# PSoC 5LP Oscilloscope and Waveform Generator v1.1 Manual
# Electronics First

This PDF will describe how to utilize a CY8CKIT-059 PSoC 5LP as a two-channel, 20 KHz bandwidth oscilloscope and waveform generator. It will also describe the various features included within the associated graphical user interface (GUI). This manual corresponds to version 1.1 of the PSoC creator files as well as version 1.1 of the graphical user interface. Currently, the GUI only supports PCs running a windows operating system. In addition, the oscilloscope described within this manual only supports positive input voltages.

Below is a list of materials needed to complete the required oscilloscope shield v1.2 board.

| Part | Quantity | Part Number | Vendor |
|---|---|---|---|
| Breadboard | 1 | 377-2646-ND | DigiKey |
| Breadboard Power Supply and Cable | 1 | - | - |
| PSoC 5LP Carrier Board | 1 | - | - |
| Multimeter | 1 | MN35-ND | DigiKey |
| Soldering Iron and Solder Wire | 1 ea. | T0052918199N-ND | DigiKey |
| USB A to Right-Angle Micro USB B Cable | 1 | USB2AUB2RA1M | Amazon |
| J1, J2, J3, J4 - 8-pin Header Pins | 4 | SAM11913-ND | DigiKey |
| J5, J6, J7 - Straight BNC Connector | 3 | 343-CONBNC001-ND | DigiKey |
| R1, R2 - 1 MΩ 1% Resistor | 2 | RNF14FTD1M00CT-ND | DigiKey |
| R3 - 51 Ohm Resistor | 1 | CF14JT51R0CT-ND | DigiKey |
| C1, C2* | 2 | | |

* C1 and C2 are compensation capacitors associated with oscilloscope channels A and B respectively. They are not strictly necessary for proper oscilloscope operation but might improve performance if desired. Discussion of compensation capacitors is included in Issue 2. Compensation Capacitors.

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# Section I: Starting Out

## Step 1. Build Oscilloscope Shield

In order to use PSoC oscilloscope and GUI one must use the appropriate Electronics First Oscilloscope Shield v1.2 printed circuit board pictured on the left below. Solder on the four female headers, J1 through J4, the two 1 MΩ resistors, R1 and R2, the single 51 Ω resistor, R3, and the three BNC connectors, J5 through J7. For now, the compensation capacitors can be excluded until later testing. A finished version of the board (excluding compensation capacitors) is shown on the right below.
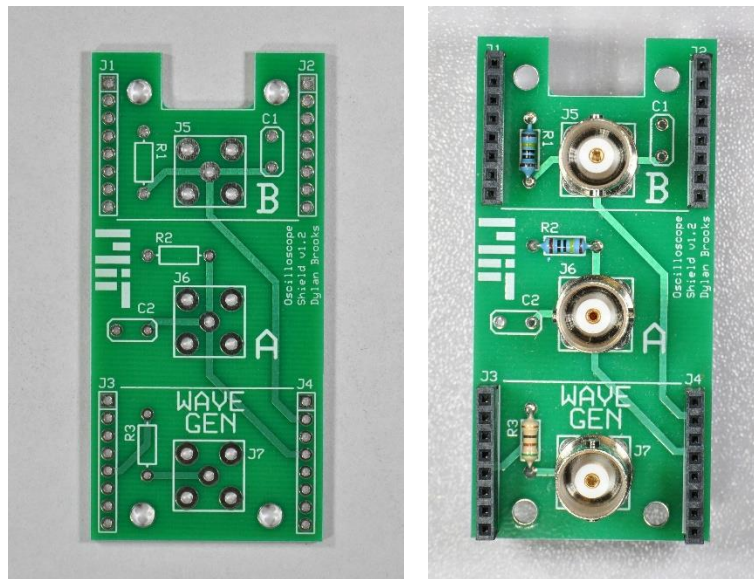


*Figure 1: Photo of a blank E First Oscilloscope Shield Board v1.2 (left). Photo of a populated E First Oscilloscope Shield Board v1.2 (right).*

Once your board has been assembled, you can insert it into the Electronics First PSoC Carrier Board v1.4. Inserting the board in the correct orientation is crucial for keeping the devices safe as well as proper performance. The notch in the shield board should be aligned with the micro-USB port on the PSoC. A picture of a finished shield board properly inserted into the PSoC carrier board is shown below.
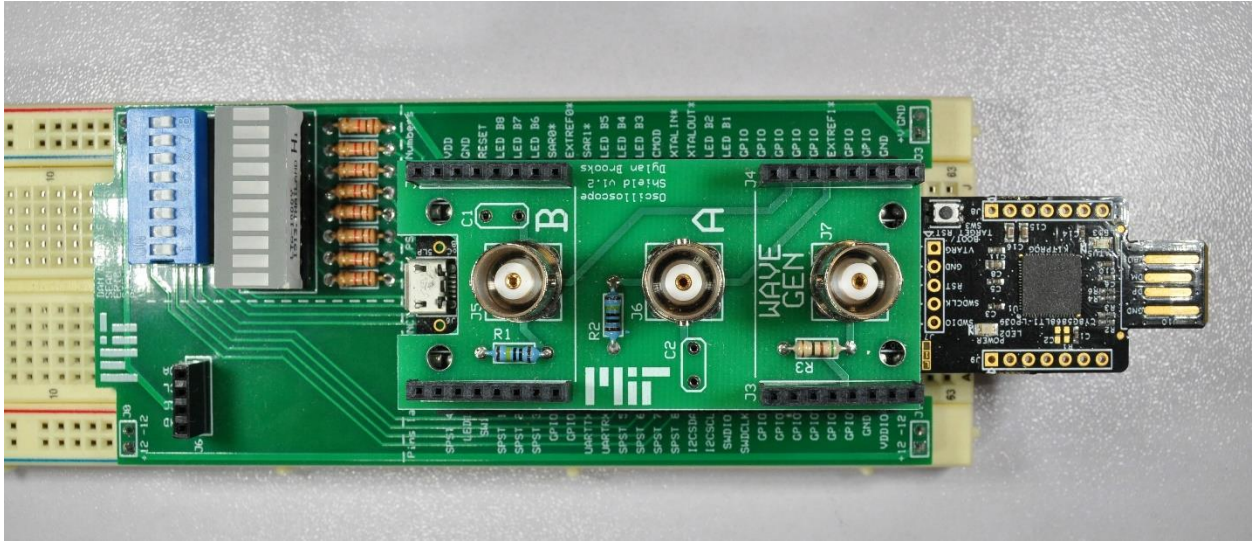
*Figure 2: Image depicting the shield board being properly inserted into the PSoC carrier board*

## Step 2. Initial Setup

In order to properly use the oscilloscope shield board, the PSoC must be programmed with the PSoC creator files associated with the oscilloscope shield board version. If your PSoC is already programmed with the necessary files, you may skip to Step 3. Running the Graphical User Interface. To program your PSoC with the necessary files, first run PSoC Creator 3.3. Next, go to File, Open, Project/Workspace. Click on Project/Workspace and locate the directory which contains the desired workspace. Then open the workspace file titled Oscilloscope_v1_0.cywrk.
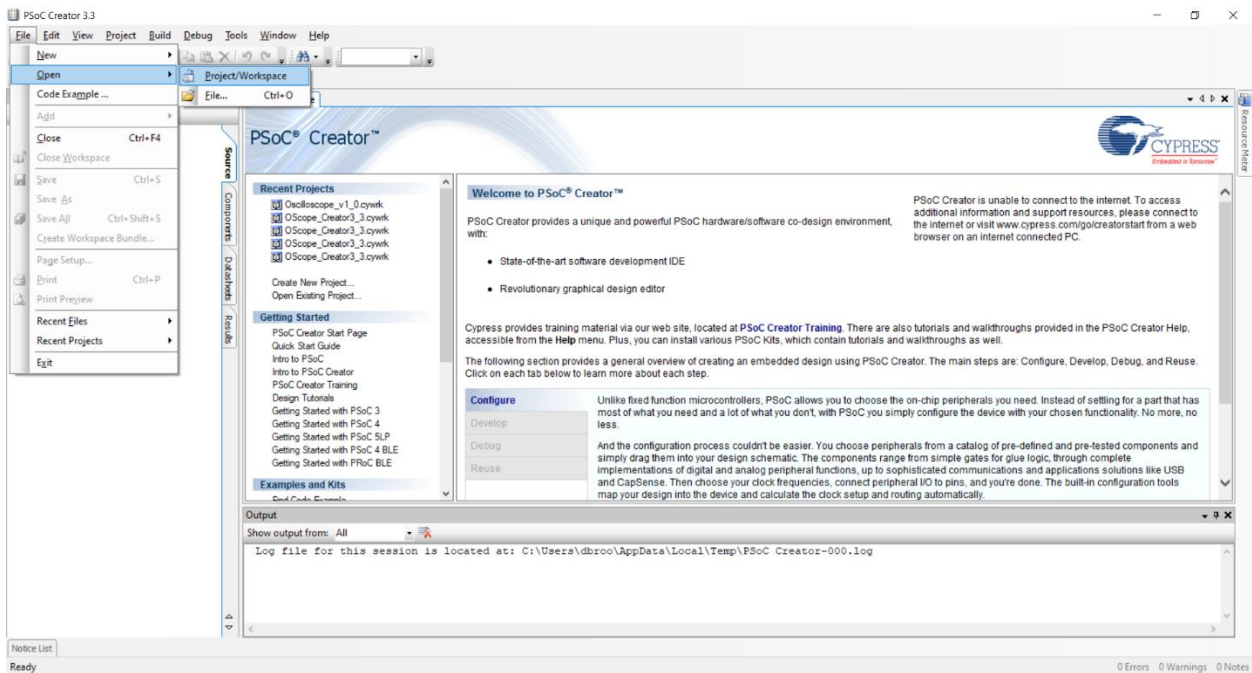


*Figure 3: Screenshot indicating how to open a PSoC Creator 3.3 workspace*

Once the workspace has been opened, navigate to Build and then Build Oscilloscope_v1_0. Click on Build Oscilloscope_v1_0 and wait for the program to finish building the necessary programming files.
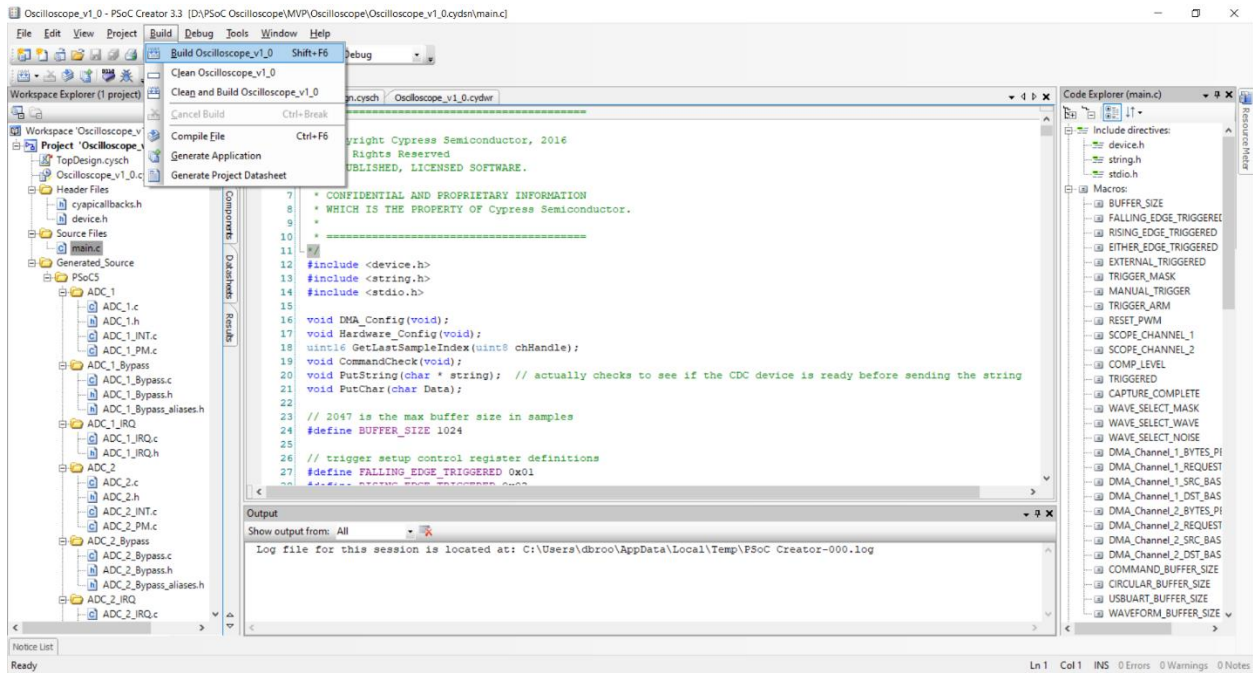


*Figure 4: Screenshot indicating how to build a project within PSoC Creator 3.3*
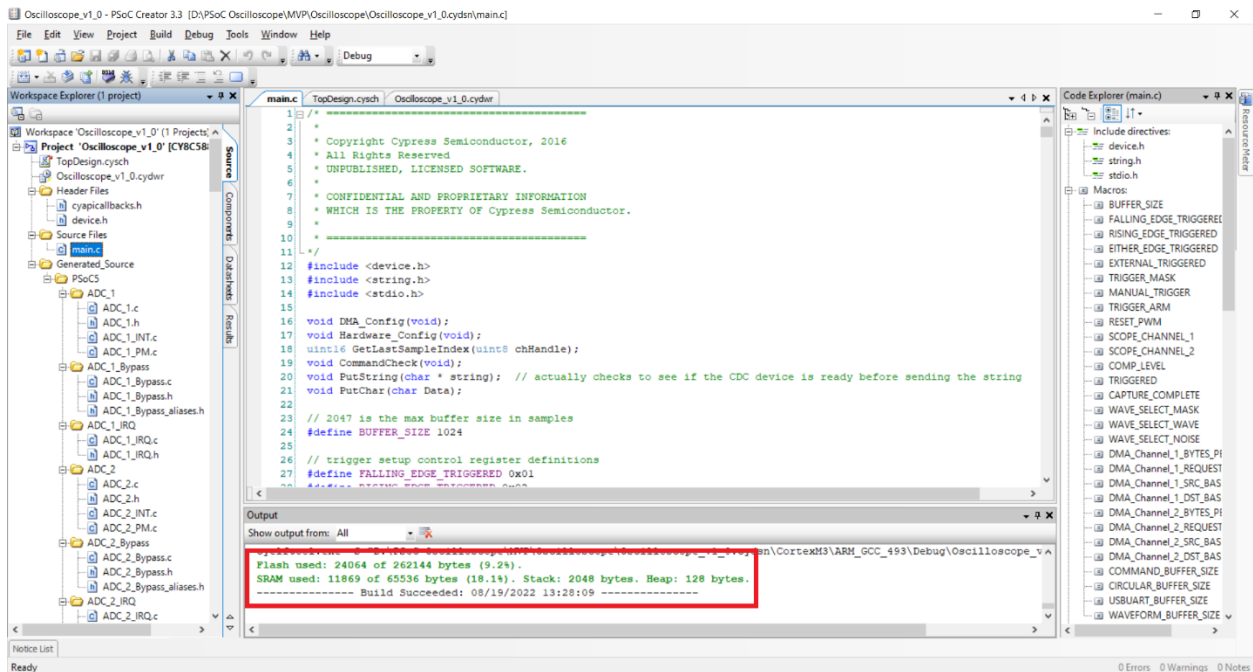


*Figure 5: Screenshot of a successful project build*

Once the build has completed, plug in your PSoC as depicted below.

*Figure 6: Photo depicting proper USB port for programming the PSoC*

When the PSoC has been connected to your PC, navigate to Debug and then Program. Once PSoC Creator has finished programming your PSoC disconnect the PSoC from your PC and close PSoC Creator.
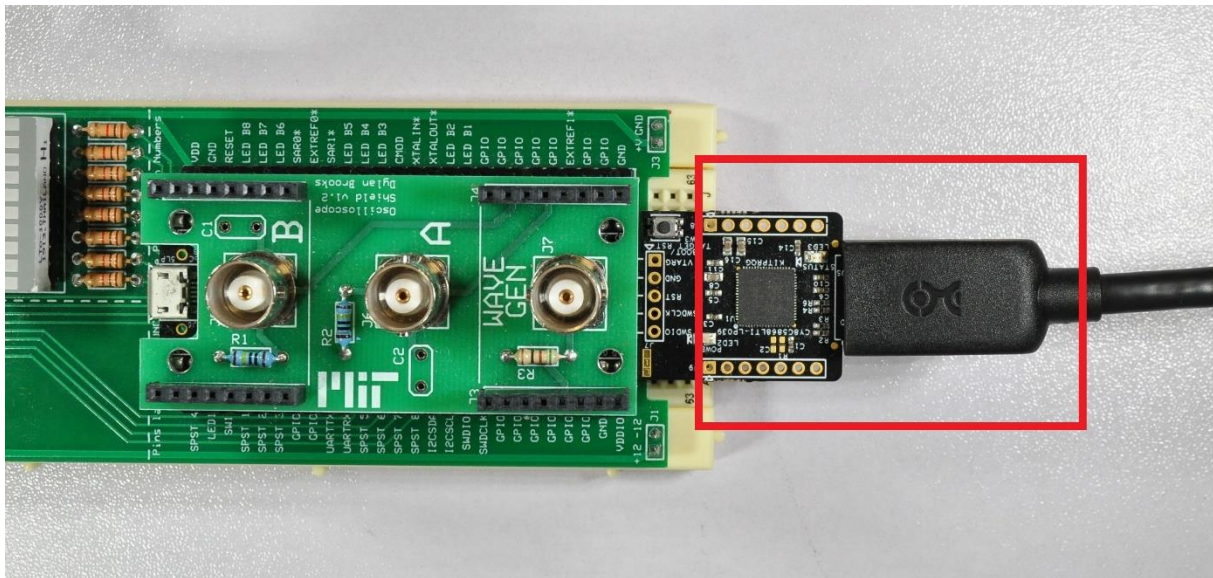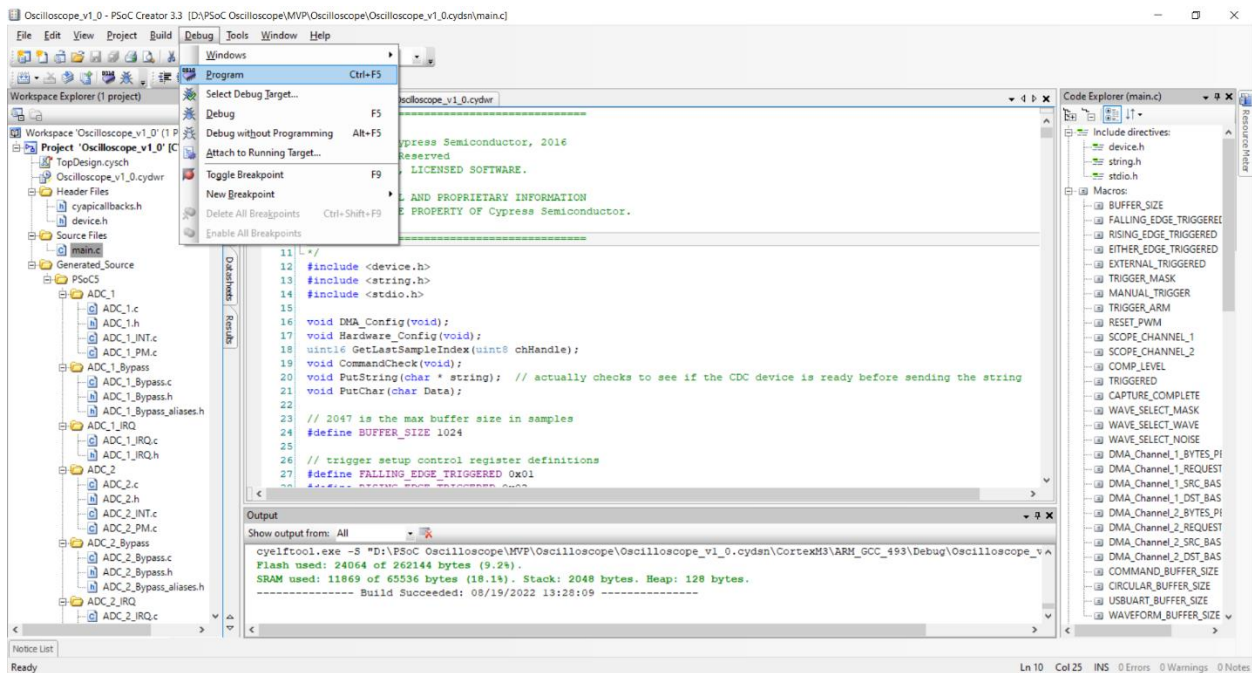


*Figure 7: Screenshot indicating how to program a project within PSoC Creator 3.3*

*Figure 8: Screenshot of a successfully programmed device*

# Step 3. Running the Graphical User Interface

With your finished shield board attached to your PSoC carrier board, plug in your PSoC using the right-angle micro-USB cable and connect the USB A end into your PC as depicted in the image below.



*Figure 9: Photo depicting proper USB port for interfacing the PSoC with the GUI*

Once your PSoC is properly connected to your PC with the shield board attached, open your PC's File Explorer and locate the directory which contains the GUI. Run ScopeGUI.exe. Upon startup the GUI should begin to search through your PC's ports until it locates the port that

your PSoC is connected to. If the GUI successfully locates the PSoC's port, it should connect and you're ready to begin interacting with the user interface. If, however, your computer was unable to connect to your PSoC, refer to Issue 1. Connecting PSoC to GUI for help.

## Step 4. Calibrating your Oscilloscope

The oscilloscope shield board as well as the GUI itself assume that all of the components are perfectly ideal components. However, no real-world components are ideal and as such your oscilloscope likely needs calibrated for proper performance. To do this we will utilize the GUI's built-in waveform generator located on the right hand side of the GUI. We will have the PSoC generate a 1 KHz square wave with a peak voltage of 1 V. To do this, we can use the sliders located within the Waveform Generator section of the GUI. First, let's set the type of waveform. Click on the button labeled "Square" on the right hand side. Next, let's set the frequency of the wave. One can either use the slider labeled frequency to adjust the frequency to a value near 1000 Hz or click the red frequency value located beside the frequency slider and input 1,000 into the input box which pops up. Finally, we will set the amplitude using the amplitude slider. Move the slider to a value of 25%. The offset slider should remain at 0. After setting these values the PSoC should be outputting an approximately 1 KHz, 1 V peak square wave through our Wave Gen BNC.
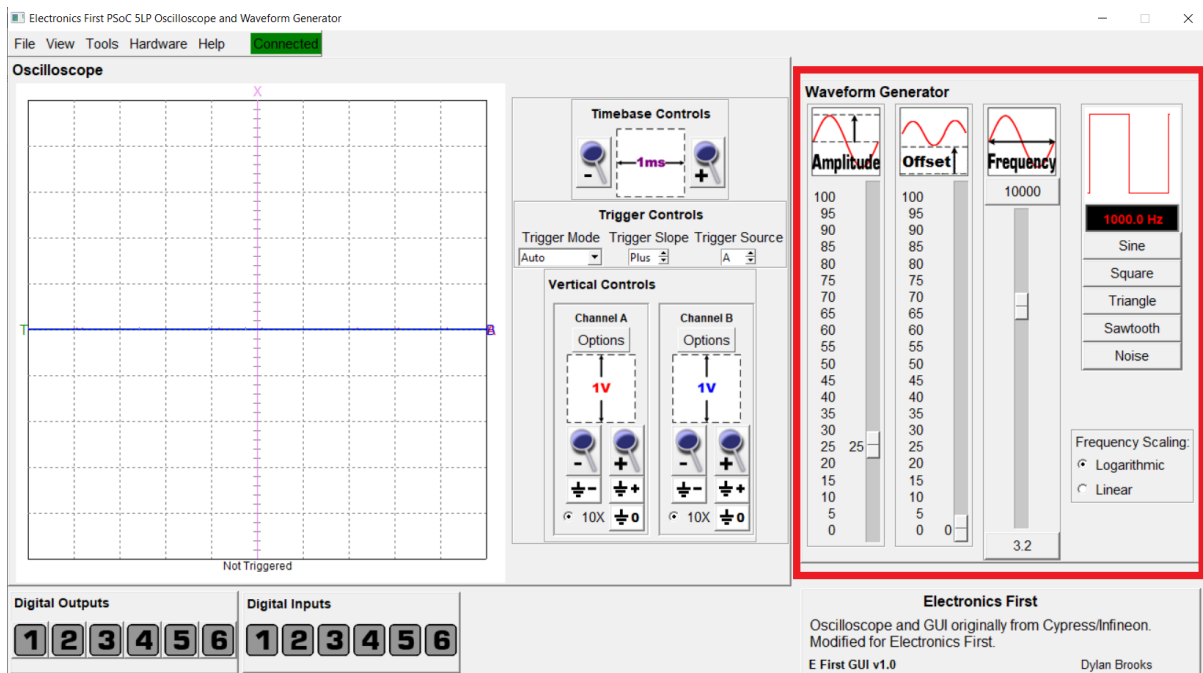


*Figure 10: Screenshot of the Waveform Generator settings used for calibration*

Now we are ready to calibrate our scope. Navigate to Tools and then Oscilloscope Calibration within the GUI. After clicking on Oscilloscope Calibration, a calibration window should appear with four calibration sliders, two for channel A and two for channel B. Each channel has an additive offset slider and a multiplicative coefficient slider. The additive offset allows you to shift each channel's plotted voltage by a constant value. This will allow us to

correct each channel's zero voltage point. Connect each channel's scope probe to its ground clip as shown below.
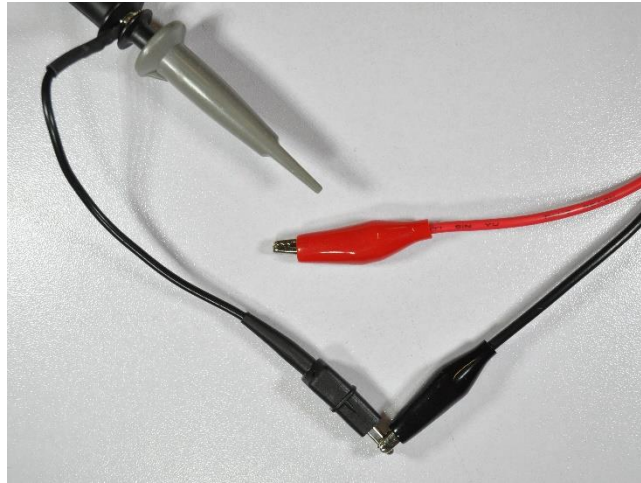


*Figure 11: Photo depicting the proper setup for calibrating the additive offset*

Next, zoom in to each channel's signal by using the corresponding vertical controls to the right of the oscilloscope plot. Set each channel to be at 50 mV. Now, using the additive offset sliders within the calibration window, change the slider values until both channel A and channel B are as close to 0 V as possible. Save these values using the Save Calibration Values button. With our calibration wave running, connect one of the scope probes to the wave gen probe as shown below. At this point, only one of the two channels can be calibrated at a time.
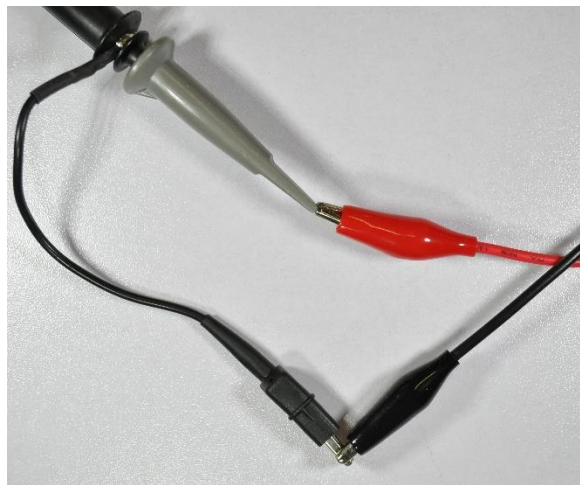


*Figure 12: Photo depicting the proper setup for calibrating the multiplicative coefficient for a single channel*

Now we will use the multiplicative coefficient slider to scale each channel's values. Set the channel being tuned to 500 mV. Using the multiplicative coefficient slider of whichever channel you connected to your wave gen probe, tune the slider value until that channel has a square wave between 0 V and 1 V (this will be two divisions when the channel is set to 500 mV). Once calibrated, disconnect the channel and repeat the process with the other channel. Once

finished calibrating both channels, be sure to press Save Calibration Values before closing the GUI. Saving your calibration values will allow the GUI to use these values when starting the GUI in the future.

Note - If you notice that your measured square wave is not very square, this implies there is an issue with that channel's capacitance. Refer to Issue 2. Compensation Capacitors to address this issue.

## Step 5. Setup Finished

Once each channel has been properly calibrated, you are ready to begin using your new PSoC oscilloscope and waveform generator. To learn more about the GUI and its features, continue on to section II in which each section and feature of the GUI will be described.

# Section II: Oscilloscope and Waveform Generator GUI

The GUI is made up of four main sections: the menu bar, the oscilloscope, the waveform generator, and the digital input and output display. Each of these sections are shown in the image below and described in detail in the proceeding subsections.
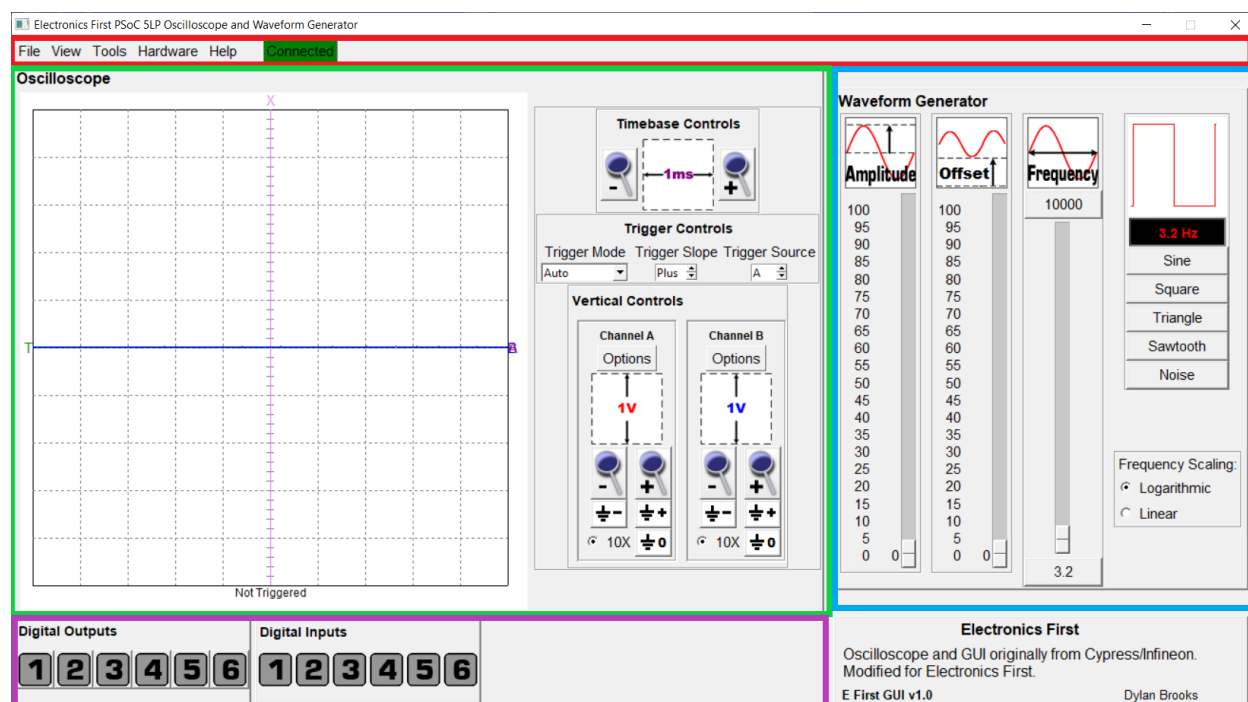


*Figure 13: Screenshot of GUI; red box indicates the menu bar, the green box indicates the oscilloscope, the blue box indicates the waveform generator, and the purple box indicates the digital input and output display*

## Subsection 1. Menu Bar

The menu bar runs along the top side of the GUI and contains five tabs—File, View, Tools, Hardware, and Help—as well as a PSoC connection status indicator. Each tab contains a set of useful features in a drop down menu when clicked.

1. File Tab
   a. Exit – Selecting exit will close the GUI and all open windows associated with the GUI
2. View Tab
   a. Dock Digital I/O Controls – Selecting this will allow the digital input and output display section of the GUI to open as its own window and be dragged to a location of your choosing. To reattach the digital input and output display simply re-click this button under the View tab.
   b. XY Mode – Selecting this will enable the oscilloscope to plot in XY mode with channel A acting as the X value and channel B acting as the Y value. Note: the channel A and channel B signals will remain enabled when entering XY mode, but can be disabled using the Options button within the oscilloscope's vertical controls section
   c. Toggle Time Cursors – This will enable two time cursors on the oscilloscope which can be dragged on screen by clicking and dragging either T1 or T2 at the top of the plot. The plot will display the difference in time between the two cursors and the frequency which corresponds to that difference in time. The time and frequency can also be moved by clicking and dragging to them to a new location. To disable these cursors, re-click the button.
   d. Toggle Channel A Cursors – This will enable two voltage cursors on the oscilloscope which can be dragged on screen by clicking and dragging either VA1 or VA2 toward the left hand side of the plot. The plot will display the difference in voltage between the two cursors based upon the settings selected for Channel A. This voltage can be moved by clicking and dragging it to a new location. To disable these cursors, re-click the button.
   e. Toggle Channel B Cursors – This will enable two voltage cursors on the oscilloscope which can be dragged on screen by clicking and dragging either VB1 or VB2 toward the left hand side of the plot. The plot will display the difference in voltage between the two cursors based upon the settings selected for Channel B. This voltage can be moved by clicking and dragging it to a new location. To disable these cursors, re-click the button.
   f. Toggle Scope Grid – This will enable or disable the oscilloscope's plot grid.
   g. Color Preferences – This allows for the complete customization of colors used within the GUI. These customizations can be saved or restored to their default colors.
   h. Auto Measurements – This will open a new window which will provide automatic measurements of features of interest for both channel A and B. This includes each channel's frequency, period, average voltage, maximum voltage, minimum voltage, peak-to-peak voltage, and root-mean-square (RMS) voltage. To close the window, click on the close button in the upper right hand corner of the window. When the button is clicked with the window already open, it will move the window back to the front of the screen.
3. Tools Tab

a. Oscilloscope Calibration – This will open a new window which provides the ability to individually calibrate channel A and B. It provides access to an additive offset (A) for each channel as well as a multiplicative coefficient (C) for each channel. These manipulate each channel's voltage based upon the equation displayed below. To close the window, click on the close button in the upper right hand corner of the window. When the button is clicked with the window already open, it will move the window back to the front of the screen.

$$V_{plotted} = C * V_{reported} + A$$

b. Math Toolbox – This will open a new window which allows for mathematical comparison of channel A and B. It will allow the user to plot the addition of channel A and B, the subtraction of channel B from channel A, or the multiplication of channel A with B. To close the window, click on the close button in the upper right hand corner of the window. When the button is clicked with the window already open, it will move the window back to the front of the screen.

4. Hardware Tab
   a. Connect – This will open a new window which will allow the user to select between automatically searching for a plugged in PSoC or manually selecting the port which the PSoC is connected to. If a PSoC is found in either case, the GUI will attempt to connect to it. For issues with connecting your PSoC, refer to section III, issue 1.

5. Help Tab
   a. About – This will display the current version of the oscilloscope and waveform generator GUI. Additionally, it will display the author and publication date.
   b. Manual (pdf) – This will open up the manual pdf corresponding to the version of the GUI which it is opened from. This manual will be opened in your system's default pdf viewer.

6. Connection Status – This allows for visualization of the PSoC and GUI connection status. When the PSoC is disconnected from the GUI it will be appear as a red rectangle inscribed with the word "Disconnected." When the PSoC is connected to the GUI it will appear as a green rectangle inscribed with the word "Connected."

## Subsection 2. Oscilloscope

The oscilloscope section of the GUI is located in the upper left hand side of the GUI. It is composed of a plot on the left hand side and the oscilloscope's controls on the right hand side. The plot will display a trace for channels A and B based upon their settings on the right hand side. Below you will find a description of each control setting for the oscilloscope.

1. Timebase Controls – This determines how much time each box represents in the oscilloscope plot. It applies to both channel A and B. The current value of time each box represents is displayed in the image. For each box to represent less time, zoom into the

traces by clicking the + icon. For each box to represent more time, zoom out of the traces by clicking the – icon.

2. Trigger Controls – This determines what type of trigger is being used. Trigger mode is set to auto-trigger. Trigger slope sets whether the trigger mode is searching for a rising or falling edge. Trigger source sets whether the trigger is on channel A or B. To set the trigger voltage, locate the T on the left hand side of the oscilloscope plot; this represents the trigger cursor. Click and drag the trigger cursors to a voltage of your choice, the voltage it will be set to is displayed in black on the plot. Because the trigger utilizes the PSoC's digital-to-analog converter (DAC), the trigger voltage can only be set to a voltage that the DAC can output. Therefore, the trigger can be set to a voltage between 0 V and 4.08 V. The X cursor on top of the oscilloscope plot represents where the trigger should be drawn. Click and drag the X cursor to a location of your choice to shift where the trigger point is drawn relative to the oscilloscope plot.

3. Vertical Controls – This determines the settings for channel A and B respectively. The Options button allows for each channel to be individually enabled or disabled as well as whether or not the signal should be inverted. The graphic below the options button depicts how much voltage each box represents for that particular channel. For each box to represent less voltage, zoom into the trace by clicking the + magnifying glass icon. For each box to represent more voltage, zoom out of the trace by clicking the – magnifying glass icon. To shift where a channel's ground is located up by one entire box, press the + ground icon. To shift where a channel's ground is located down by one entire box, press the – ground icon. To return a channel's ground to the plot's x-axis, press the 0 ground icon. To manually shift where each channel's ground is located, locate the letter of the channel you wish you shift on the right hand side of the plot. Click and drag this letter to the location of your choice. Upon release that channel's ground will remain in this location. Each channel is set to be compatible with a 10x probe as indicated by the 10x radio button.

## Subsection 3. Waveform Generator

The waveform generator (WaveGen) is located on the right hand side of the GUI. It features sliders to modify a waveform's amplitude, offset, and frequency. The WaveGen is capable of outputting sine waves, square waves, triangle waves, sawtooth waves, and random noise.

1. Amplitude – Use the amplitude slider to set the amplitude of the outputted waveform. The value corresponds to a percentage of maximum amplitude. Because the WaveGen utilizes a PSoC's DAC, it can output a maximum voltage of 4.08. So, each percentage corresponds to approximately 0.048 V.

2. Offset – Use the offset slider to set how much DC offset the outputted waveform should have above 0 V. The value corresponds to a percentage of maximum offset. Because the WaveGen utilizes a PSoC's DAC, it can output a maximum voltage of 4.08. So, each percentage corresponds to approximately 0.048 V. Subsection 4. Digital Inputs and Outputs Display

3. Frequency – Use the frequency slider to set the frequency value of the outputted waveform. The frequency can be set between 3.2 Hz and 10,000 Hz. The slider scale can

be set to move logarithmically by selecting the logarithmic radio button in the Frequency Scaling box or be set to move linearly by selecting the linear radio button. The maximum and minimum frequencies can be changed to values between 3.2 Hz and 10,000 Hz by clicking on the button at the top and bottom of the slider and inputting a value of your choice. The currently set frequency is displayed as a red value to the right of the frequency slider; this value can be clicked to open a new window allowing for the user to manually input a frequency value of choice. To choose between different types of waveforms, click on the desired waveform name on the right hand side. The currently selected waveform is displayed graphically above the currently selected frequency. To effectively turn off the waveform generator, set the amplitude slider to 0.

## Subsection 4. Digital Input and Output Display

The digital input and output display contains two boxes, one for digital outputs and one for digital inputs.

1. Digital Outputs – The digital outputs box contains buttons numbered 1 through 6. These buttons can be clicked in order to toggle whether the corresponding digital output is high or low. If the output is high, it will be colored green. If the output is low, it will be colored grey. The numbered outputs correspond to the same numbered LED pins on the PSoC carrier board.
2. Digital Inputs – The digital inputs box contains icons numbered 1 through 6 representing the current state of the digital inputs. If a pin corresponding to a digital input is being driven high, it will color the digital input icon green. If the pin is being driven low, it will color the digital input icon grey. The numbered inputs correspond to the same numbered SPST pins on the PSoC carrier board.

# Section III: Troubleshooting

## Issue 1. Connecting PSoC to GUI

If the GUI is unable to connect to your PSoC, there are a variety of things which can be tried.

1. Ensure that your PSoC is connected to your PC via the micro-USB port and not the kitprog USB A port used to program the PSoC. Do not connect the PSoC to the PC via both USB ports, only the micro-USB port. Move onto step 2.
2. Navigate to the Hardware tab in the menu bar and select Connect. Try to use the Auto-Detect option to connect the PSoC and GUI. If this does not work, go back and try the Manual Select option. If neither of these options work, move on to step 3.
3. Close the GUI window entirely. Next, unplug the PSoC from the PC and then plug it back in. Restart the GUI with the PSoC plugged in. Let the startup sequence attempt to connect to the PSoC. If the PSoC is still unable to connect to the GUI, move onto step 4.
4. Close the GUI. Run PSoC Creator 3.3 and reprogram the PSoC with the appropriate project files following the steps outlined in section I. Once the PSoC is reprogrammed, disconnect the PSoC's kitprog USB A port from the PC and connect it via the micro-USB port. Restart the GUI and allow the startup sequence attempt to connect to the PSoC.

## Issue 2. Compensation Capacitors

When calibrating your oscilloscope, you might notice that one or both of your channels is not displaying a clean square wave. This could be a result of an imbalance in capacitance between the oscilloscope probe and the oscilloscope circuit. An example of too much capacitance is shown on the left while an example of two little capacitance is shown on the right.
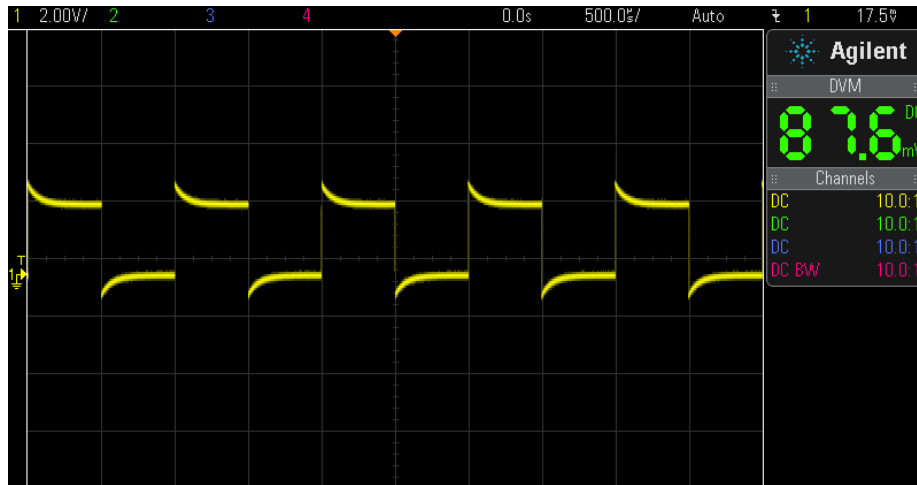


*Figure 14: An example screenshot of an oscilloscope signal with imbalanced capacitance*

If this is the case, first check whether the oscilloscope probe that you are using has a tunable capacitor built in. This could be located near the tip of the probe or at the BNC connection near the end of the probe.
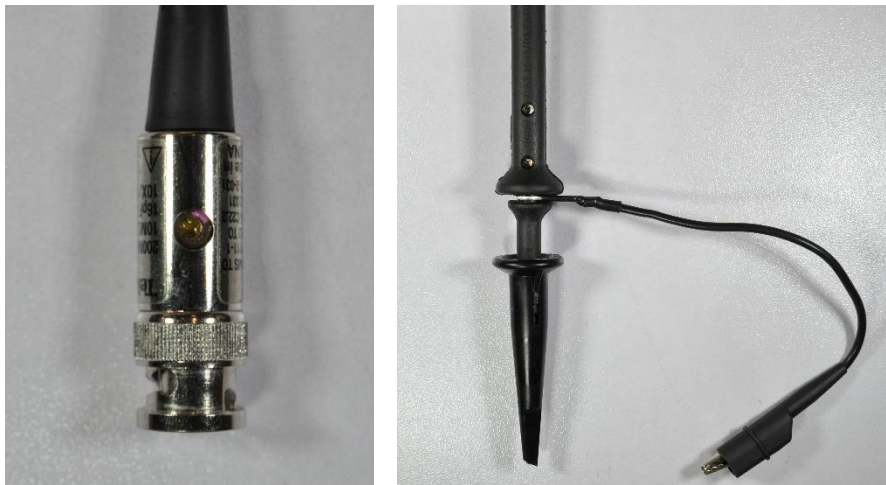


*Figure 15: Photo indicating the location of a probe compensation capacitor on the base (left) or on the tip (right)*

While connected to the calibration waveform described in section I, step 4, use a small screwdriver to turn the knob of the oscilloscope probe and watch how the square wave varies. If turning the knob one direction improves the appearance of the square wave but cannot be turned

any farther, determine whether your channel has too much capacitance or too little capacitance. This can be determined using the images below.
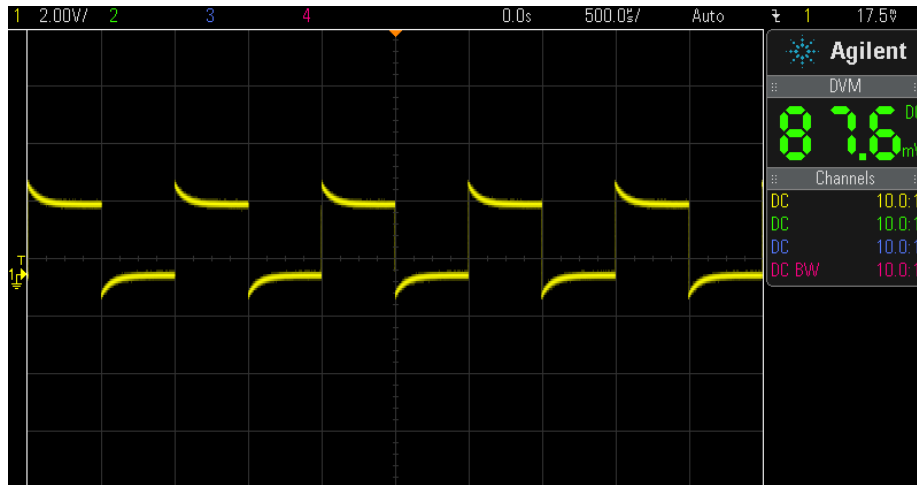


*Figure 16: Example screenshot of an oscilloscope waveform with too little capacitance*
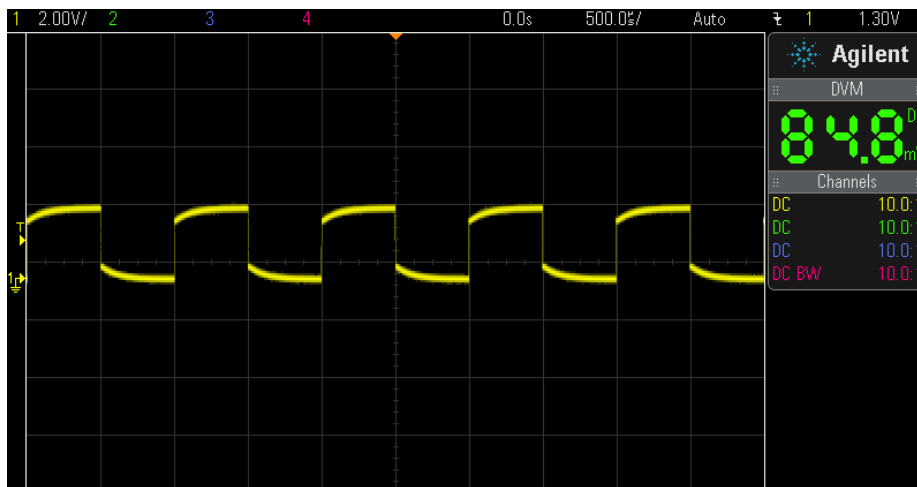


*Figure 17: Example screenshot of an oscilloscope waveform with too much capacitance*

If your system has too little capacitance, then you can solder a small capacitor in the range of picofarads to either C2 for tuning channel A or C1 for channel B. If your system has too much capacitance, then you will need to find an oscilloscope probe with less capacitance to fix the issue.

## Issue 3. Noisy Signal

If you measure signals and find them to be very noisy with a noise signal that appears to be approximately 60 Hz, try plugging your laptop charger into the wall to help establish a better earth ground connection.
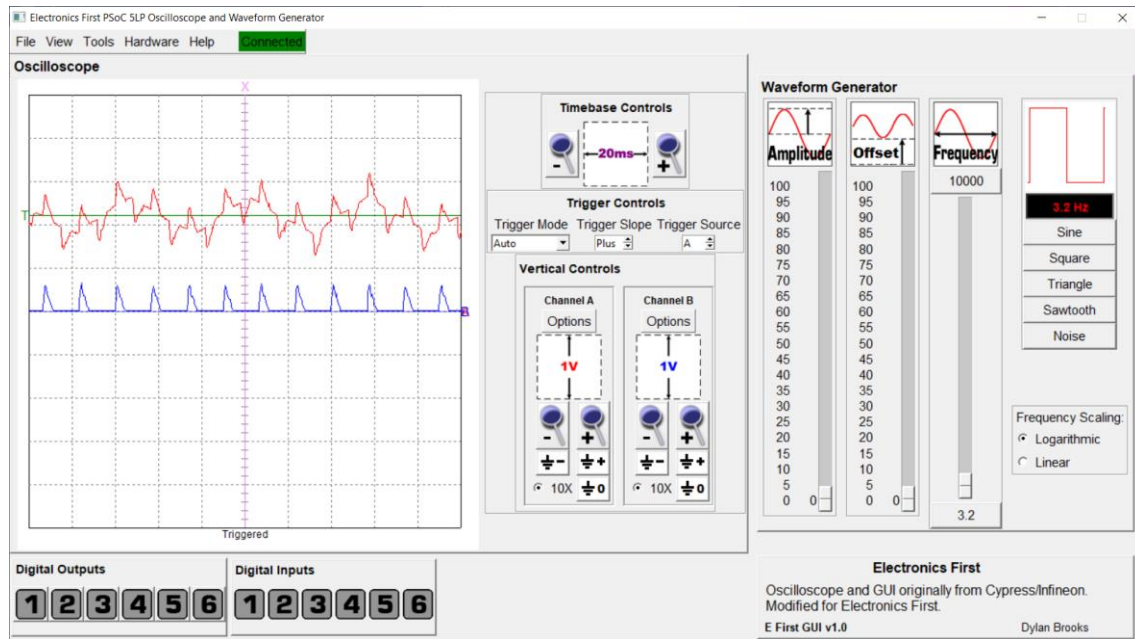
*Figure 18: Screenshot indicating a 60 Hz noisy oscilloscope measurement*

## Issue 4. GUI Window Too Large

If you find that you are unable to see some portion of the GUI on your screen, it might be because of either your screen's resolution or your display scaling on your Windows OS. The GUI was created with the intention of being operated on a screen resolution of at least 1280x720. This means that the GUI will fit entirely within a screen set at 1280x720 at 100% scaling. Or it will fit within a screen set at 1920x1080 with anywhere between 100% and 150% scaling. If you find that you are unable to see the full GUI on your screen, open up your computer's display settings and ensure that your screen resolution and display settings satisfy this requirement.

# Section IV: FAQs

# Section V: Appendix