# Oscilloscope Primer for EK307
(Based on the PicoScope Data Acquisition Module)

The *oscilloscope* is an essential tool in the design and testing of electronic circuits in all branches of engineering. A good "scope" enables you to see electrical signals produced by circuits, but it also allows you to track such non-electrical qualities as vibration, sound, magnetic flux, light pulses, heartbeats, and seismic waves, among others. These physical variables are transformed into electrical signals by way of *transducers* and *sensors*.

A key feature of the oscilloscope is its ability to measure signals that change much more rapidly than the naked eye, or even a digital voltmeter, can see. Although some oscilloscopes have time resolutions approaching a nanosecond or less, the scopes in the EK307 section of our lab can discern time increments of no larger than about a microsecond, and as large as a few minutes. Normally we will use the oscilloscope to view waveforms that change over a time scale of milliseconds.

Viewed from the general perspective of laboratory tools, the oscilloscope can simply be thought of as an instrument that plots voltages as a function of time on its display. One example of such a plot (sometimes called a "trace") is shown to the right. The various controls on the face of the oscilloscope allow the user to set both the horizontal (time) and vertical (voltage) scales of the display to match the characteristics of the waveform being observed.

Screen shot of PC-based oscilloscope
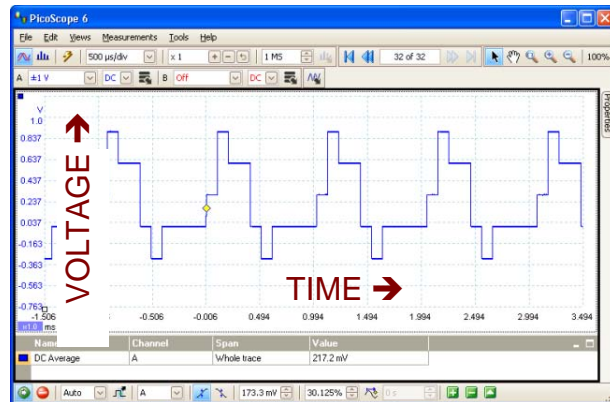
By using the features provided by the oscilloscope, you will be able to …
• …determine the evolution of voltage signals over time.
• …calculate the *frequency* of a cyclical voltage signal such as a sine, triangle, or square wave.
• …distinguish the fine features of a complicated waveform such as a heartbeat or sound signal.
• …determine the DC and AC components of a time-varying voltage.
• … tell how much *noise* (as opposed to meaningful information) is superimposed on a voltage signal.

Since their emergence as laboratory-grade instruments in the 1920's, up until about the past decade or so, oscilloscopes were solely standalone instruments having dedicated panels comprised of a screen, physical buttons, and knobs. An example of one such scope is shown to the right. Nowadays, with digitization of signals an ubiquitous phenomenon in just about everything we encounter, the oscilloscope more frequently takes the form of a small, simple data-acquisition box connected to a computer via a USB cable. The physical buttons and knobs of a self-contained scope are replaced by a graphical user interface that is accessed using a mouse and keyboard. We have adopted this newer technology for the

Stand-alone oscilloscope

EK307 lab facility because you are more likely to encounter these computer-based instruments as you enter the modern workplace or research setting.

The instrument we have chosen for EK307 is called the PicoScope 2104. This version of the PicoScope family, shown below, allows the user to display simultaneously *two* time-varying voltage waveforms on the same screen. These inputs, or "channels", are labeled A and B and are plotted, respectively, as *blue* and *red* waveforms on the computer screen. While both A and B plots must share the same time (horizontal) axis, the individual waveforms can be plotted with different voltage (vertical) axes. The PicoScope 2104 also provides a Signal Generator output, but because we have the vastly superior and more powerful Agilent bench-top function generator in our lab, we will not be using this feature of the PicoScope 2104. (Feel free, of course, to use this signal output in your experiments if you find it convenient, but the details of its operation are not covered here. It may be accessed from the graphical user interface.)

My case is bright red in the EK307 lab....

A-Channel Input
B-Channel Input

Signal Generator Output
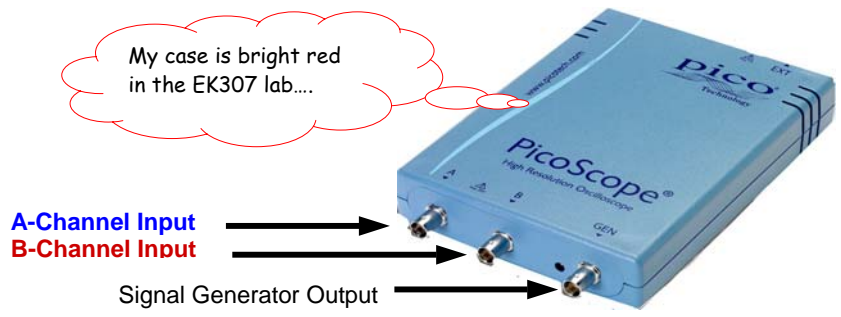
Oscilloscope Controls
The main controls of the PicoScope, found on the graphical user interface, are divided into three sections: Vertical, Horizontal, and *Trigger* controls.

Horizontal Controls

Vertical Controls

Zero volts position slider

Trigger Controls
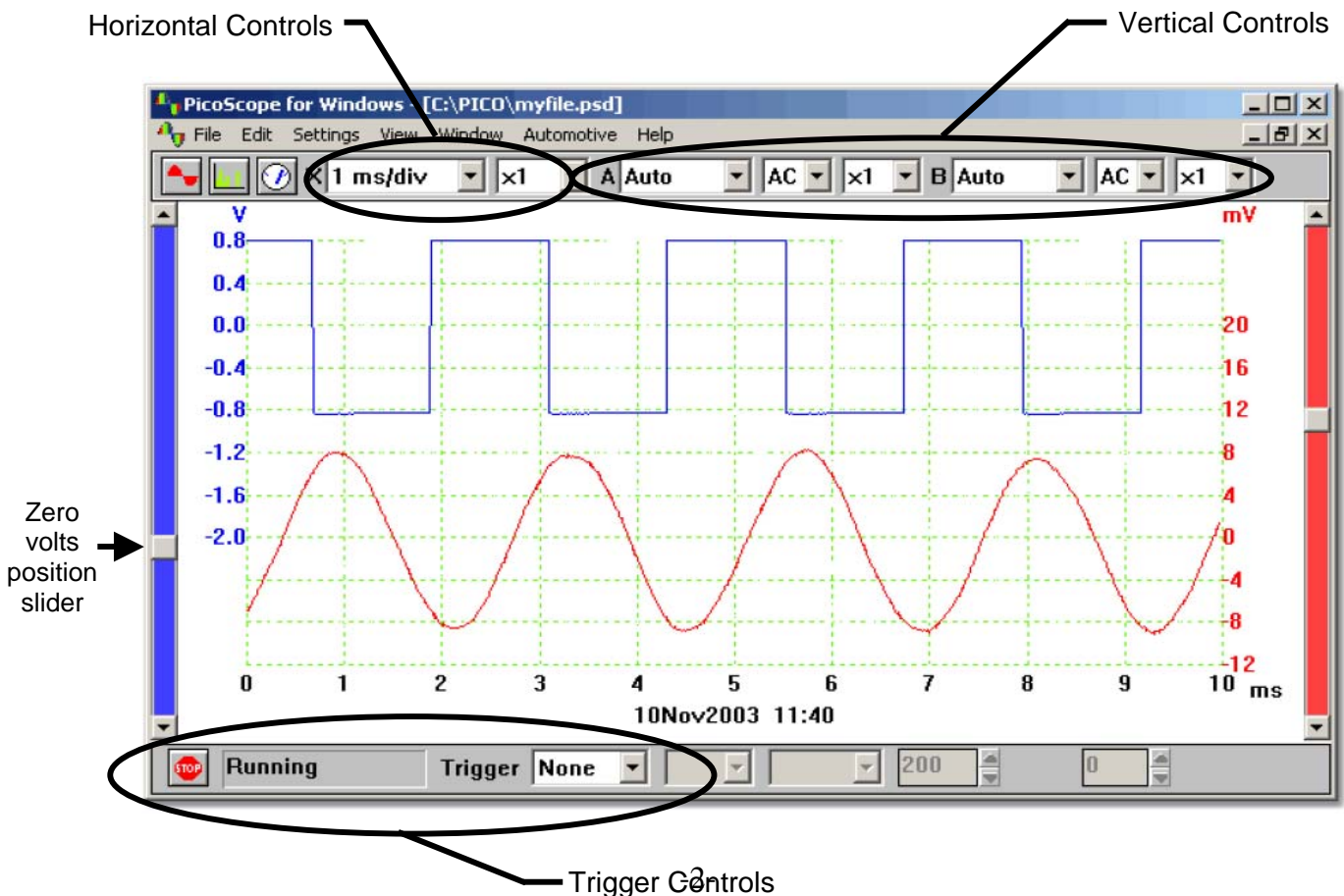
Horizontal Time Scale

The horizontal controls allow you to set the PicoScope's time scale to any of several preset values. The *timebase*, chosen from a pull-down menu in the horizontal control section, specifies the time in microseconds, milliseconds, or seconds represented by each of the ten major divisions on the screen. In the above figure, for example, the timebase is set to 1 millisecond per division, hence the total time across the entire screen from left to right is 10 ms. (Note: The timebase setting chosen from the ms/div pull-down menu is multiplied by the number immediately to its right: ×1 in the above figure.)

Voltage Scales

The vertical controls allow you to set the volts-per-division scale for both the A and B channels. Choosing AUTO from the pull-down menu will automatically set the scale to accommodate the waveform you are measuring, but we strongly recommend that you choose a specific volts-per-division setting for each channel so that you know precisely what you are measuring and gain an appreciation for exactly how the instrument works. The sliders on the blue and red position bars on either side of the screen allow you to move the zero point of each vertical axis up or down to wherever you want it.

The AC/DC setting determines whether the time-average (DC) component of the waveform is included in the display. The DC setting thus provides a plot of the entire, actual waveform as a function of time. In contrast, the AC setting provides a plot of only the *time varying* portion of the waveform with the DC component subtracted out. These settings are each useful under various circumstances. The AC setting is useful, for example, if you are trying to measure a small, time-varying signal that is superimposed on a much larger DC component.
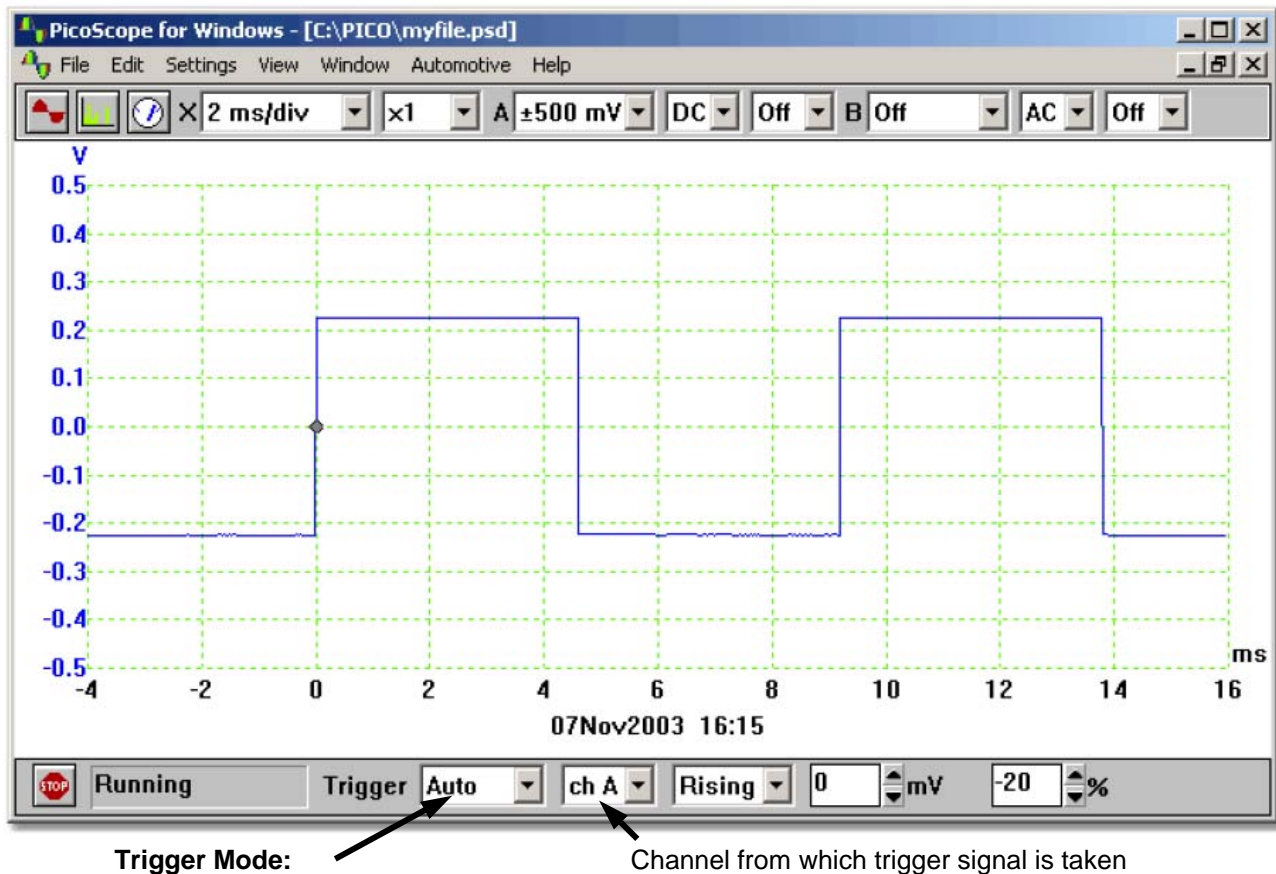
Triggering

A digital oscilloscope such as the Picoscope constantly measures and stories voltage-value data in its memory buffer as soon as it is powered up. To display the signal as you desire, the instrument needs to know at what point in time, relative to the waveform itself, to begin plotting the data on the screen. Choosing the starting time for the display to begin plotting is known as *triggering*.

The trigger point, or "triggering event", defines $t = 0$ on the graphical plot. It is set by setting a particular voltage threshold level that the observed waveform must cross before plotting can begin. This threshold can be either positive or negative. The user must also specify the input signal (A or B channel) from which the trigger is to be derived. The user can also select whether the trigger point occurs on a rising or falling slope as the waveform crosses the threshold level.

The trigger threshold and position can be set via the pulldown menus in the Trigger section of the panel, or simply by dragging the yellow diamond with the mouse to any point along the time axis.

Absent user intervention, the instrument defaults to a trigger point in the center of the screen. In the following diagram, however, the trigger point for plotting has been set to two major divisions from the far left of the screen, at a voltage level of zero volts on an upward, positive slope. Note that the portion of the waveform plotted to the left of the diamond represents data that was collected before the $t = 0$ plotting start point defined by the trigger diamond.

Trigger Mode: Channel from which trigger signal is taken

The way in which the scope reacts to the triggering event is set by the **TriggerMode**, as follows:

None: No trigger event. The PicoScope collects and displays data continuously.

Auto: Picoscope starts to display data versus time when the selected channel signal (A or B) reaches the trigger threshold level at the selected slope (↑or ↓). If no trigger signal is obtained, the scope will trigger automatically after an auto-trigger time. This setting is useful if you want to see a baseline trace independent of whether a triggering event occurs.

Repeat: PicoScope will begin plotting data only when a trigger event occurs. After displaying the data on the screen, it waits for the next trigger event before renewing the plot. This setting is useful if you want to observe a trace only when a trigger event occurs each cycle of a periodic waveform. On some scopes, this setting is called "Normal".
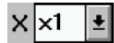
Single: The PicoScope starts displaying data only when a trigger event occurs, but stops after just one sweep of the screen even if the signal again crosses the threshold level. This setting is useful for measuring and plotting signals such as a single pulse that are not periodic– that is, occur only once.

Summary of PicoScope Controls
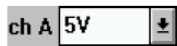
Horizontal (time):
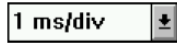
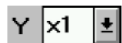|	
`1 ms/div`	Timebase
`X ×1`	X Multiplier

Vertical (voltage):

`ch A 5V`	Range
`DC`	AC/DC switch (ADC-200 series oscilloscopes only)
`Y ×1`	Y Multiplier

Channel B

`ch B Off`	Range
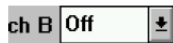
Triggering:
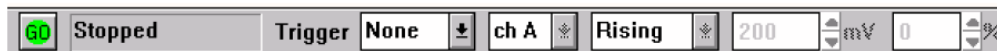
`GO`	Start and stop sampler
`Stopped`	Sampling Status
`None`	Trigger Mode
`ch A`	Trigger Channel
`Rising`	Trigger Direction
`200 mV`	Trigger Threshold
`0 %`	Trigger Delay