C H A P T E R E I G H T : *Trigger Smart*

More about Edge triggering. And introducing the SMART Trigger range for capturing complex waveform characteristics.

In this chapter, see how

To hold off with Edge Trigger

To capture rare phenomena with Glitch trigger

To set up an exclusion trigger

To determine trigger level, coupling and slope

To trigger on intervals

To use State and Edge Qualified triggers

To trigger on lost signals using Dropout trigger

To trigger on TV signals

Pattern Trigger

86

Hold Off by Time or Events

Holdoff is an additional condition of Edge trigger (see Chapter 2, "Simply Trigger"). It can be expressed either as a period of time or an event count. Holdoff disables the trigger circuit for a given period of time or events after the last trigger occurred. Events are the number of occasions on which the trigger condition is met. The trigger will again occur when the holdoff has elapsed and the trigger's other conditions are met. Use holdoff to obtain a stable trigger for repetitive, composite waveforms. For example, if the number or duration of sub-signals is known you can disable them by choosing an appropriate holdoff value. Qualified triggers operate using conditions similar to holdoff (see page 100).

HOLD OFF BY TIME

Sometimes you can achieve a stable display of complex, repetitive waveforms by placing a condition on the time between each successive trigger event. This time would otherwise be limited only by the input signal, the coupling, and Waverunner's bandwidth. Select a positive or negative slope, and a minimum time between triggers. The trigger is generated when the condition is met after the selected holdoff time, counted from the last trigger (Fig.1). Any time between 10 ns and 20 s can be selected. The delay is initialized and started on each trigger.
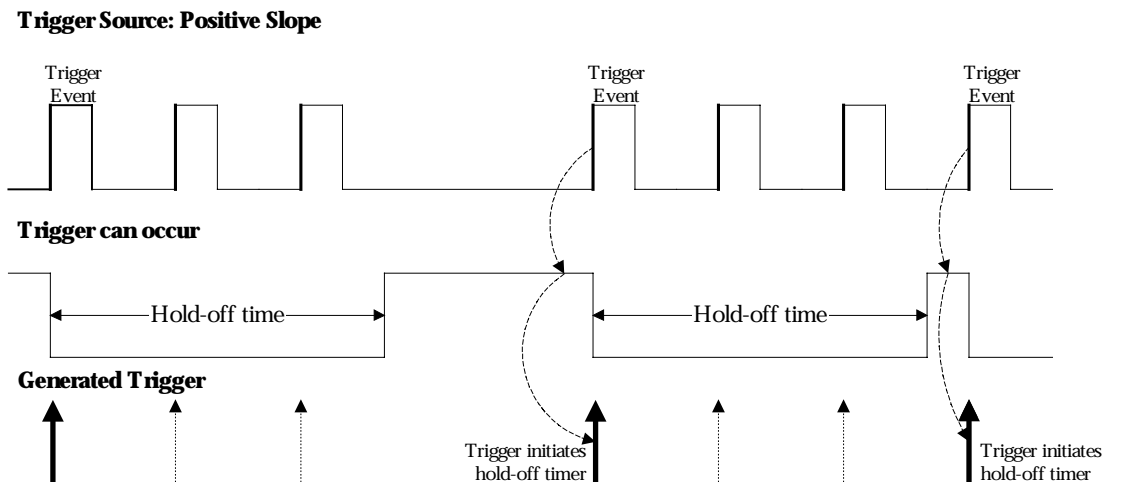
Trigger Source: Positive Slope

Figure 1. Edge Trigger with Holdoff by Time. The bold edges on the trigger source indicate that a positive slope has been selected. The broken upward-pointing arrows indicate potential triggers, which would occur if other conditions are met. The bold arrows indicate where the triggers actually occur when the holdoff time has been exceeded.

HOLD OFF BY EVENTS

Select a positive or negative slope and a number of events. An event is the number of times the trigger condition is met after the last trigger. A trigger is generated when the condition is met after this number, counted from the last trigger. The count is initialized and started on each trigger. For example, if the selected event number is two (Fig. 2), the trigger will occur on the third event. From one to 99 999 999 events can be selected.

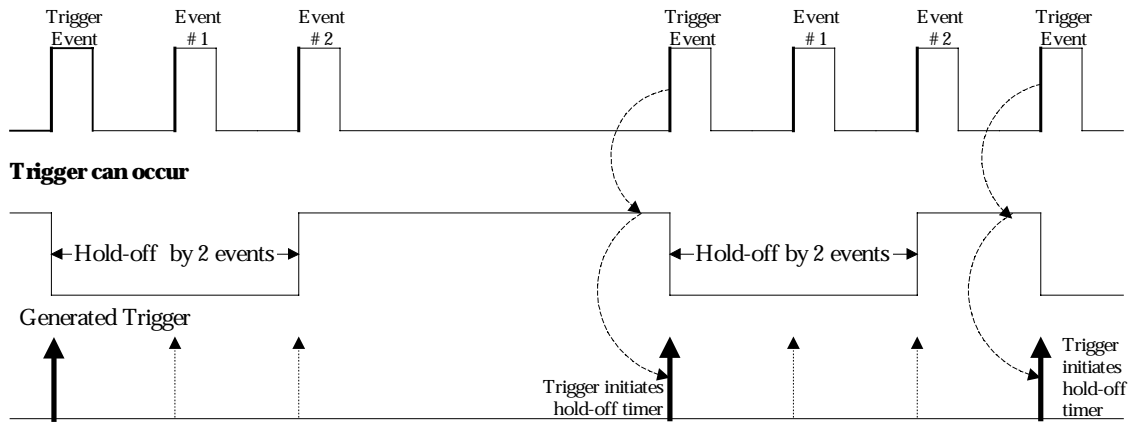**Trigger Source: Positive Slope**

Figure 2. Edge Trigger with Holdoff by Events (in this example, two events). The bold edges on the trigger source indicate that a positive slope has been selected. The broken, upward-pointing arrows indicate potential triggers, while the bold ones show where triggers actually occur after the holdoff expires.
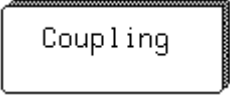
88

Trigger SMART

You have seen how to trigger on signals using Edge trigger, and the conditions of level, coupling and slope, and holdoff. Waverunner also offers a range of sophisticated triggers that enable you to trigger on these conditions, as well as many other complex waveform characteristics. Use the SMART Trigger range to set additional qualifications before a trigger is generated. Catch rare phenomena such as glitches or spikes, specific logic states, or missing bits. Capture intervals, abnormal signals, or TV signals. Trigger on state or edge qualified events and dropouts.

CATCH A GLITCH

Finding and capturing elusive glitches — abnormally wide pulses in a signal — is simple with the Glitch trigger.
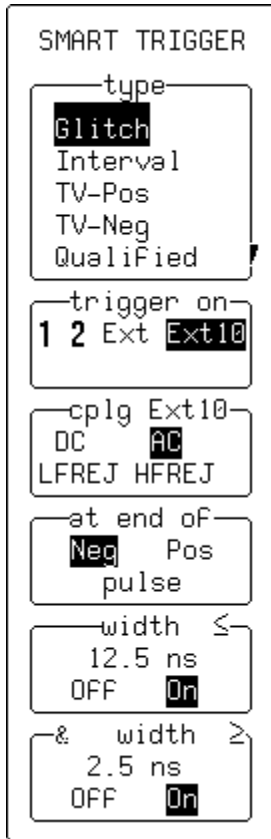
1. Connect your signal to the Waverunner.

2. Simultaneously press the second and fifth menu buttons from the top, and `1` to return the scope to its default power-up settings. And turn off any unwanted displayed trace.

3. Press the button for `Coupling` and set Coupling to match the source signal's impedance.

4. Press `AUTO SETUP` and then `STOP` to display a normal waveform. Viewing this signal during several captures would reveal the occasional glitch. The goal of the measurement is to catch this event by setting a trigger adapted to it.

5. Press TRIGGER `SETUP` and then the button to select `Edge SMART (Glitch)`

6. Press the button for `SETUP SMART TRIGGER` and display these menus:

```
SMART TRIGGER
┌──────type──────┐
│ Glitch         │
│ Interval       │
│ TV-Pos         │
│ TV-Neg         │
│ Qualified      │
└────────────────┘
┌───trigger on───┐
│ 1 2 Ext  Ext10 │
└────────────────┘
┌───cplg Ext10───┐
│ DC        AC   │
│ LFREJ HFREJ    │
└────────────────┘
┌───at end of────┐
│ Neg      Pos   │
│    pulse       │
└────────────────┘
┌───width    ≤───┐
│ 12.5 ns        │
│ OFF       On   │
└────────────────┘
┌─&   width  ≥───┐
│ 2.5 ns         │
│ OFF       On   │
└────────────────┘
```

Use these menus to set up to trigger on a glitch, or to create an exclusion trigger (see page 93).

7. Select **Glitch** to catch pulses of a chosen width. Capture narrow pulses less than or equal to, or greater than or equal to, a given time limit: the pulse's width. You can also set up to exclude or include certain events (see page 93).

8. Select the trigger source. This could be a signal on a channel, the line voltage that powers the Waverunner or the EXT connector.

9. Select the coupling for the trigger source.

10. Place the trigger point at the end of a positive or negative slope. See NOTE this page.

11. Press the button to set to **On** and to trigger if the pulse is less than or equal to the value set with the knob (range: 2.5 ns to 20 s). Use in combination with "width ≥" below.

12. Press the button to set to **On** and to trigger if the pulse is greater than or equal to the value set with the knob (range: 2.5 ns to 20 s). Use in combination with "width ≤," combined to target glitches within ("&") a certain range if the "width ≤" value is greater than the "width ≥" value. "OR" in the menu indicates that glitches above or below this range will be targeted.

NOTE: Waverunner must first "see" the pulse before it can tell its width and know exactly when to trigger. If the glitch on which you want to trigger is on a negative pulse, choose "Pos" from the <u>at end of</u> menu. But if the glitch is on a positive pulse, choose "Neg."

TIP: Use Persistence to reveal the glitch shape, then match the trigger level to the level at which the glitch appears.

NORMAL

13. Press [ ] to arm the scope. Then wait for the trigger condition to become valid. See next page.
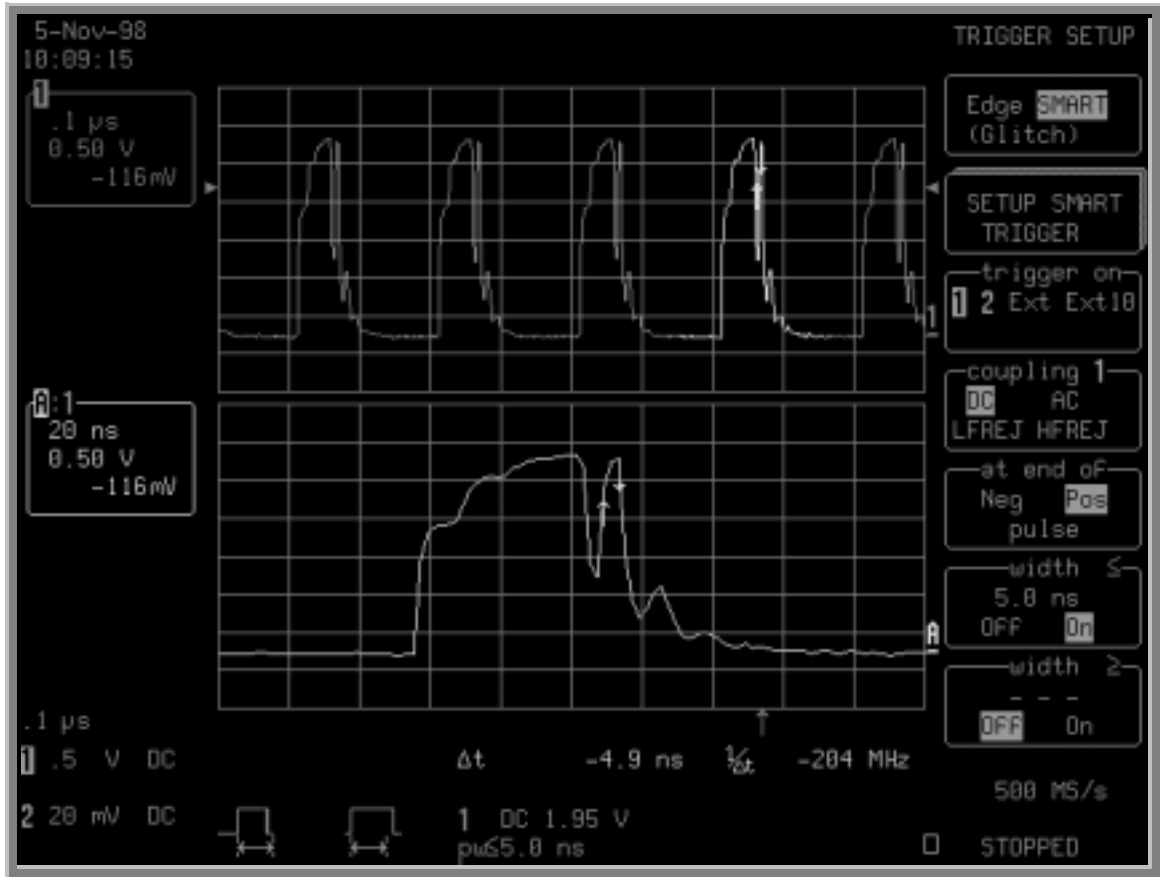
Trigger on a glitch of width ≤5.0 ns on the negative slope. Here, the glitch is marked by arrow cursors on the waveform. Trace A on the lower grid is a zoom of the waveform on the top grid. Information on the trigger is given beneath the grid.

NOTE: If, for example, the glitch's width is lower than the signal's, set the trigger to a smaller width than that of the signal. The signal's width as determined by the Waverunner trigger comparator depends on the DC trigger level. And if that level were to be set at the middle of a sine wave, for example, the width could then be considered as the half period. But if the level were higher, the signal's width would be considered to be less than the half period.

How Glitch Trigger Works

Pulse smaller than selected pulse width: *Select a maximum pulse width (Fig. 3). This glitch trigger is generated on the selected edge when the pulse width is less than or equal to the selected width.*

The timing for the width is initialized and restarted on the opposite slope to that selected. Widths of between 2.5 ns and 20 s can be selected, but typically triggering will occur on glitches 2 ns wide.
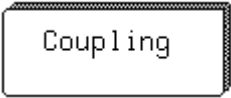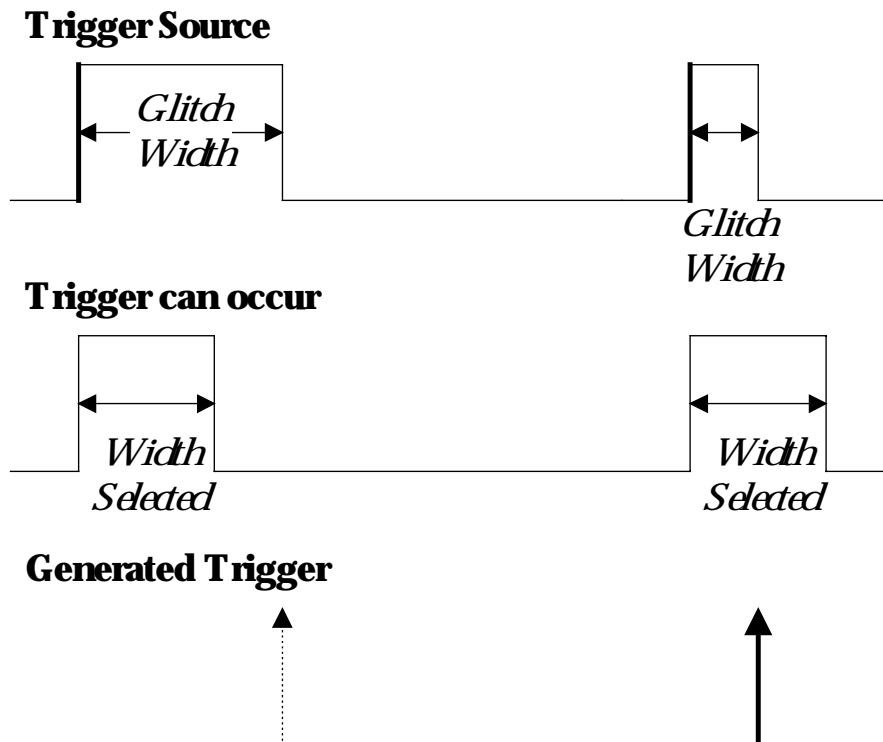

Figure 3. Glitch Trigger: in this example triggering on a pulse width less than or equal to the width selected. The broken upward arrow indicates a potential trigger, while the bold one shows where the actual trigger occurs.

CAPTURE RARE PHENOMENA

Use glitch trigger settings to select width conditions that exclude events falling inside or outside of a selected width range. Only pulses less than or equal to, or greater than or equal to, this range will generate a trigger event. Waverunner initializes the timing for the width and restarts on the slope opposite the selected edge. You can select the same width values as those for glitch trigger.

1. Connect to Channel 1, for example, a signal whose multiple glitches have a low duty cycle and that cannot be seen using Edge trigger or Analog Persistence.

2. Press the button for   Coupling   and set Coupling to match the source impedance.
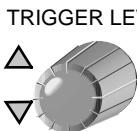
3. Press **AUTO SETUP** and then **STOP** to display a normal waveform. Viewing this signal during several captures would reveal the occasional glitch. The goal of the measurement is to catch this event by setting a trigger adapted to it.

4. Press TRIGGER **SETUP** and then the button to select   Edge SMART (Glitch)

5. Press the button to   SETUP SMART TRIGGER   to display and set up the Glitch trigger menus.

Set up the trigger to eliminate nominal pulses of a particular width. Waverunner will then only trigger on those waveforms that do not have this pulse width.

6. Press the button to select **1** from the "trigger on" menu.

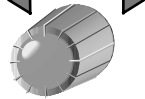7. Turn **TRIGGER LEVEL** to adjust the trigger's level to one division from the top of the pulse, for example.

8. Press the button to select **Pos** from the "at end of" menu, and **On** from the "width ≤" menu.

9. Turn the knob to set the "≤ width" value.

10. Press the button to select **On** from the "width ≥" menu, and turn the knob to set the ≥ width value.

DELAY
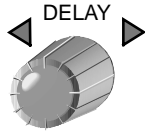
11. Turn ⬤ to set the trigger point close to mid-grid.

NORMAL

12. Press ▭ to start triggering.

TIP: Use Analog Persistence to display a history of your exceptional pulse captures, such as the one at right.

Enhance your display still further by combining Exclusion trigger with Pass/Fail testing. The trigger speeds the acquisition of exceptional pulses, while the mask testing verifies the wave shape.

Store the waveform or print the screen display to document each pulse individually.

Display waveform parameter statistics under the grid for additional information on the key waveform parameters of these pulses. Use this new information to change the trigger setup to concentrate on acquiring pulses with more specific characteristics.
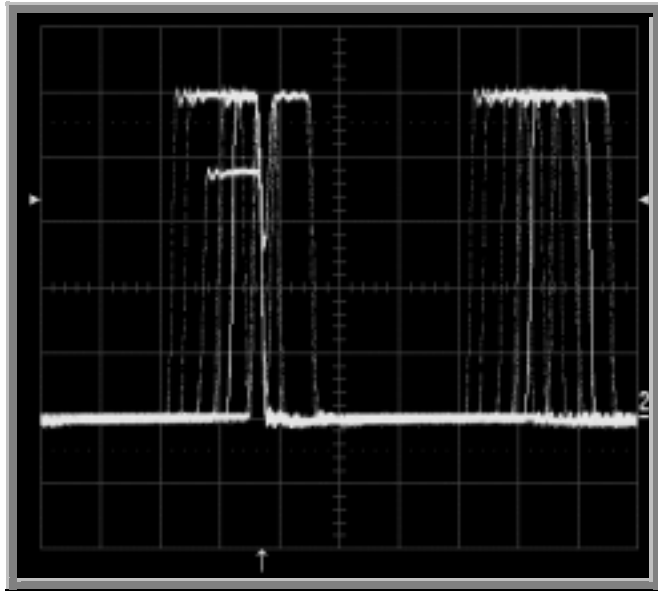
Exclusion trigger: Persistence display.

TO DETERMINE LEVEL, COUPLING, AND SLOPE

Level *defines the source voltage at which the trigger circuit will generate an event (a change in the input signal that satisfies the trigger conditions). The selected trigger level is associated with the chosen trigger source.*

Trigger level is specified in volts and normally remains unchanged when you change the vertical gain or offset. The amplitude and range of the trigger level are limited as follows:

±5 screen divisions with a channel as the trigger source

±0.5 V with EXT as the trigger source

±5 V with EXT/10 as the trigger source

None with LINE as the trigger source (zero crossing is used)

Coupling *refers to the type of signal coupling at the input of the trigger circuit. As with the trigger level, you can select the coupling independently for each source. Change the trigger source and you may change the coupling. You can choose from these coupling types:*

DC: *All the signal's frequency components are coupled to the trigger circuit for high-frequency bursts or where the use of AC coupling would shift the effective trigger level.*

AC: *The signal is capacitively coupled; DC levels are rejected and frequencies below 50 Hz attenuated.*
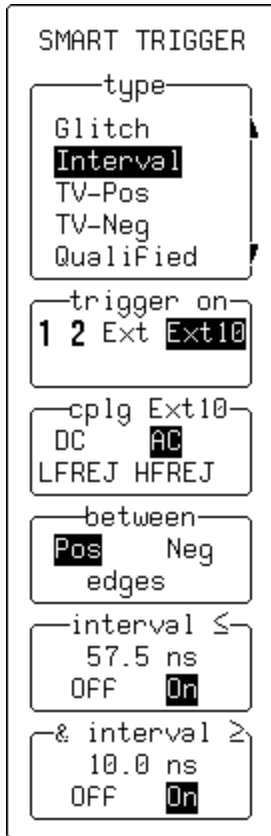
LF REJ: *The signal is coupled through a capacitive high-pass filter network, DC is rejected and signal frequencies below 50 kHz are attenuated. For stable triggering on medium to high frequency signals.*

HF REJ: *Signals are DC coupled to the trigger circuit, and a low-pass filter network attenuates frequencies above 50 kHz. It is used for triggering on low frequencies.*

Slope *determines the direction of the trigger voltage transition used for generating a particular trigger event. You can choose a positive or negative slope. Like coupling, the selected slope is associated with the chosen trigger source.*

TRIGGER ON INTERVALS

While Glitch trigger performs over the width of a pulse, Interval trigger performs over the width of an interval — the signal duration (the period) separating two consecutive edges of the same polarity: positive to positive or negative to negative. Use Interval trigger to capture intervals that fall short of, or exceed, a given time limit. In addition, you can define a width range to capture any interval that is itself inside or outside the specified range — an Exclusion trigger by Interval.

```
SMART TRIGGER
┌──────type──────┐
  Glitch
  Interval
  TV-Pos
  TV-Neg
  QualiFied
┌───trigger on───┐
 1 2 Ext  Ext10
┌───cplg Ext10───┐
 DC       AC
 LFREJ HFREJ
┌─────between─────┐
 Pos      Neg
     edges
┌───interval ≤───┐
    57.5 ns
 OFF      On
┌──& interval ≥──┐
    10.0 ns
 OFF      On
```

Use these menus to set up for triggering on an interval.
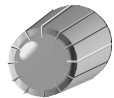
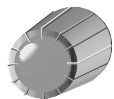1. Select **Interval**.

2. Select the trigger source.

3. Select the coupling for the trigger source.

4. Place the trigger point on the positive or negative edge of the selected pulse.

5. Select **On** to trigger if the pulse is less than or equal to the value set with the knob (range: 2.5 ns to 20 s). Use in combination with "width ≥."

6. Select **On** to trigger if the pulse is greater than or equal to the value set with the knob (range: 2.5 ns to 20 s). Use in combination with "width ≤," combined to target intervals within ("&") a certain range if the "width ≤" value is greater than the "width ≥" value. **OR** in the menu indicates that intervals above or below this range will be targeted.

96

How Interval Triggers Work

Interval Smaller: *For this Interval Trigger, generated on a time interval smaller than the one selected, choose a maximum interval between two like edges of the same slope — positive, for example (Fig. 4).*

The trigger is generated on the second (positive) edge if it occurs within the selected interval. Waverunner initializes and restarts the timing for the interval whenever the selected edge occurs. You can select an interval of between 10 ns and 20 s.

Trigger Source: Positive Slope

Interval Width

Interval Width

Trigger can occur

Selected Interval

Selected Interval

Generated Trigger

Figure 4. Interval Trigger that triggers when the interval width is smaller than the selected interval. The broken, upward-pointing arrow indicates a potential trigger, while the bold one shows where the actual trigger occurs — on the positive edge within the selected interval.

Interval Larger: *For this Interval Trigger, generated on an interval larger than the one selected, select a minimum interval between two edges of the same slope (Fig. 5). Waverunner generates the trigger on the second edge if it occurs after the selected interval. The timing for the interval is initialized and restarted whenever the selected edge occurs. You can select intervals of between 10 ns and 20 s.*

Trigger Source: Positive Slope

Interval Width — *Interval Width*

Trigger can occur

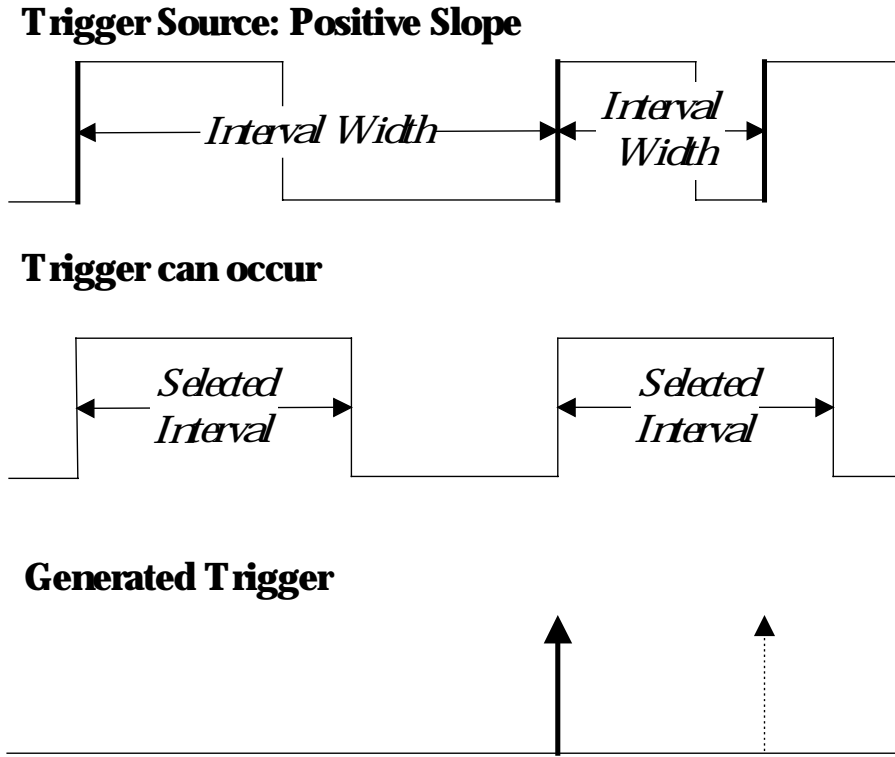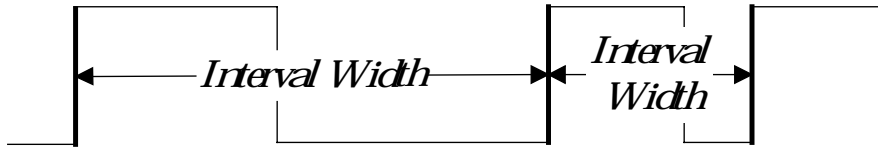*Selected Interval* — *Selected Interval*

Generated Trigger

Figure 5. Interval Trigger that triggers when the interval width is larger than the selected interval. The broken upward-pointing arrow indicates a potential trigger, while the bold one shows where the actual trigger occurs — on the positive edge after the selected interval.
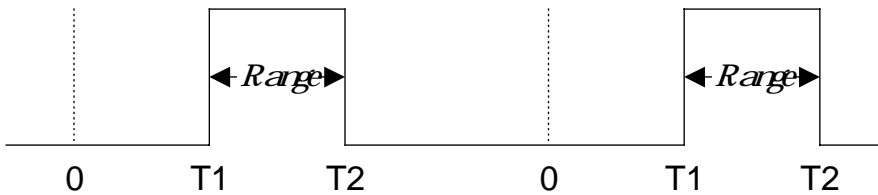
Interval Between Range: *This Interval Trigger is generated whenever an interval between two edges of the same slope falls within a selected range (Fig. 6). Waverunner initializes and restarts the timing for the interval whenever the selected edge occurs. You can select intervals of between 10 ns and 20 s.*

## Trigger Source: Positive Slope

Trigger can occur

Generated Trigger

Figure 6. Interval Trigger that triggers when the interval falls within the selected range: T1 = range's lower time limit; T2 = range's upper limit. The broken upward pointing arrow indicates a potential trigger, while the bold one indicates where the actual trigger occurs — on the positive edge within the selected range.

QUALIFY A SIGNAL

Use a signal's transition above or below a given level — its validation — as an enabling (qualifying) condition for a second signal that is the trigger source. These are Qualified triggers. With State Qualified trigger, the amplitude of the first signal must remain in the desired state until the trigger occurs. While for Edge Qualified trigger the validation is sufficient and no additional requirement is placed on the first signal. A Qualified trigger can occur immediately after the validation or within a set time after it. Or it can occur following a predetermined time delay or number of potential trigger events. The time delay or trigger count is restarted with every validation.
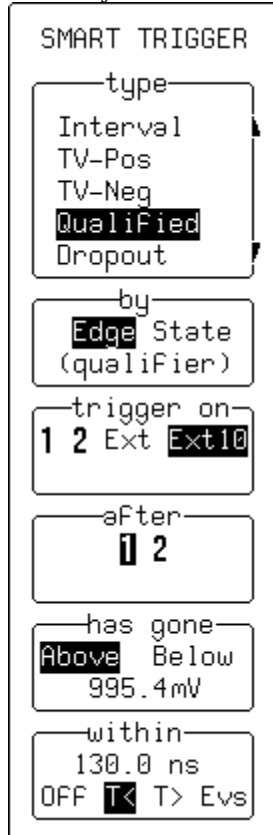
Use these menus to set up an Edge or State Qualified trigger.
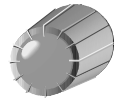
1. Select **Qualified**.

2. Select **Edge** or **State** as the qualifier. (Set conditions such as the coupling, slope, and holdoff using the Edge trigger menus.)

3. Select the trigger source. This could be a channel, EXT, or EXT 10.

4. Select the qualifier source. This could be a channel, EXT or EXT 10, depending on your choice of trigger source.

5. Turn to adjust the qualifier threshold, and press to determine whether the qualifier signal is valid once it "has gone" (Edge Qualified) or "goes and stays" (State Qualified) above or below that threshold.
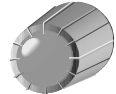
6. Specify the time limit ("within" **T<**) for accepting the trigger event. Or, specify the delay in time ("wait" **T>**) or number of trigger events ("wait" **Evs**) after a valid transition has occurred. A trigger can only be accepted after this delay. Any subsequent qualifier event restarts the count. The time value can be set in the range 10 ns–20 s. The trigger event count can be set in the range 1–99 999 999.

HOW QUALIFIED TRIGGERS WORK

State Qualified and Wait *(Fig. 7) is determined by the parameters of Time or Events.*

Time *determines a delay from the start of the desired pattern. After the delay (timeout) and while the pattern is present, a trigger can occur. The timing for the delay is restarted when the selected pattern begins.*

Events *determines a minimum number of events of the trigger source. An event is generated when a trigger source meets its trigger conditions. On the selected event of the trigger source and while the pattern is present, a trigger can occur. The count is initialized and started whenever the selected pattern begins, and continues while the pattern remains. When the selected count is reached, the trigger occurs.*
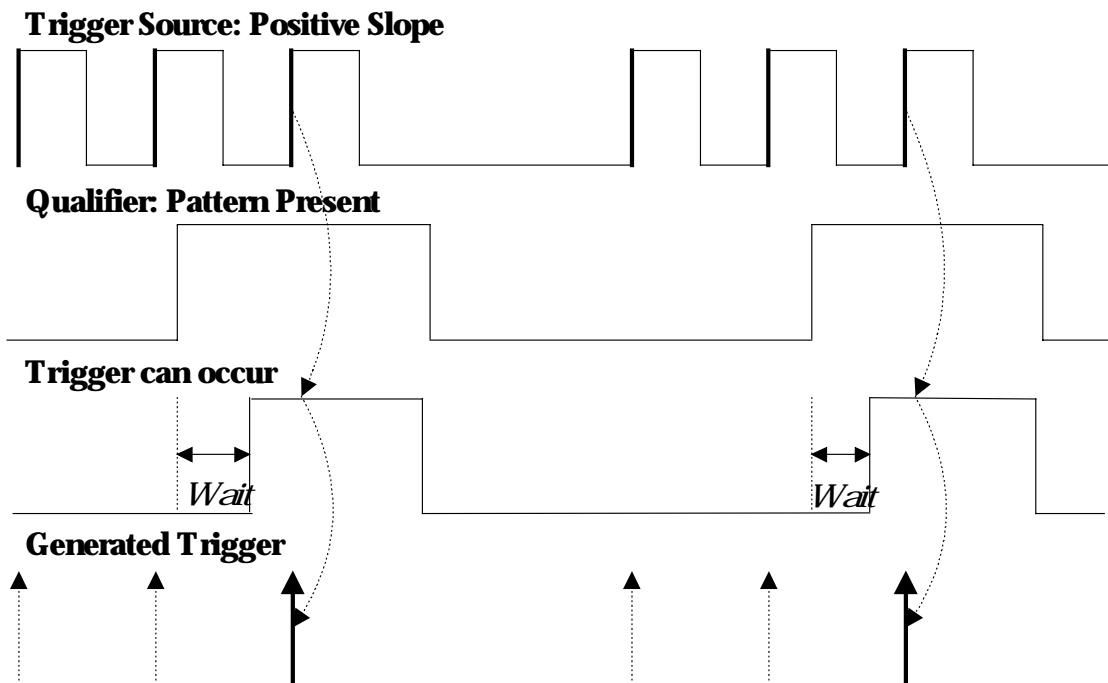

Figure 7. State Qualified and Wait: Trigger after timeout. The broken upward pointing arrows indicate potential triggers, while the bold arrows show where the actual triggers occurs.

Edge Qualified and Wait *(Fig. 8) is also conditioned by either Time or Events:*

Time *determines a delay from the start of the desired pattern. After the delay (timeout) and before the end of the pattern, a trigger can occur. The timing for the delay is restarted when the selected pattern begins.*

Events *determines a minimum number of events for the trigger source. An event is generated when a trigger source meets its trigger conditions. A trigger can occur on the selected event of the trigger source and before the end of the pattern. The count is initialized and started whenever the selected pattern begins. It continues while the pattern remains. When the selected count is reached, the trigger occurs.*
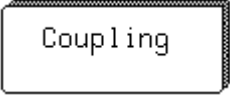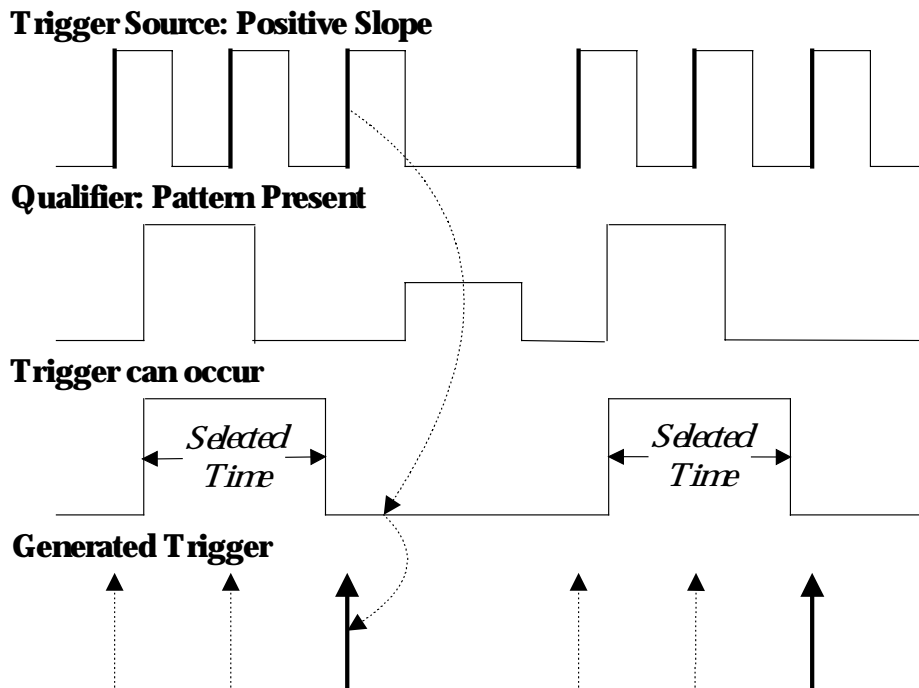

Figure 8. Edge Qualified and Wait: Trigger after timeout. The broken upward pointing arrows indicate potential triggers, while the bold ones show where the actual trigger occurs.

TRIGGER ON LOST SIGNALS

Use Dropout trigger whenever your signal disappears for a set period of time. The trigger is generated at the end of the timeout period following the "last" trigger source transition (Fig. 9, page 105). Timeouts of between 25 ns and 20 s can be selected. Dropout trigger is used essentially for single-shot applications — usually with a pre-trigger delay.
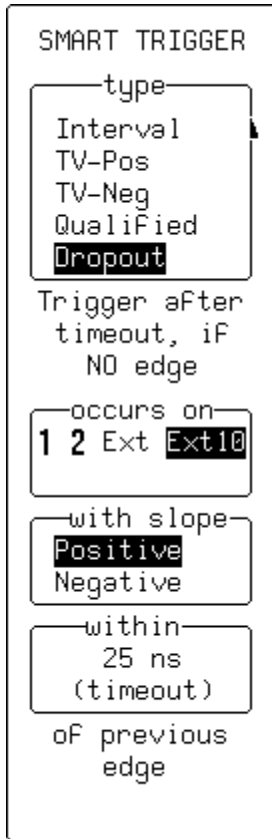
1. Connect the signal to be measured to Channel 1.

2. Press the button for ⬛ Coupling ⬛ and set Coupling to match the source impedance.

   AUTO
   SETUP
3. Press ⬛ twice to display the waveform. The following steps set the Dropout trigger to capture only the "last normal" period of the signal and transient signal.

   SETUP
4. Press TRIGGER ⬛ and then the button to select ⬛ Edge **SMART** (Glitch) ⬛

5. Press the button for ⬛ SETUP SMART TRIGGER ⬛ to display the menus shown on the next page.

```
SMART TRIGGER
┌──────type──────┐
  Interval
  TV-Pos
  TV-Neg
  Qualified
  [Dropout]
└────────────────┘
  Trigger after
  timeout, if
    NO edge
┌────occurs on────┐
 1 2 Ext [Ext10]
└─────────────────┘
┌───with slope───┐
  [Positive]
  Negative
└────────────────┘
┌──────within──────┐
    25 ns
   (timeout)
└──────────────────┘
  of previous
    edge
```

Use these menus to set up the Dropout trigger.

6.   Select **Dropout**.

> *TIP: Use Dropout Trigger when viewing signals on more than one channel (you can view the signal characteristics on a channel other than the trigger source). To trigger the scope when a signal disappears, make the timeout longer than the signal period. The Waverunner will not trigger when the repetitive signal is active, because two successive edges occur in a single period.*
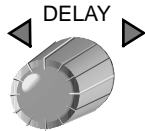
7.   Select the trigger source.

8.   Select the slope.
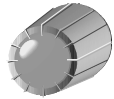
9.   Turn to set the timeout (25 ns by default).

DELAY

10.   Turn ◁ ▷ to set the trigger point to allow display of the signal's "last normal" period.

When the signal disappears, the Waverunner triggers.

HOW DROPOUT TRIGGER WORKS

Trigger Source

Trigger can occur

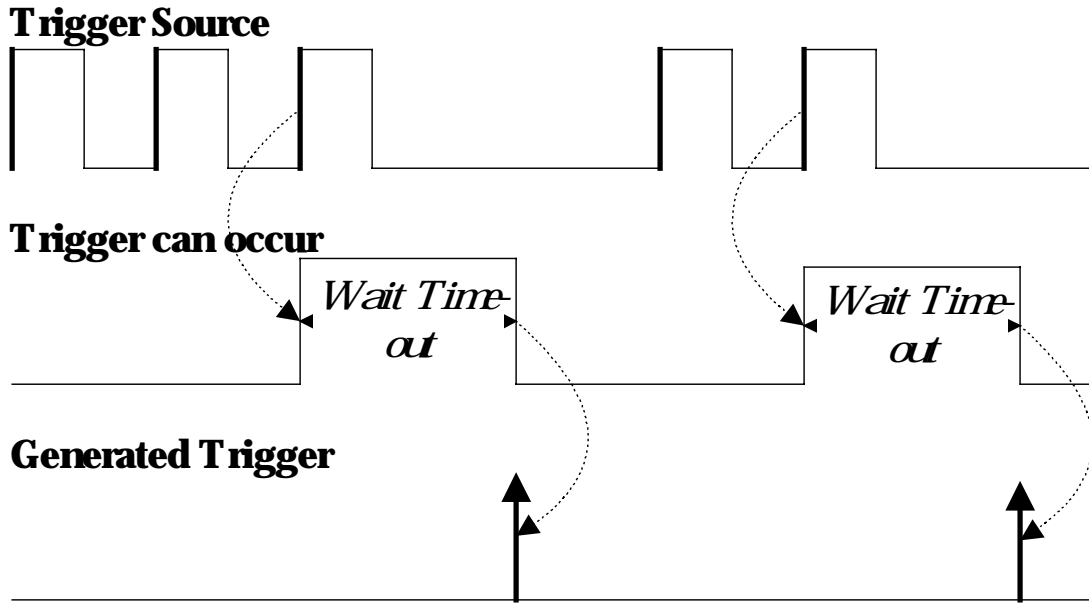*Wait Time-out*

Wait Time-out

Generated Trigger

Figure 9. Dropout Trigger: occurs when the timeout has expired. The bold upward-pointing arrows show where the trigger occurs.

TRIGGER ON TV SIGNALS

Waverunner's TV triggers provide stable triggering on standard or custom composite video signals. Use them on PAL, SECAM, or NTSC systems. A composite video signal on the trigger input is analyzed to provide a signal for the beginning of the chosen field — "any," "odd," or "even" — and for a signal at the beginning of each line. The field signal provides the starting transition, and the beginnings of line pulses are counted to allow the final trigger on the chosen line. Each field, the number of fields, the field rate, interlace factor, and number of lines per picture must be specified — although there are standard settings for the most common types of TV signals. TV Trigger can also function in a simple any-line mode.
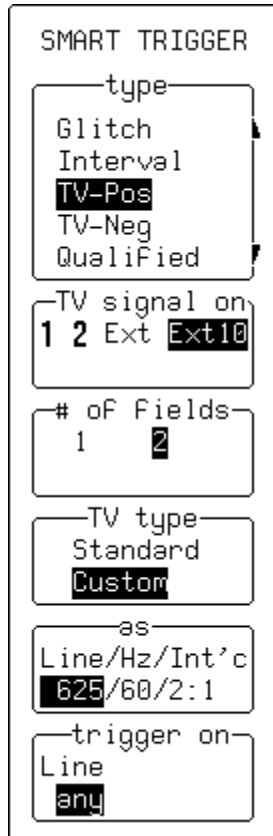
Use these menus to set up a TV trigger.

1. Select **TV-Pos** or **TV-Neg** polarity.

2. Select the trigger source.

3. Specify the number of fields or define the field number. For the LT364 series, you have the choice of **1**, **2**, **4**, or **8** fields. For all other models: **1**= odd, **2**= even.
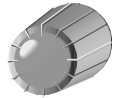
4. Select **Standard** or **Custom** TV decoding.

5. **Standard**: Select either **625/50/2:1** (PAL, SECAM) or **525/60/2:1** (NTSC) standard. **Custom**: Specify the number of lines and cycles, and set the interlacing factor for non-standard TV signals.
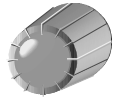
6. Define the line on which to trigger with the knob: **any** allows you to trigger on any line number.

TO USE TV TRIGGERS

Most TV systems have more than two fields. Waverunner's enhanced field counting capability (FIELDLOCK) allows you to trigger consistently on a chosen line within a signal field.

*The field numbering system is relative: the oscilloscope will trigger on odd or even fields for LT34x, LT32x, and LT22x scopes. For the LT364 series, select **1**, **2**, **4**, or **8** fields.*

***625/50/2:1 (PAL and SECAM systems):** Use for most of the standard 50-field signals. The lines can be selected in the range 1 to 626 where line 626 is identical to line 1.*

***525/60/2:1 (NTSC systems):** Use for standard 60-field NTSC signals. The lines can be selected in the range 1 to 1051, where line 1051 is identical to line 1.*

***?/50/?, ?/60/?:** For maximum flexibility, no line-counting convention is used. The line count should be thought of as a line-synchronizing pulse count. It includes the transitions of the equalizing pulses. In certain extreme cases, the field transition recognition will no longer work, and only the "any line" mode will be available.*

The enhanced field counting capability CANNOT be used for RIS acquisitions.

PATTERN TRIGGER (LT364 SERIES ONLY)

Pattern Trigger enables triggering on a logical combination of the five inputs CH 1, CH 2, CH 3, CH 4, and
EXT. This combination, called a pattern, is defined as the logical AND of trigger states. A trigger state is either
high or low: high when a trigger source is greater than the trigger level (threshold) and low when less than it.
For example, a pattern could be defined as present when the trigger state for CH 1 is high, CH 2 is low, and
EXT is irrelevant (X or don't care). If any one of these conditions is not met, the pattern state is considered
absent. Holdoff limits from 10 ns to 20 s or from 1 to 99 999 999 events can be selected.
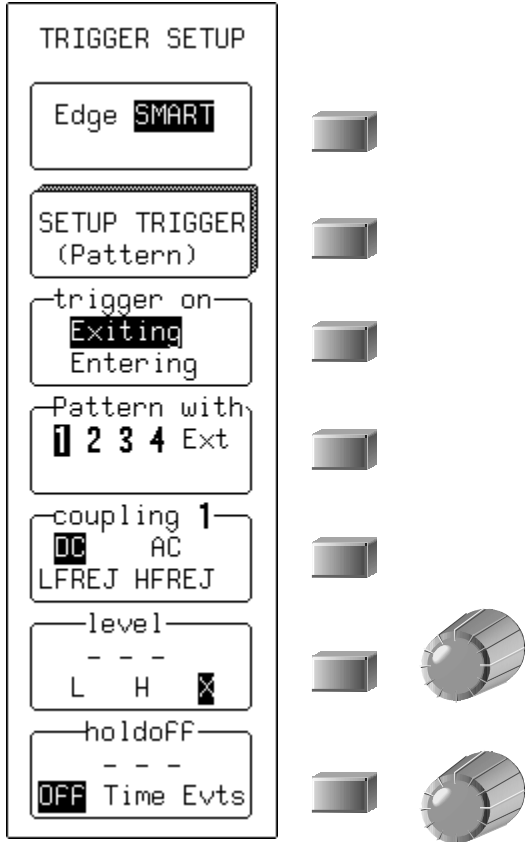
Pattern Applications

Pattern Trigger can be used in digital design for the testing of complex logic inputs or data transmission buses.
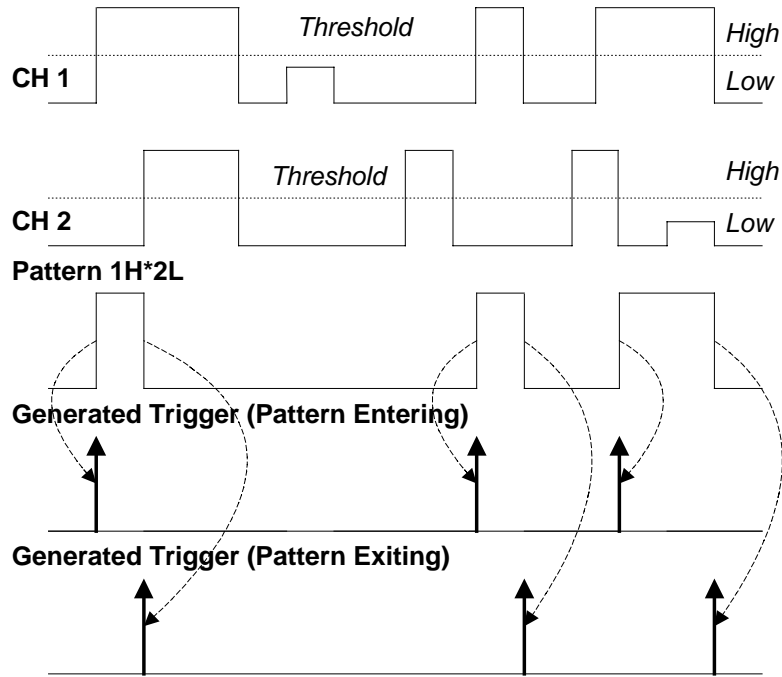
Pattern Trigger: Triggers when all pattern conditions are met. Bold arrows pointing upward show where triggers occur. Information summarizing the pattern setup is displayed.

More About Pattern Trigger

Once the pattern is defined, one of two transitions can be used to generate the trigger. When the pattern begins, called *entering* the pattern, a trigger can be generated. Alternatively, a trigger can be generated when the pattern ends, called *exiting* the pattern.

With pattern triggering, as in single source, either of these qualifications can be selected: Holdoff for 10 ns to 20 s, or Holdoff for up to 99 999 999 events.

When set to Pattern Trigger, the oscilloscope always checks the logic AND of the defined input logic states. However, with the help of de Morgan's theorem, the pattern becomes far more generalized.

Consider the important example of the Bi-level or Window Pattern Trigger. Bi-level implies the expectation of a single-shot signal's going in either direction outside a known amplitude range. To set up a Bi-level Pattern trigger, connect the signal to two inputs: Channels 1 and 2, or any other pair that can be triggered on. For example, the threshold of CH 1 could be set to +100 mV and that of CH 2 at –200 mV. The Bi-level Trigger will occur if the oscilloscope triggers on CH 1 for any pulse greater than +100 mV, or on CH 2 for any pulse less than –200 mV. For improved precision, the gains of the two channels should be at the same setting.

In Boolean notation we can write:

$$\text{Trigger} = \text{CH 1} + \overline{\text{CH 2}}$$

that is, trigger when entering the pattern CH 1 = high OR CH 2 = low.

By de Morgan's theorem this is equivalent to:

$$\text{Trigger} = \overline{\overline{\text{CH 1}} \cdot \text{CH 2}}$$

that is, trigger when exiting the pattern CH 1 = low AND CH 2 = high. This configuration can be easily programmed.

The possibility of setting the threshold individually for each channel extends this method so that it becomes a more general Window Trigger: in order to trigger the input pulse amplitude must lie within or outside a given arbitrary window.

Pattern Trigger has been designed to allow a choice of the trigger point. By choosing *1L*2H entering* the trigger will occur at the moment the pattern 1L*2H becomes true.

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