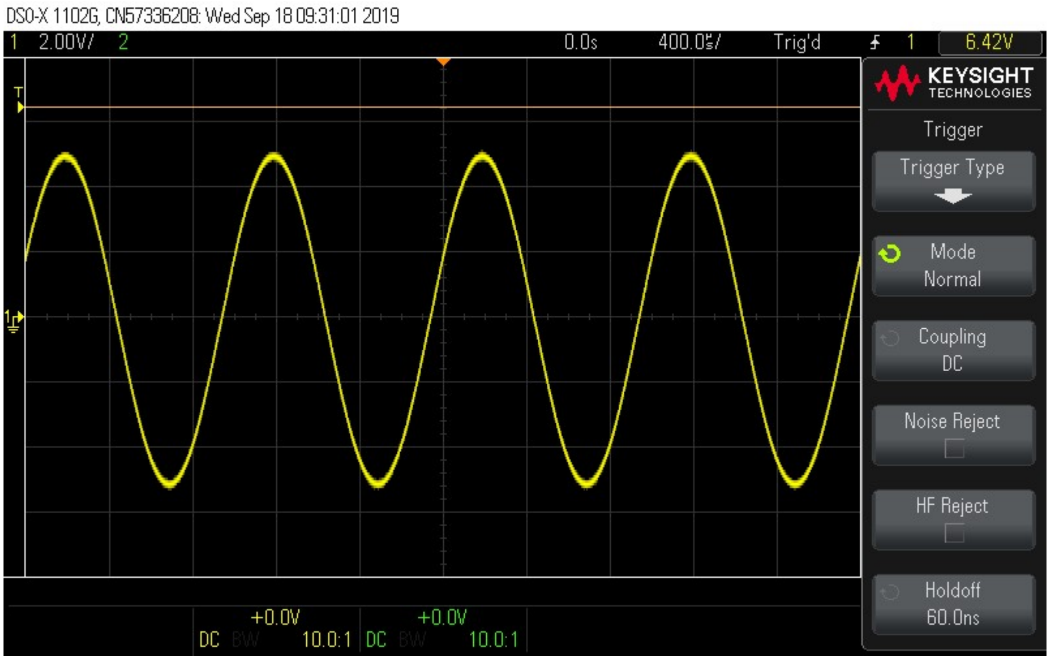


Figure 7. Trigger Mode NORM with Level Out of Range

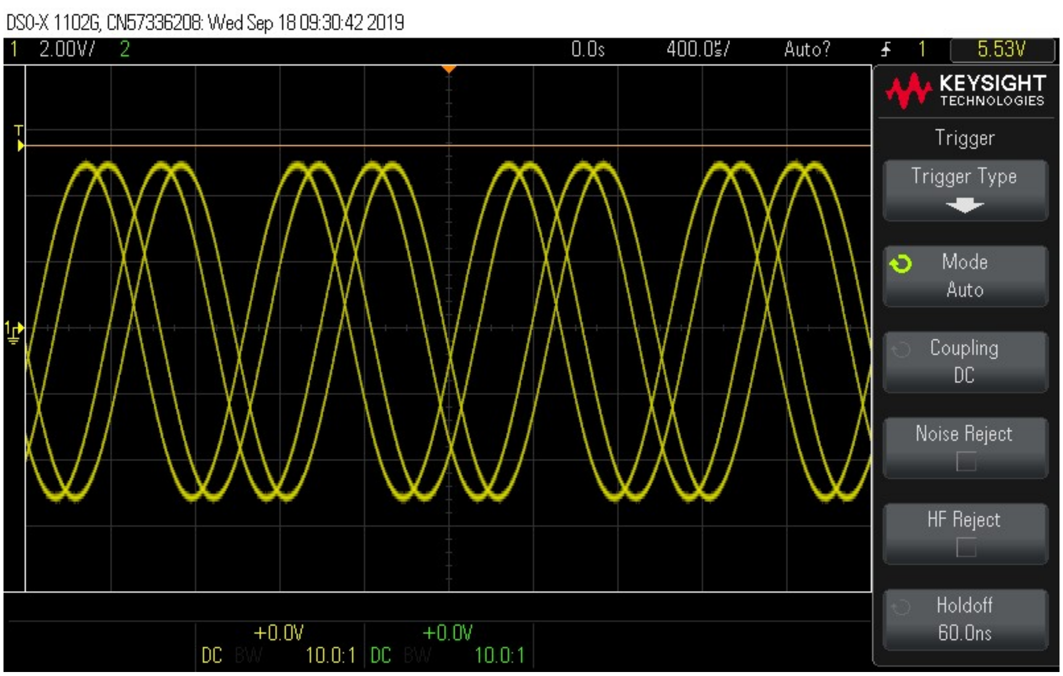


Figure 8. Trigger Mode AUTO with Level Out of Range

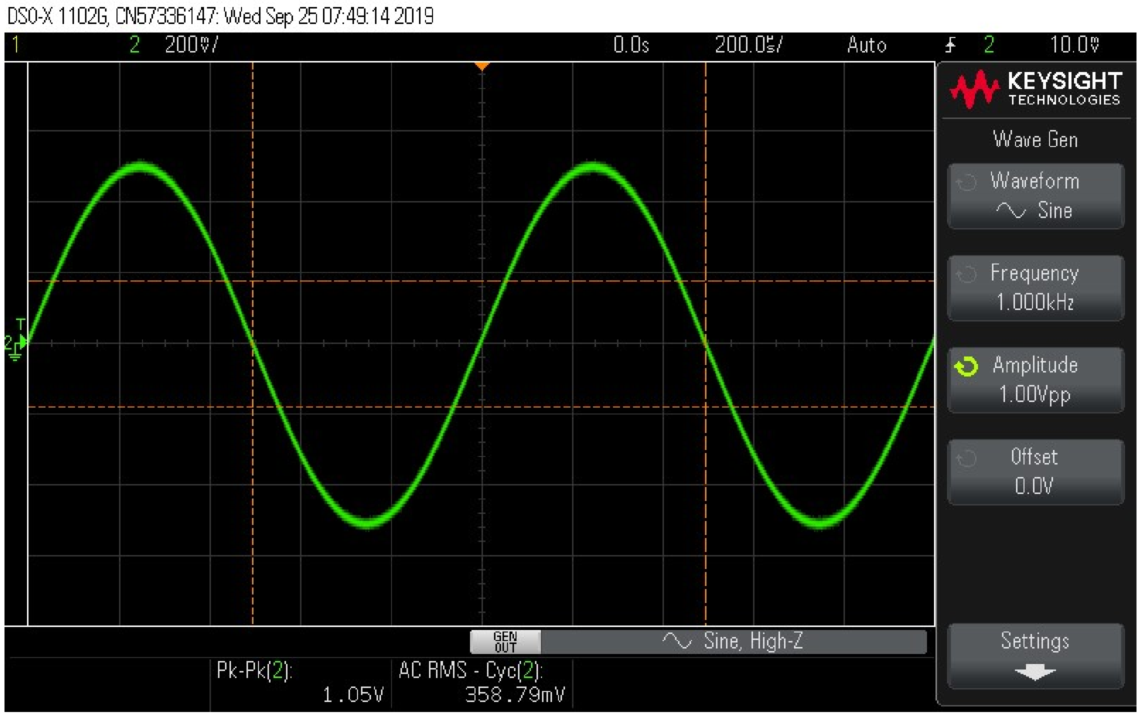


Figure 9. AC Vrms of Channel #2 without 51Ω Resistor

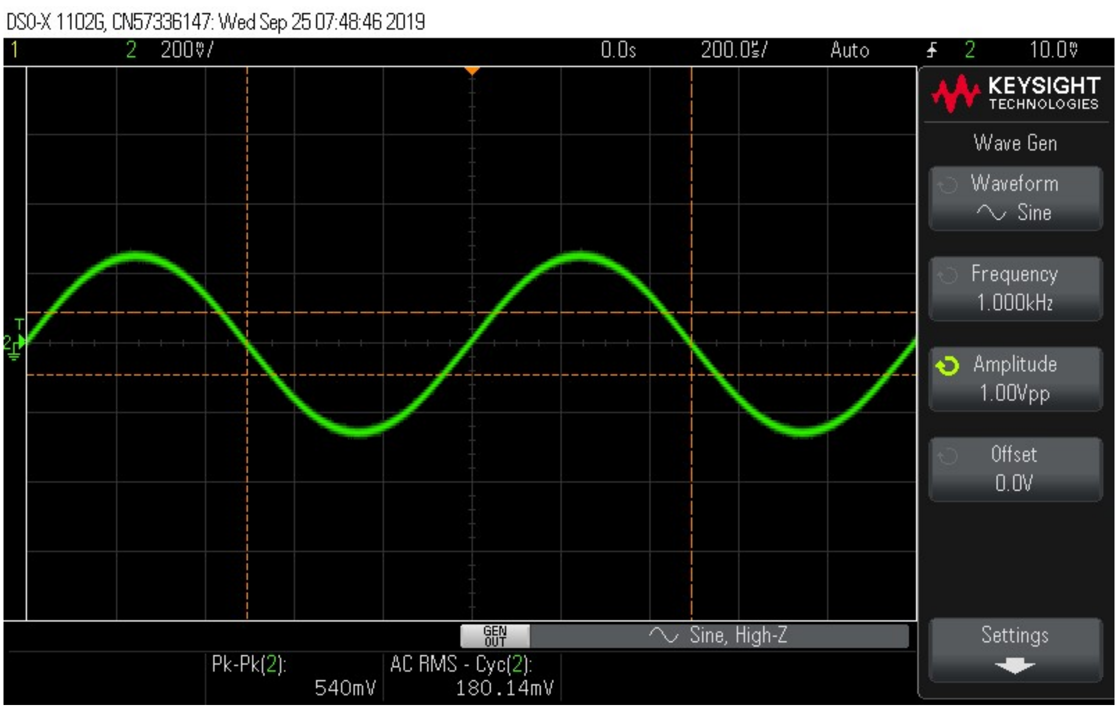


Figure 10. AC Vrms of Channel #2 with 51Ω Resistor