CHAPTER 4. THE TRIGGER SYSTEM

So far you've found that the display system draws the waveforms on the screen, the vertical system supplies the vertical information for the drawing, and the horizontal system provides the time axis. In other words, you know how the oscilloscope draws a graph; the only thing missing is the "when": when should the other circuits of your scope start drawing the signal, and when shouldn't they?

The when is the trigger and it's important for a number of reasons. First, because getting time-related information is one of the reasons you use a scope. Equally important is that each drawing start with the same "when."

Obviously the graph drawn on the screen isn't the same one all the time you're watching. If you're using the 0.05 μs SEC/DIV setting, the scope is drawing 1 graph every 0.5 μs (0.05 μs/division times ten screen divisions). That's 2,000,OOO graphs every minute (not counting retrace and holdoff times, which we'll get to shortly). Imagine the jumble on the screen if each sweep started at a different place on the signal.

But each sweep does start at the right time — if you make the right trigger system control settings. Here's how it's done. You tell the trigger circuit which trigger signal to select with the source switches. With an external signal, you connect the trigger signal to the trigger system circuit with the external coupling controls. Next you set the trigger circuit to recognize a particular voltage level on the trigger signal with the slope and level controls Then everytime that level occurs, the sweep generator is turned on. The process is diagrammed in Figure 9.

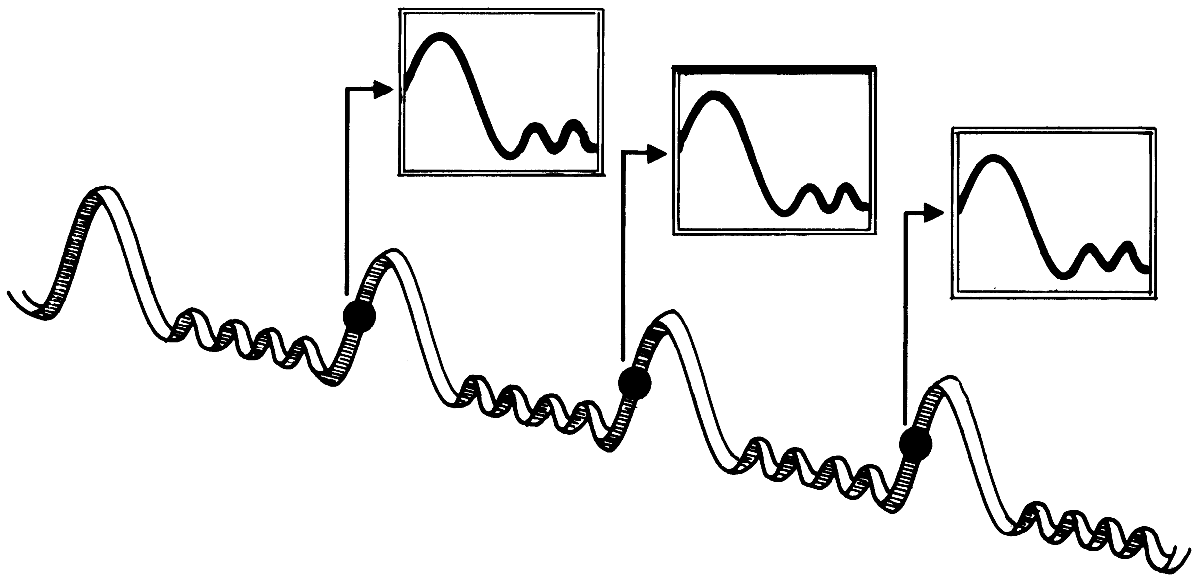

Figure 9.
TRIGGERING GIVES YOU A STABLE DISPLAY because the same trigger point starts the sweep each time. Slope and level controls define the trigger points on the trigger signal. When you look at a waveform on the screen, you're seeing all those sweeps overlaid into what appears to be one picture.

Instruments like those in the Tektronix 2200 Portable Oscilloscope family offer a variety of trigger controls. Besides those already mentioned, you also have controls that determine how the trigger system operates (trigger operating mode) and how long the scope waits between triggers (holdoff).

The control positions are illustrated by the foldout at the end of the primer. All are located on the far right of the front panel. On the 2213, the variable trigger holdoff (VAR HOLDOFF) is at the top, and immediately below it is the trigger MODE switch. Below that the trigger SLOPE and LEVEL controls are grouped. Then a set of three switches controls the trigger sources and the external trigger coupling. At the bottom of the column of trigger controls is the external trigger input BNC connector.

On dual time base 2215 scopes, there is a slightly different control panel layout because you can have a separate trigger for the B sweep.

Trigger Level and Slope

These controls define the trigger point. The SLOPE control determines whether the trigger point is found on the rising or the falling edge of a signal. The LEVEL control determines where on that edge the trigger point occurs. See Figure IO.

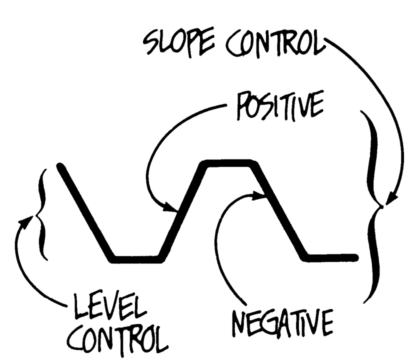

Figure 10.
SLOPE AND LEVEL CONTROLS determine where on the trigger signal the trigger actually occurs. The SLOPE control specifies either a positive (also called the *rising* orpositive-going) edge or on a negative *(falling or negative-going)* edge. The LEVEL control allows you to pick where on the selected edge the trigger event will take place.

Variable Trigger Holdoff

Not every trigger event can be accepted as a trigger. The trigger system will not recognize a trigger during the sweep or the retrace, and for a short time afterward called the ho/doff period. The retrace, as you remember from the last chapter, is the time it takes the electron beam to return to the left side of the screen to start another sweep. The holdoff period provides additional time beyond the retrace that is used to ensure that your display is stable, as illustrated by Figure 11.

Sometimes the normal holdoff period isn't long enough to ensure that you get a stable display; this possibility exists when the trigger signal is a complex waveform with many possible trigger points on it. Though the waveform is repetitive' a simple trigger might get you a series of patterns on the screen instead of the same pattern each time. Digital pulse trains are a good example; each pulse is very much like any other, so there are many possible trigger points, not all of which result in the same display.

What you need now is some way to control when a trigger point is accepted. The variable trigger holdoff control provides the capability. (The control is actually part of the horizontal system — because it adjusts the holdoff time of the sweep generator — but its function interacts with the trigger controls.) Figure 12 diagrams a situation where the variable holdoff is useful.

Trigger Sources

Trigger sources are grouped into two categories that depend on whether the trigger signal is provided internally or externally. The source makes no difference in how the trigger circuit operates' but internal triggering usually means your scope is triggering on the same signal that it is

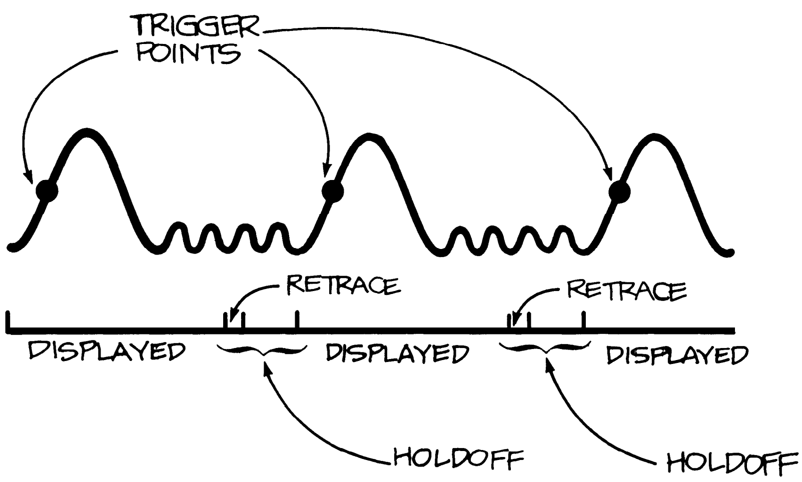

Figure 11.
TRIGGER HOLDOFF TIME ensures valid triggering. In the drawing only the labeled points start the display because no trigger can be recognized during the sweep or the retrace and holdoff period. The retrace and holdoff times are necessary because the electron beam must be returned to the left side of the screen after the sweep, and because the sweep generator needs reset time. The CRT Z axis is blanked between sweeps and unblanked during sweeps.

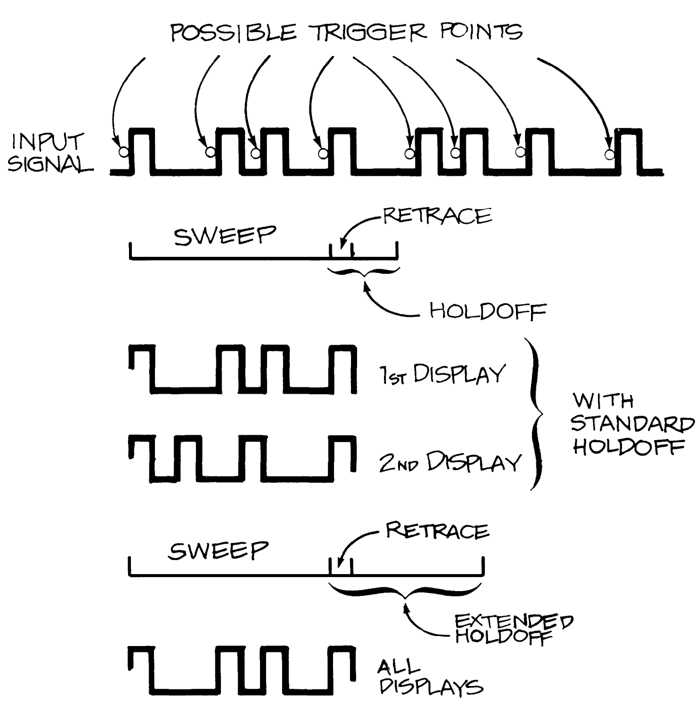

Figure 12.
THE VARIABLE HOLDOFF CONTROL lets you make the scope ignore some potential trigger points. In the example, all the possible trigger points in the input signal would result in an unstable display. Changing the holdoff time to make sure that the trigger point appears on the same pulse in each repetition of the input signal is the only way to ensure a stable waveform.

displaying. That has the obvious advantage of letting you see where you're triggering.

Two switches on the front panel (labeled SOURCE and INT) determine the trigger source. The internal triggering sources are enabled when you move the SOURCE lever to INT. In this position, you can trigger the scope on the signal from either channel, or you can switch to VERT MODE.

Triggering on one of the channels works just like it sounds: you've set the scope to trigger on some part of the waveform present on that channel.

Using the VERTICAL MODE setting on the internal source switch means that the scope's VERTICAL MODE switches determine what signal is used for triggering. If the VERTICAL MODE switches are set at CH 1, then the signal on channel 1 triggers the scope. If you're looking at channel 2, then that channel triggers it. If you switch to the alternate vertical mode, then the scope looks for triggers alternately on the two channels. If the vertical mode is ADD, then CH 1 + CH 2 is the triggering signal. And in the CHOP vertical mode, the scope triggers the same as in ADD, which prevents the instrument from triggering on the chop frequency instead of your signals.

You can see that vertical mode triggering is a kind of automatic source selection that you can use when you must switch back and forth between vertical modes to look at different signals.

But triggering on the displayed signal isn't always what you need, so external triggering is also available. It often gives you more control over the display. To use an external trigger, you set the SOURCE switch to its EXT position and connect the triggering signal to the BNC connector marked EXT INPUT on the front panel. Occasions when external triggering is useful often occur in digital design and repair; there you might want to look at a long train of very similar pulses while triggering with an external clock or with a signal from another part of the circuit.

The LINE position on the SOURCE switch gives you another triggering possibility: the power line. Line triggering is useful anytime you're looking at circuits that are dependent on the power line frequency. Examples include devices like light dimmers and power supplies.

These are all the trigger source possibilities on a 2200 Series scope:

	Switch Positions	
Trigger Source	SOURCE	INT
channel 1 only	INT	CH1
channel 2 only	INT	CH2
external	EXT	disabled
line	LINE	disabled
vertical mode (either channel 1 or 2 or both)	INT	VERT MODE

Trigger Operating Modes

The 2200 Series trigger circuits can operate in four modes: normal, automatic, television, and vertical mode.

One of the most useful is the normal trigger mode (marked NORM on the MODE switch) because it can handle a wider range of trigger signals than any other triggering mode. The normal mode does not permit a trace to be drawn on the screen if there's no trigger. The normal mode gives you the widest range of triggering signals: from DC to 60 MHz.

In the automatic (or "bright baseline") mode (labeled AUTO on the front panel): a trigger starts a sweep; the sweep ends and the holdoff period expires. At that point a timer begins to run; if another trigger isn't found before the timer runs out, a trigger is generated anyway causing the bright baseline to appear even when there is no waveform on the channel. In the 2200 Series, the automatic mode is a signal-seeking auto mode. This means that for most of the signals you'll be measuring, the auto mode will match the trigger level control to the trigger signal. That makes it most unlikely that you will set the trigger level control outside of the signal range. The auto mode lets you trigger on signals with changing voltage amplitudes or waveshapes without making an adjustment of the LEVEL control.

Another useful operating mode is television triggering. Most scopes with this mode let you trigger on tv fields at sweeps of 100 &division and slower, and tv lines at 50 μs/div or faster. With a 2200 Series scope, you can trigger on either fields or lines at any sweep speed; for tv field triggering, use the TV FIELD switch position, and for television line triggering, use the NORM or AUTO settings.

You'll probably use the normal and automatic modes the most often. The AUTO because it's essentially totally automatic, and normal because it's the most versatile. For example, it's possible to have a low frequency signal with a repetition rate that is mismatched to the run-out of an automatic mode timer; when that happens the signal will not be steady in the auto mode. Moreover, the automatic signal-seeking mode can't trigger on very low frequency trigger signals. The normal mode, however, will give you a steady signal at any rep rate.

The last 2200 Series trigger operating mode, the vertical mode, is unique in its advantages. Selecting the VERT MODE position on the INT switch automatically selects the trigger source as you read in "Trigger Source" above. It also makes alternate triggering possible. In this operating mode, the scope triggers alternately on the two vertical channels. That means you can look at two completely unrelated signals. Most scopes only trigger on one channel or the other when the two signals are not synchronous.

Here's a review of the 2200 trigger modes:

Trigger Operating Mode	Switch Settings
normal	NORM on the MODE switch
automatic	AUTO on the MODE switch
television field	TV FIELD on the MODE switch
television line	NORM or AUTO on the MODE switch
vertical mode	VERT MODE on the INT switch

Triggering Coupling

Just as you may pick either alternating or direct coupling when you connect an input signal to your scope's vertical system, you can select the kind of coupling you need when you connect a trigger signal to the trigger system's circuits. For internal triggers, the vertical input coupling selects the trigger coupling. For external trigger signals, however, you must select the coupling you want:

Coupling	Applications
DC	DC couples all elements of the triggering signal (both AC and DC) to the trigger circuit.
DC with attenuation	If you want DC coupling and the external trigger is too large for the trigger system, move the TRIGGER COUPLING switch to its DC÷10 setting.
AC	This coupling blocks DC components of the trigger signal and couples only the AC components.

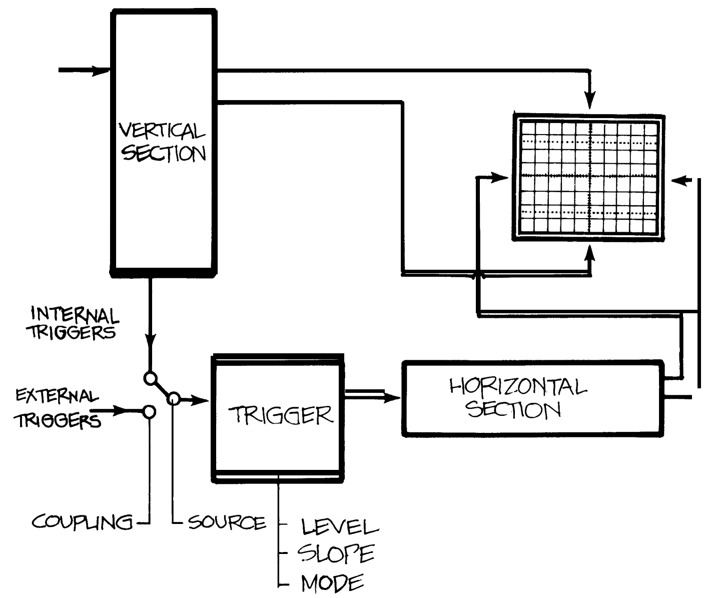

Figure 13.
THE TRIGGER CIRCUIT AND ITS CONTROLS are shown in the diagram above. Trigger source describes whether or not the trigger signal is internal or external to the scope. Coupling controls the connection of an external trigger to the trigger circuit. The level and slope controls determine where the trigger point will be on the trigger signal. And the mode control determines the operations of the trigger circuit.

Using the Trigger Controls

To review what you've learned about the trigger circuit and its controls (shown schematically in Figure 13), first make sure all your controls are in these positions:

- 0.5 VOLTS/DIV on channel 1 and VAR in its detent position;
- AC vertical coupling;
- CH 1 on the VERTICAL MODE switch;
- 0.5 ms sweep speed and no magnification or variable SEC/DIV;
- your trigger settings should be AUTO for MODE, INT for SOURCE, and CH 1 for INT

Turn your scope on with the probe connected to the channel 1 BNC connector and the probe adjustment jack. Use the foldout figure to remind yourself of the control locations and follow the directions in Exercise 5.

Exercise 5. TRIGGER CONTROLS

1. *Move the trace to the right with the horizontal POSITION control until you can see the beginning of the signal (you'll probably have to increase the intensity to see the faster vertical part of the waveform). Watch the signal while you operate the SLOPE control. If you pick +,* the signal on the screen starts with a rising edge; the other SLOPE control position makes the scope trigger on a falling edge.

2. Now *move the LEVEL control back and forth through all its travel; you'll see the leading edge climb up and down the signal. The scope remains triggered because you are using the AUTO setting.*

3. Turn the MODE switch to NORM. Now when you use the LEVEL control to move the trigger point, you'll find places where the scope is untriggered. This is an illustration of the essential difference between normal and automatic triggering.

4. You can also see the difference between the two triggering modes by using channel 2, even with that channel coupled to GND for ground. Change both the vertical display mode and the INT (2275:A&B INT) switches to CH 2. With NORM triggering, there's no signal; with AUTO, you'll see the baseline. Try it.

5. Without a trigger signal applied to the EXT INPUT BNC connector, it's impossible to show you the use of this trigger source, but the trigger MODE, SLOPE, and LEVEL controls will all operate the same for either internal or external triggers. One difference between internal and external sources, however, is the sensitivity of the trigger circuit. All external sources are measured in voltage (say 750 millivolts) while the in ternal sources are rated in divisions. In other words, for internal signals, the displayed amplitude makes a difference. Now change the VERTICAL MODE and INT switches back to CH 7, and switch to the NORM mode. Use the LEVEL control and notice how much control range there is. Now change the CH 7 VOLTS/D/V switch to 0.7 V and use the LEVEL control. There's more control range now.

6. The alternate-channel triggering with vertical mode triggering can't be demonstrated without two unrelated signals on the channels, but you'll find it useful the first time such an occasion comes up. You can take another look at the difference between the normal and auto trigger operating modes. Move the LEVEL control slowly in the NORM mode until the scope is untriggered. Now switch the trigger operating mode to AU TO and note that the waveform is automatically triggered.