

# Introduction to the Tektronix TDS210 Oscilloscope

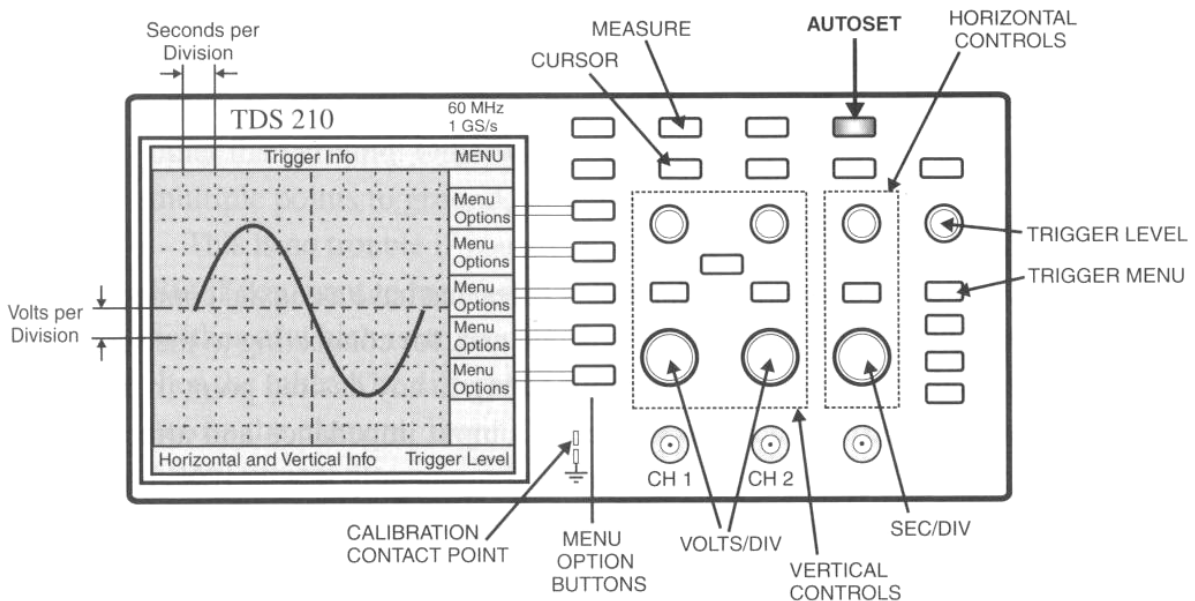
From Daniel M. Kaplan and Christopher G. White, *Hands-On Electronics*, Cambridge University Press, Cambridge, 2003.

## 1.3 Oscilloscope

With its many switches and knobs, a modern oscilloscope can easily intimidate the faint of heart, yet the scope is an essential tool for electronics troubleshooting and you must become familiar with it. Accordingly, the rest of this laboratory session will be devoted to becoming acquainted with such an instrument and seeing some of the things it can do.

The oscilloscope we use is the Tektronix TDS210 (illustrated in Fig. 1.4). If you don't have a TDS210, any dual-trace oscilloscope, analog or digital, can be used for these labs as long as the bandwidth is high enough—ideally, 30 MHz or higher. While the description below may not correspond exactly to your scope, with careful study of its manual you should be able to figure out how to use your scope to carry out these exercises.

The TDS210 is not entirely as it appears. In the past you may have used an oscilloscope that displayed voltage as a function of time on a cathode-ray tube (CRT). While the TDS210 can perform a similar function, it does not contain a CRT (part of the reason it is so light and compact).



**Figure 1.** Illustration of the Tektronix TDS210 digital oscilloscope. The basic features to be used in this tutorial are marked. Note and remember the location of the 'AUTOSET' button—when all else fails, try autose!t!

Until the 1990s, most oscilloscopes were purely 'analog' devices: an input voltage passed through an amplifier and was applied to the deflection plates of a CRT to control the position of the electron beam. The position of the beam was thus a direct analog of the input voltage. In the past few years, analog scopes have been largely superseded by digital devices such as the TDS210 (although low-end analog scopes are still in common use for TV repair, etc.).

A digital scope operates on the same principle as a digital music recorder. In a digital scope, the input signal is sampled, digitized, and stored in memory. The digitized signal can then be displayed on a computer screen.

One of your first objectives will be to set up the scope to do some of the things for which you may already have used simpler scopes. After that, you can learn about multiple traces and triggering. In order to have something to look at on the scope, you can use your breadboard's built-in function generator, a device capable of producing square waves, sinusoidal waves, and triangular waves of adjustable amplitude and frequency. But start by using the built-in 'calibrator' signal provided by the scope on a metal contact labeled 'probe comp' (or something similar), often located near the lower right-hand corner of the display screen.

Note that a leg folds down from the bottom of the scope near the front face. This adjusts the viewing angle for greater comfort when you are seated at a workbench, so we recommend that you use it.

### **1.3.1 Probes and probe test**

Oscilloscopes come with probes: cables that have a coaxial connector (similar to that used for cable TV) on one end, for connecting to the scope, and a special tip on the other, for connecting to any desired point in the circuit to be tested. To increase the scope's input impedance and affect the circuit under test as little as possible, we generally use a '10X' attenuating probe, which has circuitry inside that divides the signal voltage by ten. Some scopes sense the nature of the probe and automatically correct for this factor of ten; others (such as the TDS210) need to be told by the user what attenuation setting is in use.

As mentioned above, your scope should also have a built-in 'calibrator' circuit that puts out a standard square wave you can use to test the probe (see Fig. 1.4). The probe's coaxial connector slips over the 'CH 1' or 'CH 2' input jack and turns clockwise to lock into place. The probe tip has a spring-loaded sheath that slides back, allowing you to grab the calibrator-signal contact with a metal hook or 'grabber'.

An attenuating scope probe can distort a signal. The manufacturer therefore provides a 'compensation adjustment' screw, which needs to be tuned for minimum distortion. The screw is usually located on the assembly that connects the probe to the scope, or, occasionally, on the tip assembly.

- Display the calibrator square-wave signal on the scope. If the signal looks distorted (i.e., not square), carefully adjust the probe compensation using a small screwdriver. (If you have trouble achieving a stable display, try 'AUTOSET'.)
- Check your other probe. Make sure that both probes work, are properly compensated, and have equal calibrations. Sketch the observed waveform.

(Consult your oscilloscope user manual for more information about carrying out a probe test.)

Note that each probe also has an alligator clip (sometimes referred to as the 'reference lead' or 'ground clip'). This connects to the shield of the coaxial cable. It is useful for reducing noise when looking at high-frequency (time intervals of order nanoseconds) or low-voltage signals. Since it is connected directly to the scope's case, which is grounded via the third prong of the AC power plug, it must never be allowed to touch a point in a circuit other than ground! Otherwise you will create a short circuit by connecting multiple points to ground, which could damage circuit components.

This is no trouble if you are measuring a voltage with respect to ground. But if you want to measure a voltage drop between two points in a circuit, neither of which is at ground, first observe one point (with the probe) and then the other. The difference between the two measurements is the voltage across the element. During this process, the reference lead should remain firmly attached to ground and should not be moved! (Alternatively, you can use two probes and configure the scope to subtract one input from the other.)

**Warning:** *A short circuit will occur if the probe's reference lead is connected anywhere other than ground.*

### **1.3.2 Display**

Your oscilloscope user's manual will explain the information displayed on the scope's screen. Record the various settings: timebase calibration, vertical scale factors, etc.

- Explain briefly the various pieces of information displayed around the edges of the screen.

The following exercises will give you practice in understanding the various settings. For each, you should study the description in your oscilloscope user's manual. The description below is specific to the TDS210; if you have a different model, your manual will explain the corresponding settings for your scope.

### **1.3.3 Vertical controls**

There is a set of 'vertical' controls for each channel (see Fig. 1.4). These adjust the sensitivity (volts per vertical division on the screen) and offset (the vertical position on the screen that corresponds to zero volts). The 'CH 1' and 'CH 2' menu buttons can be used to turn the display of each channel on or off; they also select which control settings are programmed by the push-buttons just to the right of the screen.

- Display a waveform from the calibrator on channel 1. What happens when you adjust the POSITION knob? The VOLTS/DIV knob?

### **1.3.4 Horizontal sweep**

To the right of the vertical controls are the horizontal controls (see Fig. 1.4). Normally, the scope displays voltage on the vertical axis and time on the horizontal axis. The SEC/DIV knob sets the sensitivity of the horizontal axis, i.e. the interval of time per horizontal division on the screen. The POSITION knob moves the image horizontally on the screen.

- How many periods of the square wave are you displaying on the screen? How many divisions are there per period? What time interval corresponds to a horizontal division? Explain how these observations are consistent with the known period of the calibrator signal.
- Adjust the SEC/DIV knob to display a larger number of periods. Now what is the time per division? How many divisions are there per period?

### **1.3.5 Triggering**

Triggering is probably the most complicated function performed by the scope. To create a stable image of a repetitive waveform, the scope must 'trigger' its display at a particular voltage, known as the trigger 'threshold'. The display is synchronized whenever the input signal crosses that voltage, so that many images of the signal occurring one after another can be superimposed in the same place on the screen. The LEVEL knob sets the threshold voltage for triggering.

You can select whether triggering occurs when the threshold voltage is crossed from below ('rising-edge' triggering) or from above ('falling-edge' triggering) using the trigger menu (or, for some scope models, using trigger control knobs and switches). You can also select the signal source for the triggering circuitry to be channel 1, channel 2, an external trigger signal, or the 120 V AC power line, and control various other triggering features as well.

Since setting up the trigger can be tricky, the TDS210 provides an automatic setup feature (via the AUTOSET button) which can lock in or almost any repetitive signal presented at the input and adjust the voltage sensitivity and offset, the time sensitivity, and the triggering to produce a stable display.

- After getting a stable display of the calibrator signal, adjust the LEVEL knob in each direction until the scope just barely stops triggering. What is the range of trigger level that gives stable triggering on the calibrator signal? How does it compare with the amplitude of the calibrator waveform? Does this make sense? Explain.

Next connect the scope probe to the breadboard's function generator - you can do this by inserting a wire into the appropriate breadboard socket and grabbing the other end of the wire with the scope probe's grabber. The function generator's amplitude and frequency are adjusted by means of sliders and slide switches.

- Look at each of the waveforms available from the function generator: square, sine, and triangle. Try out the frequency and voltage controls and explain how they work. Adjust the function generator's frequency to about 1 kHz.

- Display both scope channels, with one channel looking at the output of the function generator and the other looking at the scope's calibrator signal. Make sure the vertical sensitivity and offset are adjusted for each channel so that the signal trace is visible.
- What do you see on the screen if you trigger on channel 1 ? On channel 2?
- What do you see if neither channel causes triggering (for example, if the trigger threshold is set too high or too low)?
- How does this depend on whether you select 'normal' or 'auto' trigger mode? Why? (If you find this confusing, be sure to ask for help, or study the oscilloscope manual more carefully.)

### **1.3.6 Additional features**

The TDS210 has many more features than the ones we've described so far. Particularly useful are the digital measurement features. Push the MEASURE button to program these. You can use them to measure the amplitude, period, and frequency of a signal. The scope does not measure amplitude directly. How then can you derive the amplitude from something the scope does measure?

- Using the measurement features, determine the amplitude, frequency, and period of a waveform of your choice from the function generator,

You can also use the on-screen cursors to make measurements.

- Use the cursors to measure the half-period of the signal you just measured.
- Explain how you made these measurements and what your results were.

(A feature that comes in particularly useful on occasion is signal averaging; this is programmed via the ACQUIRE button and allows noise, which tends to be random in time, to be suppressed relative to signal, which is usually periodic.)