Lab 01 - Lab Equipment

Introduction

This lab will introduce you to the 4 basic instruments on the laboratory bench. These instruments are a feature of every real engineering laboratory.

Digital Multimeter (DMM)

The digital multimeter is capable of measuring DC voltage, AC voltage, DC current, AC current, resistance, capacitance, diodes, frequency, period, temperature, and display statistics on the measurements such as average and standard deviation. The DMM is therefore a very versatile measuring device, and most engineers will have a portable DMM in their tool kit!

DC Power Supply

For professional design and testing, a constant DC voltage is usually required where the voltage can be adjusted from the front panel – such devices are DC power supplies. A power supply may have one pair of terminals, or two (a 'dual' power supply) or three pair (a 'triple' power supply). Some can be operated in series or parallel. You need to become familiar with the laboratory power supplies so that in future when you need to use one you know how they operate.

Digital Storage Oscilloscope (DSO)

The DSO is another versatile tool for the engineer. Oscilloscopes display voltage waveforms with respect to time. A DSO has the ability to sample and store voltage waveforms, giving it the ability to "capture" transient waveforms and also the ability to perform mathematical operations on the sample values. Like any tool though, it has its limitations, and careful operation is required to interpret results correctly.

Function Generator (FG)

Another useful device for testing is the "function generator". This device is capable of generating sinusoidal, triangular, square and arbitrary waveforms of varying frequency and amplitude. It is generally used as the "input signal" to a circuit so that a circuit's time and frequency characteristics can be determined.

Objectives

1. To become familiar with setting up a DSO.
2. To become familiar with basic time and voltage measurement techniques using a DSO.
3. To review the operation of a dual and triple power supply.

Equipment

- 1 Digital Storage Oscilloscope (DSO) - Keysight InfiniiVision DSOX2004A
- 1 Function/Arbitrary Waveform Generator - Siglent SDG1020
- 1 Programmable DC Power Supply - Siglent SPD3303C
- 1 Digital Multimeter - Siglent SDM3045X
- Variable resistor - UTS
- 4mm leads (assorted colours), 2 BNC to 4mm leads

Safety

This is a Category A laboratory experiment. Please adhere to the Category A safety guidelines (issued separately).

Multimeter I

The digital multimeter (DMM) will be used to measure several of the "fundamental" electrical phenomena - voltage, current and resistance. This section will explore the operation and connections of the multimeter for the measurement of resistance. In later sections, we will use it to measure voltage and current.

Figure 1-1-1

Digital Multimeter (DMM)

Conceptually, the digital multimeter in a circuit behaves differently depending on what is being measured.

Multimeter II

Voltage Measurement

For voltage measurement, the DMM appears to be like an extremely high-valued resistor - we can approximate it as an "open circuit" - an infinite resistance. A voltmeter is specifically designed to appear as an extremely high resistance so that it does not draw current from the measured circuit. Using Ohm's Law:

$$V = RI$$

this means that the current through the DMM is $I = \frac{V}{R} = \frac{V}{\infty} = 0$. The circuit symbol for a voltmeter is:

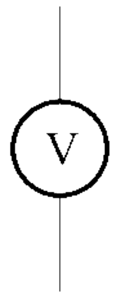


Figure 1-1-2

Safety: It is safe to connect voltmeters between any two points in a low voltage circuit, i.e. in this lab you can connect the voltmeter to any points in the circuits that you build, and across the power supply or function generator. Such a connection is known as a parallel connection.

Voltmeters are connected in *parallel* with the voltage to be measured.

An example of a circuit with a voltmeter connected is shown below:

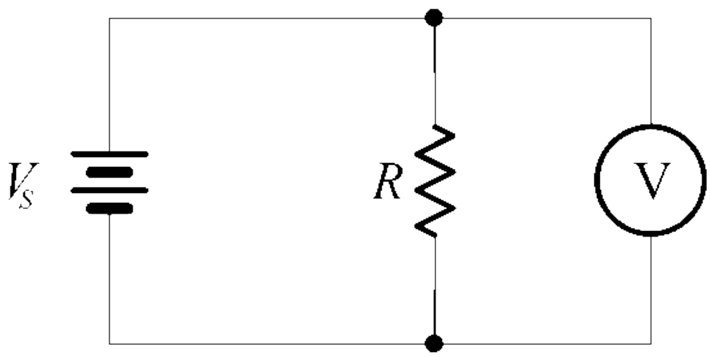


Figure 1-1-3

This circuit will measure the voltage across the resistor (which also happens to equal the voltage of the battery).

The unit of voltage is the volt (V).

Multimeter III

Current Measurement

For current measurement, the DMM appears to be like an extremely low-valued resistor - we can approximate it as a "short circuit" - a zero resistance. An ammeter (note the name does not have a *p* in it!) is specifically designed to appear as an extremely low resistance so that it does not affect the voltage in the measured circuit. Using Ohm's Law:

$$V = RI$$

this means that the voltage across the DMM is $V = RI = 0.I = 0$. The circuit symbol for an ammeter is:

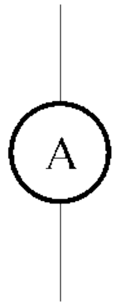


Figure 1-1-4

Safety: It is **NOT** safe to connect ammeters between any two points in a circuit! Doing so would create a "short circuit" between the two points, and could damage both the circuit and the meter. The ammeter must be connected so that the current to be measured actually goes *through* the meter - this inevitably means that the circuit must be "broken" and the ammeter placed into the circuit at the break.

Ammeters are connected in *series* with the current to be measured.

An example of a circuit with an ammeter connected is shown below:

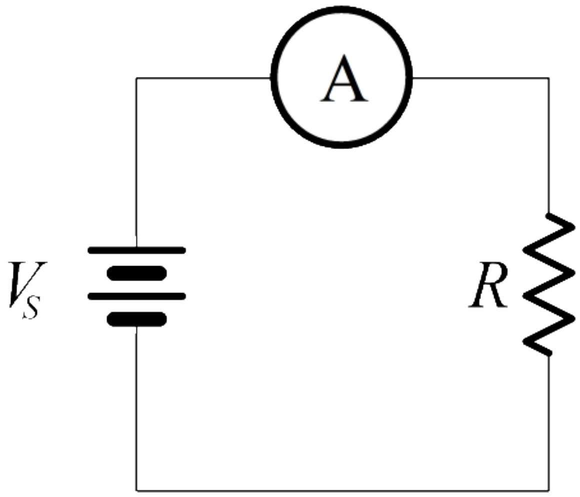


Figure 1-1-5

This circuit will measure the current through the resistor (which also happens to equal the current through the battery).

The unit of current is the ampere, often shortened to "amp" (A).

Multimeter IV

Resistance Measurement

For resistance measurement, the DMM passes a (usually small) current through the device or component and measures the resulting voltage drop - thus finding the resistance by Ohm's Law $R = V/I$. Therefore, all power must be disconnected from the device or component before the measurement is made. Depending on the circuit, this may require removal of the component from the circuit entirely whilst the measurement is made. The circuit symbol for an ohmmeter is:

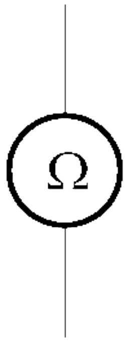


Figure 1-1-6

Safety: It is **NOT** safe to connect ohmmeters between any two points in a circuit! Doing so would "inject" an additional current into the circuit, possibly causing damage. Usually, you need to remove the circuit component entirely from the circuit before measuring its resistance. Sometimes (depending on the circuit) you can remove one side of a component or device from the rest of the circuit and measure across it.

Ohmmeters are connected *directly across* the device or component to be measured.

An example of a circuit with an ohmmeter connected is shown below:

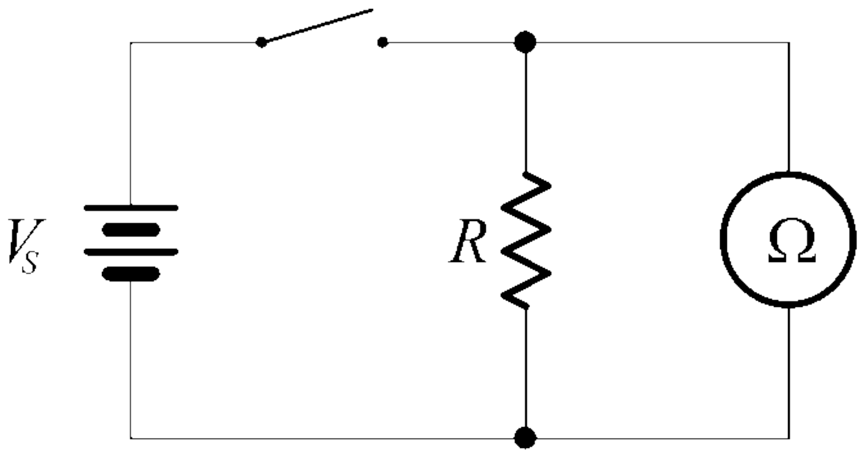


Figure 1-1-7

This circuit will measure the resistance of the resistor (note that the battery has been **disconnected** because the switch is open).

The unit of resistance is the ohm (Ω).

Multimeter V

Measuring Resistance

We are going to set up the DMM in order to measure resistance.

1. Turn the DMM on.

2. Set the digital multimeter to read DC Resistance on the Auto range by pressing the Ω2W key (Ω2W stands for ohm - 2-wire. There is also a 4-wire method for measuring resistance which we will not use in this lab).

3. Connect a red 4mm lead (obtained from the lead rack) to the red terminal marked with:

   and the word "*HI*". This red socket acts as the "high" or "positive" for voltage, resistance, diode test and capacitance measurements.

4. Connect a black 4mm lead (obtained from the lead rack) to the black terminal marked "*LO*". In many meters this is also marked "*COM*" which stands for "common".

5. Connect the supplied switchable resistor via the "alligator clips" to the ends of the 4mm leads, being careful to match the colors. Your setup should look like this:

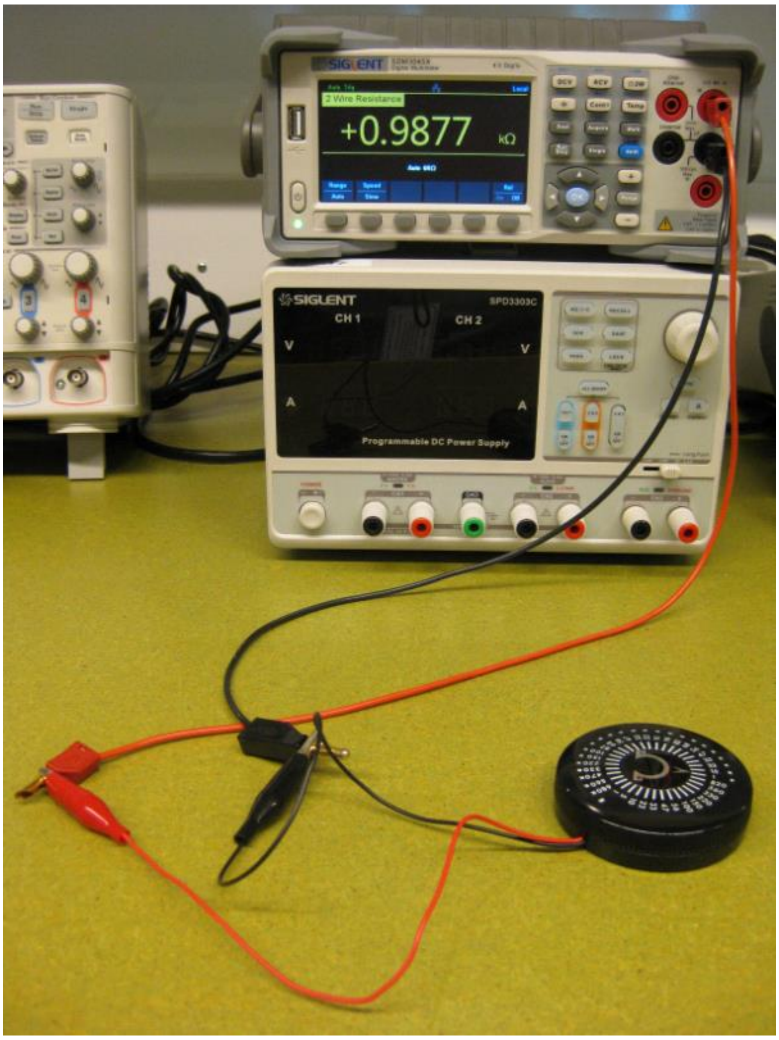


Figure 1-1-8

Multimeter VI

6. Set the switchable resistor to the following values, and record the DMM readings in Table 1-1-1.
   In the "% Difference" column, calculate the difference between the measured resistance value and the labelled resistance value, and express this as a percentage compared to the nominal (labelled) value.

Table 1-1-1

Resistor	Measured Value (4 significant digits)	% Difference (2 significant digits)
22 Ω		
220 Ω		
330 Ω		
1 kΩ		

7. Disconnect the switchable resistor from the 4mm leads.

DC Power Supply I

The DC power supply is separated into two identical and adjustable power supplies, and one selectable supply. Each adjustable power supply has an independent output voltage (0 to 30 V DC) and a current limit (>0 to 3 A) as well as a digital display. The selectable supply can be switched between 2.5 V, 3.3 V and 5 V (these voltages are often used for digital logic circuits).

The adjustable power supplies are capable of independent operation, or connected in series (to provide up to 60 V DC @ 3 A), or connected in parallel (to provide up to 30 V DC @ 6 A).

Figure 1-2-1

The green 4mm terminal in the centre of the two adjustable supplies, labelled "GND" for "ground", is connected directly to the earth pin of the mains supply lead.

The red terminal provides a positive voltage output with respect to the black terminal.

Neither the red terminal nor the black terminal is internally connected to the EARTH, in this way the output voltages are said to be "floating" with respect to earth, just like a battery.

DC Power Supply II

Adjustable DC Power Supplies

Conceptually, the dual adjustable power supplies looks like this under default settings:

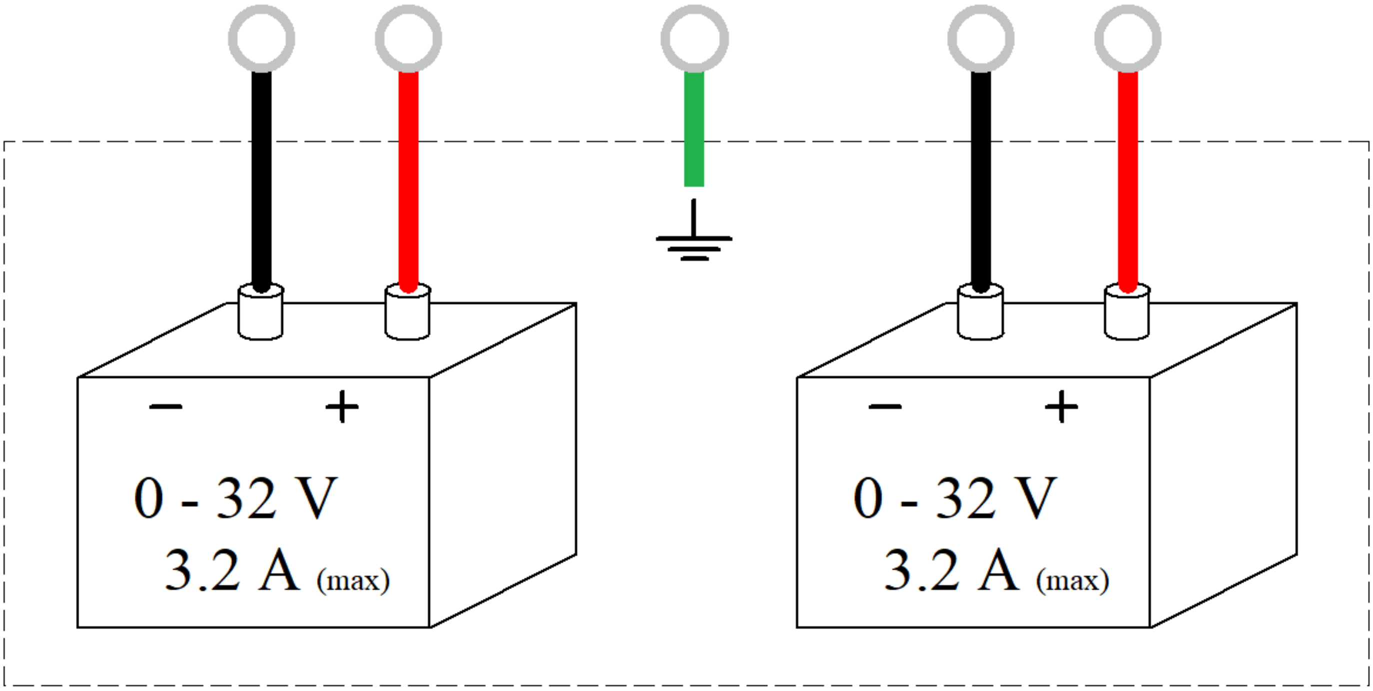


Figure 1-2-2

Setting up the DC Supply

We are going to set up the power supply for a 10 volt output on the CH1 pair of output connectors.

Setting the Output Voltage

1. Turn the DC power supply on.

2. Ensure the CH1 button is illuminated (if it is off, press the CH1 button so that it is on). This means that the general purpose knob will control channel 1.

3. Ensure that the V button is illuminated (if it is off, press the V button so that it is on). This means that the general purpose knob will control the voltage.

4. Ensure that the ON-OFF button below the CH1 button is off. This means the channel 1 voltage is not connected to the output terminals.

   It is good practice to ensure you have the right voltage set before enabling the outputs.

5. Turn the general purpose knob and set the Channel 1 voltage to 10 V. You should see the LHS display changing to reflect the voltage you are setting via the knob.

Setting the Current Limit

Safety: It is good practice to set a current limit. This limits the amount of output current from the power supply and hence reduces the risk of damage if something goes wrong with your circuit or measurements.

1. Push the A button so that it is illuminated. This means that the general purpose knob will control the current limit.

2. Turn the general purpose knob and set the Channel 1 current limit to 0.2 A (200 mA). You should see the LHS display changing to reflect the current limit you are setting via the knob.

DC Power Supply III

Enabling the Output

1. Push the ON-OFF button below the CH1 button so that it is illuminated. The output voltage is now connected to the corresponding red and black output terminals. Notice how the current display dropped from 0.2 to 0 when the output was turned on. When the output is turned off, the display will show what has been programmed as the limit. When the output is turned on, the display will show what the actual current leaving the power supply is.

Measuring Voltage and Current

We are going to use the DMM to measure the output voltage and output current of the power supply.

1. Set the DMM to read DC Voltage on the Auto range by pressing the DCV key.

2. Connect 4mm leads from the left-hand channel 1 power supply to the DMM. Your setup should look like this:

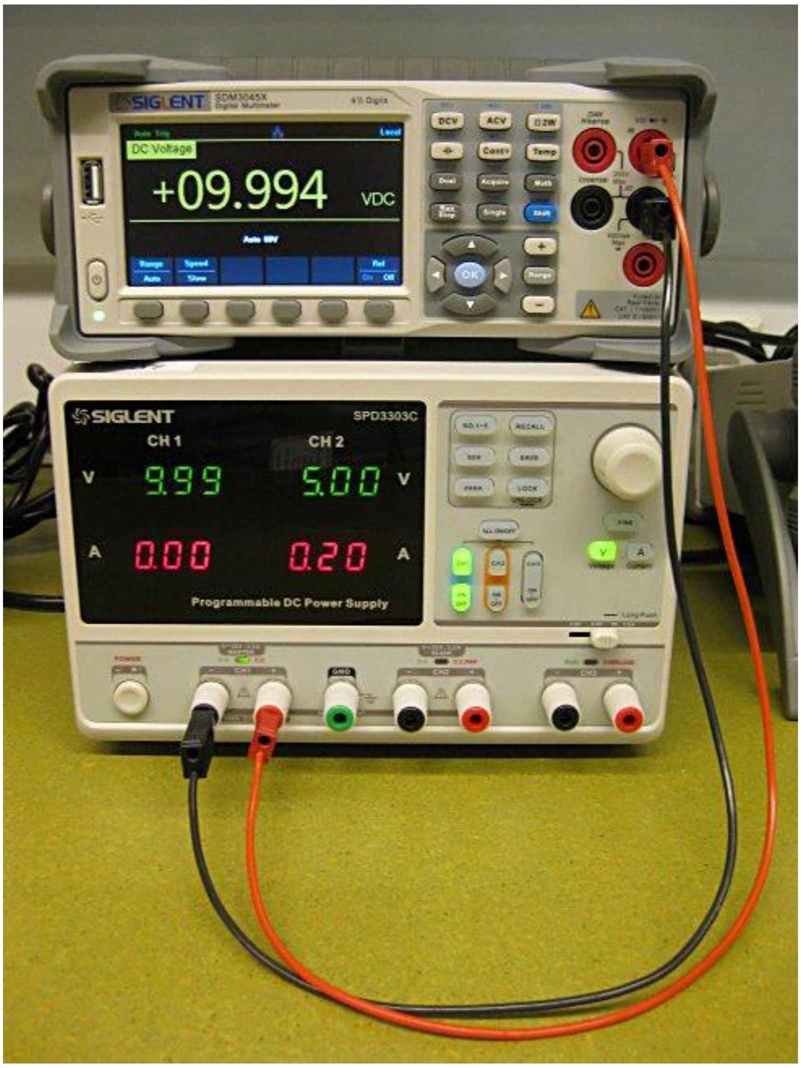


Figure 1-2-3

3. Record the DMM reading:

$V=$	

Tip: If you need an accurate output voltage reading, always use a digital multimeter connected to the output voltage at the load, not at the supply, since there may be a voltage drop in the leads due to the lead resistance, if the current is large.

DC Power Supply IV

4. Turn the channel 1 output **off** by pushing the ON-OFF button below the CH1 button. The ON-OFF button should not be illuminated, indicating that the voltage supply output has been internally disconnected.

5. Change the red lead on the DMM so that it connects to the bottom red terminal, which is used to measure current.

6. To measure current, we need to change the function of the DMM to an ammeter. On the DMM press the blue SHIFT key - this indicates that we are going to choose the secondary or "shifted" function of a button. Then press the DCV key - note the small writing above the DCV key - it says DCI which stands for DC current. The DMM is now acting as a DC ammeter.

7. Turn the channel 1 output **on** by pushing the ON-OFF button below the CH1 button. The ON-OFF button should be illuminated. Your setup should look like this:

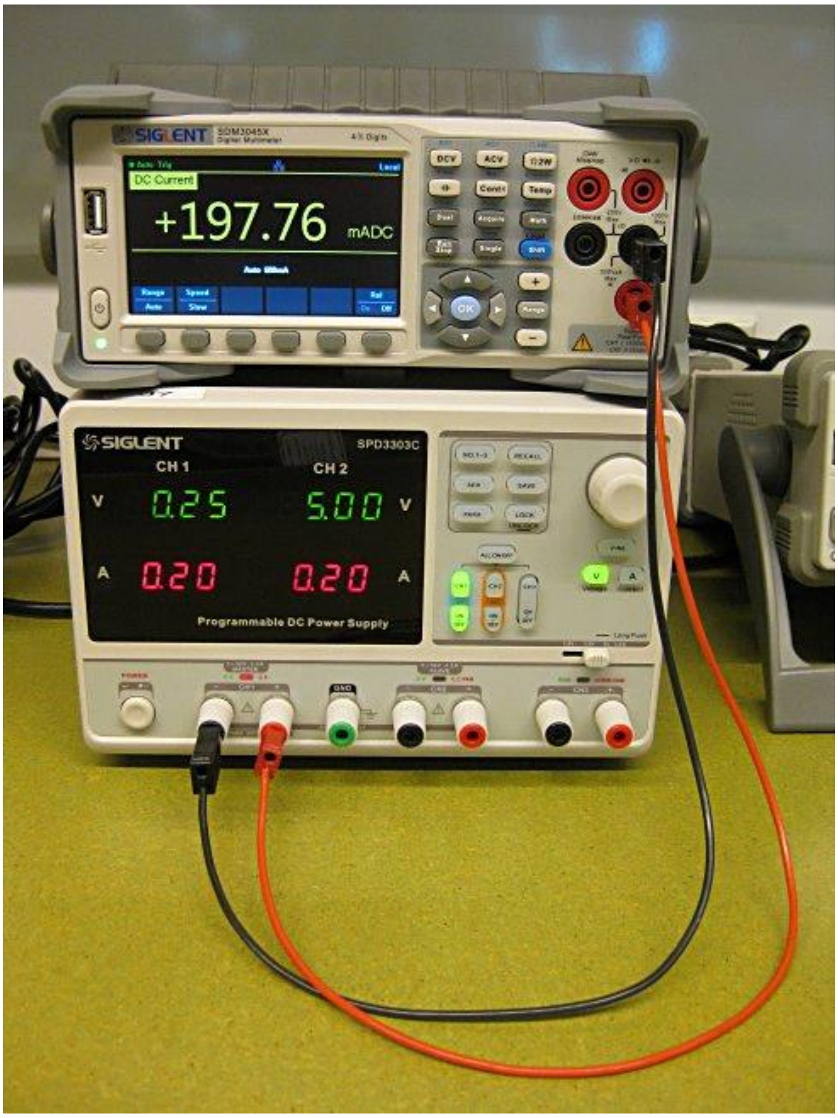


Figure 1-2-4

8. Record the DMM reading:

$I=$	

Can you explain the reading?

Hint: The red LED above the channel 1 outputs labelled CC (constant current) is illuminated.

9. Remove the 4mm leads from both the DC power supply, and the DMM before proceeding to the next section.

DC Power Supply V

Using Dual Supplies in Series

In this section we are going to demonstrate the various methods of 'taking an output' from the adjustable power supplies. Each output of the power supply is ‘floating’ with respect to earth at the general power outlet (GPO), and thus is similar to a battery.

1. Enable series mode on the power supply by pressing the ser key. Note that the two channels are now "linked" in series and each independent voltage supply will have exactly the same voltage - channel 1 is termed the "master" and channel 2 is termed the "slave". The channel 2 voltage will now "track" the channel 1 voltage if you change it by turning the general purpose knob (try it and return the voltage back to 10 V).

2. Now measure the voltage between the ‘-’ terminal on the left-hand side (CH1) and the ‘+’ terminal on the right-hand side (CH2) of the power supply.
   You should get 20 V, because you have programmed the supplies to operate in series mode. In series mode, an internal connection is applied as shown below in blue:

Voltage between ‘plus’ (red) and 'minus' (black) =	

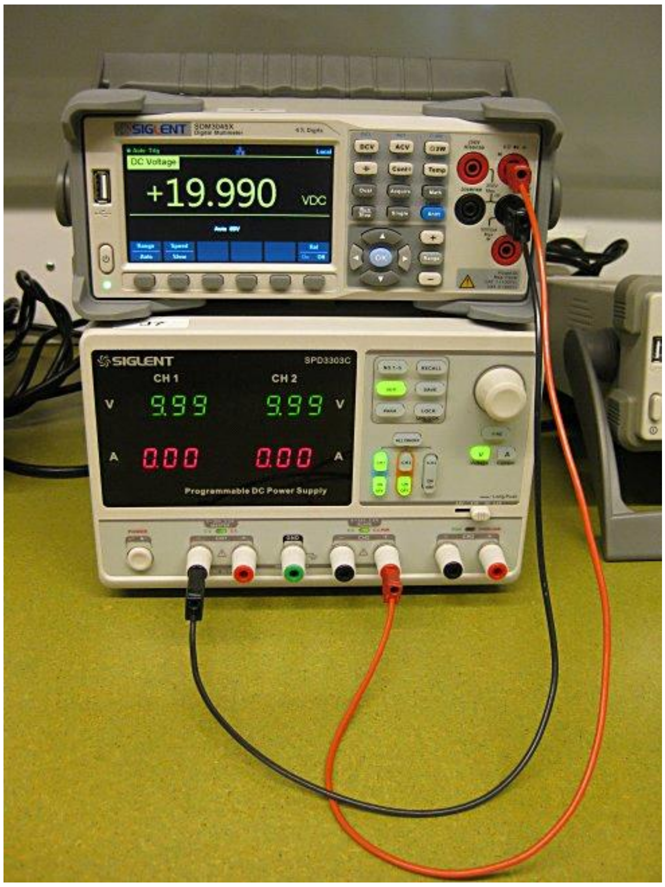


Figure 1-2-5

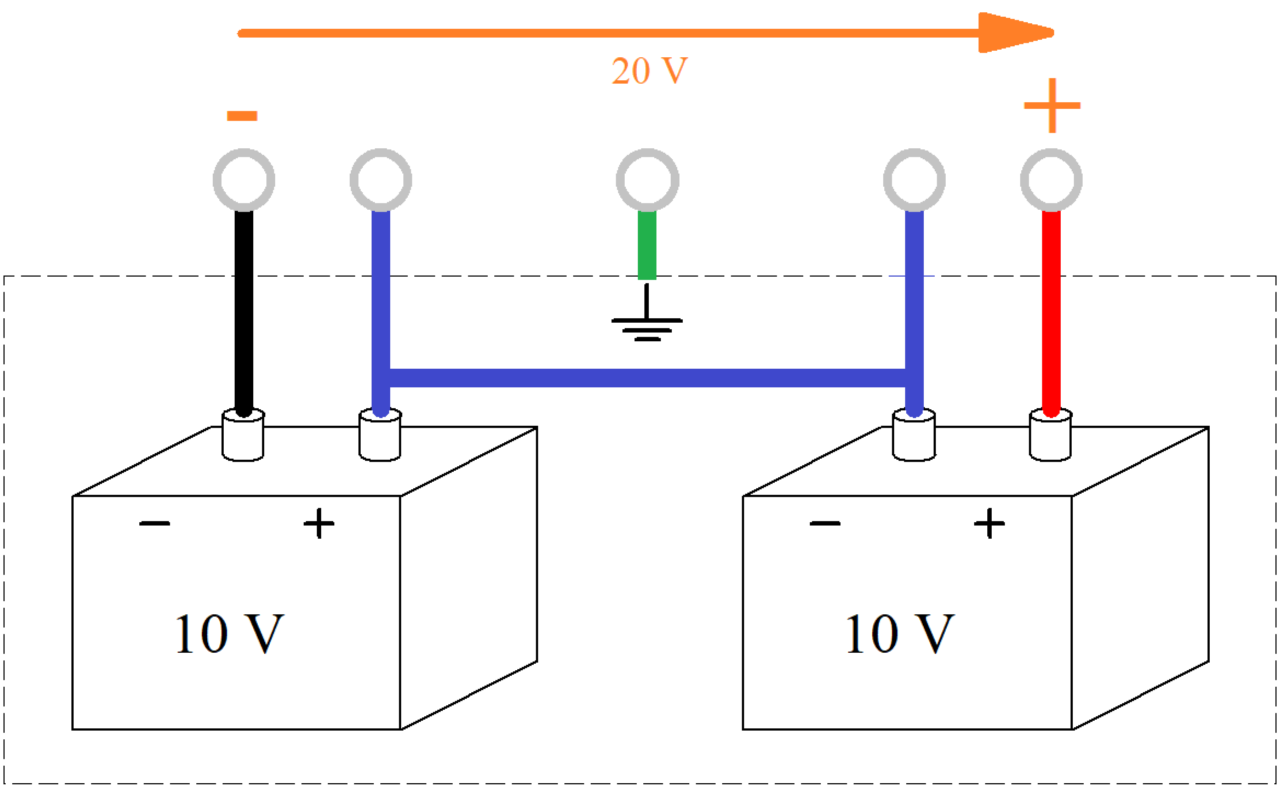


Figure 1-2-6

DC Power Supply VI

3. Considering the blue interconnection terminals as a ‘common’ voltage reference, measure the voltage between this common (blue) and each of the other two terminals (black, red).

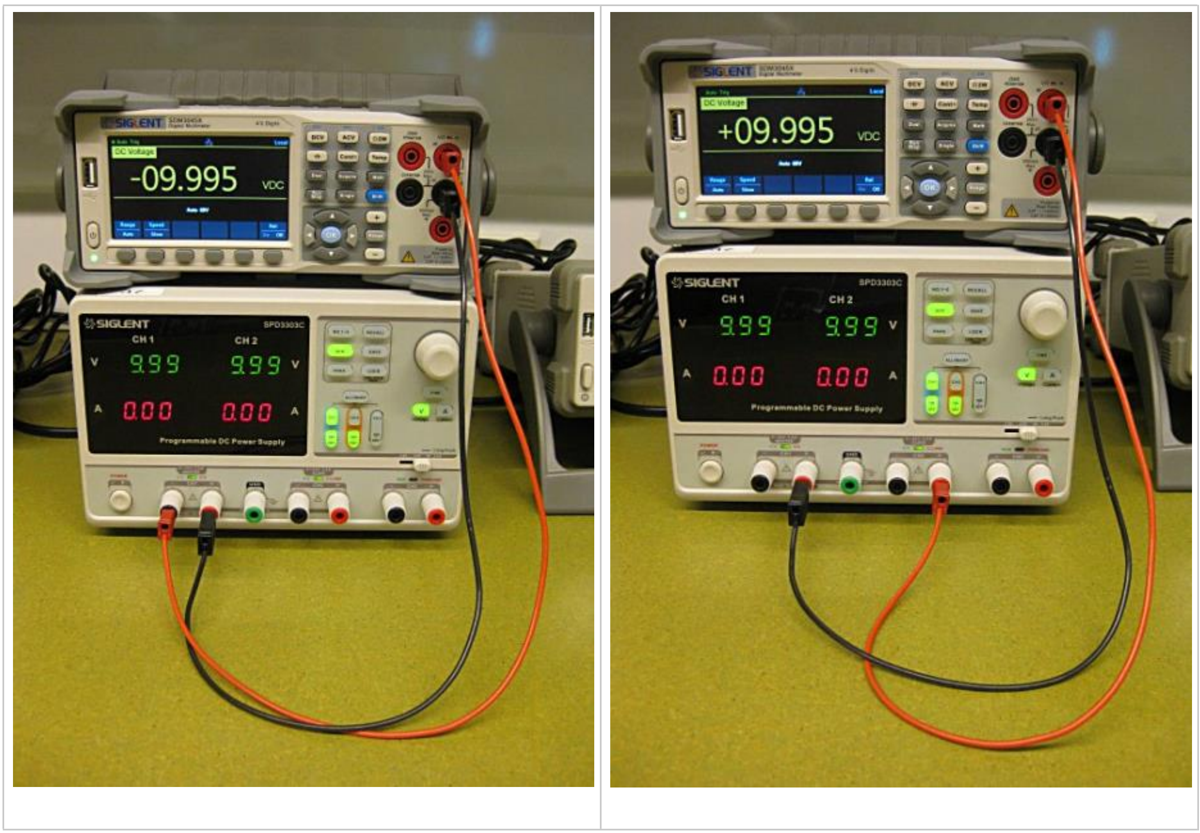


Figure 1-2-7

You should get -10 V across channel 1 and +10 V across channel 2.

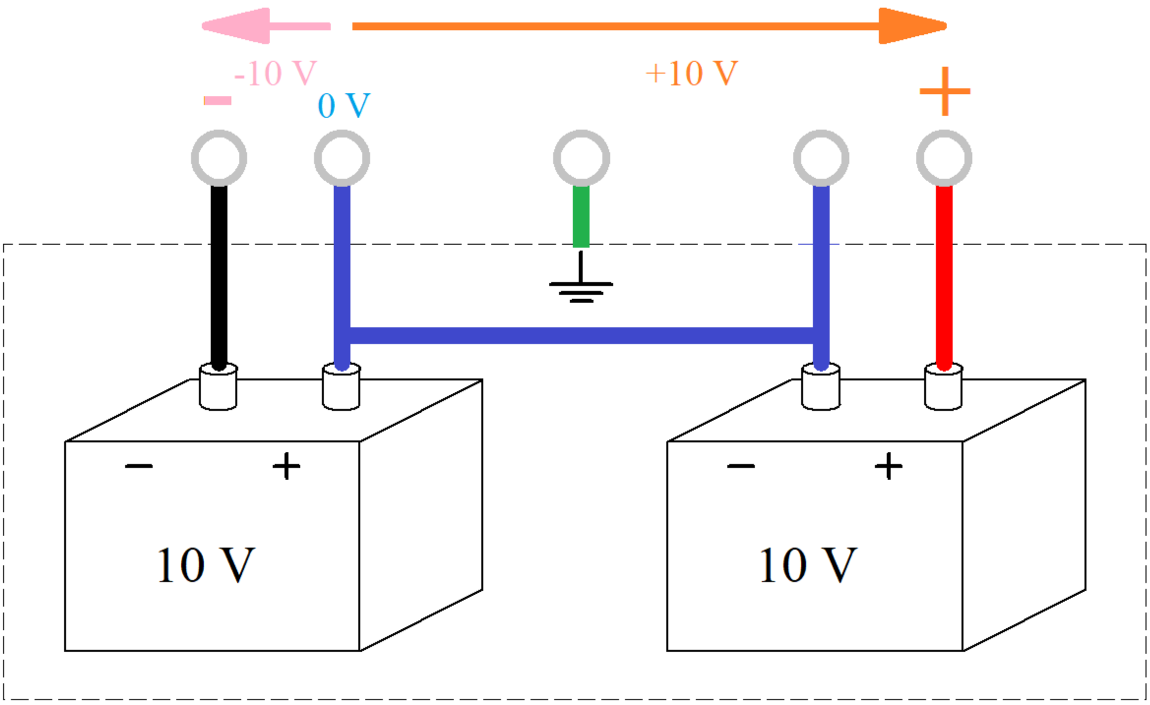


Figure 1-2-8

Voltage between ‘plus’ (red) and common (blue) =	
Voltage between ‘minus’ (black) and common (blue) =	

★ *This is the way we get a ‘plus and minus supply’ for analog circuits.*

Function Generator I

The function generator, also known as a waveform generator, can generate a variety of alternating voltage waveforms. The most common alternating waveforms are sine, square and triangle, as shown below:

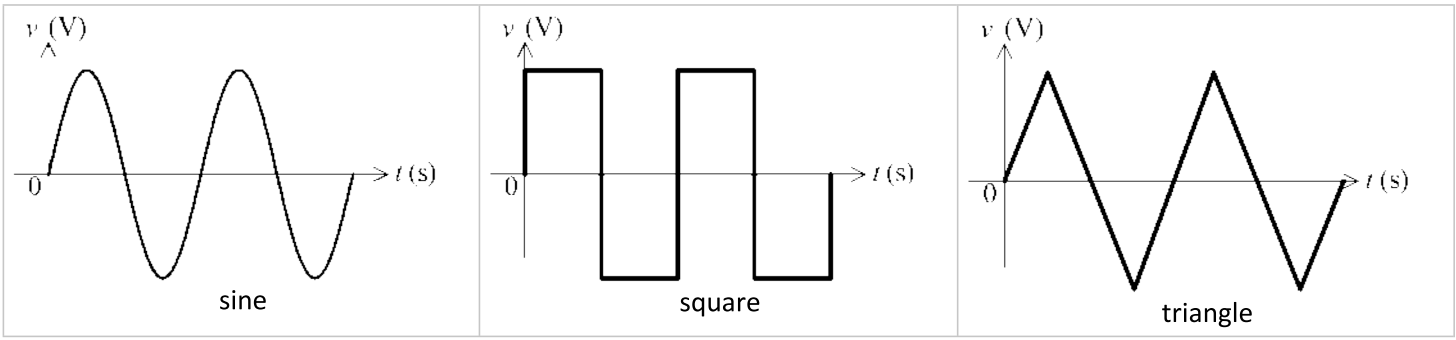


Figure 1-3-1

The name "function generator" derives from the fact that these waveforms can be expressed as mathematical functions.

The particular model of function generator in the lab has the ability to generate an "arbitrary" waveform which means that it can be programmed to generate any periodic waveform we like. It has several interesting and useful "arbitrary" waveforms built in, such as pulses, ramps, and cardiac waveforms (which mimic the electrical signals of the heart). For this reason, the function generator is also known as an arbitrary waveform generator, often shortened to "arb".

Our function generator also has the capability of producing two independent waveforms, labelled channel 1 (CH1) and channel 2 (CH2).

Figure 1-3-2

To observe a waveform generated by the function generator, we need to observe the output voltage on an instrument known as an oscilloscope. The oscilloscope displays a graph of voltage versus time, similar to the pictures shown in Figure 1-3-1.

For this section we will set the function generator up and give step-by-step instructions to observe the output on the oscilloscope. The oscilloscope will then be looked at in detail in the next section.

Function Generator II

Function Generator Setup

1. Turn the Function Generator (FG) on. Note that the FG defaults to a 1 kHz sinusoidal waveform upon startup. Also note that the default frequency is 1 kHz and the amplitude is 4 V peak-to-peak (these "attributes" of the waveform will become clearer in the next section). The menu on the right of the screen also has a yellow bar at the top, indicating that the buttons and menu system will change the output on Ch1 (yellow) as opposed to Ch2 (blue).

2. With reference to Figure 1-3-3 below, in the menu on the right of the display, note that it says "Sine" at the top (1) (it defaults to a sinusoid on startup) and that the top "softkey" is labelled "Freq" (2). This means that the numeric entry keypad (3) and the general purpose knob (4) will control the setting of the frequency. Also note the section below the pictorial representation of the sinusoid (5) has the Frequency listed as 1.000 000kHz and that the "1" is highlighted (6). This means that turning the general purpose knob will change this digit. You can select the "active" digit using the directional arrow keys (7) beneath the general purpose knob.

Figure 1-3-3

3. Change the frequency to 2 kHz by either:
   - turning the general purpose knob; or
   - typing **2** using the numeric keypad and selecting **kHz** for the units.

4. Press the Ampl softkey (the second softkey from the top) and set the amplitude to **3 V peak-to-peak (Vpp)**.

5. Enable the Output of channel 1 by illuminating the Channel 1 output button.

Function Generator III

Setting up the Digital Storage Oscilloscope (DSO)

1. Turn the DSO on and ensure the DSO has been set to its default setup configuration, by pressing the Default Setup key on the front panel.

2. Connect the leads coming from the DSO Channel 1 to the FG Channel 1 output.

3. There is a knob above the illuminated 1 key which controls the vertical scale - this is known as the Vertical Volts/Div knob. Turn it so that the scale for Channel 1 is set **500 mV/div** (a status line at the top of the DSO will tell you the vertical scale setting - it's at the top left hand side).

4. You should be observing a sinusoid exactly the same as the picture below:

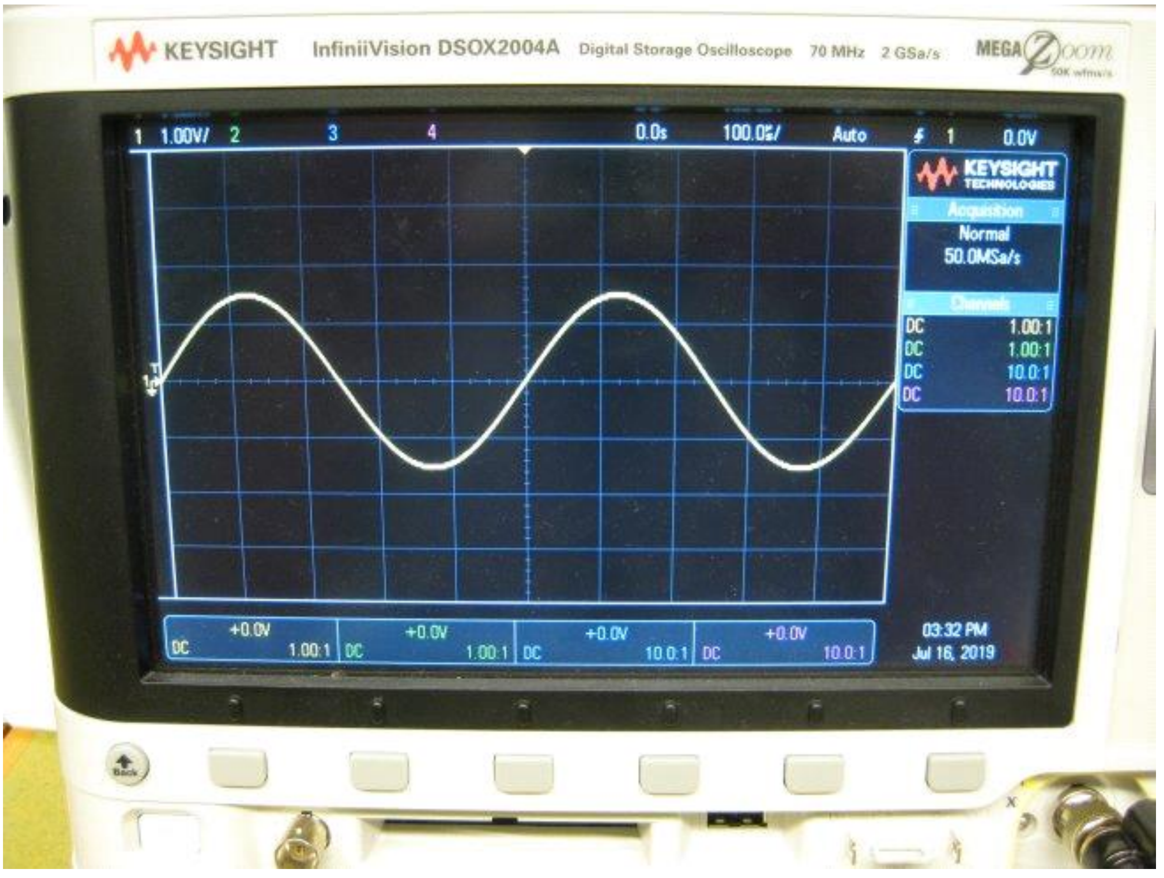


Figure 1-3-3

Changing the FG Waveform

1. Change the FG wave shape to square, then ramp, then back to sinusoid, whilst observing the waveforms on the DSO.

2. **Ensure the DSO is displaying a sine wave, as this will be the starting point for the next section.**

Digital Storage Oscilloscope I

Oscilloscopes are a critical tool for making voltage and timing measurements on today's analog and digital electrical circuits. An oscilloscope is the one measurement tool that you will use more than any other instrument to test, verify, and debug your designs.

An oscilloscope is an electronic measurement instrument that monitors voltage signals and then graphically displays these signals in a simple voltage versus time format.

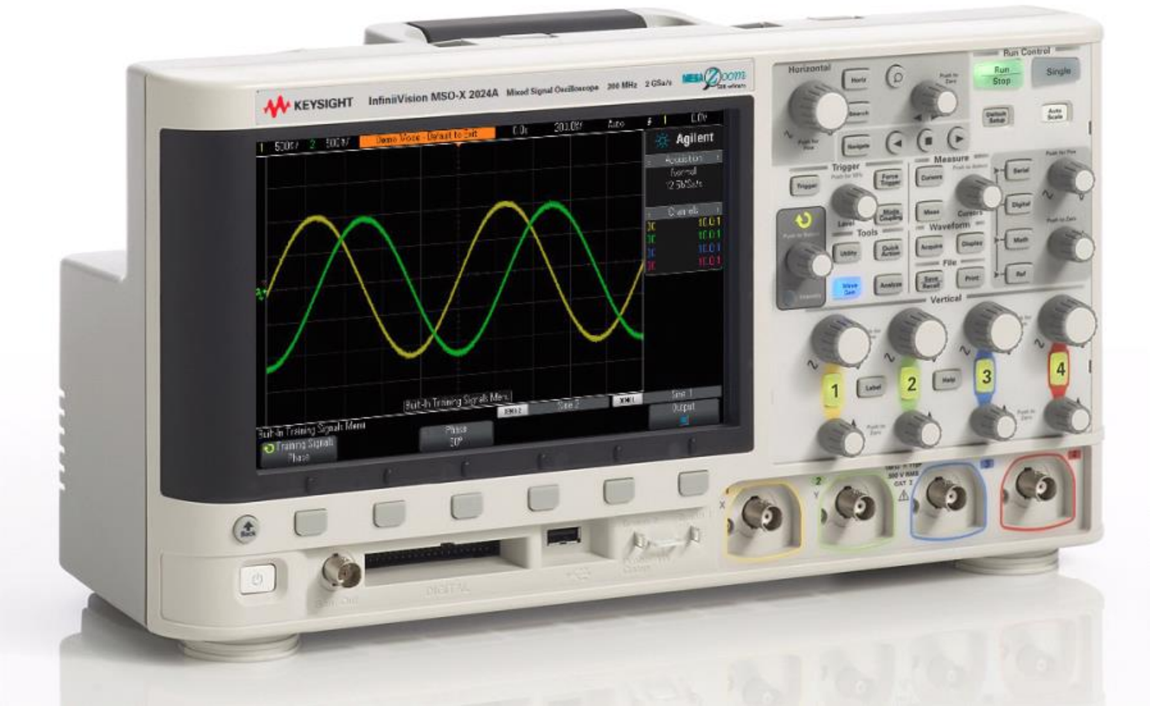


Figure 1-4-1

The type of oscilloscope that you will be using is called a digital storage oscilloscope; sometimes simply referred to as a DSO. The DSO can capture and display either repetitive or "single-shot" signals, and includes an array of automatic measurements and analysis capabilities that should enable you to characterize and analyse your circuits accurately.

Digital Storage Oscilloscope II

Probes

The first task when making oscilloscope measurements is typically to connect the oscilloscope "probes" between the device-under-test and the scope's input BNC connectors. Oscilloscope probes provide a relatively high "input resistance" at the test point. A high resistance connection is important in order to isolate the DSO from the circuit being tested since we don't want the DSO and its probe to change the characteristics of the signals under test.

There are a variety of different kinds of DSO probes that are used for specific types of measurements, but the probes that we use in the lab are simply "BNC to 4mm leads".

Tip: The "BNC to 4mm leads" are used simply for student convenience. Most probes usually have small tips to be able to connect to things such as device pins or circuit board test headers. You will see these probes later in the course and in industry.

These probes are known as "10:1 passive probes'". "Passive" simply means that this type of probe does not include any "active" components such as transistors or amplifiers. "10:1" means that this probe will attenuate (reduce) the input signal received at the scope's input by a factor of 10.

When using a standard passive probe, all scope measurements should be performed between the signal test point and ground (earth).

The probe's black lead is connected to the ground via the mains lead and the GPO - it must be connected to **only one point in a circuit**, otherwise you will create a short-circuit.

You cannot measure voltages across a mid-circuit component using this type of probe. If you need to measure the voltage across a component that is not grounded, you could either use the scope's subtraction math function (covered in later labs) while measuring the signals at both ends of the component relative to ground using two channels of the scope, or you could use a special differential active probe.

Tip: If the DSO starts up with "factory default settings", or this has been selected via a menu function, then the DSO will start up assuming that you are using the "normal" 10:1 passive probes that come with the scope. For our use of the DSO in the lab, you must manually enter the probe attenuation factor of the lab's "BNC to 4 mm leads", which is 1:1. Once the scope knows what the probe attenuation factor is, the scope provides compensated readouts of all vertical settings so that all voltage measurements will be referenced to the input signal at the probe tip. If you find that your voltages appear to be 10 times bigger than you expect, an incorrect probe attenuation factor is the most likely cause.

Digital Storage Oscilloscope III

Front Panel

Let's begin by first getting acquainted with the most important controls/knobs on the DSO.

Horizontal Controls

Near the top of the DSO are the "Horizontal" controls shown in Figure 1-4-2.

Figure 1-4-2

The larger knob sets the horizontal scaling in seconds/division. This control sets the X-axis scaling of the displayed waveform. One horizontal "division" is the Δ-time between each vertical grid line. If you want to view faster waveforms (higher frequency signals), then you will set the horizontal scaling to a smaller sec/div value. If you want to view slower waveforms (slower frequency signals), then you typically set the horizontal scaling to a higher sec/div setting. The smaller knob in the Horizontal section sets the horizontal position of the waveform. In other words, with this control you can move the horizontal placement of the waveform left and right. The scope's horizontal controls (s/div and position) are often called the scope's main "timebase" controls.

Vertical Controls

The controls/knobs near the bottom of the DSO in the Vertical section (just above the input BNCs) set the vertical scaling of the scope.

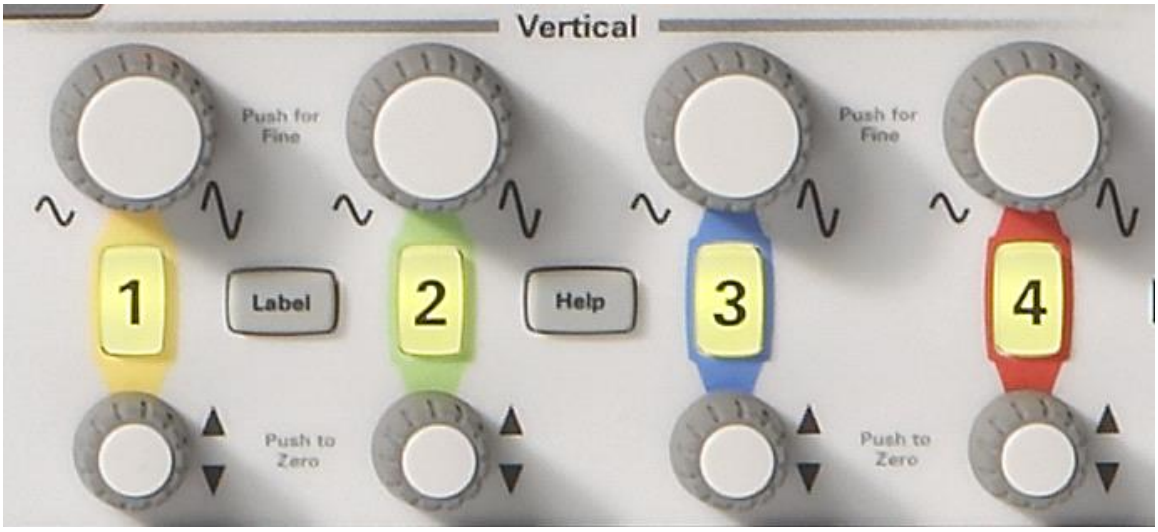


Figure 1-4-3

The larger knob for each input channel in the Vertical section sets the vertical scaling factor in Volts/division. This is the Y-axis graphical scaling of your waveforms. One vertical "division" is the Δ-volts between each horizontal grid line. If you want to view relatively large signals (high peak-to-peak voltages), then you would typically set the Volts/div setting to a relatively high value. If viewing small input signal levels, then you would set the Volts/div setting to a relatively low value. The smaller controls/knobs for each channel in the Vertical section are the position/offset controls. You use this knob to move the waveform up and down on the screen.

Digital Storage Oscilloscope IV

Trigger Level

Another very important DSO setup variable is the trigger level control/knob shown in Figure 1-4-4.

Figure 1-4-4

This control knob is located near the centre of the scope's front panel; just below the section labelled **Trigger**. Triggering is probably the least understood aspect of an oscilloscope, but it is one of the most important capabilities of a scope that you should understand. We will cover oscilloscope triggering in more detail as we get into later labs.

Notation

When reading the following instructions, anytime you see a word highlighted in purple, such as Help, this is referring to a front panel key (or button) located on the right-hand side of the oscilloscope. When the key is pressed, a unique menu with "softkey" selections associated with that particular front panel function will be activated. "Softkeys" are the 6 keys/buttons located below the scope's display. The functions of these keys change depending upon which menu has been activated.

Now locate the Entry control knob shown in Figure 1-4-5.

Figure 1-4-5

This is the knob just to the right of the scope's display in the dark shaded area. We will be using this knob quite frequently to change an array of setup variables and selections that don't have dedicated front panel controls. Any time you see the curled green arrow:

on a softkey selection; this is an indication that the Entry knob controls this variable.

You will be asked to perform various and wide-ranging tasks with the DSO during the laboratories, so it is important that you become familiar with its capabilities and limitations.

Digital Storage Oscilloscope V

Making Measurements on Sine Waves

In this section you will learn how to use the scope's horizontal and vertical scaling controls in order to properly set up the scope to display a repetitive sine wave. In addition, you will learn how to make some simple voltage and timing measurements on this signal.

Waveform Positioning

1. Ensure that the DSO is displaying a sinusoid, as described in the previous section.

2. Rotate the Horizontal position knob to move the waveform left and right.

3. Press the Horizontal position knob to set it back to zero (0.0 seconds at centre-screen).

4. Rotate the channel-1 vertical position knob to move the waveform up and down. Notice that the ground indicator on the left also moves up and down and tells us where 0.0 Volts (ground level) is located on this waveform.

5. Press the channel-1 vertical position knob to set ground (0.0 V) back to centre-screen.

Waveform Measurements

Let's now make some measurements on this repetitive sine wave. Notice that the oscilloscope's display is basically an X versus Y graph. On our X-axis (horizontal) we can measure time, and on our Y-axis (vertical) we can measure voltage. When a repetitive input signal is applied to an oscilloscope, we are able to observe dynamic (continuously updated) graphing of our waveforms.

Our X-axis consists of 10 major divisions across the screen with each major division being equal to the sec/div setting. In this case, each horizontal major division represents 100 microseconds of time, assuming that the scope's timebase is set to 100.0 µs/div as instructed earlier. Since there are 10 divisions across the screen, then the scope is showing 1 ms of time (100.0 µs/div x 10 divisions) from the left side of the display to the right side of the display. Notice that each major division is also divided into 4 minor divisions, which are displayed as tick marks on the centre horizontal axis. Each minor division would then represent 1/4 div × 100.0 µs/div = 25.0 µs.

Our Y-axis consists of 8 major divisions vertically with each major division being equal to the V/div setting, which should be set at 500 mV/div. At this setting, the scope can measure signals as high as 4 Vp-p (500 mV/div x 8 divisions). Each major division is divided into 5 minor divisions. Each minor division, represented as tick marks on the centre vertical axis, then represents 100 mV each.

Digital Storage Oscilloscope VI

1. Estimate the period (T) of the sine wave by counting the number of (major) divisions from the 0.0 V level of a rising edge (centre-screen) to the 0.0 V level of the next rising edge (at the right side of the screen); then multiply by the s/div setting:

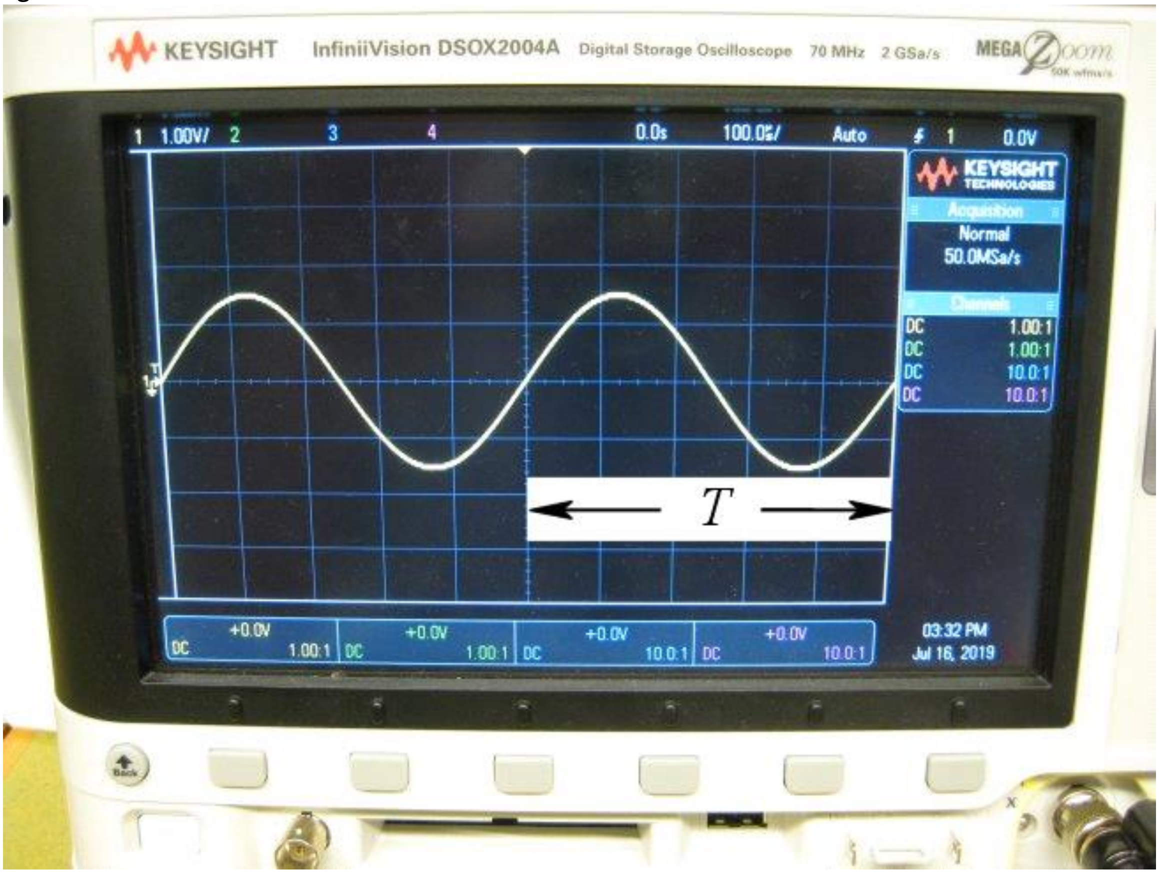


Figure 1-4-6

$T=$	

What is the frequency of the sine wave?

$f=1/T=$	

2. Estimate the peak-to-peak voltage of this sine wave by counting the number of (major) divisions from the sine wave's negative peak to the positive peak; then multiply by the V/div setting:

$V_{pp}=$	

3. Let's now use the scope's "cursors" function to make these same voltage and timing measurements; but without having to count divisions and then multiply by scaling factors. First, visually locate the "Cursors" knob in the Measure section of the front panel as shown in Figure 1-4-7:

Figure 1-4-7

4. Press the Cursors knob; then rotate this knob until “X1” is highlighted; then press again to select (if you don’t press the knob a second time after dialling to the “X1” cursor, a time-out will occur and then the X1 cursor will automatically be selected and the menu will close).

5. Rotate the Cursors knob until the X1 cursor (#1 timing marker) intersects with a rising edge of the sine wave at a particular voltage level. **Hint**: Align the cursor at a point on the waveform where it crosses one of the horizontal grid lines.

6. Press the Cursors knob again; rotate this knob until “X2” is highlighted; then press again to select.

7. Rotate the Cursors knob until the X2 cursor (#2 timing marker) intersects with the next rising edge of the sine wave at the same voltage level.

8. Press the Cursors knob again; rotate this knob until “Y1” is highlighted; then press again to select.

9. Rotate the Cursors knob until the Y1 cursor (#1 voltage marker) intersects with the negative peaks of the sine wave.

10. Press the Cursors knob again; rotate this knob until “Y2” is highlighted; then press again to select.

11. Rotate the Cursors knob until the Y2 cursor (#2 voltage marker) intersects with the positive peaks of the sine wave.

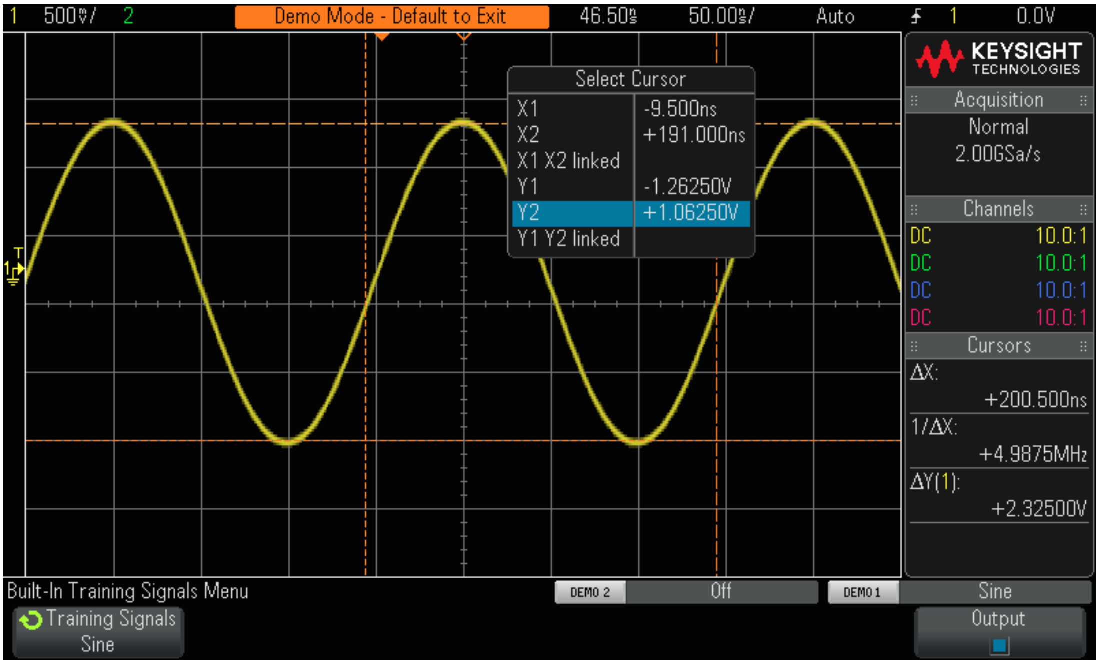


Figure 1-4-8

12. What are the period, frequency, and peak-to-peak voltage of this signal (cursor read-out is on the right-hand side of the display)?

Period T	$\Delta X=$	
Frequency f	$1/\Delta X=$	
Peak-to-peak voltage	$\Delta Y(1)=$	

The most common method used to measure time and voltage on an oscilloscope is the “division counting” method we used first. Although divisions must be counted and then multiplied by scope settings, engineers that are familiar with their scopes can quickly estimate the voltage and timing parameters of their signals… and sometimes a rough estimation is all that is required to know if a signal is valid or not.

Using cursors should provide a slightly more accurate measurement and take the guess work out of the measurement. Most of today’s scopes also provide an even more accurate and faster way to make many parametric measurements automatically.

Digital Storage Oscilloscope VIII

Oscilloscope Triggering

You can think of oscilloscope "triggering" as "synchronized picture taking". When an oscilloscope is capturing and displaying a repetitive input signal, it may be taking tens of thousands of pictures per second of the input signal. In order to view these waveforms (or pictures), the picture-taking must be synchronized to "something". That "something" is a unique point in time on the input signal.

1. Ensure that the DSO is displaying the sinusoidal signal from the previous section.

2. Press the Trigger front panel key.

3. Your scope's display should now look similar to Figure 1-4-9.

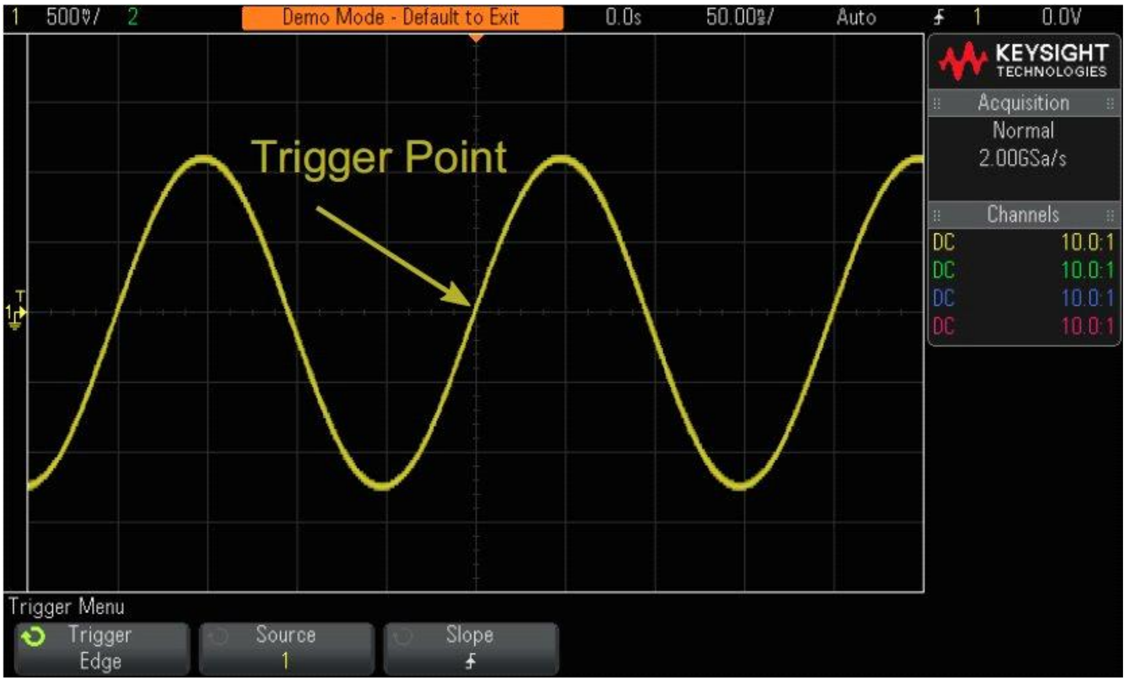


Figure 1-4-9

Using the scope's default trigger conditions, the scope should be triggering on a rising (slope selection) edge (trigger type selection) of the sine wave that is being probed and captured by channel-1 (source selection) as this signal crosses the 0.0 V level (trigger level setting). This point in time is shown at centre-screen (both horizontally and vertically) if the horizontal position control is set to 0.0 sec (default setting). Waveform data captured before the trigger point (left side of display) is consider negative time data, while waveform data captured after the trigger point (right side of display) is considered positive time data.

Note that the "filled" orange triangle near the top of the display indicates where the trigger time point (0.0 s) is located. If you adjust the horizontal delay/position, this orange triangle will move away from centre-screen. The "hollow" orange triangle at centre-screen (only visible if the delay/position is not 0.0 s) indicates the time location of the delay setting when using the scope's default "center" reference.

4. Rotate the Trigger Level knob clockwise to increase the trigger level voltage setting.

5. Rotate the Trigger Level knob counter-clockwise to decrease the trigger level voltage setting.

As you increase the trigger level voltage setting, you should observe the sine wave shifting in time to the left. If you decrease the trigger level voltage setting, the sine wave will shift to the right. When you initially turn the trigger level knob, a horizontal orange trigger level indicator will appear, and the exact trigger voltage setting is always displayed in the upper right-hand corner of the scope's display. If you stop rotating the trigger level knob, the orange trigger level indicator will time-out and disappear after a few seconds, but there is still a yellow trigger level indicator shown outside the waveform graticule area on the left to indicate where the trigger level is set relative to the waveform.

6. Rotate the Trigger Level knob to set the trigger level to exactly **500 mV** (1 division above centre-screen). Note that the exact trigger level is displayed in the upper right-hand corner of the display.

7. Press the **Slope** softkey and then select a **Falling** edge trigger condition.

   The sine wave should now appear to be inverted 180 degrees with a falling edge of the waveform synchronized to centre-screen as shown in Figure 1-4-10.

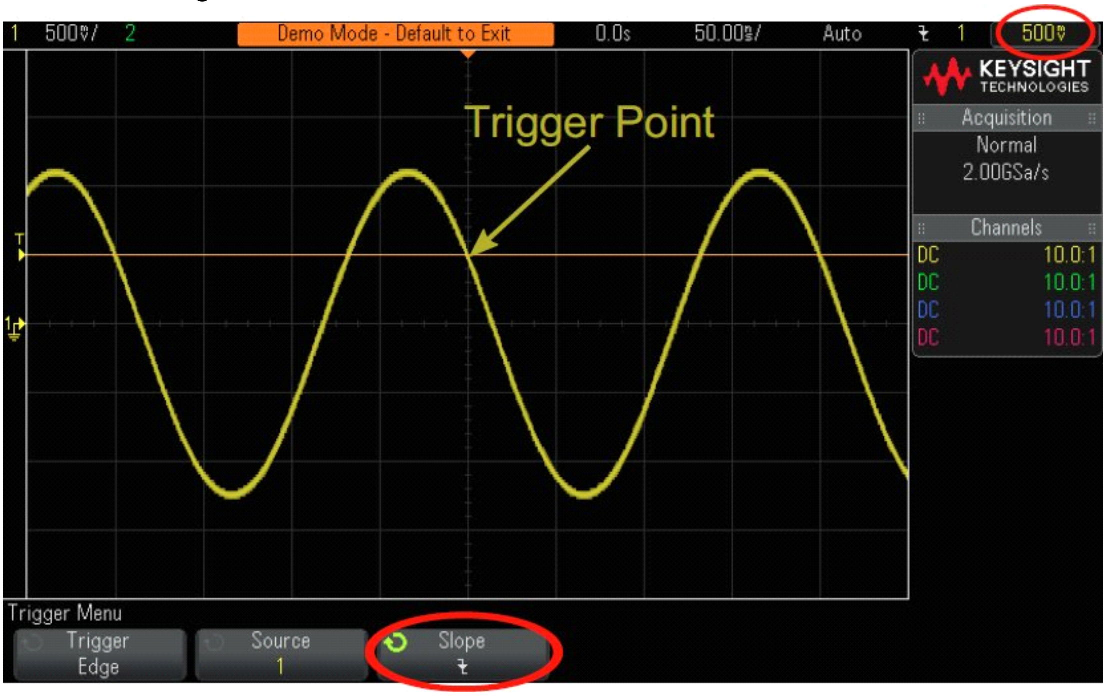


Figure 1-4-10

8. Increase the trigger level voltage setting until the orange level indicator is above the positive peaks of the sine wave (approximately +1.5 V).

   With the trigger level set above the sine wave, the scope's acquisition and display (repetitive picture taking) is no longer synchronized to the input signal since the scope can't find any edge crossings at this particular trigger level setting. Your scope's display should now look similar to Figure 1-4-11. The scope is now "auto triggering".

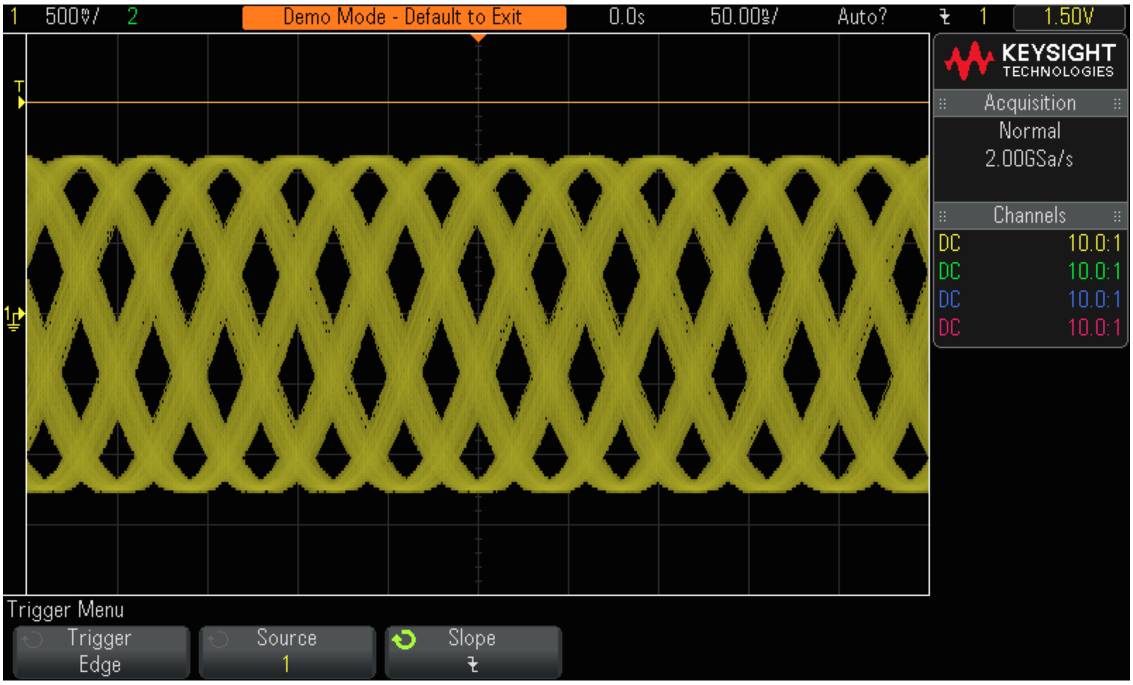


Figure 1-4-11

Auto Trigger is the scope's default trigger mode - if the scope doesn't find a valid trigger condition (edge crossing of the sine wave in this case) after a period of time (the time varies and depends on the scope's timebase setting), then the scope will generate its own asynchronous trigger and begin taking pictures (acquisitions) of the input signal at random times. Since the "picture taking" is now random, rather than synchronized to the input signal, all we see is a "blur" of waveforms across the screen. This "blur" of waveforms should be a clue to us that our scope is not triggering on the input signal.

Digital Storage Oscilloscope X

9. Press the Trigger Level knob to automatically set the trigger level to the approximate 50% level. A stable sine wave should now appear again since we have set a valid trigger level (50% of the waveform's excursions from minimum to maximum, i.e. half way, corresponding to 0.0 V).

10. Disconnect the channel-1 probe from the function generator.

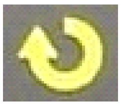
    With the channel-1 probe disconnected from our signal source, we should now see a baseline 0.0 V DC signal. Since with this 0.0 V DC signal we no longer have any edge crossings, and hence the scope has nothing to trigger on; the scope again "auto triggers" in order to show us this DC level signal.

    In addition to the default **Auto Trigger** mode, the oscilloscope also has another user-selectable trigger mode called the **Normal Trigger** mode. Let's now see how the **Normal Trigger** mode differs from the **Auto Trigger** mode.

11. Re-connect the channel-1 probe to the function generator. You should see the triggered sine wave again.

12. Press the [Mode/Coupling] front panel key (to the right of the Trigger Level knob).

13. Rotate the Entry knob

	to change the trigger mode selection from **Auto** to **Normal**. At this point you should not see any difference in the displayed waveform.

14. Disconnect the channel-1 probe from the function generator again.

    You should now see the last acquisition (last picture) that occurred before the probe was disconnected. We do not see the 0.0 V DC level trace that the **Auto Trigger** mode displayed. When the **Normal Trigger** mode is selected, the scope will display waveforms *if and only if* the scope detects valid trigger conditions (edge crossings in this case).

15. Rotate the trigger knob clockwise in order to set the trigger level at +2.00 V (which is above our sine wave).

16. Re-connect the channel-1 probe to the function generator.

    The sine wave is now connected and being input to the scope, but where is our repetitive display of this signal? Since we are using the **Normal** trigger mode, the scope still requires valid edge crossings, but since the trigger level is set above the waveform (@ +2.00 V), there are no valid edge crossings. So as you can see with the **Normal** trigger mode, we don't have any clue as to where our waveform is, and we can't measure DC.

17. Press the Trigger Level knob to automatically set the trigger level to the approximately 50% level. Your scope should begin to show repetitive waveforms again.

    At this point you may be wondering when to use the **Normal** trigger mode. The **Normal** trigger mode should be used when the trigger event occurs very infrequently (including single-shot events).

Automatic Time Measurements

1. Set the FG to a **3 V_{pp} 20 kHz** sinusoid. Set the DSO time base to **200 µs/div**.

2. Press the Meas key on the DSO. Note that the frequency is automatically displayed.

Automatic Voltage Measurements

Be careful when using the automatic voltage measurements – the DSO can't differentiate between a noise peak and a signal peak.

1. Press the Meas key. Measure the Peak-Peak voltage of Channel 1.

$V_{pp} =$	