EXPERIMENT NUMBER 2
# BASIC OSCILLOSCOPE OPERATIONS

The oscilloscope is the most versatile and most important tool in this lab and is probably the best tool an electrical engineer uses. This outline guides you through the basic operations of a specific oscilloscope, an AGILENT DSO-X 3012A, 2 channel, dual time base scope with a DC-100 MHz vertical-amplifier bandwidth. Almost any modern scope will have the same control functions, and a good understanding of this scope will give you confidence in the use of any scope.
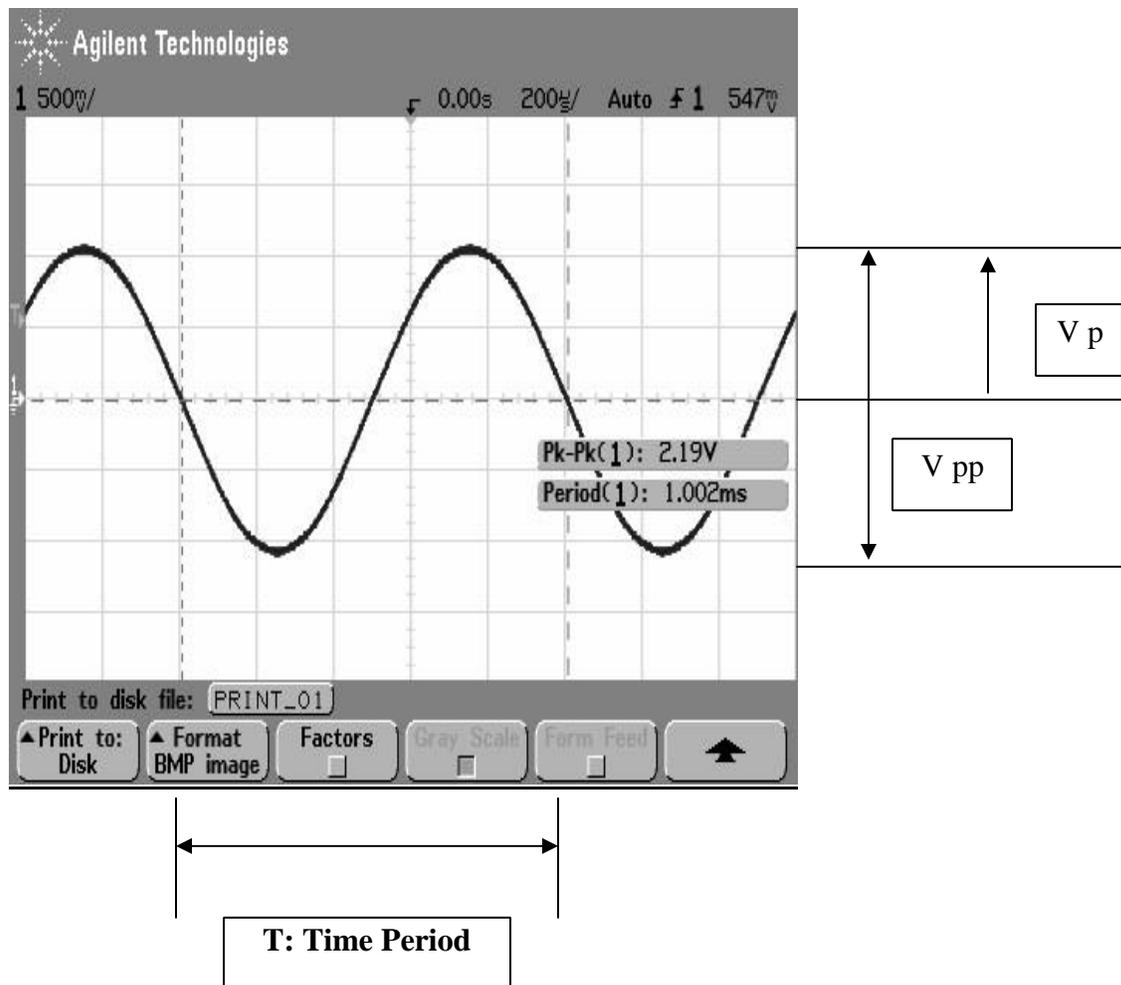
DAY 1

Introduction to signal types:

1. **DC (Direct Current) signal**: A voltage level that remains constant with respect to time is called DC signal. To describe a DC signal, only the voltage level needs to be known.
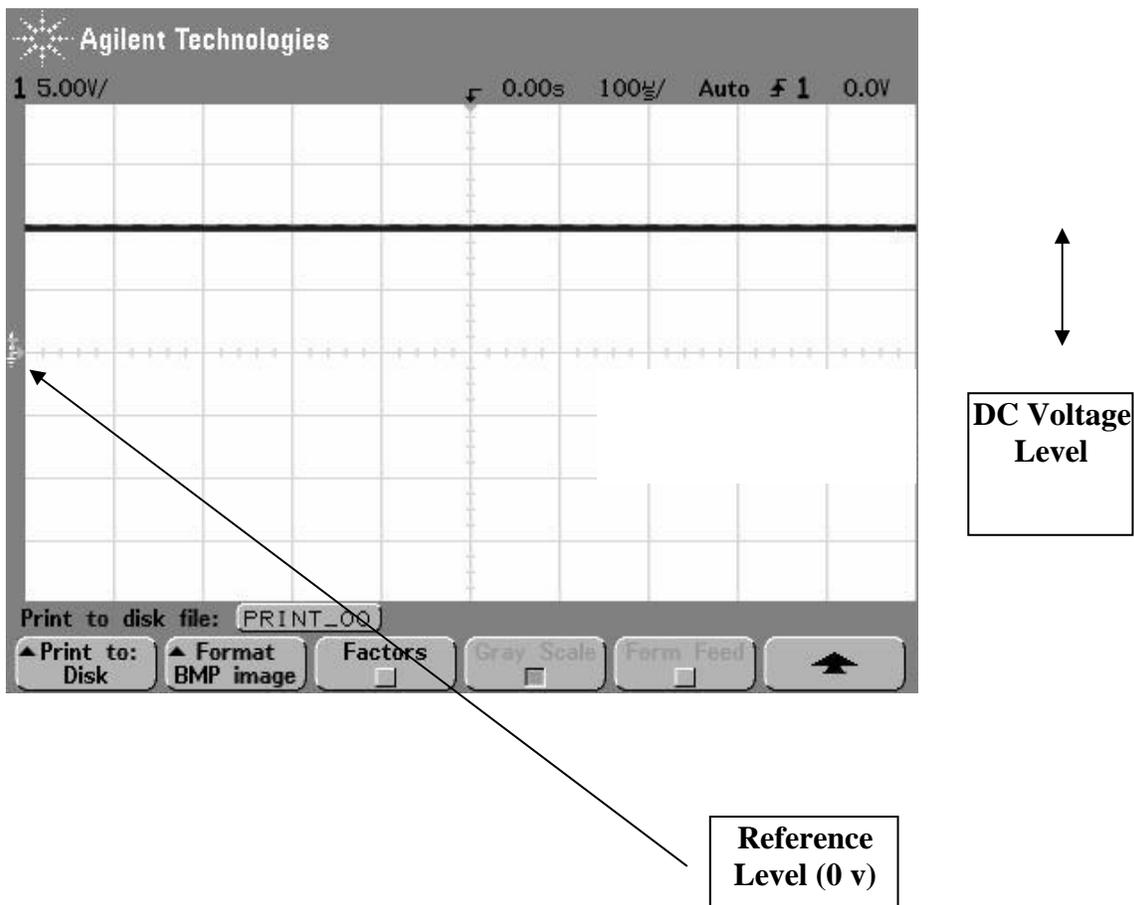
2. **AC (Alternating Current) signal**: If the voltage level varies with time, then the signal is called an AC signal as shown below.

To describe a sine wave, some characteristics of a sine wave need to be known or measured. When you see a sine wave you are seeing a varying voltage with respect to time in a cyclic fashion as shown in the figure. One complete cycle which is one positive half cycle and one negative half cycle constitutes one complete cycle of the waveform. The time taken for this signal is called the period (T) of this waveform and is measured in seconds. The number of times one cycle of the waveform repeats in one second is called the frequency of the waveform and is measured in cycles per second or Hz (Hertz). If the signal repeats itself then it is a periodic waveform otherwise it is aperiodic in nature. This describes the basic timing characteristic of the waveform. There are other timing measurements that can be done and you will be introduced to them as and when they are required for any particular experiment. The other major characteristic of a periodic waveform is the voltage level or the amplitude. There are various ways to define this characteristic. The figure shows two such definitions. The peak value of the voltage (Vp), and the peak-to-peak value of the

voltage (Vpp). In addition, it is possible to characterize voltage levels in terms of the average and RMS value. These later definitions will be described in subsequent exercises. Peak, peak-to-peak, average and RMS values can also be applied to periodic signals that are not sinusoid, such as square and triangle waves. Again these periodic non-sinusoid signals will be discussed in subsequent exercise.

Now you are ready to look at using the most important tool in this lab, the oscilloscope.
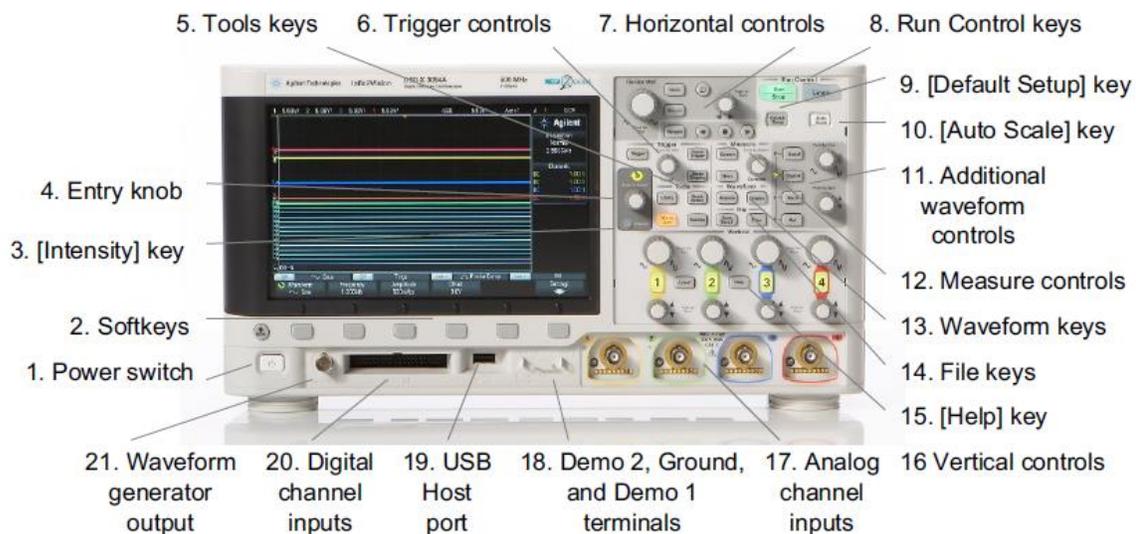
The oscilloscope sitting in front of you has the following main sections.
1. The screen
2. The Vertical Section
3. The Horizontal Section
4. The Trigger Section
5. The Measurement section
6. Disk Storage Section

While doing the experiments and learning to use the oscilloscope, you will be required to record all observed data and waveforms. This oscilloscope has built in features to store the current screen in a few formats. This part is explained to you first so that you don't need to draw the waveforms that you observe. Store them in a USB storage drive and attach them later to your final draft of the write up.

Saving the waveform:

After stabilizing the waveform and obtaining all the required measurements pertaining to the waveform, perform the following steps to save the waveform. This is the simplest way of saving waveforms for future reference.
1. Press the **Save/Recall** key to display the Save/Recall menu. You will find a menu pop-up (called the soft menu) on the bottom of the screen. Each displayed icon on the menu has a push button key associated with it located below the screen. These push buttons are called soft keys.

2. Press the **Formats** softkey to display the Formats menu. The oscilloscope allows you to store the screen images in three formats. The *CSV* (Comma Separated Variable) store values of the displayed channels and math waveforms suitable for spread sheet analysis. *BMP* and *PNG* formats store the complete screen image, including the status line and softkeys.

3. Choose the *PNG* format and wait until you see a clear waveform and the measurements that you have taken.

4. Press the front panel **Press to Save** key to start transfer to the drive.

Now you are ready to start understanding the details of the oscilloscope,

Oscilloscope Operation I: Looking at the "Vertical Section"

This oscilloscope supports two inputs. Therefore you can observe two external signals simultaneously. There are some internally generated signals that can be observed along with the two applied signals, but they will be discussed later. The vertical section has the following controls and buttons associated with it:

1. Each channel has an input to which the signal is applied, a volts/div knob (in the Vertical section marked) that helps in enlarging or shrinking the vertical size of the oscilloscope pattern (trace) and a position control knob (marked) for positioning of the waveform on the screen. These are mainly to assist in viewing the waveform under observation.

2. There is a channel key (named '1' and '2') which pops up the soft menu for the respective channel.

3. There is a math key, when pushed opens up a soft menu that allows the user to perform mathematical operations with the signal on either, or in some cases both, input channels.

Experiments with the vertical section.
⇒ When you first switch on the oscilloscope, it is advisable to use the default factory settings (press the **Default Setup** softkey). After you have gained some experience and confidence, you can use your own personal settings.

⇒ **PROBE CHECK**: Each oscilloscope passive probe must be compensated to match the input characteristics of the oscilloscope channel to which it is connected. A poorly compensated probe can introduce significant measurement errors.

    1. Input the Probe Comp signal by connecting your probe to ground and probe comp

    2. Press **Default Setup** softkey to recall the default oscilloscope setup.

3. Press **Auto Scale** button to automatically configure the oscilloscope for the Probe Comp signal.
4. Press the channel key to which the probe is connected (**1** or **2**).
5. In the Channel Menu, press **Probe**.
6. In the Channel Probe Menu, press Probe Check; then, follow the instructions on- screen. When probe check is completed, you should see the message "probe check passed".

⇒ Connect a DC signal from the DC power supply to the channel 1 of the oscilloscope. One rule to stabilize waveform quickly is to use **Auto Scale** feature of the oscilloscope. Press the **Auto Scale** button located on the front panel of the oscilloscope. You will notice that the oscilloscope automatically makes some adjustments and stabilizes the waveform. Observe the location of the ground level and the level of the signal.

⇒ Turn the volts/div (**Vertical**) knob clock wise and anti-clockwise in steps and observe what happens. You should notice the volts/div changing on the top left hand corner of the screen. The volts/div knob changes in a 1:2:5 sequence (e.g. 0.1, 0.2, 0.5, 1, 2 5 etc).

⇒ Turn the position knob for channel 1, notice the effect and write down your observation in your lab notebook

⇒ Pressing the channel '1' push button brings up the soft menu.

1.1. Signal Coupling: This oscilloscope supports 2 types of signal coupling. Pressing the **Coupling** soft key, allows you to choose the signal coupling. DC coupling allows a complete transfer of the signal arriving at the oscilloscope inputs. It has all the components, DC and AC. Choosing AC coupling, inserts a capacitor in series with the signal there by allowing pure AC signal to pass through to the input circuits.

1.2. The **BW LIMIT** soft key allows you to clean your signal. If you have a very fuzzy waveform, which is basically a clean signal with high frequency noise over it, this feature inserts a filter removing all the high frequency noise. Mainly used for improving signal quality for accurate measurements.

1.3. The **FINE** soft key is used to provide smaller increments or decrements in the volts/div knob. Press the **FINE** soft key and try changing the volts/div knob and observe the difference.

1.4. The **INVERT** soft key is used to provide a 180 degree phase shift, negate it, to the signal. It is useful for doing many mathematical operations.

2. **Quick Measurements**: This oscilloscope has built in capabilities that allow the user to take simple measurements quickly. This is introduced in this section so you can perform some more experiments with the vertical section. To use this feature, press the **MEAS** key located on the front panel. This brings up a soft key menu. Press the **Source** soft key to choose the channel on which you want to perform the quick measurement. Choose the **Type** soft key to choose the measurement you want to perform on the signal and then press the **Add Measurement** soft key. You should

notice the measured reading appear just above the soft key menu. The screen can hold up to three measurements. You can clear the current measurements, by pressing the **Clear Meas** soft key.

3. **<u>Measurement using Cursors</u>**. The cursor feature allows the user to make custom voltage or time measurements.

    3.1. Once you have obtained a stable display, press the **Cursors** key and the press the **Mode** soft key. Choose *Manual* mode. ΔX, $1/\Delta X$, ΔY values are displayed. ΔX is the difference between the X1 and X2 cursors (time difference) and ΔY is the difference between the Y1 and Y2 cursors (voltage difference).

    3.2. Press the **Source** soft key to select the source for your cursor. Using Manual mode allows you to perform operations on analog and math waveforms.

    3.3. **Cursor** soft key allows you to select either X cursors or Y cursors for adjustment.

        3.3.1. X cursors are vertical dashed lines that adjust horizontally and normally indicate time relative to the trigger point. Y cursors are horizontal dashed lines that adjust vertically and normally indicate voltage. It can change while using math operations.

        3.3.2. X1 and X2 : The **X1** cursor (short-dashed vertical line) and **X2** (long-dashed vertical line) adjust horizontally and indicate time relative to the trigger point. The cursor values for the selected waveform source are displayed within the X1 and X2 soft keys. The difference between X1 and X2 , ΔX and $1/\Delta X$ are displayed above the soft keys. You can individually select X1 or X2 and adjust them to the positions required for measurements.

        3.3.3. Y1 and Y2: The **Y1** cursor (short-dashed horizontal line) and **Y2** (long-dashed horizontal line) adjust vertically and indicate values relative to the waveform's ground point. The cursor values for the selected waveform source are displayed within the Y1 and Y2 soft keys. The difference between Y1 and Y2: ΔY are displayed above the soft keys. You can individually select Y1 or Y2 and adjust them to the positions required for measurements.

        3.3.4. Select **Y1 Y2 linked** to adjust the Y1 and Y2 cursors together by turning the cursor knob. The ΔY value will not change since the cursors adjust together.

        3.3.5. Select **X1 X2 linked** to adjust the X1 and X2 cursors together by turning the cursor knob. The ΔX value will not change since the cursors adjust together.

4. **Exercises:**

    $\Rightarrow$ Apply a 5 volts DC signal to channel 1

- Choose different types of signal coupling, observe the effect it has on the waveform under observation and note your conclusion in your lab note book
- Change the volts/div setting and note the effect of increasing and decreasing the setting on the waveform. Manually calculate the voltage level by counting the number of the divisions and multiplying it by the volts/div. Try

this at different volts/div settings. Explain which volts/div setting gives the most accurate answer?

- Measure the voltage level using the quick measure feature by measuring the maximum and the average value. Try to use the cursor feature to measure the voltage level. (** Please store the waveforms for each on screen measurement you take).

⇒ Connect a 1 KHz sine wave from the signal generator to channel 1.

- On the signal generator panel, press the **Channel** button: change **Output** to On
- Press the **Output Load** button: select **Set To High Z**
- On the signal generator panel, Press the **Waveforms** button.
- Select desired waveform **Sine**
- Select desired frequency and amplitude (100mVpp)

⇒Press **Auto Scale** to stabilize the signal. Use the position knob to bring the ground level of the waveform to the center of the screen. Try to observe the effect of different types of signal coupling on the waveform. Note your observations on the effects of changing the signal coupling.

⇒ Observe the effect of increasing and decreasing the volts/div on the waveform. Measure the peak-peak voltage, maximum and minimum voltage using both the quick measurement feature as well as cursors. Measure the average value of waveform. Measure the **RMS value** of the waveform using **quick measurement** and a **DMM**. Record your observations and store the waveforms.

⇒ The instructor will explain the concept of DC offset. Introduce some into your signal using the signal generator (e.g.: 20mV). Observe the effect of AC and DC signal coupling on the sine wave. With the DC offset still there, try to measure the average value using cursors and using the formula

(Positive peak voltage + Negative peak value)/2

Measure the average value using the quick measurement and compare it with the calculate value.

⇒ Connect a 1 KHz triangular and square wave. Observe the effect of increasing and decreasing the volts/div on the waveform. Measure the peak-peak voltage, maximum and minimum voltage using both the quick measurement feature as well as cursors. Measure the average value of waveform. Measure the RMS value of the waveform using quick measurement and a DMM. Record your observations and store the waveforms.

DAY 2

Oscilloscope Operation II: Looking at the "Horizontal Section"

The horizontal section provides the timing control on the waveform that is being observed. It has the following controls and buttons associated with it.

1. There is a secs/div (Horizontal scale) knob marked $\wedge\!\!\vee\wedge$ that helps in modifying the horizontal scale and a horizontal position control knob marked ◄► for positioning of the waveform on the screen. These are mainly to assist the viewer in ease of viewing the waveform under observation and making time measurements.

   ⇒ Connect a 1 KHz sine wave from the signal generator to channel 1 of the oscilloscope and stabilize the signal using **Auto Scale** feature. Turn the secs/div knob clock wise and anti-clockwise in steps and observe what happens. You should notice the secs/div changing on the screen. It will light up, when you adjust this setting. The secs/div knob changes in a 1:2:5 sequence (e.g. 0.1, 0.2, 0.5, 1, 2 5 etc).

   Try to measure the period of the waveform by measuring the number of horizontal divisions and multiplying it by the secs/div. Try this at different settings.

   Verify your results by finding the period of the signal. The period is the reciprocal of the frequency. Measure the period using the 'X' cursors and the quick measurement feature and record your observations.

   Save your waveforms, for both the measurements, on your USB drive.

   ⇒ Turn the horizontal position knob, notice the effect and note down your observation.
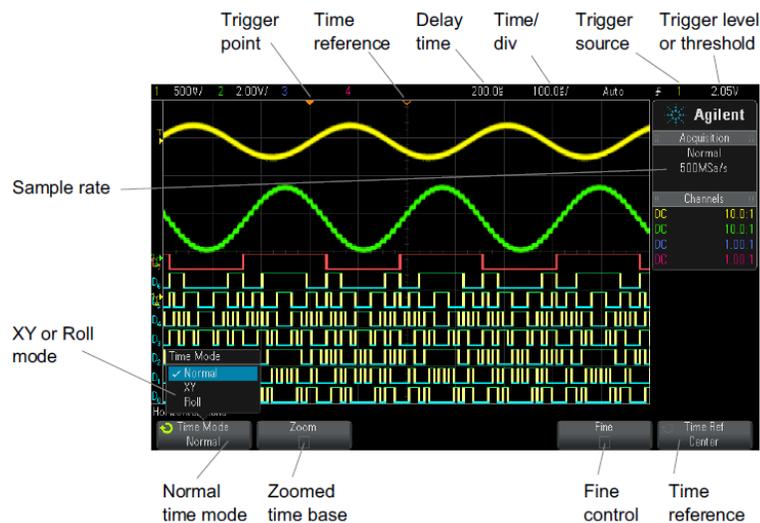
2. Press **Horiz** soft key to access the horizontal section menu. There is a **Time Mode** soft key at the bottom right of the display panel.

⇒ You will find the **Normal** mode checked. The other modes that can be chosen are the **Roll** and the **XY** mode.

⇒ Connect a very low frequency signal (e.g. 1Hz), press the **Roll** softkey, observe what happens to the waveform and note down your conclusion.

⇒ **Zoom**, formerly called **Delayed sweep** mode, is a horizontally expanded version of the normal display. It allows you to; expand a portion of the main waveform to observe the timing details more clearly. Pressing this key, divides the screen into two parts. The top half of the display shows the main waveform in the normal time/div window and the bottom half displays the expanded waveform using a faster Zoom time/div window. The Zoom window is a magnified portion of the normal time/div window. You can use **Zoom** to locate and horizontally expand part of the normal window for a more detailed (higher-resolution) analysis of signals. Turning the secs/div knob allows you to select the range of the original waveform you want to observe. The horizontal position control knob allows you to shift the selected region left or right.

Practice with different settings of the secs/div and the position control and note down your observation. Save the screen image on your USB drive.

⇒ Measure the rise and fall times of the voltage using the **Zoom** and **Cursor** measurement feature of the oscilloscope.

⇒ The X-Y feature will be explained when you do the dual signal operation.

⇒ **Time Ref Center** key: When you stabilize the signal, you will see, on the top center of the screen, an inverted triangle that depicts the timing reference. You can set this timing reference to either, center, left or right by pressing the **Time Ref** soft key. If you turn the horizontal position knob you will find the waveform shifting and the delay between the current position and the time reference will be displayed on the screen temporarily. Practice this feature and note down your observations.

Oscilloscope Operation III: Looking at the "Trigger Section"

Triggering of the signal under observation is very important as it provides synchronization between the vertical and horizontal deflection system. Generally the signal under observation is used to extract the trigger signals that are needed to generate accurate horizontal sweep signals to display the waveform. Pressing the **Mode Coupling** button (in the Trigger section) brings up the trigger menu on the screen.

⇒ Connect a 1 KHz sine wave to channel 1 and stabilize it. By rotating the trigger knob (the knob left to the **Mode Coupling** button), you should notice the trigger level and the starting point of the signal changing. This will also depend on the position of the timing reference that you have set, the default setting is center.

⇒ Pressing the **Mode** soft key brings up two options. **Auto,** and **Normal**. Rotate through these two options. Take the trigger level, using the trigger level knob beyond the display range and notice the affect and differences in the two modes. (The **Auto** mode tries to stabilize the signal for you but sometimes it doesn't actually stabilize well. It automatically updates. **Normal** mode allows you to stabilize it yourself but it doesn't update automatically new signal inputs from waveform generator. You have to switch back to **Auto** to get it to update.)

⇒ Reduce the frequency of the signal to about 5-10 Hz. And try to stabilize the signal using all the modes and conclude, which one of them is most suitable for observing low frequency signals.

⇒ Pressing the **Coupling** soft key gives you a few choices on the type of coupling that is desired. Generally the signal under observation is given to the trigger circuit to extract the trigger signal. If the signal is composed of many frequencies or has DC offset added into it, you might have to choose the right coupling for the job. **DC** coupling allows all the components of the signal to the trigger circuit and can be used for all signals, but mostly suited for observing very low frequency signals. **AC** coupling removes any DC and very low frequency signals and is mainly suited for observing signals with DC offset. **LF** (low frequency) **reject** is mainly used for observing very high frequency signals, rejecting any low frequency noise.
Practice by stabilizing low frequency signals, high frequency signals and signals with offset using different types of coupling and note down your observations.

⇒ The **Noise Rej** soft key is used to remove any high frequency noise to allow a clean signal to enter the trigger circuit.

⇒ The **HF Reject** It is just the opposite to the **LF reject**

⇒ **Hold off**: Trigger holdoff sets the amount of time the oscilloscope waits after a trigger before re- arming the trigger circuitry. Use the **holdoff** to trigger on repetitive waveforms that have multiple edges (or other events) between waveform repetitions. Increase the Hold off time by turning the entry knob and observe what happens to the signal and note down conclusions on where this feature can be used.

⇒ **External Triggering** If you would like an external signal to trigger your signal under observation, connect the calibrator signal to channel 2 and connect a sine wave, from the signal generator, to channel 1. The **Trigger** softkey can be used to change the source to external. Try to change the frequency of the input signal and observe which frequencies can be stabilized using the calibrator signal.

⇒ There are some ways in which the oscilloscope employs triggering of signals. (Use 1khz sine wine.) We are going to observe the **EDGE Triggering** in detail. Press the **Trigger** button and then press the **Trigger Type** softkey to bring up the trigger menu. The default settings include is **edge** for triggering, channel 1 as the **source,** and slope as **rising.** With **edge** selected, try to vary the trigger level and observe the trigger being selected from the positive slope of the signal. Observe what happens when you choose the **falling** slope and turn the trigger level knob.

⇒ Channel 1 will be chosen as the source of triggering since only channel 1 has a signal connected to it. Remove the signal from channel 1 and connect it to channel 2, select channel 2 (vertical section), deselect channel 1 and press auto scale. Now checking the edge menu you will find that channel 2 is the source of the signal. This feature will become more apparent when you do the dual signal operation.

⇒ Pressing the **Source** soft key and select **line** triggering. This feature connects the supply line voltage coming from the mains to the trigger circuit. Using this feature and changing the frequency of the input signal try to find the frequencies that you can stabilize. (You will observe that you can only stabilize very low frequencies easily.)

Oscilloscope Operation IV: Looking at the "Dual Signal Operation"

⇒ Connect the calibrator signal to channel 1 and a 1 KHz sine wave to channel 2. You will have to select both the channels to switch them on. Try to stabilize both the channels. Choose channel 1 as your source for triggering and then choose channel 2 as your source and note down your observations. What does this tell you about the two signals that you are trying to observe simultaneously? Now remove the calibrator signal from channel 1 and connect the TTL output (use the sync port below the Trigger button) from the function generator and try to stabilize both the signals. Note down your observations and conclusion of the stability

⇒ Using a splitter, connect a 1 KHz sine wave to both the channels, stabilize them and press the math function button. You can perform a few math functions using the 2 signals under observation. Use AC signal coupling for both the channels. How will you add and subtract the 2 waveforms? Be sure to save the waveforms. Remove channel 2 and try to observe the integrated and differentiated wave form by using the respective soft keys. Do they match with the theoretical calculus?

⇒ Looking at the **XY** mode. In the XY mode the timing signal is removed from the horizontal deflection system, and channel 2 signal is diverted to the horizontal deflection plates. Channel 1 is given to the vertical deflection system. This leads to a X-Y graph (the details and applications will be explained by your instructor). Connect 2 sine waves of the same frequency and observe the X-Y pattern. Try the same with two square waves and two triangular waves. Note your observations in the difference between the X-Y pattern for the sine wave and triangular wave. Save your waveforms on your USB drive.