# ECE 3254 Lab 2 notes

Edited 08-31-2009

**Oscilloscope** - Graphically displays a time varying voltage waveform. The voltage waveforms are applied to the vertical inputs, where they are sampled and displayed on the Y axis. A horizontal time base moves the display along the X axis, which is a time line. The scope can be used to determine waveform amplitude, frequency, period, phase, DC and AC components, noise, shape, etc. NOTE: The oscilloscope is designed to capture and display time varying waveforms – it is not the best instrument for measuring DC voltages!

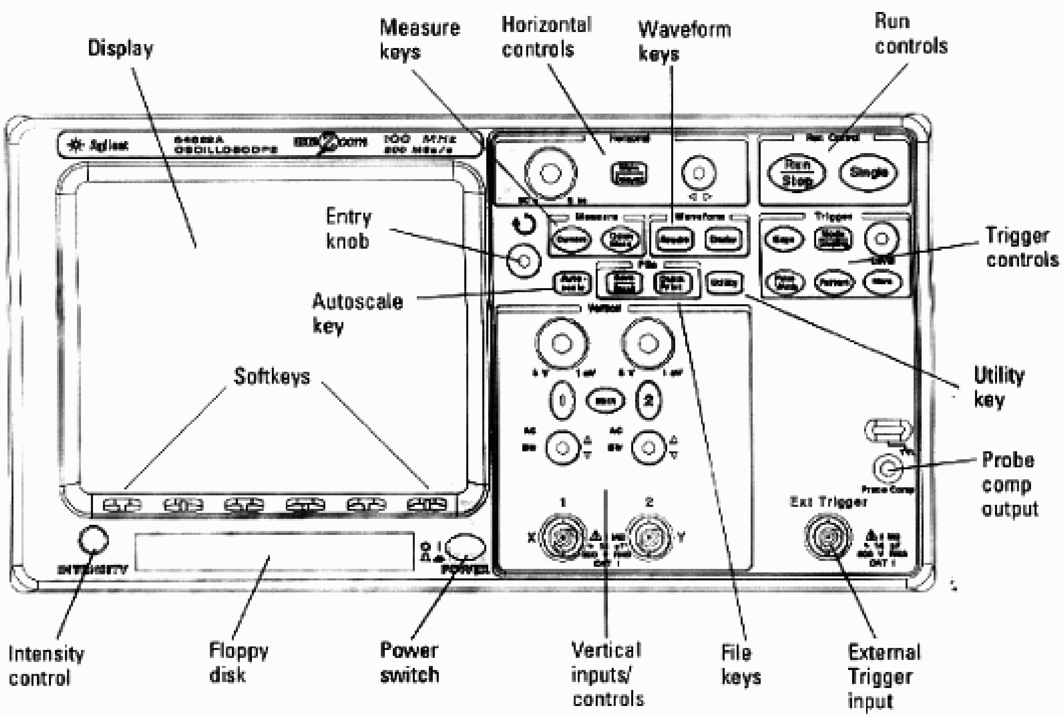
**SCOPE RULE #1 Always return the scope to the default setting**

- when the scope is first turned on (power off does not reset the scope)
- when the scope display does not make sense or disagrees with what you are expecting

To reset to default: press the "save recall" button, then the "default setup" softkey

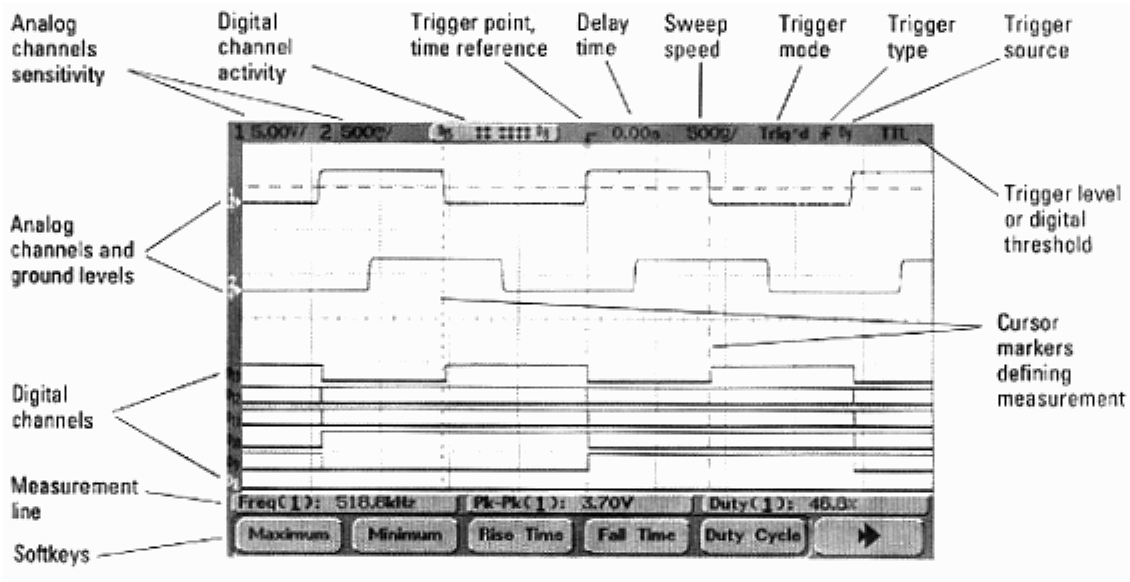
Familiarize yourself with the front panel and display of the oscilloscope using the figure below. Note that there are input connectors and controls for two vertical channels, a trigger input connector and trigger controls, horizontal time base controls, menu buttons and softkeys for scope control, and a calibrated output for probe checking (Probe comp output).

54620-series Oscilloscope Front Panels




54621A and 54622A 2-Channel Oscilloscopes Front Panel

The scope display screen contains the displayed waveform, information about channel acquisition and setup, movable cursors, reference voltages, measurement results, and softkeys used for measurement parameter setup.




**Interpreting the display**

**Status Line:** The top line of the display contains vertical, horizontal, and trigger information.

**Display Area:** The display area contains the waveform acquisitions, channel identifiers, and analog trigger and ground level indicators.

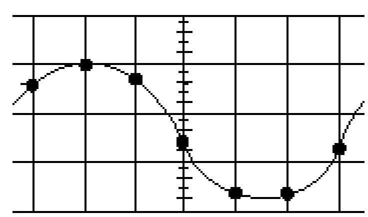
**Measurement Line:** This line normally contains automatic measurement and cursor results, but can also contain display advanced trigger setup data and menu information.

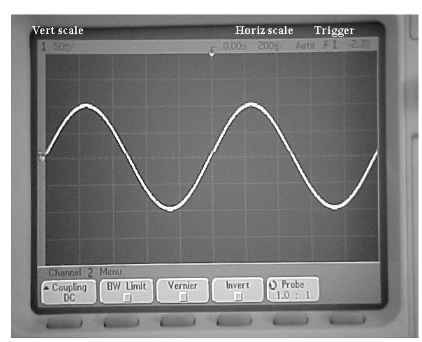
**Softkeys**: The softkeys allow you to set up additional parameters for front panel keys.

**Oscilloscope Operation and Use**

Analog scopes have been replaced by digital sampling scopes, which use an A→D converter to capture the waveform. The A→D converter must be fast enough to quickly sample and store high frequency waveform data points. Scope A→D accuracy and resolution are secondary to speed. The accuracy and resolution also depend on the vertical scale because a higher voltage scale attenuates the signal down to a few data bits. For best measurement accuracy, you should always try to display the waveform as close to full scale as possible.

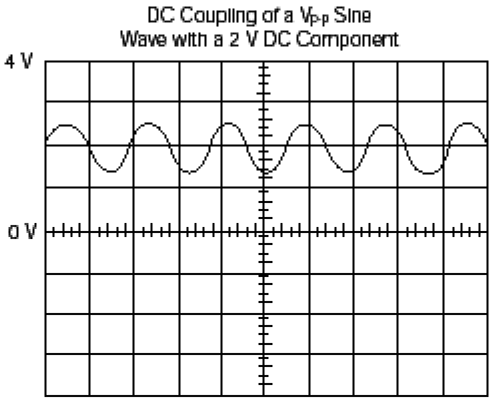
The A→D converter captures a series of **8 bit data points** on the waveform. 8 bits provide a resolution of 256 possible voltage levels, divided evenly over the scope's 3 inch vertical display. These points are stored in memory and then displayed on the screen by a processor, using interpolation to smooth the waveform shape between data points.

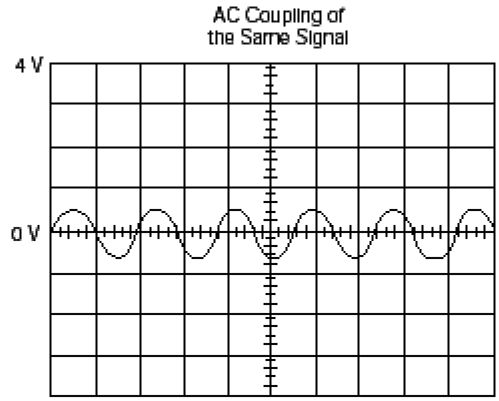





The Agilent 54622A scope display contains the reproduced waveform(s), information about the scope settings, and a soft key menu. Vertical sensitivity ranges from 5V/div to 1mV/div. The position controls move the traces up/down on the CRT.

**Input coupling** may be AC or DC. AC coupling, which is essentially a capacitor added in series with the input to the A→D converter, strips the DC component from a waveform before it reaches the display. (remember: DC current does not pass through a capacitor, but AC current does.)




The **horizontal section** controls the sweep rate, which ranges from 50s/div to 5ns/div and adds a horizontal position control to change the horizontal position of the trace. Also, the main/delayed switch is located in this section.

The **scope trigger** stabilizes the waveform. If the horizontal sweep begins randomly, the scope display is too unstable to see anything, so the trigger determines where, on a waveform's voltage and slope, the display trace begins each time. The trigger source can come from either input channel, the external trigger input connector, or the AC power line.

> Normal trigger mode freezes the display until the waveform reaches the trigger setting. Caution: Even when there is a waveform going into the scope, normal mode can keep the display blank if the trigger condition is not met.
>
> Auto mode allows the display to run even when the trigger condition is not met. If the input waveform does not trigger the scope, the display will be unstable but you can see that there is an input signal.

**Other convenient scope features:**

- **Autoscale** automatically sets the horizontal, vertical, and trigger values based on a best guess of what the scope thinks is an input signal. When you press Autoscale, the scope looks for and acquires the strongest AC waveform it can find. WARNING: Autoscale may not display what you want, especially if the input is a DC voltage.
- The **Quick measure button** displays values for the waveform maximum voltage, minimum voltage, RMS voltage, peak to peak voltage, period, frequency, and phase. **NOTE:** This may or may not be more accurate than your eyes. Quick measure is convenient, but its function is secondary to displaying the waveform. Also, for best accuracy with Quick Measure, the displayed waveform should occupy as much of the display screen as possible to provide more bits of data resolution for the Quick Measure measurement system, but Quick Measure will not accurately measure waveforms that spill over the top or bottom of the display. For some signals, quick measure may not give accurate measurements. Always use your eyes to verify that quick measure is reporting reasonable values.
- There are four **Cursors** that can be used to measure time and voltage of specific points on a waveform

**Function Generator** The Agilent 33120A Function Generator can produce Sine, square, pulse, triangular, and ramp waveforms up to 15 MHz. The waveform shape, frequency, amplitude, duty cycle, and DC offset may be set from the front panel or with the Labview software on the computer. The output termination is 50Ω by default, and must be changed to Hi-Z for measurement with the Oscilloscope or meters.

The sync output connector provides a 5V pulse, corresponding to the beginning of the generated waveform, for use with external scope triggering or frequency counters. External triggering with the sync pulse will allow us to overlay waveforms in later lab experiments.

**Labview** software allows us to use the computer to change instrument, function generator, and power supply settings. Data from the meters and scope display can be captured as data points and jpeg image files. The Labview software also enables us to perform AC frequency and DC voltage sweeps, capturing a circuit's output response over an input frequency or voltage range.

The main Labview menus are:

- Wave - changes the function generator settings.
- Scope - changes the scope settings and captures waveforms.
- AC sweep - measures the circuit voltage response while varying the input frequency. Always check the measurement device and generator settings before hitting "GO".
- DC sweep - measures the circuit voltage response while varying the input voltage.
- Buffer - displays and manipulates the captured data and waveforms.

NOTE: When you hit the "GO" button, the instrument settings are changed to what has been set in Labview. There are default settings in the Labview menus that will overwrite the instrument state.

**RMS voltage** - The average voltage value of a sinusoidal waveform is 0V. But $P = VI = V^2/R = I^2R$. To calculate the power produced by an AC voltage, we must use the effective voltage, called the "Root Mean Square voltage" (abbreviated $V_{RMS}$). $120V_{RMS}$ and $120V_{DC}$ will produce the same power in a given load. FWIW: $120V_{RMS}$ has a peak voltage of $120\sqrt{2} = 170Vp$, and a PP voltage of 170x2 = 340Vpp.

$V_{RMS} = [1/T \int_0^T v^2(t)dt]^{1/2}$

Given a generic AC waveform with a DC offset $v(t) = A + B\sin\omega t$

$v^2(t) = (A + B\sin\omega t)^2$ = (write the equation in Prelab assignment)

Substitute the trig identity $\sin^2\omega t = ½(1 – \cos 2\omega t)$

Plug your $v^2(t)$ equation into the $V_{RMS}$ equation
(Note: you may use $V^2_{RMS}$ = [----] instead of $V_{RMS}$ = [----]$^{1/2}$ to simplify the equation until later)

Crunch the integral and plug in the limits to get the equation for $V_{RMS}$ or $V^2_{RMS}$
(Note: the definite integral $\int_0^T \sin\omega t = 0$, and $\int_0^T \cos 2\omega t = 0$)
(If you were working with $V^2_{RMS}$, take the square root of both sides)

You must write the complete derivation on you prelab assignment to receive credit!

Other waveform shapes must be squared and integrated over one period (use the RMS equation). For a square wave, the output is at $V_{max}$ for ½ period, then at $V_{min}$ for 1/ period.