Oscilloscope User's Guide

A close-up look at the high-performance general-purpose oscilloscope and how to use it for making tests and measurements

By Vaughn D. Martin

If you recently purchased an oscilloscope (or have had one for some time, for that matter) and want to use it effectively, you will have to become thoroughly familiar with all its controls and how to use them. Failure to do this will shortchange you on the sizeable investment you (or your employer) made for this powerful and versatile test instrument.

At the very least, the typical scope is a device that displays visual images of electrical waveforms and, as such, is extremely informative. But the scope is also a very effective measuring instrument as well. For example, depending on how you use it, your scope can serve as a sensitive ac or dc voltmeter or ammeter, a frequency counter, or a phase-difference meter. It can also serve as an indicator of short and open circuits, a component condition tester, or a semiconductor (diode and transistor) junction tester. In fact, the more you learn about your scope, the more you will discover you can do with it.

In this article, we will explore scope controls and functions, suggesting methods to use to make various tests and measurements. Since control layouts and features vary from one manufacturer to another, our procedures will be specific to the Textronix 2200 Series of scopes. This series is representative of modern, relatively low-cost, high-performance scopes. Therefore, the information presented should be readily transferrable to any of a number of different scope brands, whether B&K-Precision, Beckman, Leader, or other makes.

The two models that make up the Tektronix 2200 Series are the 2213 single-timebase delayed and the 2215 dual-timebase delayed scopes. The two differ only slightly, mainly in the triggering section. Note in Fig. 1 how the controls are logically arranged into five groups, each corresponding to a specific function. If you have a scope from a different manufacturer, you should be able to translate the procedures detailed to suit the particular model you have.

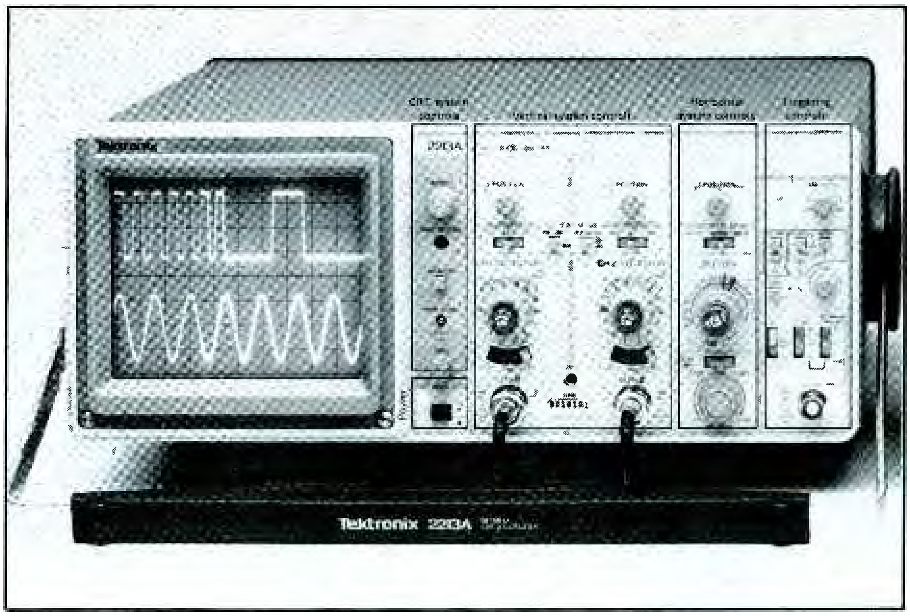


Fig. 1. Controls on front panel of Tektronix 2200 Series oscilloscopes (Model 2213 shown) are logically grouped according to function.

Getting Started

After unpacking your scope—and *before* you begin using it to make tests on your bench—it is important that you familiarize yourself with and check out the operation of all its controls. At the same time, compensate any probes that may have come with the oscilloscope.

Most measurements made with an oscilloscope require use of an attenuator probe (Fig. 2). Such probes usually have a switch on them. In one position, the switch passes the input signal directly to the scope's input. In the other position, the switch diverts the incoming signal to an attenuator network that divides the signal amplitude by 10 before delivery to the scope's input.

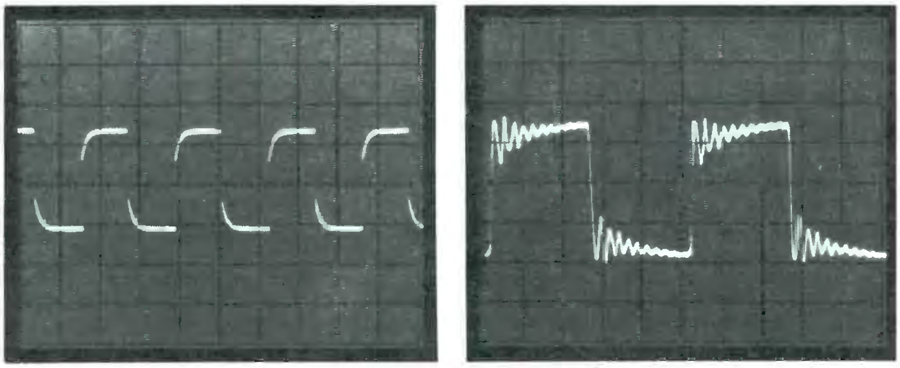
Compensation of a probe involves a simple procedure. After plugging the probe's cable into the desired scope input channel, you touch the probe tip to the internal calibrate output on the scope's front panel. Then you turn the tip in both directions while observing the screen. When the trace consists of a series of perfectly symmetrical square waves with no sign of sloping or "ringing," the probe is compensated.

If your scope has more than one channel, each should have a probe specifically compensated for it. With any given input channel, use only the probe compensated for it. (Use some means of identification to keep track of probe/channel combinations.)

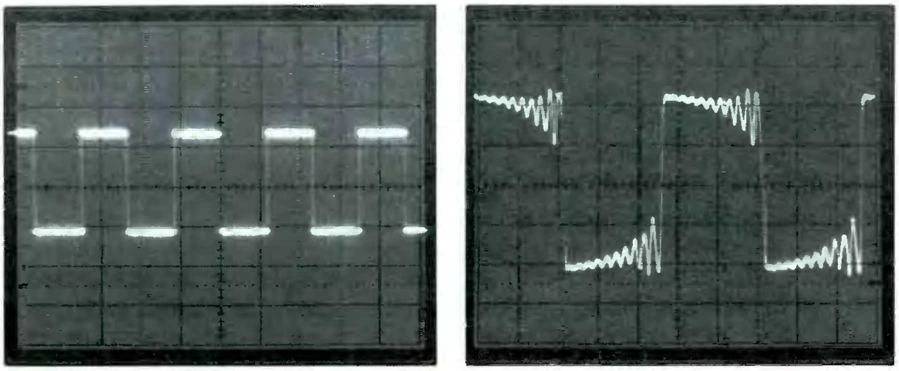
Figure 3 illustrates a series of waveforms that might be obtained as you compensate a probe. The two waveforms in the center represent what would be observed with a perfectly compensated probe. The top and bottom waveforms represent an overcompensated and an undercompensated probe, respectively. The photos on the left are the waveforms obtained as a probe was being compensated.

The photos on the right in Fig. 3 represent a 1-MHz square wave obtained with various probe conditions. Before you conclude that all three waveforms are identical, note

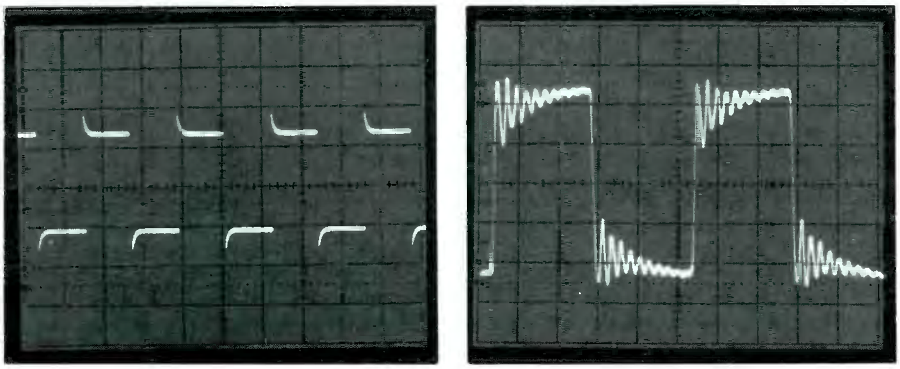
Fig. 2. Most measurements with a scope require use of attenuator probes, like this Tektronix one.



UNDERCOMPENSATED



COMPENSATED



OVERCOMPENSATED

Fig. 3. Improperly compensated probes can distort waveforms displayed on the CRT screen. Shown here are probe-adjustment and 1-MHz square-wave signals as they appear with proper and improper compensation. Note amplitude and ringing on the square wave (right) with different compensation.

carefully how the center trace traverses 4.5 voltage intervals and the 1-MHz square waves with an undercompensated probe has only a 3.5-division peak-to-peak amplitude. With an overcompensated probe, the ringing on the square wave, which represents the probe's ability to settle down and allow the scope to display the actual shape of the square wave, is far greater.

Getting Acquainted

Before you can effectively use your scope, you must become acquainted with its various controls and how to use them to perform a variety of tests and measurements. The following should help you get started.

There are a number of scope calibrators made expressly for checking out the vertical and horizontal controls of a scope. The procedure for using them is as follows:

•Check all vertical controls: Variable controls (CH 1 and CH 2 VOLTS/DIV) should be in their detented calibrated positions. Make sure CH 2 is not inverted, unless you want it to be. Check the vertical mode switches to make sure the signals from the proper channels will be displayed. Check the two vertical VOLTS/DIV switches for correct settings, and do not forget to use the VOLTS/DIV readout that matches the probe setting (×1 or ×10). Check the input coupling switches; use DC for direct coupling or AC for alternate coupling.

•Check the horizontal control settings: Magnification should be off (red CAL knob on the SEC/DIV switch pushed in). Set the SEC/DIV switch to its detented calibrated position. Make sure the horizontal mode switch is set where you want it to be—NO DLY for no delay, INTENS when you want an intensified zone, or DLY'D for delayed sweep (A, ALT or B for the Model 2215).

•Check the trigger system controls to make sure your scope will select the correct slope on the trigger signal. Also, make sure the trigger holdoff control is at its minimum setting.

Amplitude And Time Measurements

These are the two most fundamental measurements made with a scope. All others are derived from them.

Amplitude Measurements. To make these, do the following:

1) Connect the probe to CH 1 input and to the probe adjust jack. Attach the probe's ground strap to the collar of the CH 2 input. Make sure you use the probe compensated for channel 1 and all variable controls are set to their detented positions.

2) Set TRIGGER MODE to NORM for normal triggering and HORIZONTAL MODE to NO DLY (A for the Model 2215). Make sure channel 1 coupling is set to AC, TRIGGER SOURCE is set to INT, INT is set to CH 1, and VERTICAL MODE is on CH 1.

3) Use the TRIGGER LEVEL controls to display a stable trace. Move the VOLTS/DIV switch until the square wave is about five divisions high on the screen's graticule. Now adjust the SEC/DIV switch to obtain a display of two cycles. The settings should be 0.1 V on the VOLTS/DIV switch and 0.2 ms on the SEC/DIV switch.

4) Use the CH 1 VERTICAL POSITION control to move the square wave so that its top is on the second horizontal graticule line from from the top of the screen. Then use the HORIZONTAL POSITION control to move the trace so that the bottom of one cycle intersects the center vertical graticule line.

5) Count the number of major and minor divisions down the center vertical graticule line (assign whole numbers like 1, 2, etc., to major divisions and decimal numbers like .1, .2, etc., to minor divisions) and multiply by the setting of the VOLTS/DIV switch to obtain the value of the measurement. For example, 5.0 divisions times 0.1 volt equals 0.5 volt. (If the voltage of the probe adjust square wave in your scope is different from this example, it is because the signal is not a critical part of your scope and tight tolerances and exact calibration are not required.)

Time Measurements. These measurements are best made against the center horizontal graticule line. Use the instrument settings from above, centering the square wave vertically with the VERTICAL POSITION control. Then use the HORIZONTAL POSITION control to line up one rising edge of the square wave with the second from the left graticule line. Make sure the next rising edge intersects the next horizontal graticule line.

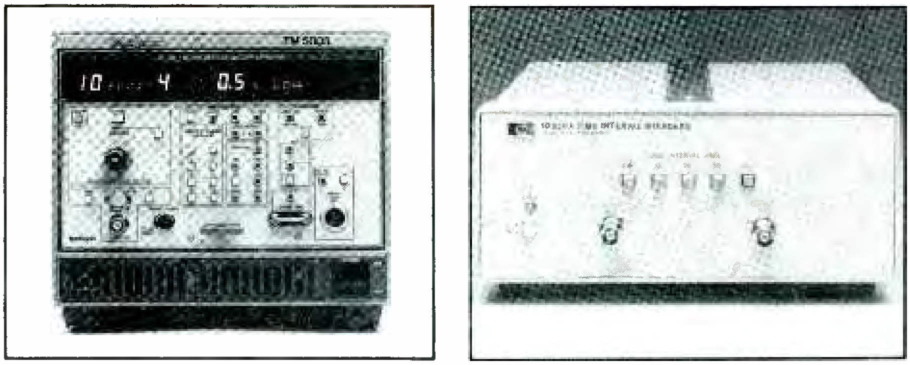


Fig. 4. The CG5001 programmable oscilloscope calibrator from Tektronix offers a wide range of test capabilities (A, left). Hewlett-Packard's 10236A time interval standard (B, right) offers outputs from 5 to 100 ns.

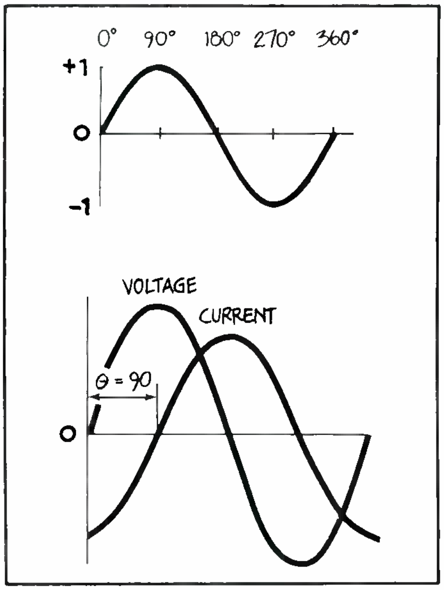


Fig. 5. To determine phase shift between two signals, measure distance between identical points on both, such as at the zero-crossing point.

Count the major and minor divisions across the center horizontal graticule line from left to right and multiply by the SEC/DIV switch setting. For example, 5.7 divisions times 0.2 ms equal 1.14 ms. (Again, if the period of the probe adjust square wave in your scope is different from that obtained in this example, the signal is not a critical part of your scope's calibration.)

Derived Measurements

These are the result of calculations made from direct measurements like those previously cited. Frequently, pulse-width, phase and X – Y measurements are examples of derived measurements.

Pulse-Width Measurements. There are time intervals for generating very precise pulse widths (Fig. 4B). To quickly and easily measure the width of the probe adjust square-wave pulse, set your scope to trigger on and display channel 1. (Your probe should still be conntected to the channel 1 input and the probe adjust jack from the previous examples.) Use 0.1 ms/division and the NO DLY horizontal mode (A sweep for the Model 2215). Use AUTO triggering on the positive slope and adjust trigger level to obtain as much of the leading edge as possible on the screen. Switch the coupling on channel 1 to ground and center the baseline on the center graticule line.

Now use ac coupling to center the signal on the screen as you make pulse measurements at the 50% point of the waveform. Adjust the HORIZONTAL POSITION control to line up the 50% point with the first major vertical graticule line on the left side of the screen. Count the divisions and subdivisions along the center horizontal line. Multiply by the SEC/DIV setting to obtain pulse width.

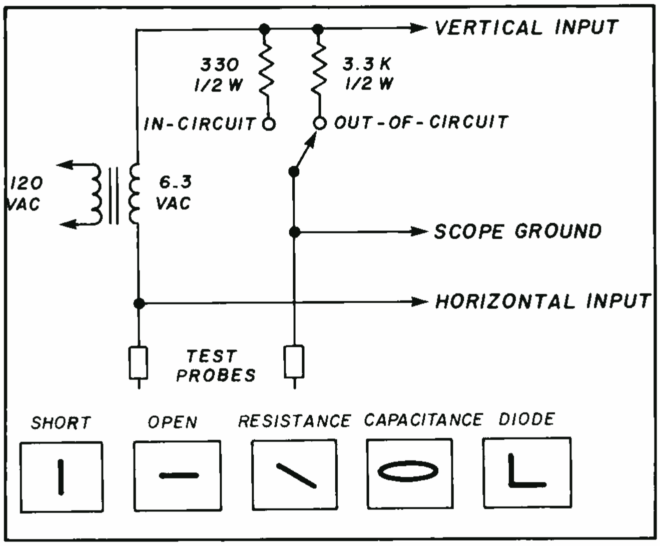


Fig. 6. Frequency measurements with Lissajous patterns require a sine wave of known frequency on one channel. This allows you to determine the frequency of any other signal applied to the other channel by interpreting the resulting pattern displayed on the scope's CRT screen.

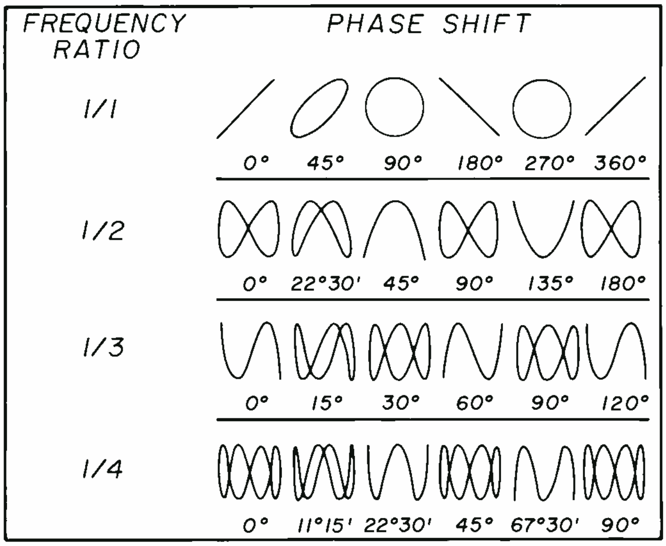


Fig. 7. X-Y checking requires this transistor test circuit to be connected to a scope set to the X-Y mode. Patterns below schematic indicate the component's out-of-circuit condition. In-circuit patterns will differ because of resistors and capacitors associated with the component.

Phase Measurements. A waveform has phase, which is the amount of time that elapses since the onset of the cycle to a given point, measured in degrees. There is also a phase relationship that exists between two or more different-frequency waveforms, known as phase shift.

There are two ways to measure phase shift between two waveforms. One is to feed a separate waveform into each input of a dual-channel scope and view the two directly in the chop or alternate mode, with triggering on either channel. If you choose this method, adjust trigger level for a stable display, and measure the period of the waveforms. Then increase sweep speed to display something like the second drawing in Fig. 5. Measure the horizontal distance between the same points on the two waveforms. The phase shift is the difference in time between the two waveforms divided by the period and multiplied by 360 to obtain degrees.

The other method for measuring phase involves use of the scope's X-Y mode. On the front panel of the scope, you will find the vertical channel inputs labeled X and Y and the last position on the SEC/DIV switch labeled XY. When you use the XY position, the scope's time base is bypassed, and the channel 1 input signal becomes the vertical axis and channel 2 signals becomes the horizontal axis of the scope's display. In the X-Y mode, you can input a different sinusoid on each channel to display a Lissajous pattern, whose shape indicates the phase difference between the two signals. Examples of Lissajous patterns are shown in Fig. 6.

Phase measurements using Lissajous patterns are usually limited by the frequency response of the horizontal amplifier, which is typically designed with far less bandwidth than the vertical channels in an ordinary general-purpose scope. Specialized X-Y scopes and monitors, however, have almost identical vertical and horizontal systems and are therefore, more suitable for this measuring application.

X-Y Measurements. In addition to determining the phase shift of two sinusodial signals with a Lissajous pattern, the X-Y capability can also be used for other measurements as well. Lissajous patterns can be used to determine the frequency of an unknown signal when you have a signal of known frequency on the other channel. This frequency measurement can be very accurate, depending on how accurately you know the known signal to be and if both signals are *sine* waves.

Component checking in service and production situations is another X-Y application. It requires only a simple transistor checker, like that shown in Fig. 7.

There are many other applications for X-Y measurements in television servicing, engine analysis, and two-way radio servicing, to mention just a few areas. In fact, any time you have interdependent but not time-dependent physical phenomena, X-Y measurements are the way to go.

Next month, in the conclusion of this article, we'll go even deeper into the use of the oscilloscope for testing and measuring. **ME**