# MAE 3340 *INSTRUMENTATION SYSTEMS*

## Laboratory Exercise 4
## Basic Electronic Test Equipment

NAME: ______________________________________

SECTION ______________________________________

**Introduction**:

This exercise is designed to acquaint students with the basic electronic tools used in mechanical instrumentation. Completion of this lab sheet will constitute the write up required for this lab. This lab will span two week with Part 1 being completed during week 5 lab sessions, and Part 2 completed during week 6.

***Please populate the question areas using typed text (cut and paste or attached, typed sheets is acceptable) or VERY NEAT!!!! handwriting.*** Answer every underlined question explicitly.

Instruments to be evaluated include:

*a) digital voltmeters (DVM's)*
*b) signal generators*
*c) digital and analog oscilloscopes*
*d) National Instruments Analog-to-Digital and Digital-to-Analog*

**Digital Voltmeter (DVM)**: The digital voltmeter measures both AC and DC voltages and currents over a wide range, along with resistance. The display on the meter is called a "three and a half" digit display, with the first digit capable of displaying +1, 0, or -1 (counts for half a digit), plus three additional digits. The bench digital voltmeter (DVM) and the hand held digital multi-meter (DMM) used in this laboratory are typical of a class of low cost devices often used for measurement purposes. Voltages are measured across ***(e.g., in parallel with)*** a component, while currents are measured through ***(e.g. in serial with)*** a component.

*Resistance measurements must be made with NO POWER applied to the measured device. Make certain that the DVM is NOT set to measure resistance when wired to measure voltage or current.*

Front panel buttons select the maximum measured range. Make certain the AC/DC (alternating current/direct current) button corresponds to the proper type of waveform for your measurement, since the measurement of AC and DC voltages is fundamentally different.

**Signal Generators and Oscilloscopes:** To learn how to use the oscilloscope, we will run a LabVIEW VI that will generate several waveforms one at a time. Your job is to fill Table 1 below using the scope and meters.

**SETUP, Part 1: Waveform Measurements**

Connect DAC0 on the National Instruments **NI-BNC 2120** Connector Block the oscilloscope input channel 1, and DAC1 to scope's channel 2. Also connect to the Fluke 8010a bench meter, HP 34401A meter, and handheld-DMM input terminals. See Figure 1. As required use BNC splitters, BNC 2-wire adapters, and Banana-jack plugs.

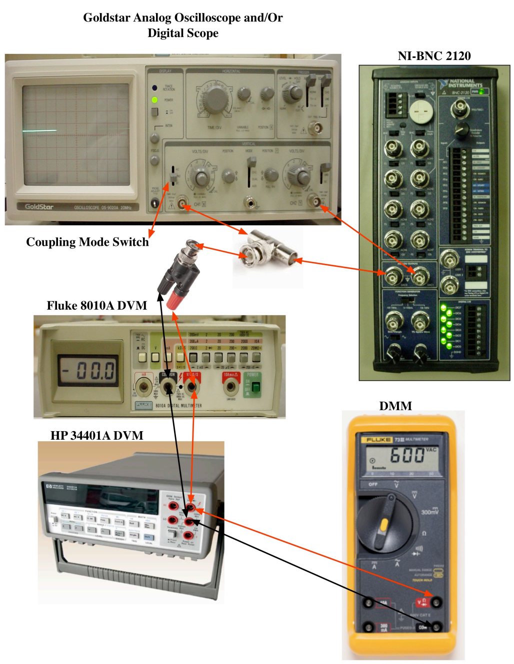



**Figure 1. Lab 4, Part 1 Wiring Setup.**

Set the mode selector to channel 1 on the oscilloscope. Set the "coupling" mode switch to "AC". Bring up the LabVIEW VI *signallab.vi*. There should be a shortcut to this VI on the desktop. If not the VI can be downloaded from the Lab 4 section of the web page. There is a knob that allows you to select the various waveforms. Figure 1 shows a picture of the VI front panel.

Using the techniques demonstrated in class, fill in the table below. Use the following codes for waveform shapes: (**s**) sine, (**sq**) square, (**t**) triangle, (**saw**) sawtooth. ***You need only fill in the duty cycle column for the square waves.*** Use the amplitude and ground definitions ***from Fig.4.9 in Beckwith.*** If the signal does not appear stationary on the oscilloscope display, adjust the trigger controls (level, source) appropriately until you get a fixed image. Analyze the 6 waveforms shown in Table 1 and on the Lab 4 lecture notes and fill in the table below. *Signallab.vi* Waveforms *0-5 and* will be used in this lab Part 1. Wave 10, and the red control box with the ***"Wave 10- Parameters (Dual Waves)"*** will not be used for this part of the lab.

**Table 1: Part 1 Single Waveform Lab Test Results**

| **Waveform #** | **0** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|---|
| **Wave Shape** | | | | | | |
| **Oscilloscope Peak-to-Peak Amplitude** | | | | | | |
| **Oscilloscope Frequency** | | | | | | |
| **RMS *(AC)* Fluke Bench** | | | | | | |
| **RMS *(AC)* DMM Handheld** | | | | | | |
| **RMS *(AC)* HP Bench** | | | | | | |
| **Duty Cycle** | | | | | | |

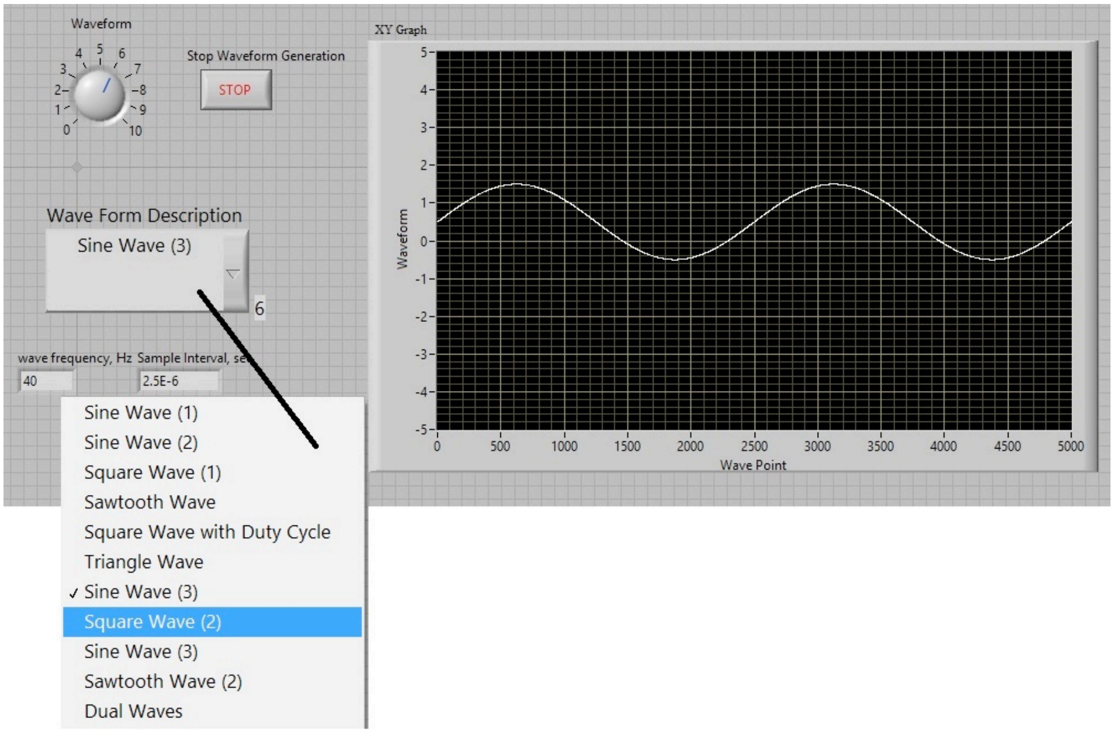
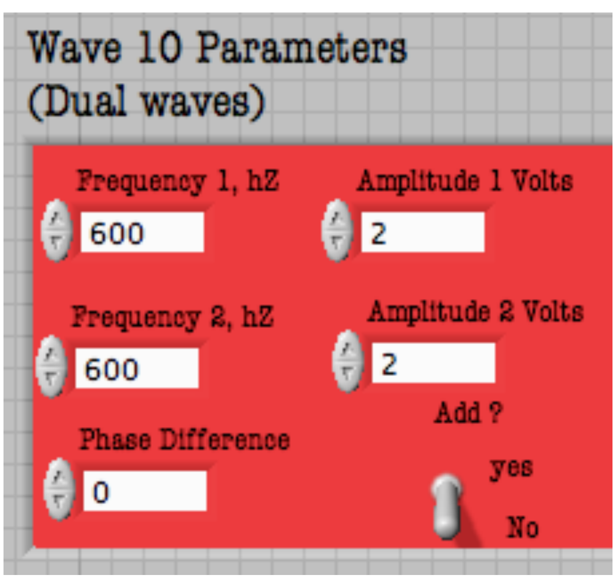



**Figure 2. Signallab.vi for Lab 4 Waveforms.**

*Why do the Oscilloscope Peak-to-Peak amplitudes, and the displayed A/C voltage levels on the Bench-top and handheld multi-meters differ?*




Next, set the waveform dial to number 10. When in the position 10, waveforms are output from DAC0 and DAC1. You can both signals simultaneously by selecting "dual" on the osciulloscope. This action activates channel 2 on the scope (in addition to channel 1). On the Digital scope select the Chan1/Chan 2 buttons until both signals display. The vertical controls for channel 2 are identical to those for channel 1 and are on the right hand side of the scope. On the .VI *Signallab.vi*, in the "Red" control box with the ***"Wave 10-Parameters (Dual Waves)," Set the amplitudes of both waves to 2 volts, and the frequency to 600 hZ. Set the Phase Difference to 90 degrees. The "Add?"***

***switch should be set to Off.*** Start the VI, you should see two sine waves. Stop VI

*Based on the peak time spacing of the two waves, calculate the phase difference between the two waves. Compare to the set phase angle value.*

*(Hint:*

$$\phi = \omega \cdot \Delta t \rightarrow \boxed{\begin{array}{c} \phi = \text{Phase difference between waves} \\ \omega = \text{radian frequency of wave} \\ \Delta t = \text{time difference between waveforms} \end{array}}$$

Now set the phase difference in the "Red Box" to zero and set both wave amplitudes to 2 V. Put the scope in “add” mode, which adds the waveforms in channel 1 and 2 together. Start the VI.

*What is the amplitude and frequency of the added wave?*

Now set the frequency of waveform 2 to 650 Hz. Start the VI.

*What is the amplitude and frequency of the added wave? Is there more than one amplitude? Frequency?*

Complete columns and rows of Table 2 below.

**Table 2: Part 1 Dual Waveform Lab Test Results from Scope.**

| **Waveform # 10** | | | |
|---|---|---|---|
| **Frequency Wave 1 (hZ)** | **Frequency Wave 2 (hZ)** | **Carrier Frequency** | **"Beat" Frequency** |
| 600 | 600 | | |
| 600 | 650 | | |
| 600 | 675 | | |
| 600 | 700 | | |
| 600 | 725 | | |

Now vary the waveform 2 amplitude and phase difference, *describe what happens.*

<u>Based on the in class discussion of Heterodyned waveforms, *justify the observed results*.</u>

<u>*Calculate the "carrier" and "beat" frequencies and compare to the observed vales of Table 2.* (Complete table 3)</u>

**Table 3: Calculated Heterodyne "Carrier" and "Beat" Frequencies.**

| **Waveform # 10** | | | |
|---|---|---|---|
| **Frequency Wave 1 (hZ)** | **Frequency Wave 2 (hZ)** | **Calculated Carrier Frequency** | **Calculated "Beat" Frequency** |
| 600 | 600 | | |
| 600 | 650 | | |
| 600 | 675 | | |
| 600 | 700 | | |
| 600 | 725 | | |

Re-run the *signallab.vi*. with the selector on "0" -- sine wave 1. Now switch the coupling mode switch on CHAN1 on the Oscilloscope to "DC." <u>What happens to your signal display? Why?</u>

Repeat the process using signal 4 *(the square wave*), switching between A/C and D/C coupling on the Oscilloscope. <u>Now what happens to your signal display? Why?</u>

*Look up the term* "A/C coupling" *and write that definition down. How does this phenomenon apply here?*

DESCRIPTION:

**Part 1 Lab Discussion: AC Oscilloscope Signal Triggering**

Based on classroom discussion, describe what triggering does and the physical conditions required for triggering.

DESCRIPTION:

Using the triangular wave input, move the signal to the right of the screen as far as possible. Adjust the triggering level and slope and observe exactly where the signal triggers the sweep (e.g., triggering level and slope). How does the scope display appear when the triggering voltage exceeds the signal magnitude?

DESCRIPTION:

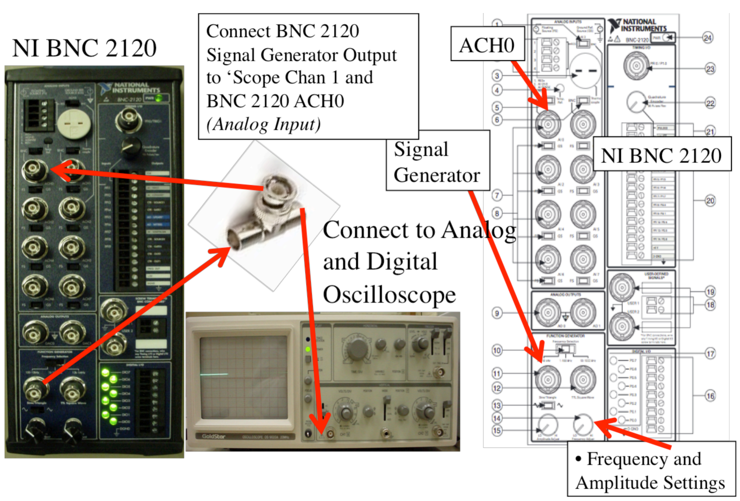
Based on the material in your text, the in-class discussion, and the scope primer on the Lab 4 web page, what happens when the triggering source is placed in the "line" and "external" positions? Why?

DESCRIPTION:

**SETUP, Part 2**: **AC Signal Measurements:**

This section will continue developing the use of the basic lab instruments, and emphasis is on Alternating Current (AC) measurements. On the analogue scope, set the time base to 0.2 sec/div, with the triggering source on "*CH1*" and the mode on "*auto*". Use a watch to see if the beam actually is traveling at the indicated rate by timing the interval required for the beam to move from one end of the screen to the other. Connect to the oscilloscope as shown by figure 3 with the *BNC 2120 signal generator "sine wave" output* put connected to your *oscilloscope chan1* and also to the *BNC 2120 ACH0 (analog input channel 0). As shown in the Lab 4 lecture notes, slide 52, ensure that ACH0 switches are set for "BNC" input, and "FS" (floating source) input. The left hand knob below the signal generator output BNC terminals adjusts the signal amplitude. The right hand knob adjusts the frequency.*

1. Set the signal generator on the NI BNC 2120 terminal block to produce a *2 Volt peak-to-peak (p-p) 1000 Hz (kHz) sine wave*. Adjust the scope sensitivity and time sweep so that you get a clear display of the signal. From the screen display, practice measuring the peak-to-peak voltage and the frequency of the signal.




2. *Open the DAQlab.vi. Again, there should be a link on your desktop to this VI. If not download from the Lab 4 notes section of the MAE 3340 web page*. Choose the appropriate number of samples to show at least two full periods of the *1 kHz waveform*, and select the sampling rate to be at least 5 times larger *(sps = 15 x 1000 Hz)* than the selected wave output frequency. Run the VI. *If you have too many or too few samples to show two full periods, adjust the number of samples appropriately*. From the *DAQlab.vi* display, estimate the peak-to-peak voltage and the signal period and frequency. Populate the first

column of Table 3. Use the Digital Oscilloscope to precisely set the output frequency.

*3.* *Now set the sample rate to 2500 sps*. Run the VI again and compare the samples waveform *(ACH0)* to the analog scope image. From the DAQlab.vi display, estimate the peak-to-peak voltage and the signal period and frequency. Populate the second column of Table 3. *Describe what happens to the sampled signal?*

4. *Now set the sample rate to twice the wave-form frequency (2000 sps)*. Run the VI again and compare the samples waveform *(ACH0)* to the analog scope image. From the DAQlab.vi display, estimate the peak-to-peak voltage and the signal period and frequency. Populate the second column of Table 3. *Describe what happens to the sampled signal?*

5. *Now set the sample rate to 3/4$^{th}$ of the wave-form frequency (750 sps)*. Run the VI again and compare the samples waveform *(ACH0)* to the analog scope image. From the DAQlab.vi display, estimate the peak-to-peak voltage and the signal period and frequency. Populate the second column of Table 3. *Describe what happens to the sampled signal?*

6. *Now set the sample rate to 1/2$^{th}$ of the wave-form frequency (500 sps)*. Run the VI again and compare the samples waveform *(ACH0)* to the analog scope image. From the DAQlab.vi display, estimate the peak-to-peak voltage and the signal period and frequency. Populate the second column of Table 3. *Describe what happens to the sampled signal?*

7. *Now set the sample rate to 1/4$^{th}$ of the wave-form frequency (250 sps)*. Run the VI again and compare the samples waveform *(ACH0)* to the analog scope image. From the DAQlab.vi display, estimate the peak-to-peak voltage and the signal period and frequency. Populate the second column of Table 3. *Describe what happens to the sampled signal?*

8. Now set the sample interval to *1/10$^{th}$* of the signal frequency *(100 sps)*. Run the VI again and compare the samples waveform *(ACH0)* to the analog scope image. Again use the DAQlab.vi display to estimate the peak-to-peak voltage and the signal period and frequency. Populate the third column of Table 3. *Describe what happens to the sampled signal*

9. Now repeat the measurements from the previous paragraph with the sample rates set at {15000, *2500, 2000, 750, 500, 250, and 100 sps}*; but generate this time a 2V p-p, 250Hz sine wave. Populate rows 8-14 of Table 3.

10. Next, change the sine/triangle switch to form a triangle wave. Set the peak-peak voltage at 2 volts and the output frequency at 1000Hz. Repeat the process again with sample rates set at {1*5000, 2500, 2000, 750, 500, 250, and 100 sps}*. Populate rows 15-21 of Table 3.

11. Finally, repeat the process for the triangle wave, with the peak-peak voltage at 2 volts and the output frequency now set at 250Hz. Repeat the process again with sample rates set at {1*5000, 2500, 2000, 750, 500, 250, and 100 sps}*. Populate rows 22-28 of Table 3.

**Table 3: Part 2 Lab Test Results.**

| **Wave** | **Set P-P Voltage** | **Set Frequency** | **Sample rate** | **Observed P-P Voltage from** *DAQlab.vi* | **Observed frequency from** *DAQlab.vi* |
|---|---|---|---|---|---|
| Sine | | | | | |
| **1** | 2 V | 1000 Hz | 15,000 sps | | |
| **2** | 2 V | 1000 Hz | 2500 sps | | |
| **3** | 2 V | 1000 Hz | 2000 sps | | |
| **4** | 2 V | 1000 Hz | 750 sos | | |
| **5** | 2 V | 1000 Hz | 500 sps | | |
| **6** | 2 V | 1000 Hz | 250 sps | | |
| **7** | 2 V | 1000 Hz | 100 sps | | |
| * | * | * | * | * | * |
| Sine | | | | | |
| **8** | 2 V | 250 Hz | 15,000 sps | | |
| **9** | 2 V | 250 Hz | 2500 sps | | |
| **10** | 2 V | 250 Hz | 2000 sps | | |
| **11** | 2 V | 250 Hz | 750 sps | | |
| **12** | 2 V | 250 Hz | 500 sps | | |
| **13** | 2 V | 250 Hz | 250 sps | | |
| **14** | 2 V | 250 Hz | 100 sps | | |
| * | * | * | * | * | * |
| **Triangle** | | | | | |
| **15** | 2 V | 1000 Hz | 15,000 sps | | |

| | | | | | |
|---|---|---|---|---|---|
| **16** | 2 V | 1000 Hz | 2500 sps | | |
| **17** | 2 V | 1000 Hz | 2000 sps | | |
| **18** | 2 V | 1000 Hz | 750 sps | | |
| **19** | 2 V | 1000 Hz | 500 sps | | |
| **20** | 2 V | 1000 Hz | 250 sps | | |
| **21** | 2 V | 1000 Hz | 100 sps | | |
| * | * | * | * | * | * |
| **Triangle** | | | | | |
| **22** | 2 V | 250 Hz | 15,000 sps | | |
| **23** | 2 V | 250 Hz | 2500 sps | | |
| **24** | 2 V | 250 Hz | 2000 sps | | |
| **25** | 2 V | 250 Hz | 750 sps | | |
| **26** | 2 V | 250 Hz | 500 sps | | |
| **27** | 2 V | 250 Hz | 250 sps | | |
| **28** | 2 V | 250 Hz | 100 sps | | |

For both the sine wave and triangular wave cases *describe the observed differences in the signals as the sample rates change from 15000 to 100 sps. for the 1000 Hz wave compared to 250 Hz wave?*

DESCRIPTION:

Look up the term "*Signal Aliasing*". *Write down the definition, and describe how this definition applies to the observed phenomena in the previous paragraph.*

DESCRIPTION: