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:	1.77	1.773	1.7677	0.29
Triangle:	1.44	1.44	1.443	0.277
Square:	2.50	2.48	2.5	0.8

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:	1.77	1.75	1.7677	1.0
Triangle:	1.45	1.42	1.443	1.594
Square:	2.50	2.23	2.5	10.8

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:	1.77	0	1.7677	100

Triangle:	1.44	0	1.443	100
Square:	2.50	0	2.5	100

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: DMM does not have enough bandwidth to measure accurately at higher frequency. DMM had increasingly worse accuracy at higher frequencies.

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

ANSWER HERE: DMM perform poorer when measuring square or triangle waves over sine waves. This is probably due to square and triangle waves being composed of multiple waves thus the error stacks up.

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.

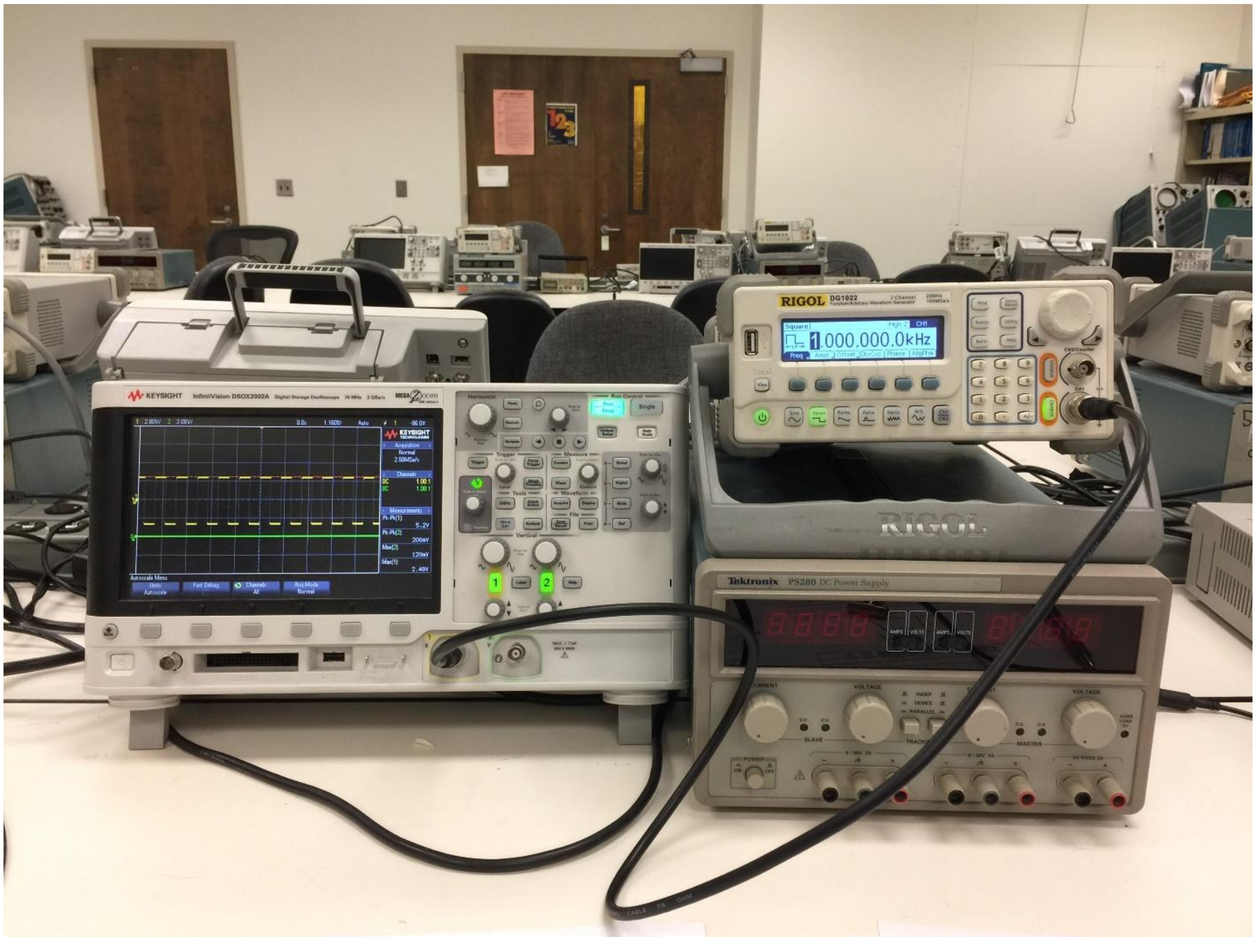

FIGURE 2-7 Connecting the Function Generator to the Oscilloscope

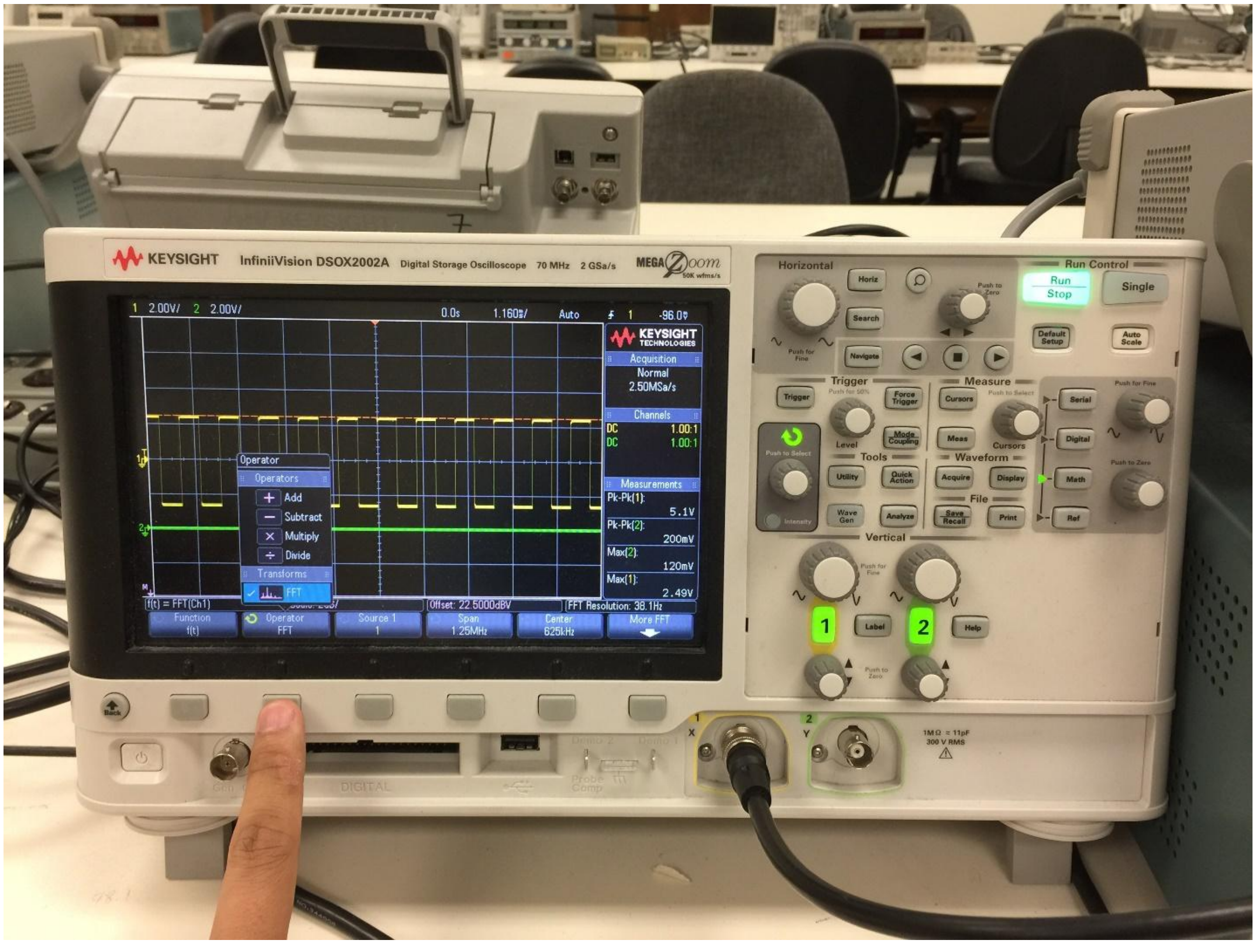

FIGURE 2-8a Choosing the FFT operator

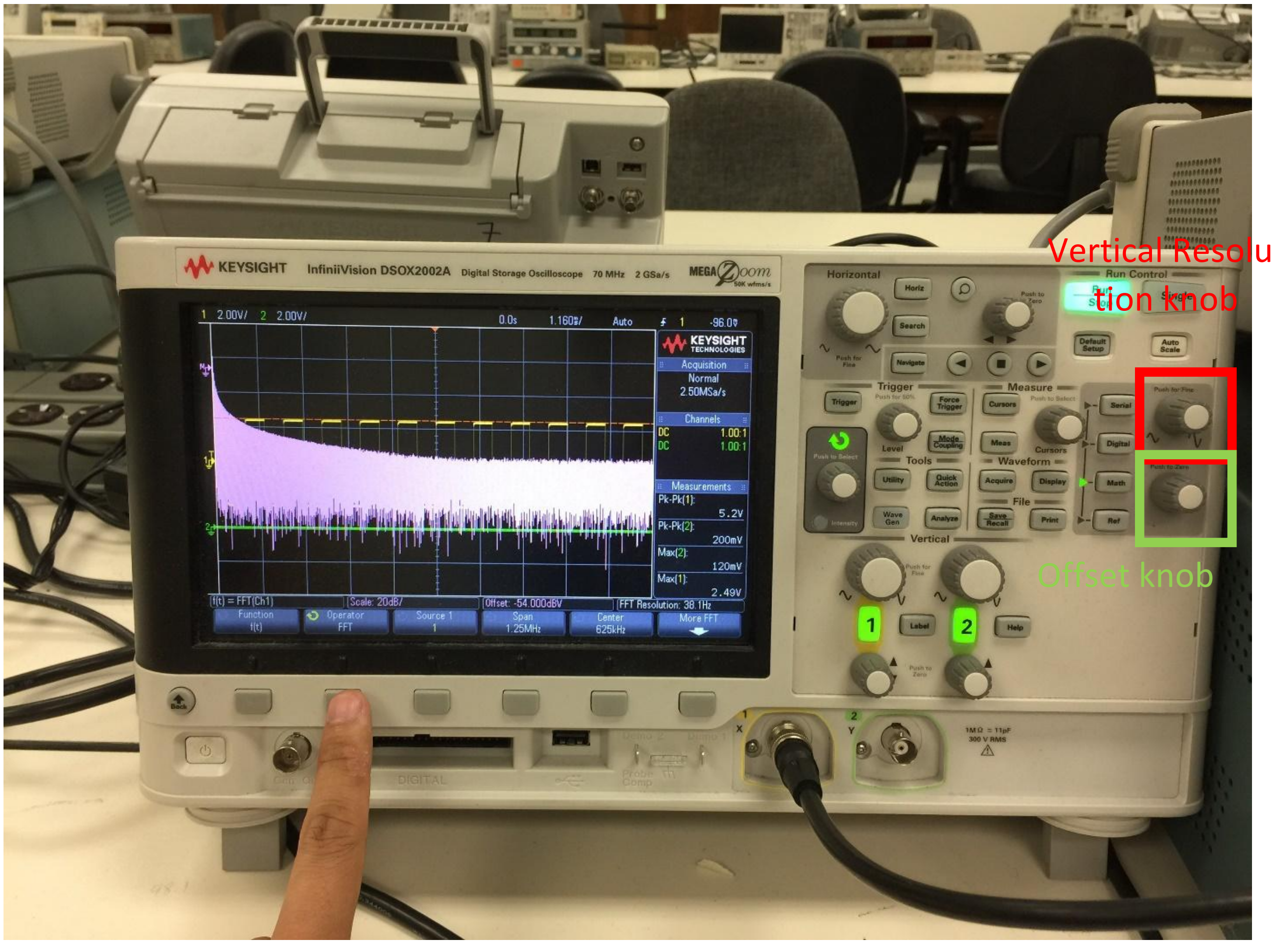

FIGURE 2-8b The Initial Spectrum

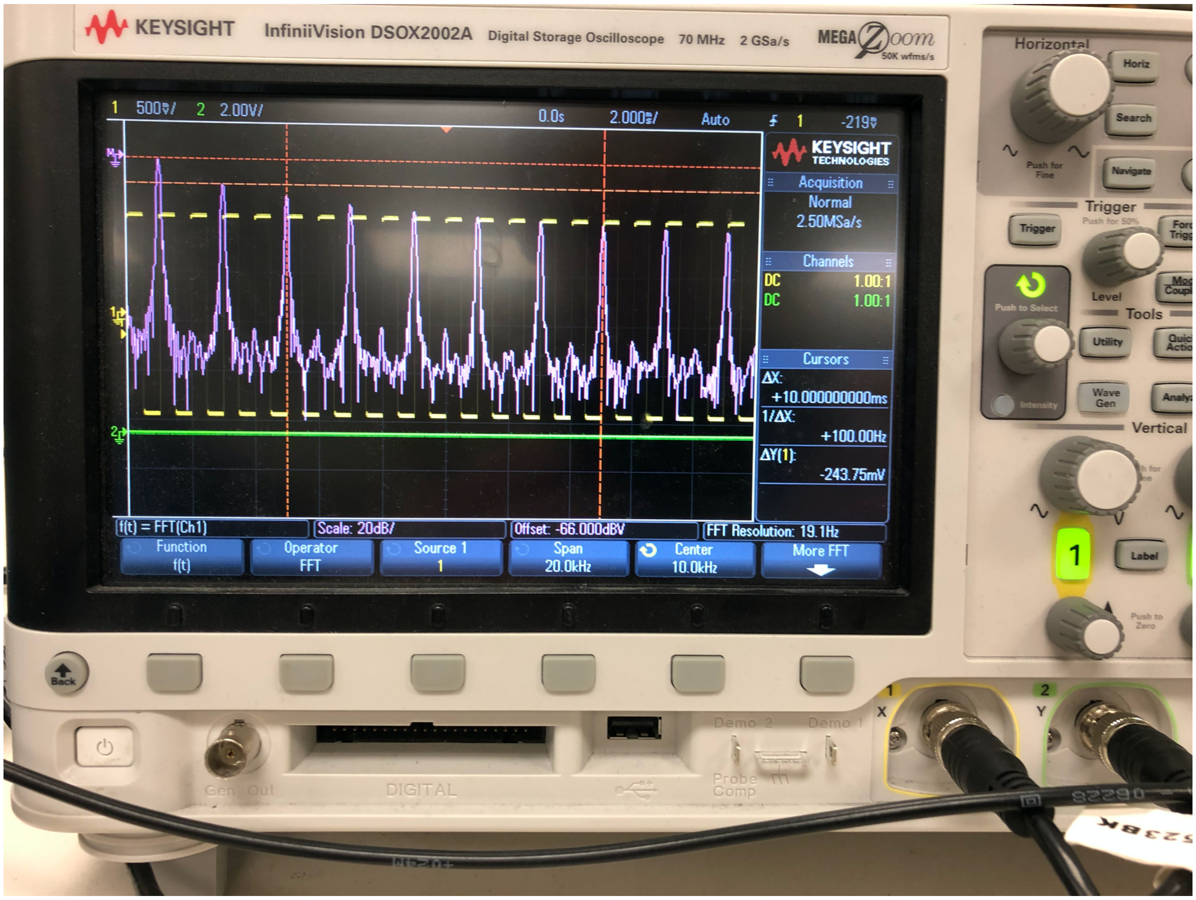

FIGURE 2-9 Adjusting the Span and Center

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	-55.36	$-\infty$
3	-9.55	-9.54
4	-61.43	$-\infty$
5	-14.01	-13.98
6	-64.57	$-\infty$
7	-15.88	-16.90
8	-65.23	$-\infty$
9	-19.03	-19.08
10	-65.89	$-\infty$

End of Lab 2.