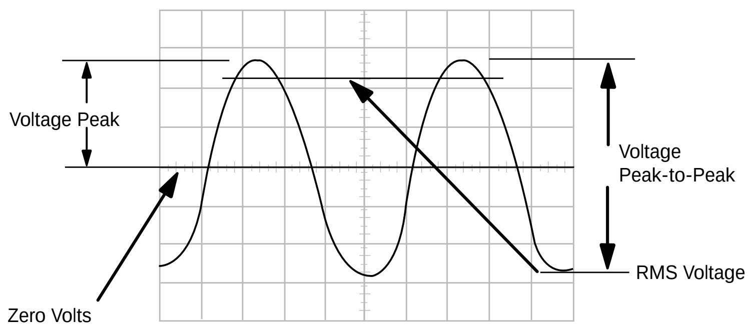

Figure 66. *Voltage peak (V_p) and peak-to-peak voltage (V_{p-p}).*

When you compensate the probe, always attach any accessory tips you will use and connect the probe to the vertical channel you plan to use. This will ensure that the oscilloscope has the same electrical properties as it does when you take measurements.

Oscilloscope Measurement Techniques

This section reviews basic measurement techniques. The two most basic measurements you can make are voltage and time measurements. Just about every other measurement is based on one of these two fundamental techniques.

This section discusses methods for taking measurements visually with the oscilloscope screen. This is a common technique with analog instruments, and also may be useful for "at-a-glance" interpretation of DSO and DPO displays.

Note that most digital oscilloscopes include automated measurement tools. Knowing how to make measurements manually as described here will help you understand and check the automatic measurements of DSOs and DPOs. Automated measurements are explained later in this section.

Voltage Measurements

Voltage is the amount of electric potential, expressed in volts, between two points in a circuit. Usually one of these points is ground (zero volts) but not always. Voltages can also be measured from peak-to-peak – from the maximum point of a signal to its minimum point. You must be careful to specify which voltage you mean.

The oscilloscope is primarily a voltage-measuring device. Once you have measured the voltage, other quantities are just a calculation away. For example, Ohm's law states that voltage between two points in a circuit equals the current times the resistance. From any two of these quantities you can calculate the third using the following formula:

Voltage = Current * Resistance

$$\textbf{Current} = \frac{\textbf{Voltage}}{\textbf{Resistance}}$$

$$\textbf{Resistance} = \frac{\textbf{Voltage}}{\textbf{Current}}$$

Power Law: Power = Voltage * Current

Another handy formula is the power law: the power of a DC signal equals the voltage times the current. Calculations are more complicated for AC signals, but the point here is that measuring the voltage is the first step toward calculating other quantities. Figure 70 shows the voltage of one peak (V_p) and the peak-to-peak voltage (V_{p-p}).

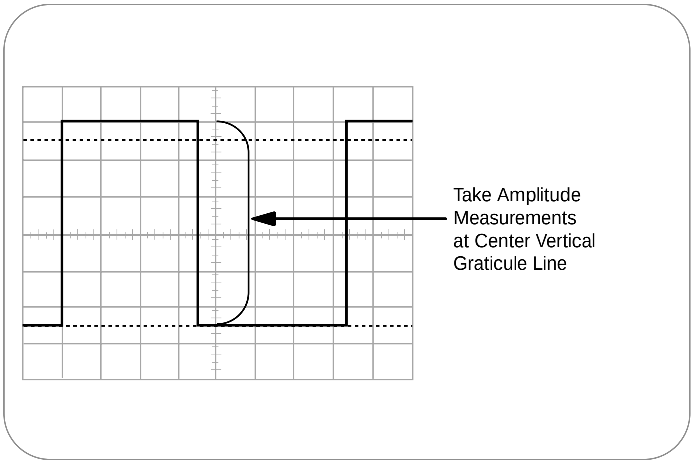

Figure 67. *Measure voltage on the center vertical graticule line.*

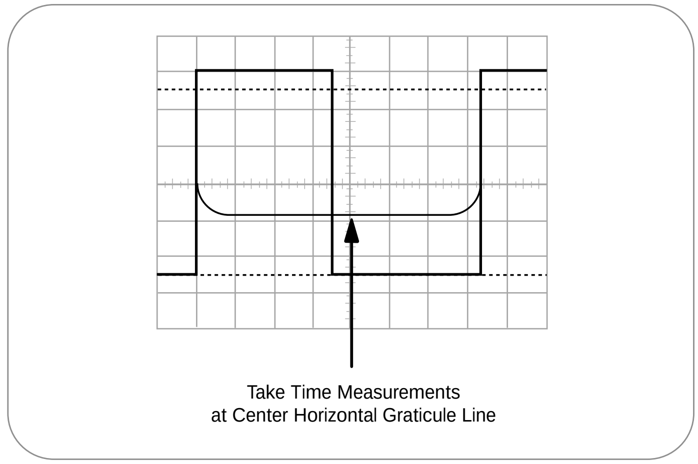

Figure 68. *Measure time on the center horizontal graticule line.*

The most basic method of taking voltage measurements is to count the number of divisions a waveform spans on the oscilloscope's vertical scale. Adjusting the signal to cover most of the screen vertically makes for the best voltage measurements (see Figure 67). The more screen area you use, the more accurately you can read from the screen.

Many oscilloscopes have on-screen line cursors that let you make waveform measurements automatically on-screen, without having to count graticule marks. A cursor is simply a line that you can move across the screen. Two horizontal cursor lines can be moved up and down to bracket a waveform's amplitude for voltage measurements, and two vertical lines move right and left for time measurements. A readout shows the voltage or time at their positions.

Time and Frequency Measurements

You can make time measurements using the horizontal scale of the oscilloscope. Time measurements include measuring the period and pulse width of pulses. Frequency is the reciprocal of the period, so once you know the period, the frequency is one divided by the period. Like voltage measurements, time measurements are more accurate when you adjust the portion of the signal to be measured to cover a large area of the screen, as illustrated in Figure 68.

Pulse Width and Rise Time Measurements

In many applications, the details of a pulse's shape are important. Pulses can become distorted and cause a digital circuit to malfunction, and the timing of pulses in a pulse train is often significant.

Standard pulse measurements are pulse width and pulse rise time. Rise time is the amount of time a pulse takes to go from a low to high voltage. By convention, the rise time is measured from 10% to 90% of the full voltage of the pulse. This eliminates any irregularities at the pulse's transition corners. Pulse width is the amount of time the pulse takes to go from low to high and back to low again. By convention, the pulse width is measured at 50% of full voltage. Figure 69 (see next page) illustrates these measurement points.

Pulse measurements often require fine-tuning the triggering. To become an expert at capturing pulses, you should learn how to use trigger holdoff and how to set the digital oscilloscope to capture pretrigger data, as described in the Systems and Controls of an Oscilloscope section. Horizontal magnification is another useful feature for measuring pulses, since it allows you to see fine details of a fast pulse.

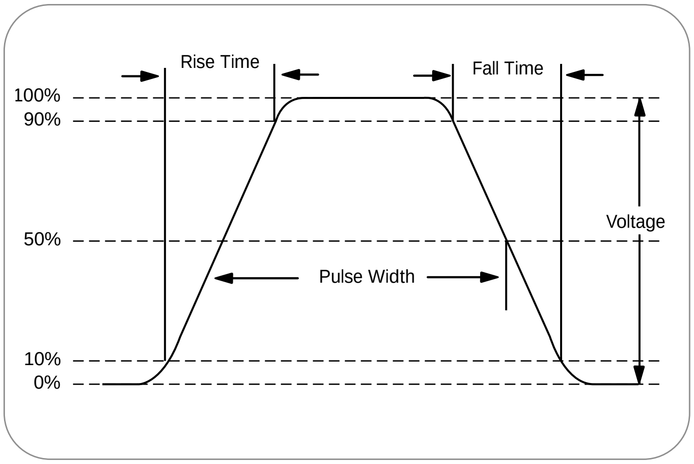

Figure 69. Rise time and pulse width measurement points.

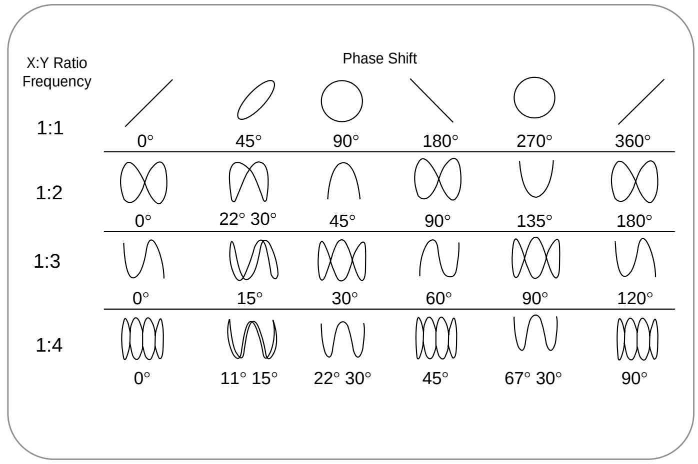

Figure 70. Lissajous patterns.

Phase Shift Measurements

One method for measuring phase shift – the difference in timing between two otherwise identical periodic signals – is to use XY mode. This measurement technique involves inputting one signal into the vertical system as usual and then another signal into the horizontal system – called an XY measurement because both the X and Y axis are tracing voltages. The waveform that results from this arrangement is called a Lissajous pattern (named for French physicist Jules Antoine Lissajous and pronounced LEE–sa–zhoo). From the shape of the Lissajous pattern, you can tell the phase difference between the two signals. You can also tell their frequency ratio. Figure 70 shows Lissajous patterns for various frequency ratios and phase shifts.

The XY measurement technique originated with analog oscilloscopes. DSOs may have difficulty creating real-time XY displays. Some DSOs create an XY image by accumulating triggered data points over time, then displaying two channels as an XY display.

DPOs, on the other hand, are able to acquire and display a genuine XY mode image in real-time, using a continuous stream of digitized data. DPOs can also display an XYZ image with intensified areas. Unlike XY displays on DSOs and DPOs, these displays on analog oscilloscopes are typically limited to a few megahertz of bandwidth.

Other Measurement Techniques

This section has covered basic measurement techniques. Other measurement techniques involve setting up the oscilloscope to test electrical components on an assembly line, capturing elusive transient signals, and many others. The measurement techniques you will use will depend on your application, but you have learned enough to get started. Practice using your oscilloscope and read more about it. Soon its operation will be second nature to you.