Time Dependent Measurements

This week's experiments will give you the opportunity to learn the basic operations of an oscilloscope and a function generator.

Setting up Function Generator and Oscilloscope

1. Turn on both the function generator (Figure 2-1a) and oscilloscope (Figure 2-2).
2. Connect the function generator's CH1 output to the CH1 input of the oscilloscope.
3. Press the function generator Output button next to the CH1 connector if it is not lit.
4. You will now learn to display the input signal properly by using the three basic functions of the oscilloscope: Horizontal control, Vertical control, and Triggering.
5. [INITIALIZATION]
    a. Press the Save/Recall button in the Measure section of the controls.
    b. Push the Recall soft switch.
    c. Push the "Load from setup_0" soft switch.
    d. Press the "Press to Recall" soft switch. This is your starting point.
6. The display should be similar to that shown in Figure 2-1.

FIGURE 2-1. .Unstabilized, Horizontally and Vertically Incorrect, Sinusoid Display.

7. [HORIZONTAL] Using the large Horizontal knob (in the horizontal section of the controls), 

turn it counterclockwise (CCW) until the sweep rate annunciator (circled) indicates “1.000 ms/”. The display should like similar to Figure 2-2, but be very jittery.

FIGURE 2-2. Unstabilized, Vertically Incorrect Sinusoid Display.

8. [VERTICAL] Using the large Channel 1 knob (in the vertical section of the controls), 

turn it CCW until the Channel 1 sensitivity annunciator (circled) indicates “1.00V/”. The display should like similar to Figure 2-3, but be very jittery.

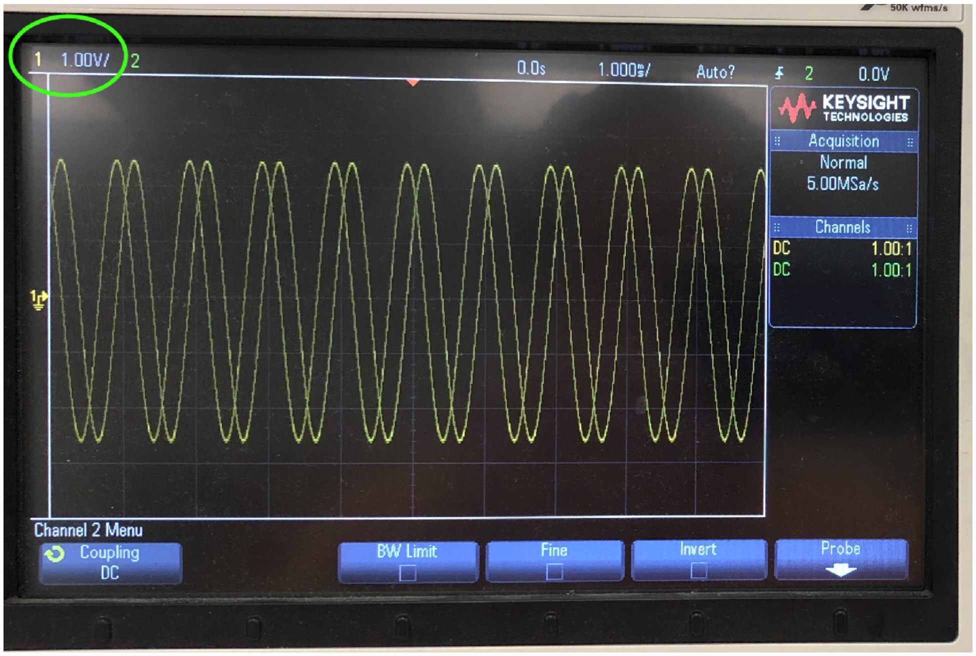
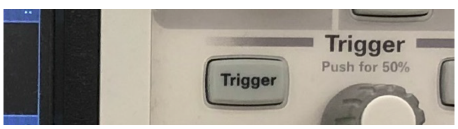


FIGURE 2-3. Unstabilized Sinusoid Display

9. [TRIGGER] Push the “Trigger” button (in the trigger section of the controls) 

to bring up the Trigger menu for the soft switches. Push the “Source” soft switch. Select Ch. 1 either by repeatedly pushing the soft switch, or by turning the Soft Switch Control Knob (the knob with the illuminated curved arrow next to it). The display should look similar to Figure 2-4, but now be very stable.

FIGURE 2-4. Stabilized Sinusoid Display

10. You have just controlled the oscilloscope with your own hands. Triggering will be further explored later in this experiment.

11. [BONUS FEATURE] In the Measure section of the controls, push the “Meas” button. The Measurements section of the display will appear, showing the RMS voltage of the input signal on Ch. 1. So now you can see that the oscilloscope can behave like a DMM.

12. Push the Type: soft switch, and turn the Soft Switch Control Knob to Frequency. Push the knob or the Add Measurement soft switch to select Frequency. Note all the other measurements that the oscilloscope will make for you.

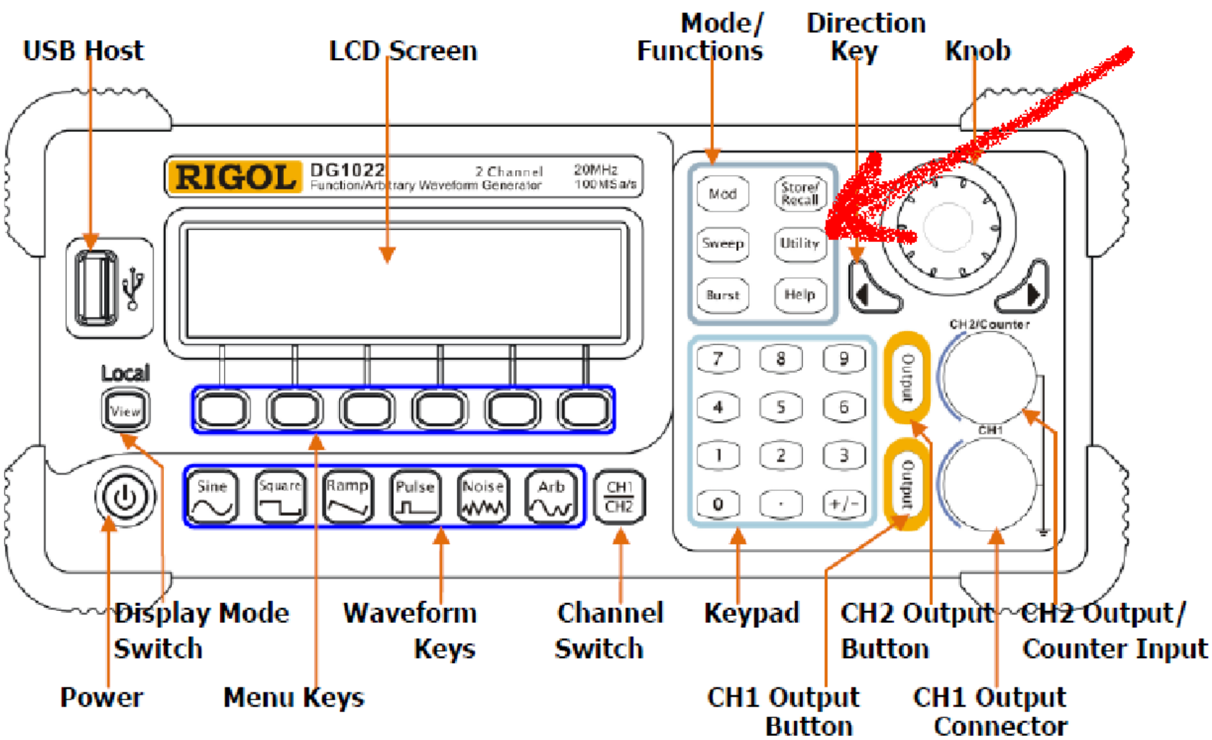


FIGURE 2-5a: DIGITAL Signal Generator (front)

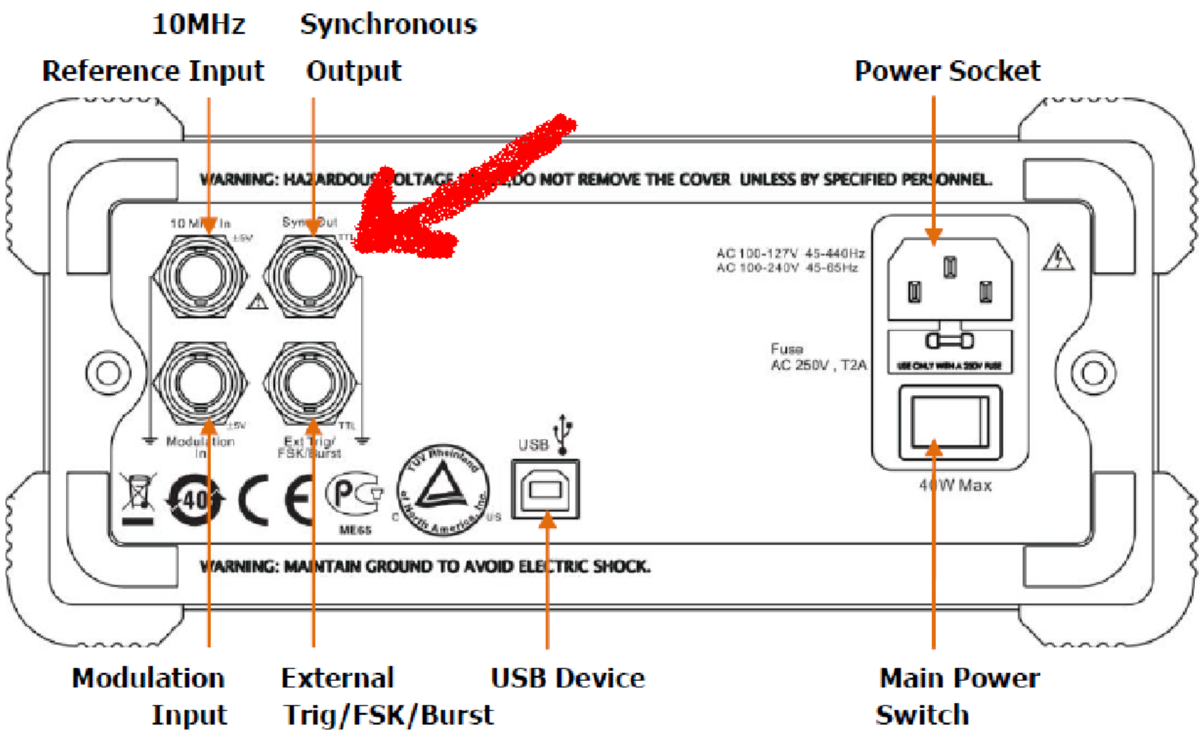


FIGURE 2-5b: DIGITAL Signal Generator (back)

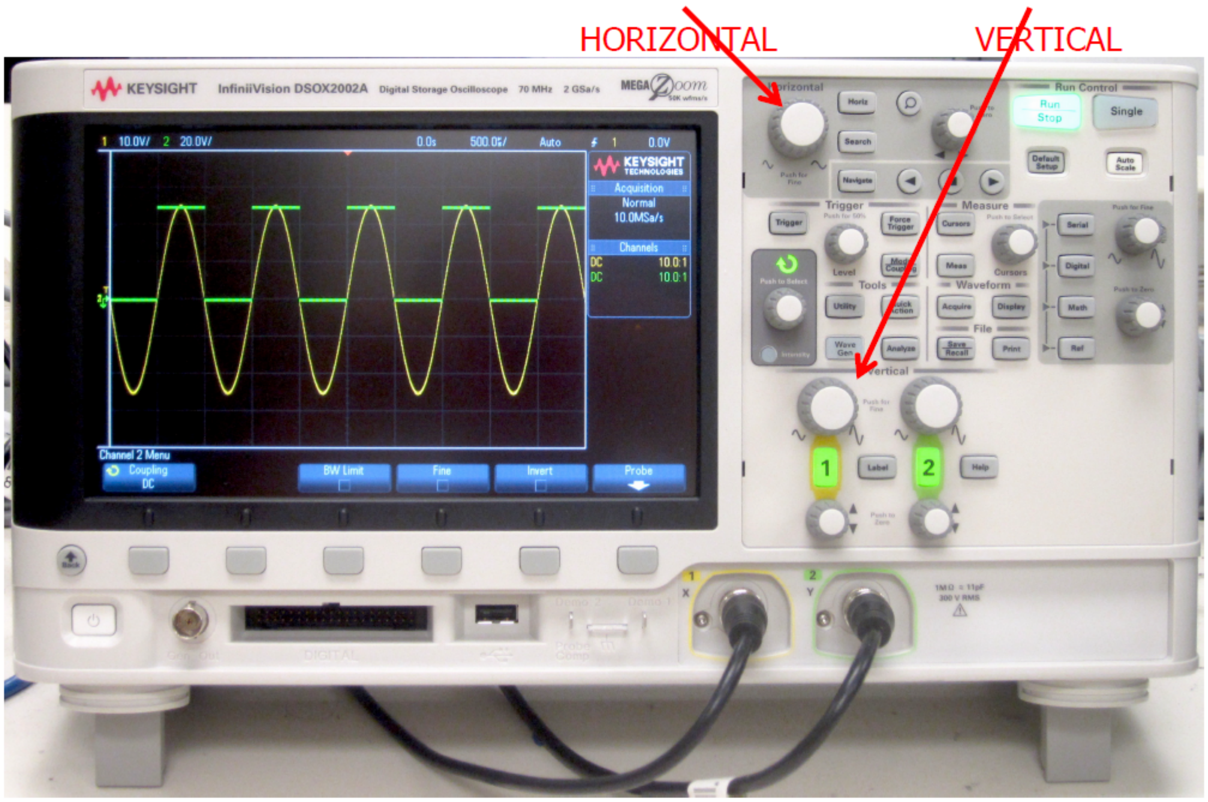


FIGURE 2-6: OSCILLOSCOPE

Understanding Triggering

<u>Setup</u>: using a BNC tee and two BNC-to-BNC cables, Connect the function generator Sync Out connector (Figure 2-5b) to the oscilloscope Channel 2 and to the oscilloscope External Trigger In connector on the back of the oscilloscope. Push the Utility button on the front of the function generator. The display will show “Sync Off”. Turn the Sync On.

To understand the trigger function of the scope, select the trigger control. We wish to control the triggering by first selecting the trigger menu and setting the source to be channel 1. With the trigger in Edge mode, the Level knob can now be used to control the voltage level at which the scope will start its measurement, i.e. its time reference point or trigger point. Note: if a trigger voltage point is selected that is outside of the range of voltages on channel 1, then the scope will not display new data and will indicate on the display “not triggered” or “waiting for trigger”, etc.

A small “T” in the left margin indicates the trigger level. Its color indicates which channel has been selected to be the triggering channel. Adjust the trigger level to obtain a stabilized display. The display will now say “Auto”. Adjust the trigger level and note its effect on the position of the waveform.

Note the level control also allows the slope of the level to be observed. Change the slope (or sense) from increasing to decreasing back and forth to note the effect on the display. Set the trigger level about halfway between 0 and the maximum value of the waveform. Now adjust the voltage level of the function generator and note the position of the “0” time changes with amplitude and that, as the voltage of the function generator gets small, the trigger will eventually fail to work.

Now change the trigger input to CH 2 or EXT TRIG, whichever channel the Sync Out of the function generator is connected to on the oscilloscope.

Note that the trigger will now remain constant regardless of the magnitude of the sinusoidal signal. This is the prime reason for the use of a sync output.

BUT NOTE: you will rarely need to use the sync signal from the back of the function generator (in this course). Your signals will be clean enough that you can trigger your display from the signal that you want to examine. We include this merely to show you that this capability is available when needed.

Beginning the Experiment

Change the mode of the function generator from sine to triangular and then square. Note each of these waveforms. The actual voltage levels can be measured by using the voltage cursor function of the scope. Push the Cursor button under “Measure” and using the “Cursors” soft switch and selector knob, measure the Vpp amplitude of a sinusoidal wave, i.e. the peak-to-peak amplitude.

Using your digital multi-meter on the AC voltage settings, measure the voltage of the waveform. Compare the scope and multi-meter indicated voltages. Do this for sine, square, and triangular waves. The following are three sets of similar measurements, comparing the DMM to the oscilloscope. We will measure the RMS voltage values for a low frequency (100 Hz) with 5 Vpp, a medium frequency (2 kHz) with 5 Vpp, and a high frequency (25 kHz) with 5 Vpp.

A BNC T-connector will be useful so that the DMM can be used at the same time as an oscilloscope.

WORK SHEET HERE: (100 Hz)				
Wave Form	Oscilloscope Measured V_{rms}	DMM Measured V_{rms}	Calculated Theoretical V_{rms}	$\frac{\lvert Theoretical\ V_{rms} - DMM\ V_{rms} \rvert}{Theoretical\ V_{rms}}$ (%)
Sine:				
Triangle:				
Square:				

WORK SHEET HERE: (2 kHz)				
Wave Form	Oscilloscope Measured V_{rms}	DMM Measured V_{rms}	Calculated Theoretical V_{rms}	$\frac{\lvert Theoretical\ V_{rms} - DMM\ V_{rms} \rvert}{Theoretical\ V_{rms}}$ (%)
Sine:				
Triangle:				
Square:				

WORK SHEET HERE: (25 kHz)				
Wave Form	Oscilloscope Measured V_{rms}	DMM Measured V_{rms}	Calculated Theoretical V_{rms}	$\frac{\lvert Theoretical\ V_{rms} - DMM\ V_{rms} \rvert}{Theoretical\ V_{rms}}$ (%)
Sine:				

Triangle:				
Square:				

What's your observation regarding the DMM reading's accuracy over different frequencies within the same waveform? Can you guess why that's the case?

ANSWER HERE:

Does DMM perform poorer when measuring square or triangular waves over sine waves? Can you guess why that's the case?

ANSWER HERE:

Spectrum Analyzer – Knowing how your input signals are constructed

In this part of the lab you'll be learning how to display and analyze your input signal in the frequency domain, as well as learning how other types of periodic signals (e.g. square waves) are formed from sinusoids with different frequencies.

Setting up your Oscilloscope for Spectrum Analyzing

1. Turn on both the function generator and oscilloscope.
2. Connect the function generator's CH1 output, making sure that the output is on (press the output button if it is not lit), to the CH1 input of the oscilloscope.
3. Set the frequency of the function generator to square wave output at 1 kHz with amplitude of around 1V (Figure 2-7).
4. On the oscilloscope, push the "Math" button and choose the "FFT" (fast-fourier transform, a mathematical transform that takes a signal from time domain to frequency domain, more details can be found in course ECE 102 and 113) operator (Figure 2-8a). Once you've done the above steps you should be seeing a picture similar to what's shown in Figure 2-8b.
5. Adjust the "Span" of the spectrum to be around 20 kHz and the "Center" of the spectrum to be around 10 kHz (Figure 2-9). Now you are able to see a representative spectrum of a square wave.
6. Make sure that in the CH1 Menu, your Probe is set to 1x.

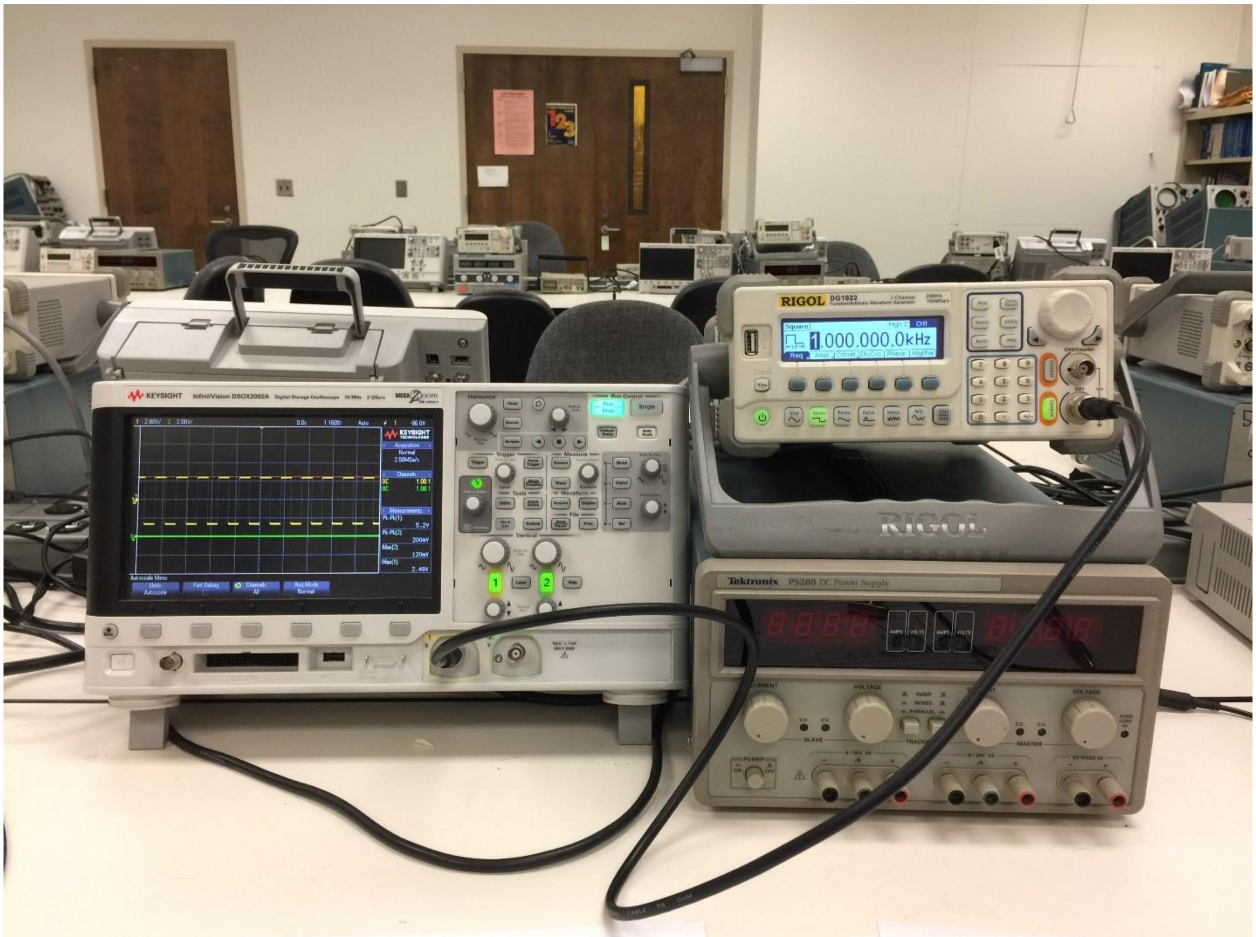


FIGURE 2-7 Connecting the Function Generator to the Oscilloscope

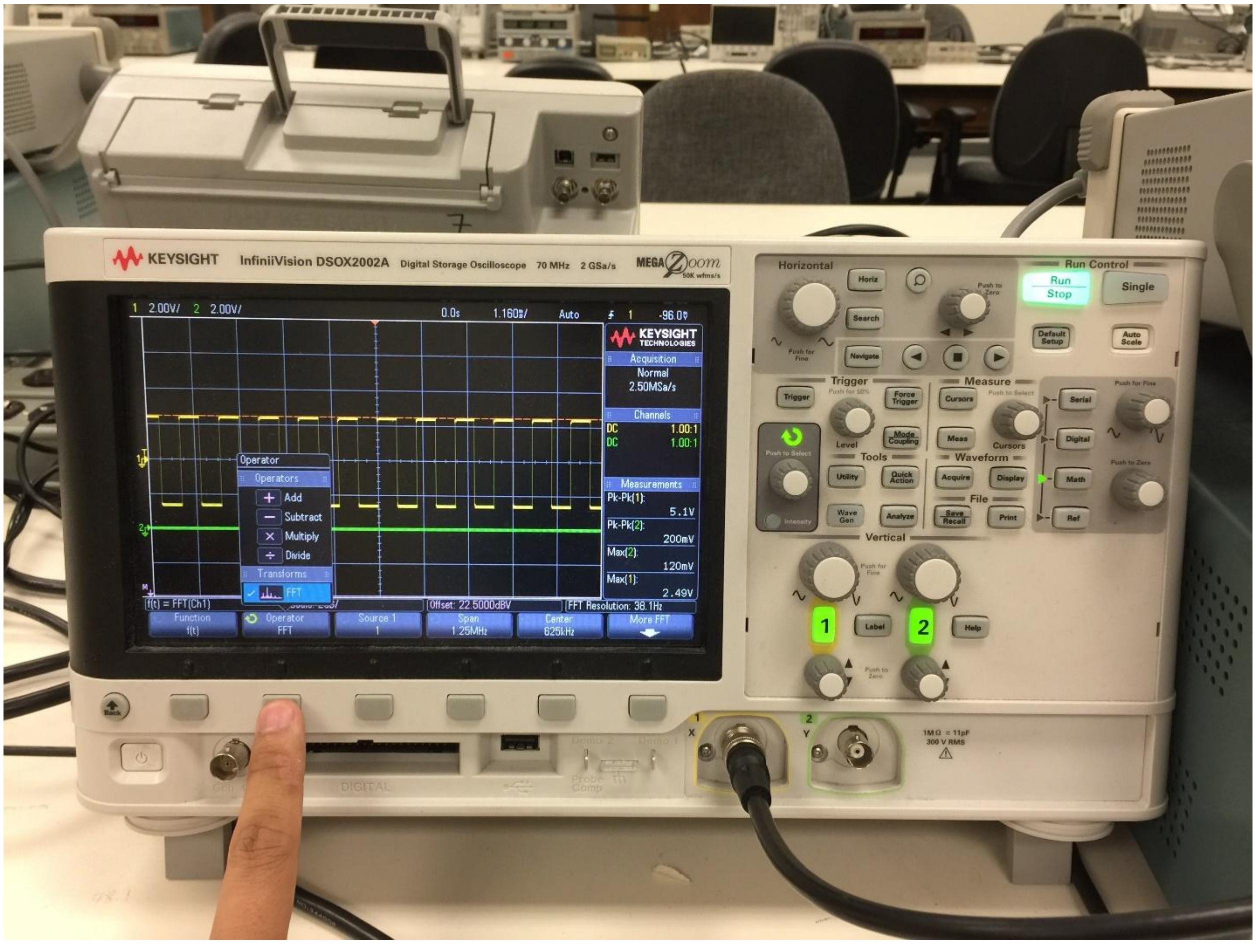


FIGURE 2-8a Choosing the FFT operator

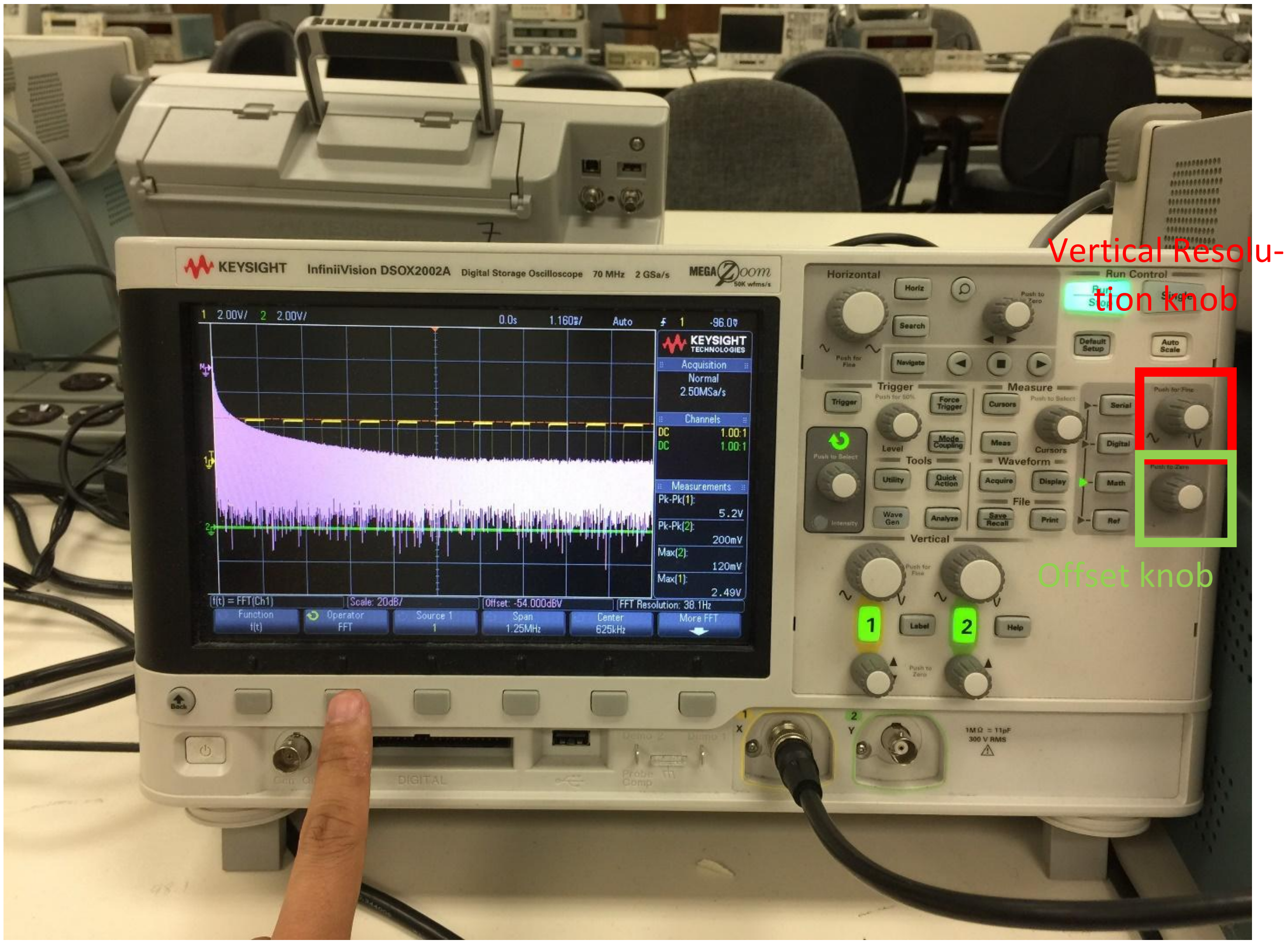


FIGURE 2-8b The Initial Spectrum

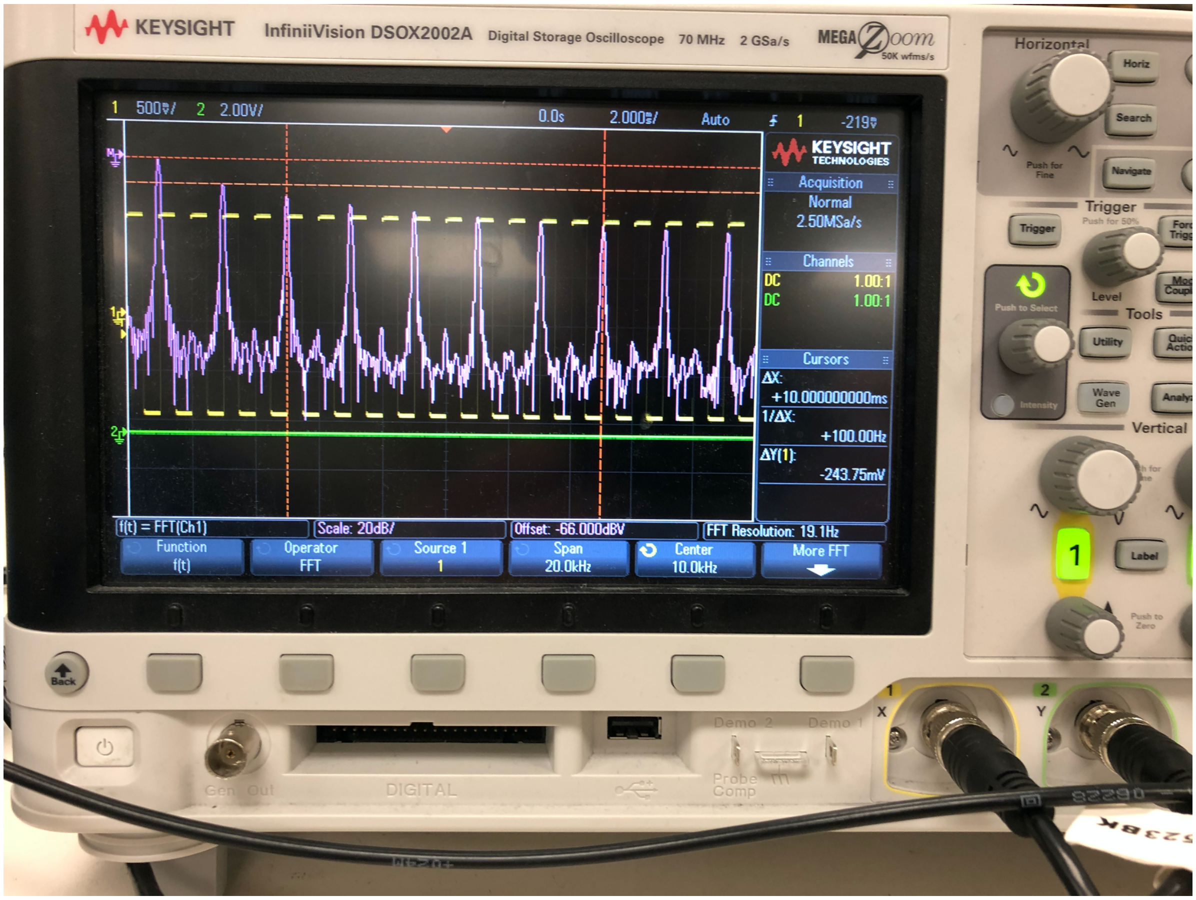


FIGURE 2-9 Adjusting the Span and Center

The nature of square waves – Limits in measuring systems

Square wave response requires a higher frequency response from the measuring system than sinusoidal waves. As you can see in the spectrum analyzer experiment, square waves can be thought of as being formed from a fundamental sinusoidal wave whose period is the same as the square wave plus higher frequency components (all odd integer multiples, or harmonics, of the fundamental frequency) to make up the sharp rise and flat top associated with the square wave.

Therefore, as your measuring system goes to its high frequency limit, the sharp rise and fall of the square wave will be lost due to the lack of these higher frequency components being accurately displayed. This is known as the Gibbs phenomenon, which you will have a chance to look at later.

A closer look at the spectrum of a square wave

In this part of the experiment we will be comparing the frequency components of a square wave to their amplitudes in theory. That is, only odd harmonics should appear (1 kHz, 3 kHz, 5 kHz, etc.) and the ratio of the various harmonic amplitudes to that of the fundamental should be 1/N where N is the harmonic 1: 1/3: 1/5: 1/7: … etc.)

Note again: the spectrum analyzer display the data in logarithmic manner, called dB (decibel) defined as a ratio of powers:

$$dB = 10 * log\left(\frac{Power_{test}}{Power_{reference}}\right) = 20 * log(\frac{V_{test}}{V_{reference}})$$

The logarithm display gives greater detail over a wide dynamic range and is therefore commonly used in engineering.

In the following experiment we will be taking the first harmonic (the first peak, AKA the *fundamental harmonic*) as the reference voltage and try to use the magnitude of the first 10 harmonics as the test voltages, in order to compare them with the first harmonic. (Think: first harmonic is at the first peak; is it also true that second harmonic is where the second peak is?). You can use the cursor functionality in the oscilloscope to help you read the difference in dB scale between the first peak and every other peak:

1. Push the "cursor" button and choose the Y1 cursor.
2. Select "Math" in the "Source" button menu.
3. Align the Y1 cursor with the first peak value.
4. Align the Y2 cursor to each of the other peaks and fill in the chart below:

WORK SHEET HERE (SQUARE WAVE ANALYSIS)		
N^{th} Harmonic	Measured value in dB scale: $20 * log\left(\frac{V_{Nth\ harm.}}{V_{1st\ harm.}}\right)$	Theoretical value in dB scale: $20 * log\ (1/n)$, n=odd; $-\infty$, n=even.
1	0	0
2		
3		
4		
5		
6		
7		
8		
9		
10		

End of Lab 2.