General electronic instrumentation

In the world of mechanical devices today, most measurements are made by electronic instrumentation, not the crude mechanical devices of the past. Most of these newer devices are actually a modern combination of a mechanical device and electronic sensing element. Many of the measurements a mechanical engineer makes are done with specialized calibrated equipment, but some are still made with basic electronic instruments, and the readings interpreted by the operator. This mini-lab is designed to introduce you to some of the more common basic instrumentation and its use. It will also allow you to conduct some measurements and familiarize yourself with these instruments.

There are a wide variety of instruments on the market today, but the most common that a mechanical engineer would see include Multi-meters, Frequency Counters, Oscilloscopes, Strip chart recorders, Function Generators, and Spectrum Analyzers.

1.0 Multi-Meter

The multi-meter is the most common electronic instrumentation in use. It is a combination meter that is capable of measuring, resistance, voltage (AC and DC) and usually current. In addition some meters are capable of measuring capacitance, frequency and other variables. An example of one of these meters is the Fluke 189 hand held multi-meter.

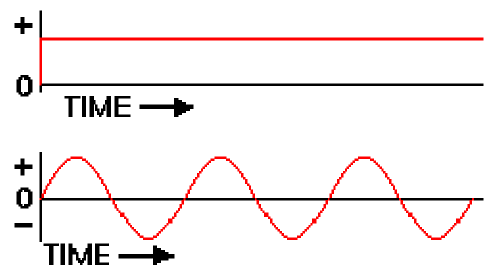
This type meter is very common in most shops and is portable and easily used. This meter is capable of measuring AC and DC Voltage (down to 0.000001 Volts and as high as 1000 Volts), Resistance, Capacitance, Temperature, Current (Down to 0.000001 Amps and as high as 10 Amps). In addition it is capable of catching maximum and minimum values and saving them in memory. A versatile meter like this is most commonly used by service personnel, but can easily be used by anyone. In addition this meter is a ***True RMS*** meter, which will be explained in more detail later.

In addition to handheld meters such as this one, less expensive hand held meters with less functions are available. On the other end of the spectrum, bench top meters such as the Fluke 47 and HP 3470 meters are common. These two bench top meters contrast each other with a very wide difference in resolution and accuracy.

Most meters, and multi-meters are classified in by the number of digits of the display. Each full digit registers 0 – 9, and a half digit will register only a 0 or a 1. A three and a half digit display would then be capable of measuring from -1999 to +1999, with the decimal point being located some place in that range depending on the capability of the meter, and the measurement being taken.

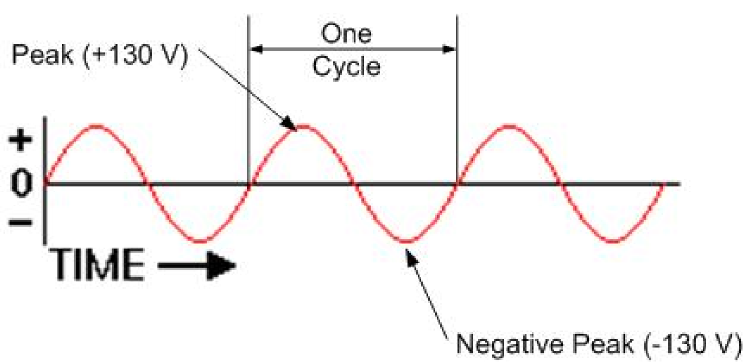
1.1 Voltage Measurements

Voltage measurements come in two flavors, AC and DC. These stand for Alternating Current and Direct Current respectively. In the world of electronics, those signals that are steady or nearly steady voltages, those that change at rates of less than 1 cycle per second, are commonly referred to as DC measurements. Thos that have a generally repetitive wave form that change at rates faster than 1 cycle per second (or 1 hertz) are considered to be AC signals. The most common AC signal that you will encounter is the 60Hz AC wall power. This voltage varies with time at a rate of 60 cycles per second. The DC value is a measure of the average voltage over the period of time. If you look at one complete cycle of the AC waveform, you will see that the average value is 0. Does this mean that it has no voltage? The answer to that is no. In the world of AC waveforms the effective voltage is called the RMS voltage. Lets start by defining some terms.



- **Peak Voltage -** The voltage value at the local maximum point in the cycle graph. The Voltage measure is from 0 to this maximum.

- **Peak to Peak Voltage –** The Peak to Peak voltage is measured from the cycle minimum value to the cycle maximum value. As an example if the ac waveform below the P-P voltage would be 260 Volts (130 – (-130)).

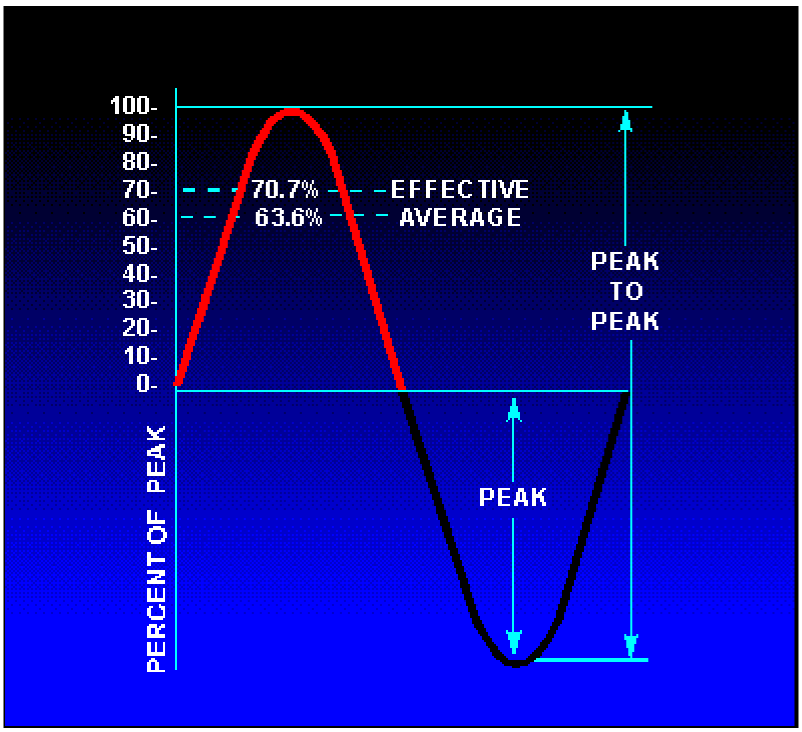


- **Average Voltage –** The average voltage is the arithmatic average of the positive half of the cycle. In a standard sinusoidal wave form this value is 0.637 * Peak Voltage.

- **RMS or Effective Voltage –** This is the Root-Mean-Square calculation of the AC signal. This is the measure of how much work can be done by the AC power source. The RMS value for a sinusoidal wave form is = .707 * Peak Voltage. For non sinusoidal signals, the RMS value must be calculated. Taking one cycle of AC signal and breaking it into many small samples, you can calculate the RMS value based on the following formula.

$$x_{\mathrm{rms}} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} x_i^2} = \sqrt{\frac{x_1^2 + x_2^2 + \cdots + x_N^2}{N}}$$

As you can see in the following diagram, the RMS value is not the same thing as the average value. If the signal being measured is not truly sinusoidal or non-symmetric in any way, the RMS value will vary from the standard 0.707 value. In the above example we saw a sinusoidal waveform with a peak value of 130V. The RMS value of this signal would be 91.9 Volts. This is the value your typical multi meter will read in the AC mode.



- **True RMS –** A meter that will break down the waveform into tiny slices and make the mathematical RMS calculation (above) and display the result of this calculation is called a True RMS voltmeter. These meters will generate an accurate RMS value for even non- symmetric signals.

In today's market there are literally thousands of small hand held millimeters. Most operate on the same principals. Each measurement is handled by the meter with some specific circuitry to convert the signal into a small DC voltage. This small DC voltage is the only actual measurement that the meter processes into the display. Most meters

(Non-True RMS Meters) will convert the AC wave into a DC signal that represents the peak voltage value. This value is then converted to RMS by a 1.414:1 Voltage divider.

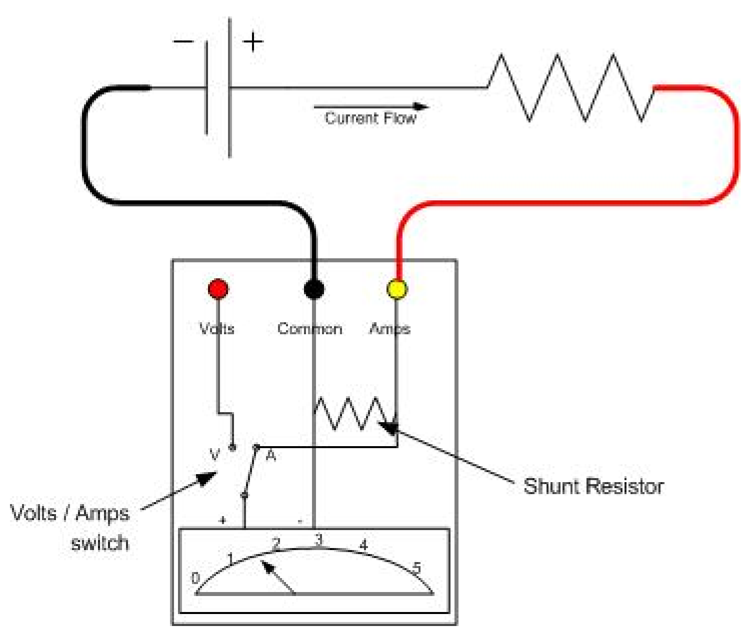
Both DC and AC voltage values are then fed thru a series of voltage divider networks, based on the range selection, to bring the final DC level under two volts. This value is then converted by an Analog to Digital conversion chip and displayed as a digital number.

1.2 Resistance

Resistance measurement is conducted by the same method in all meters. A fixed, known current is applied to the resistance value that is being measured, and the resulting voltage developed is used to quantify the resistance value. This is all based on Ohm's law, which by now you should have been exposed to in your Physics course. The range of the resistance determines the amount of current applied. Lower resistance values require higher current values to generate an accurately measurable voltage. All resistance readings are made in Ohms, or multiples of Ohms (K- x1,000 M – x1,000,000). In general readings above a few MegOhms are considered to be open circuits.

1.3 Current

Current measurements are made on one of two ways. The first and most straightforward method is the reverse of the Resistance measurement. In this configuration, the unknown current is applied thru a known, but very small, resistance, and the resulting voltage is measured. Many hand held multi-meters will measure currents of up to 10 Amps. Frequently a second resistance value for current will be available that is larger, allowing much smaller currents to be measured accurately. The second method utilizes field effect properties of currents flowing thru conductors. By wrapping a coil of wire around the wire, the field effects of the current flow thru the wire will induce a current in the coil. In this way the current can be measured without the resistance being installed. This method is typically used for higher current flows and can be used for readings in the thousands of amps. Most hand held multi-meters that measure current will have a special input jack for the positive lead of the current measurement. Failure to change to this location can cause considerable damage to the multi-meter, since the total current flow would be trying to go thru the voltage measuring circuit. Some higher end meters will handle this with internal relays to avoid the problems caused by neglecting to switch the leads.

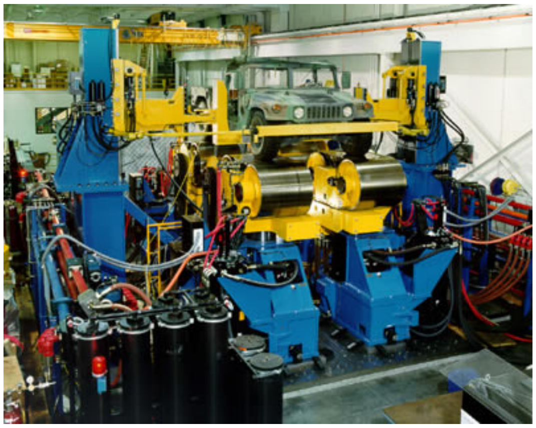


2.0 Frequency Counter

A second common instrument found in any well used instrumentation shop is the Frequency counter or meter. In its most simple form the meter measures the amount of time it takes from one positive going pulse to the next positive going pulse, and the result is displayed as a number of cycles per second or Hertz. This function is built into some higher end hand held multi-meters, but there are many more sophisticated bench top frequency meters available. Most of these meters let you control exactly how you look at the signal being measured. Common settings are weather the signal is triggered going positive or going negative, and at what level this happens. They may also let you look at the pulse period, positive going portion or negative going pulse time, duty cycle and other more advanced configurations involving two input signals, such as time from the pulse on one channel to the pulse on the other channel. All these abilities can be useful when investigating how a particular mechanism or system if functioning. In this course we will only use the simple functions of frequency and period.

3.0 Function Generator

Function or frequency generators are a class of instrument that are useful for creating a repetitive signal of a various form. In the mechanical world this is most commonly used to generate signals to drive test apparatus. As an example, a vehicle chassis may be connected to a large shaker assembly, and this assembly is vibrated and moved in a motion that simulates going down a bumpy road. In this way a vehicles durability can be tested and its motion analyzed, without the need to actually drive it down the road. This might be important if your job is to prove that it will last 100,000 miles of rough road. Your test drivers will certainly appreciate that the machine can spend 24/7 bouncing the truck around instead of the truck spending those miles bouncing their kidneys around.



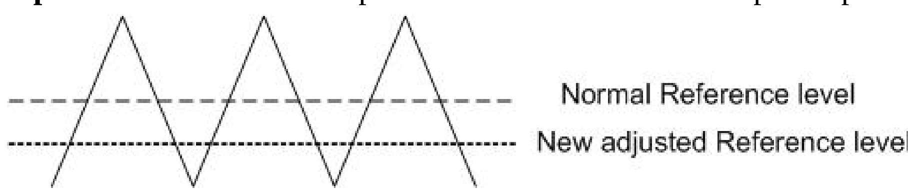
There are two classes of function generator. The first is a standard signal generator that can create a repetitive signal of a sine, triangle or square wave. An example of this type of instrument is the Tenma 5015. This unit is a reasonably simple function generator with a few more advanced features.

The most important and basic portions of this unit are the frequency control section, the function select section, the amplitude section and the output section.

- **Frequency Control Section**: The frequency section consists of a series of buttons (Labeled in BLUE) that select a course *range* setting, and a dial (Labeled ***FREQ***) that will is linearly adjustable for a fine adjust. Once the range has been selected with the appropriate button, the dial will allow you to adjust the frequency within the range of 0 to 2x range button. As an example, if I select the 1K button I can adjust the frequency from 0 to 2KHz. Different instruments will handle this in slightly different ways, but the range / vernier selection method is the standard on most lower end units. Many new higher end units do this whole selection digitally.

- **Function Section**: The function selection is a set of buttons (labeled in Red) that select between the a square wave, triangle wave and sine wave output. This particular meter also includes a knob that allows the user to change the duty cycle from the standard 50% symmetry. The *cal* position of the ***DUTY*** knob locks the meter in a symmetric waveform. Moving the knob from the cal position allows the user to modify the symmetry of the waveform from 10% on to 90% on.

- **Amplitude Section**: The amplitude section controls the output amplitude of the



  wave form. Most frequency generators utilize a simple vernier control knob for the output signal control. This vernier control adjusts the output level of the variable outputs from 0 to 100%. Notice that I do not indicate the actual output voltage at this time. Some higher end units will control this digitally and indicate the actual voltage that is being output. The amplitude section of this meter also includes an OFFSET adjustment that allows the user to bias the signal by an amount either positive or negative to the standard reference. This offset allows signals to be biased above or below the normal 0 volts level. This can be very important if you are working with a circuit that requires only a positive voltage signal.

- **Output Section**: The output section of the instrument actually outputs the signal that has been defined. Most output stages have at least two outputs and possibly three. The two primary outputs you will find are an a 50Ohm output and a TTL or trigger output. The digital level output provides a simple square wave output that matches the frequency of the settings. This is most commonly used to drive digital input circuitry without fear of negative voltages destroying circuits. This particular meter also includes a switch that will lock it in a 5V signal level for TTL or a variable voltage level for CMOS inputs. The 50Ohm Output generates the variable voltage and duty signal that has been defined by the controls. Its output is set at a 50 Ohm impedance but can be used for any impedance level above that value. If you don't fully understand what this means, don't worry, any friendly EE type can spend the next hour defining it for you. What you do need to remember is that if you are trying to feed a 50 Ohm input, you MUST have a 50 Ohm output.

The Attenuator selection is used to lower the maximum voltage of the output. This attenuator has selections for -20 db and – 40 db. This set of buttons will allow you to set a maximum peak to peak voltage of 23V, 2.3V, 0.23V and 0.023V by selecting none, -20, -40 and both -20 and -40 respectively.

This particular generator also has additional functions for *triggering*, and *gating*, which control when the signal is sent and *sweep*, which is allowing the frequency to vary at a predetermined rate. This particular model also provides for a simple frequency counter as described in section 2.0 by simply pushing a button.

The second type of function generator a mechanical engineer may face is what is an **arbitrary wave form generator**. In our example of testing a vehicle as if its actually on the road, it is easy to see that a road is generally not describes as a simple repetitive sine wave, but rather a complex variable wave form, representing the actual changes in road surface, complete with bumps and pot holes. Using a function generator similar to the one above would be good to test a particular frequency, but would not do a good job of simulating this type of more complex environment. The arbitrary wave form generator will allow you to program these complex waves, and then play back these waveforms repeatedly. Most mechanical systems are fairly slow functions, and a PC with a fast analog output card can do a very good job of this type of function. If you need to deal with faster signals, a good example of a dedicated generator is the Tektronix AWG710B. This unit is capable of creating waveforms up to 4.2 Billion points per second, or nearly 2 Gigahertz. Visit http://www.tektronix.com for more information on this type of device.

4.0 Strip Chart Recorder

Working with different mechanical systems, it is often advantageous to look at what a signal is doing over a period of time. You could sit with a meter and record a reading every so often, but this could get very tedious, especially if the signal you are looking at takes hours or days to complete. The solution to this falls into two categories: Computer data acquisition and strip chart recorder.

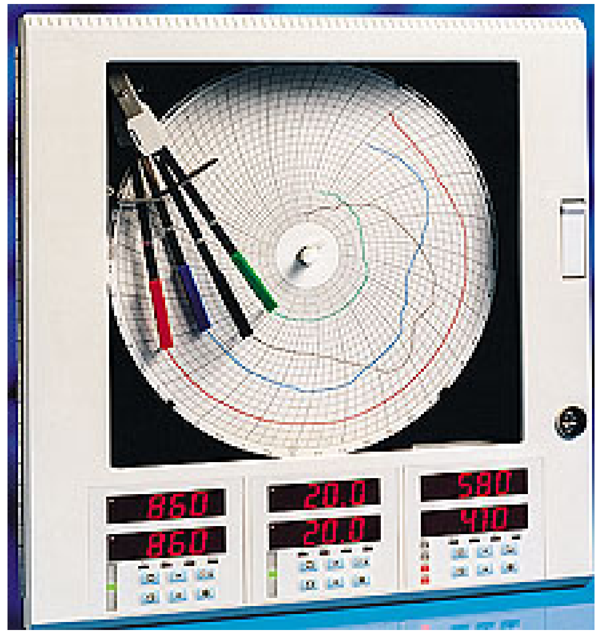
The strip chart recorder was originally developed in 1930's. While these units did not have the accuracy that newer units do, the strip chard recorder is still a valuable tool for slow period wave forms. The strip chart recorder uses two motor drives to generate a time based wave display on a continuous roll grid paper. One motor drive system controls the rate at which the paper moves under a pen, and the second motor drive controls the movement of the pen side to side over that paper.

Looking at the lower left of the picture, you can see a set of controls to manage the paper feed. The controls to the right control the motion of two pens.

Paper motion can be varied from extremely slow (mm/hr) to fairly fast (mm/second) depending on the model of chart recorder. Most uses run in the mm/min range. This particular model has an adjustable dial for increments of speed, and push button to select between a high rate of feed and a low rate of feed. There is also a button to stop the paper motion so you don’t waste paper while you are preparing your measurement.

The pen control section has a number of controls. These controls allow the user to select from a variety of pre-calibrated voltage ranges or a non-calibrated variable range. In addition to the maximum range setting, there is also a zero offset adjustment. These two controls allow you to adjust what voltage the two edges of the paper represent. For instance you may want to look at the signal from 4V to 5V only. Setting one edge of the paper to 5V and the other to 0V would leave your entire signal in only $1/5^{th}$ of the paper, making it hard to discern the signal values. By adjusting the 0 offset to 400%, and the range to 1V, the width of the paper now becomes 4V on one edge and 5V on the other, giving you good resolution of the signal. Each manufacturer handles this differently. Some give you an adjustment labeled in %, some in volts and some models, like the one used in this lab, only give you an unlabeled linear adjustment. The important thing with using a strip chart recorder is that you must have some general idea of what your signal will look like, and to set up the recorder you need to know what your current voltage value is. For this reason strip chart recorders are frequently used with a volt meter wired in parallel.

Some applications use chart recorders that record on a continuous round or cylindrical paper chart. Some examples are water level recorders and seismic recorders. Some applications, such as nuclear power plants, are required by law to record certain values on paper output recorders.



The above two recorders are typical circular recorders. These type recorders are generally set to rotate once every twelve or twenty four hours.

Drum recorders, such as seen at the left, are used to record data over long periods of time. As the drum rotates, the recoding needle is indexed slightly to one side, allowing the drum to record for many revolutions. This is typically done when there is only a small amount of data to be recorded, but it may occur at some instant over a long period of time. Drum recorders such as this may record for as long as a week between roll changes.

All of these devices are used to record voltages in the time domain. The signal, however must be fairly slow in response, since the recorder is a mechanical device with obvious speed limitations in its movement. For faster responding signals an oscilloscope is used.

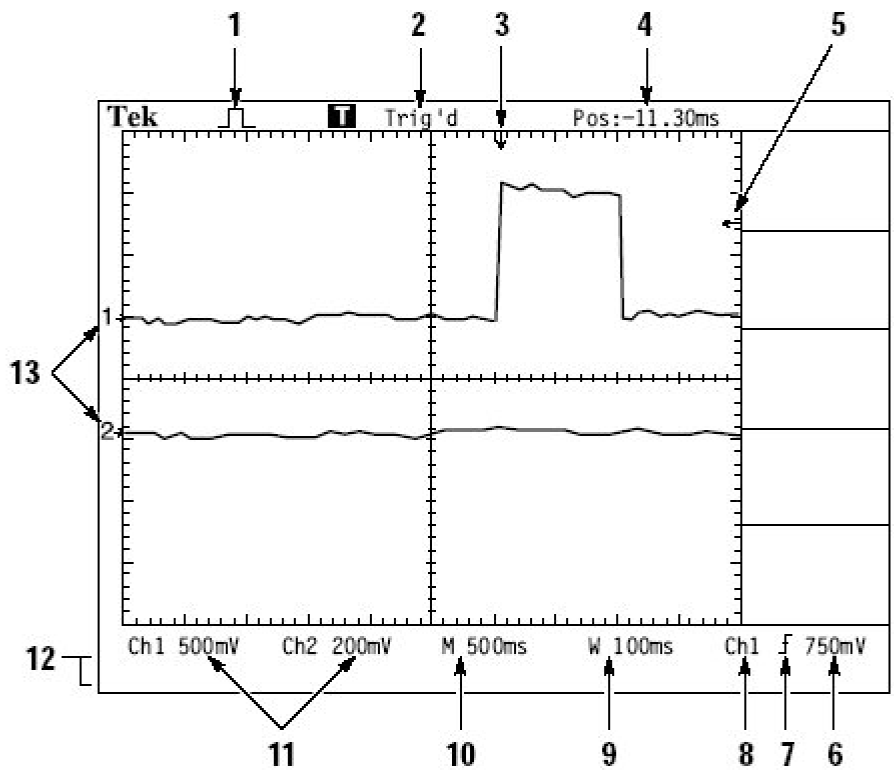
5.0 Oscilloscope

The basic premise of an oscilloscope is similar to that of a chart recorder, with the pen no longer being an ink device, but a beam of electrons, and the paper being a glass tube with a phosphor coating. When the beam of electrons strike the phosphor, it glows. The beam of electrons is deviated from left to right with time, and up and down with voltage. The resulting image is a small “page” of voltage vs. time. Unfortunately the beam must continue to “paint” this image for it to remain so you could see it. This was only good for repetitive signals, however, it had the advantage that it was extremely accurate for signals that were too fast for the chart recorder. By installing a triggering section to display the same portion of the wave form over and over at the same point in time, the device became a standard and useful tool. Over time “persistent” phosphors were created that allowed a recording of only a single sweep of the electron beam. With the advent of the computer age, it soon became more cost effective to use a small processor to record the image to memory and display it on a small computer screen. The digital storage oscilloscope (DSO) was born. Today nearly all oscilloscopes you will encounter are of this variety. The basic operation is still the same as it was in the old days, but with more goodies and fru-fru. Each input channel still reads voltage and has adjustments for where the 0 voltage “beam” is vertically on the display, and how much the “beam” is deflected vertically for each volt of input. The horizontal section still controls how fast the “beam” travels across the display, just as it did for the old electron tube display. The trigger section has become much more potent and feature filled, but its primary purpose is still to tell the “beam” when to start its trip across the display. In its simplest terms the DSO and the old Cathode Ray Tube Oscilloscope function in the same way, and still display similar information.

The Tektronix TDS210 used in the lab has vertical deflection controls for each of the two input channels, a horizontal display section controlling the sweep, and a trigger section as described above. In addition to these basic features there are a number of menu driven selections to control measurements and cursors.

5.1 Vertical Controls

The vertical input is the portion of the oscilloscope that reads the voltage on input connector and converts it into a vertical deflection of the “beam” or trace. There are several parts of this section that affect how the input is read and how it is displayed. Some of these selections are controlled by a menu on the display. The vertical display is controlled in volts per division. If you look at the display you will find a grid with horizontal and vertical grid lines. Setting the vertical deflection to 500mv per division, (#11 on the display) means that each major grid line vertically represents one half volt of deflection (each minor tick mark represents 0.1V). A wave displayed taking up 2 grid lines vertically would then be a 1 Volt P-P signal.



5.1.1 Vertical Coupling

The vertical coupling selection had three basic settings; **GND**, **AC** and **DC.**

The **GND** setting sets the input channel to ground, allowing you to adjust the 0 volts trace to a location on the screen where you want it to be. If the signal you are planning to look at is mostly positive, you would want to adjust this to the lower part of the screen to give you the most screen for the actual display of the signal. On this particular scope the 0 level is also indicated by a small arrow with the channel number on the left hand edge of the screen.

The **AC** setting couples the input voltage to the amplifier thru a capacitor. The effect of this is to chop off any DC voltage level in the signal, allowing you to amplify the AC portion of the waveform for better resolution. An example of this might be looking at a small signal of a few millivolts, that is “riding” on a 24V power supply line.

The **DC** setting allows the whole signal, DC and AC components to be amplified and displayed. This is the mode most commonly used.

5.1.2 Probe

Most oscilloscopes have a limited amount of vertical deflection available. In order to allow the scope to adequately display a signal of a few millivolts P-P, the maximum input voltage is frequently limited to a value around 5 volts per division, or 50 V P-P. Since there would obviously be cases where you want to look at voltages larger than this, attenuating probes are used. Typical values for these probes are x10, x100 and x1000. A x10 probe will attenuate the actual input signal by a factor of 10, making a 100V P-P signal, look like a 10V P-P signal to the scope. Many scopes automatically sense the probe type and adjust accordingly, but many lower end scopes, this one included, do not do this automatically. There is a menu selection that allows you to set the value from x1, x10, x100 and x1000. While the setting of this selection will not actually affect the way the signal is displayed, many of the features that display values will be affected. The displayed value of volts per division may well indicate that the signal is only 5 volts per division when in fact it is really 50 volts per division with the x10 probe attached.

5.2 Horizontal Section

The horizontal amplifier section controls the deflection of the beam in the horizontal direction. Since the beam is deflected at a constant rate, the display generates a voltage vs. time display. The horizontal amplifier section had a number of functions that it can do, such as zoom, expanded, or x/y, but we will concentrate on the basic modes of operation.

The speed of the trace across the screen is set in a time per division increment. Digital scopes such as the one you are using in this lab can have a very wide range of selections, from as low a few microseconds per division to several seconds per division. The upper speed is limited by the scope “bandwidth” or speed, in this case 60MHz.

5.2.1 Horizontal Menu

The TDS210 uses a series of menus as well as knobs to control the horizontal section. The **Horizontal menu** button brings up a menu that contains a number of items. The first is a mode selection labeled Main | Window Zone | and Window. For the purposes of this course, all work will be done in Main mode.

Farther down the menu there is a selection for what the level knob controls. The two choices here are hold off and level. This should be in the level mode unless you are adjusting the hold off. Hold off is an amount of delay from when the trigger occurs until the scope actually acquires the data. For the purposes of this course it will be easiest to leave the hold off set to 500nS.

5.2.2 Display Menu

The second button that is part of the horizontal section is the **DISPLAY** button brings up a menu with several items on it. The two lowest are the display contrast settings. These are simple increase and decrease presses.

The **type** menu selection controls if the wave is displayed in dot format, or vector format. The vector format draws lines between the dots that represent each sample point.

The **persist** selection allows the wave form to be “held” on the display for some period of time. This can be useful if you are trying to see if the wave form is changing in some way. Normally this is in the off mode.
Format is a selection between YT and XY. This control determines if the X axis is controlled by time or by the voltage input from channel 2. For most work you will be using the YT mode.

5.2.3 Horizontal controls

The horizontal section had two knobs that control the speed and placement of the waveform X axis. The SEC/DIV knob adjusts the time base of the display. The position knob adjusts where on the screen the trigger (or 0 time) point is located. Neither knob is labeled with any indication of where it is placed. Instead, the scope displays on the screen the results of the knob motion. The currently selected seconds per division is displayed below the trace, on the screen at the center bottom. The trigger position is displayed by a small arrow at the top of the display with the trigger status above it.

5.3 Trigger Section

Like the horizontal section, the trigger section of the scope is managed by a number of controls and menus. Each control or menu selection impacts how the trigger section operates or interacts with the horizontal section. Recall that the purpose of the trigger section is to tell the horizontal section when to begin displaying the wave form.

5.3.1 Trigger Menu

The trigger menu has a number of selections that can significantly affect the operation of the display.

The **Edge / Video** selection controls how the trigger section works. Video is generally useful when looking at composite video data streams and will not be used in this course. The *EDGE* selection should be highlighted for use.

The **slope** selection determines if the slope of the desired trigger point is on the *rising* or *falling* portion of the wave. Normally it is used in the rising selection.

The **source** tells the trigger section where it is getting the signal from. It can be either *Channel 1*, *Channel 2* or the *external* connector. There are also two more specialized selections of *ext/5* and *AC*. The *AC* selection allows the scope to be triggered from the ac power supply that feeds the scope. This can be useful if you are looking at the AC power on the wall outlet. For most things you will be using the *CH1* mode.

The next selection is of great importance. The **Mode** selection controls how the trigger section treats the wave form. There are three modes here. *Auto*, *normal* and *single*. The In normal mode the waveform is displayed following each trigger event, and if no trigger even has occurred, it will continue to show the last displayed information. In older scopes there was a selection that allowed the trace to run freely. This is handy when you are looking to see if you have any signal, or you don't know what the signal looks like. The *auto* mode uses this free run mode to allow the wave to be displayed until it receives a trigger signal, and then it will lock the display do normal mode, displaying only the waveform that conforms to the trigger selection. If there has been no trigger for some period of time, the scope will then revert back to a free run mode. This is a most useful feature and probably the most common selection used. *Single* mode captures one pass of the wave form, and only one pass. This is handy if you are looking for the first occurrence of a signal, or there is only one occurrence. The single mode must be "enabled" manually for each trace it is to capture. This is a useful mode, but you will probably not be using it in this course.

The final selection is the **coupling** selection. Like the input channels, the trigger can be *DC* or *AC* coupled to the input signal. This allows small AC signals riding on larger DC values to be used for triggering.

5.3.2 Acquire Menu

The Acquire menu is part of the trigger section on the TDS210 scope. There are a few selections, but the general purpose is to control how the waveform is managed by the scope.

The choices on this menu are *Sample*, *Peak Detect* and *Average*. To understand this sections settings you need to understand that a digital oscilloscope is much like a computer data acquisition system. Every x amount of time, the system takes a reading of the value on the input of an analog-to-digital converter, and the voltage value at that instant is the data point that is displayed on the screen. In *sample* mode the value that is acquired at x time is displayed directly on the screen. This is the most common mode of operation. In the *Peak Detect* mode the system feeds the signal thru a peak detection circuit, which is reset after each acquisition. In this way the system will acquire and display the PEAK voltage value that occurred between the last sample and the current sample. This can be useful for capturing waveforms with very fast spikes on it. The third mode is an average mode. In this mode the display system keeps track of the n samples and displays the average of those n samples. The number of samples is set in the next box down. You should understand that it is not n samples in time, but n samples occurring at the same point in time following the trigger event. This can be useful in dealing with difficult signals, but should be used with caution or you will get displayed waveforms that do not represent the actual wave you are measuring. One simple example is that if you don't properly trigger a sine wave, and then do an average, what you will end up with is a simple flat line, and the moving sine wave (with respect to the trigger) is averaged. To understand this setting, apply a sine wave to the scope, set the triggering so you can see about two full cycles on the display, and set the averaging to 64. by adjusting the trigger level up and down, causing the system to either trigger or not trigger, you can see how the averaging affects the waveform.

5.4 Additional resources

There are three additional resources available for your use on the oscilloscope. These are all available for download in PDF form from the course web page.

TDS210 Users manual : The complete users guide for this device with explicit details on all controls and functions.

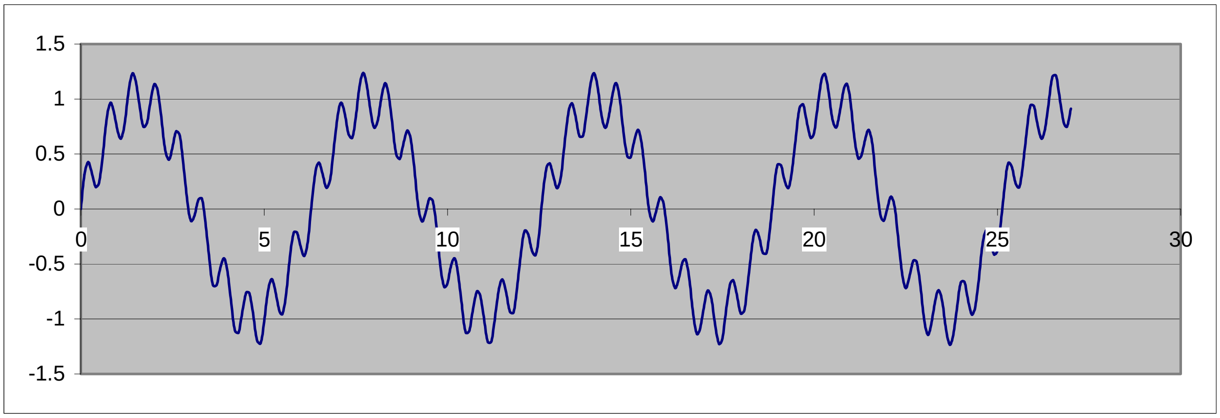
TDS210 Training manual: This manual is used for training on how to use the scope. This has excellent detailed descriptions of how each control works and how and when to use it.

XYZ's of Oscilloscopes: This is a primer on how oscilloscopes in general work and the differences between analog and digital scopes.

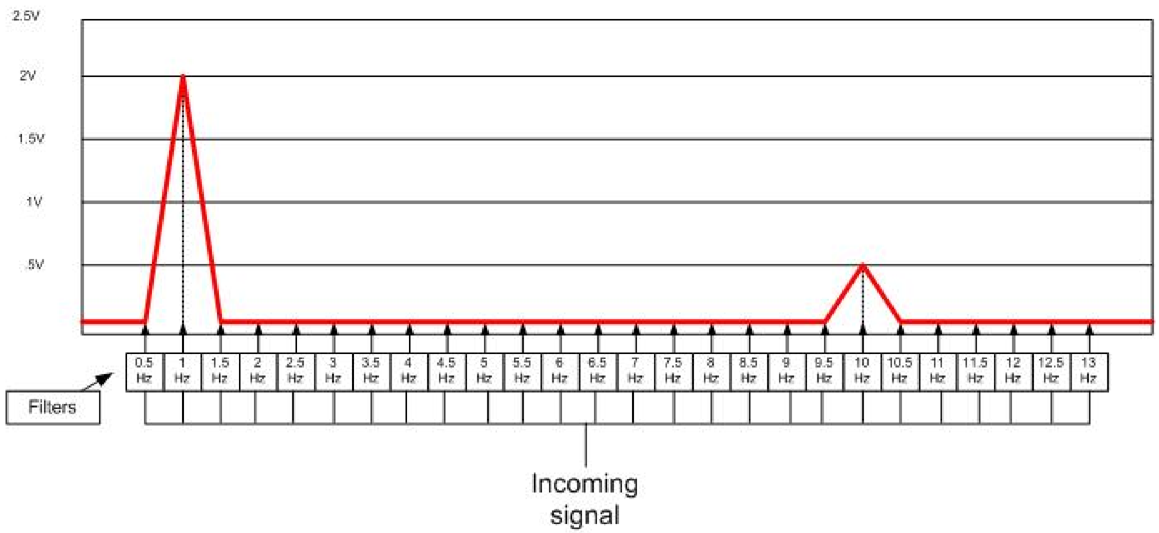
6.0 Spectrum analyzer

While the oscilloscope is a wonderful tool, there are times when it is valuable to view a waveform in the frequency domain, rather than the time domain. One common application is when working with vibrations of structures. Where the oscilloscope displays a wave form of voltage vs. time, the spectrum analyzer displays a waveform of voltage vs. frequency. This data can be obtained from a specialized instrument, such as the HP 3582, shown below, or from more general purpose tools such as an FFT module in a digital oscilloscope, or a computer data acquisition system running a virtual instrument.

Many people have trouble with the concept of the spectrum analyzer. The simplest model for how one of these systems works, is that there are lots of individual frequency filters. Each filter being set to one specific frequency. If the incoming signal has a component that matches this frequency, the analog voltage level of that component is displayed.



As an example the above waveform contains two sine waves, one at 1 Hz with an amplitude of 2 Volts P-P, and a second component that is 10Hz, with a 0.5V P-P amplitude.



By using the filter set model, you can see that the system would be displaying a 2 volt peak at 1Hz and a 1/2V peak at 10Hz and nothing else if the compound signal shown above were input to the filter set. Now obviously this would not be practical to do for a wide range of frequencies, but this shows the basic concept of how a frequency domain signal is displayed. In the actual analyzer, the waveform is captured, and then mathematically reduced to determine how much of each frequency component is in the measured waveform. It is easy to see that for lower frequencies, you would need to collect enough data to actually determine if there is a low frequency portion of the signal.

As a general rule you need a sampling time at least 5 times longer than the period of the lowest frequency you are trying to resolve. As you dial the device to a higher and higher end frequency, it is easy to see that the resolution between frequencies grows greater by necessity.

Much like an oscilloscope, there are input channel selections for maximum amplitude, and a horizontal section that is now based in frequency instead of time. There is also a trigger section to tell the system when to start collecting data. Adjusting these sections are similar to those of an oscilloscope. The important thing to remember is that the inputs must be set so that the largest component of the input signal does not exceed the input channel capabilities. This condition, called an overload, distorts the wave form and the readings you would get are not accurate. This particular device has a red indicator light that blinks on when the voltage exceeds the channel settings. If this happens you must change to the next higher channel setting, and reset the data cycle. An overload message on the display will help prompt you to take these actions. Some higher end systems have the ability to auto-scale the inputs and do this for you.

The horizontal section of most spectrum analyzers have a variety of setup modes. This particular unit has a 0-25KHz setting, a 0 start setting and a frequency center setting. For most things the 0 start setting is used. This setting allows the user to select the end frequency, and it sets the start frequency to as close to 0 as it can based on the desired end frequency. Since it is actually impossible to get a true 0 Hz frequency input, this is typically a very small frequency value, but not truly 0. The center frequency mode is very useful for looking at a specific frequency and a narrow band around that frequency. There are also a variety of signal averaging setting to help with highly variable signals.

The display section allows you to zoom into the wave form vertically to view lower amplitude peaks. This does not affect the actual data, but simply magnifies the display for convenience. It also allows you to capture a base line reading and then subtract that reading from a newly acquired reading. This is a handy feature when looking for changes in a signal. The device will also let you scale the display to linear, or db display units.

In general the setup of a spectrum analyzer is sensitive to the many different buttons and selections, and this is a particularly simple unit. If you are interested in more detail on the use of this device, you may download the users guide at the department tech shop web site.

Basic Instrumentation Lab Experiment 1

The purpose of this experiment is to acquaint you with the basic operation of measuring voltage, current and frequency with an assortment of standard instruments.

Procedure:

Using a multi-meter or equivalent, measure and record each of the following points on box #1 with respect to the black common point.

TP1	AC Volts	_________	DC Volts	________
TP2	AC Volts	_________	DC Volts	________
TP3	AC Volts	_________	DC Volts	________

Set the meter up to read current and measure the "current" connections on box #1 in each switch position.

1	DC Amps	_________
2	DC Amps	_________
3	DC Amps	_________

Using a strip chart recorder and test box #2, determine and sketch the waveform shape, frequency and peak to peak voltage for each of the points TP1, TP2 and TP3. Be sure to include the zero voltage reference on your sketch.. Constant voltage points are provided for your reference.

TP1: Sketch

Voltage P-P ___________

Frequency ___________

TP2: Sketch

Voltage P-P ___________

Frequency ___________

TP3: Sketch

Voltage P-P ___________

Frequency ___________

Using an oscilloscope and the frequency box, draw the wave form and record all the relevant voltage values to fully describe the waveform amplitudes.

(Hint: Each waveform has two distinct frequencies that are compounded.)

TP1

TP2

Extension:

Select one of the following to do.

1) Using the HP 3478A multimeter and three boxes, experiment with the settings of number of digits, (3, 4 and 5). How does this setting affect your readings and what implication does this have for using the meter?

2) Using the function generator as a signal source, determine what, if any, effect frequency has on the accuracy of AC signal measurement with the chart recorder. You may wish to use the Oscilloscope in parallel with the Strip chart recorder for these tests.

Questions:

For each of the following situations, determine and record the **most suitable** piece of test equipment for the job. Assume that you will have to purchase of the equipment for the test. Go on the internet and find the price vendor and model number of the device you have selected. Feel free to choose equipment other than those available in the lab. Your answer should include the reasons you selected this particular item to your boss.

1) You are measuring the voltage output of a temperature controller feedback signal in an effort to tune the PID control loop. The system has a response time of about ten minutes for a ten degree temperature rise. You need to track the amount of change in the temperature of the system following a disturbance to adjust the controller parameters.

2) You have a speed feedback signal on a conveyor system that is unstable. The feedback is an analog tachometer that generates an DC signal directly proportional to the speed. The control system provides a DC analog output that corresponds to the commanded speed to the drive motor. You must determine if the controller is changing the speed because of a problem with the feedback tachometer, or if the tachometer is working properly and the controller is at fault.

3) You are trying to repair the fault in a safety circuit for a welding robot. The controller is showing that an error exists in the circuit, but the circuit contains several switches wired in series. You need to locate the proper switch and determine if it is broken or if a valid fault exists (such as an over travel really sitting on the switch). You have been provided with a schematic by the manufacturer of the system.

Basic Instrumentation Lab Experiment 2

The purpose of this experiment is to acquaint you with the basic operation of frequency domain measurements.

Procedure:

> Using the frequency counter, spectrum analyzer and LabVIEW signal express, determine what frequencies are contained in the compound signal generated on TP1 and TP2 of the frequency box. Use signal express to capture the shape of the waveform and verify your results.

TP1

TP2

Run “signal out program 1” on the computer, and determine what frequencies are found in the signal, and what the signal shape is. You will have to connect the “signal out” BNC cable to your instrumentation. You can use LabVIEW signal express to view the waveform while the computer is generating the waveform.

Repeat this process using program 2.

Program 1

Program 2

Extension:

Select one of the following to do.

1) Using LabVIEW signal express, determine the characteristics of the signal generated by program 3.

2) Given the provided microphone assembly, determine what frequencies, if any, are inherent in the background noise in the lab room.

Questions:

For each of the following situations, determine and record the **most suitable** piece of test equipment for the job. Assume that you will have to purchase of the equipment for the test. Go on the internet and find the price vendor and model number of the device you have selected. Feel free to choose equipment other than those available in the lab. Your answer should include the reasons you selected this particular item to your boss.

1) You have a blower and motor that is part of an exhaust stack feeding a scrubber leading to a two hundred foot chimney, moving 25000 cubic feet of exhaust from your process to the scrubber every minute. As you stand on the platform near the fan you can feel the whole platform vibrate. You need to determine if the problem is in the one hundred horsepower motor (1750 RPM), the belt drive system, or the six foot diameter fan wheel (70 RPM). Since you can not take the system down to disassemble and inspect it, you need to measure the vibrations. In addition to an appropriate vibration sensor outputting a voltage that is representative of motion of the vibration, what instrumentation do you need to determine where the imbalance resides?

2) You are working in a plant with a pump feeding 30 gallons per minute of cooling water to a process. For unknown reasons the system is running hot, and the production engineer believes that the amount of water being fed to the heat exchanger is no longer adequate. To verify this, you must check the water flow. Fortunately the manufacturer of the system installed a test flow meter that is supposed to output an ac sign wave proportional to the flow with a calibration of 175 hertz @ 10 GPM.

3) You are working on your outboard engine at home, and suspect that the tachometer in the dash is no longer correct. You wish to check it and a friend told you that you can read the speed by measuring the signal going to the primary side of the ignition coil. What device would you go purchase? If the engine has one coil for each cylinder, and was idling at 1000 RPM, what frequency would you expect to see? (Remember that a two stroke engine fires each cylinder every revolution.) If this were a 4 cylinder 4 stroke engine with a single coil, what frequency would you expect to see?