

## Triggering on CompuScope digitizers

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CompuScope digitizers feature state-of-the-art triggering.

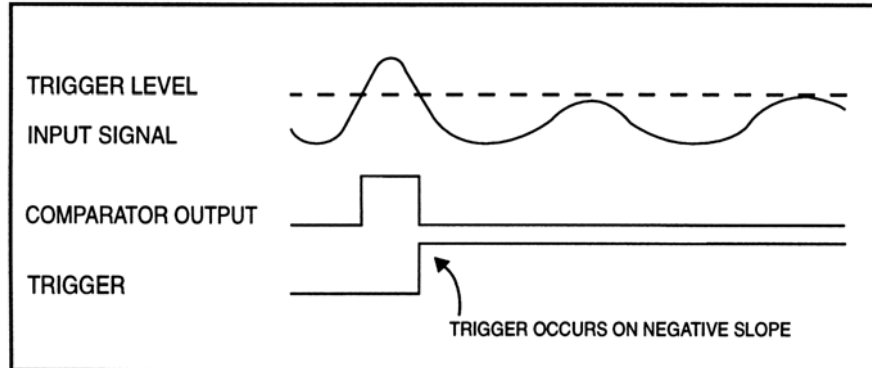
This section describes the architecture and logical organization of GaGe CompuScope triggering functionality. The description applies to all software environments, including GageScope, CsTest+ and any CompuScope Software Development Kit. Once the required triggering functionality is understood, the user should consult the appropriate software manual for directions on implementing the required triggering mode from a specific software environment.

### Simple Triggering

CompuScope digitizers offer a wide variety of complex triggering possibilities, which vary depending on the model. Understanding and implementing the various complex triggering modes is not straightforward. The majority of GaGe customers, however, only require simple CompuScope triggering, which is therefore addressed in this section. Simple triggering is defined as using a single trigger source (e.g. Channel 1, Channel 2, External) on one independent CompuScope card or on the Master CompuScope within a Master/Slave CompuScope system

CompuScope trigger circuitry is designed to provide trigger functionality similar to that of an oscilloscope, so that a user can easily replace a digital oscilloscope in a test set-up with a CompuScope card. As with an oscilloscope, a user can select the trigger source, trigger level and trigger slope using software commands.

Each time the selected trigger source signal crosses the trigger level, the on-board triggering circuitry monitors it for the slope selected by the user. When the appropriate slope is detected, a digital trigger signal is generated within the CompuScope hardware. The illustration below shows an input signal with an accompanying trigger level. The output of the trigger comparator circuitry is shown below, together with the final qualified internal digital trigger signal, which becomes HIGH only if the slope of the input signal is negative as it crosses the trigger level.



*Figure 1: Generation of a trigger signal – negative slope*

Simple triggering is implemented simply by assigning the required trigger source to Trigger Engine #1. The trigger configuration is specified by providing the trigger Slope setting (positive or negative) and the trigger level, which is specified as a percentage (between  $\pm 100\%$ ) of the input range that is used as the trigger source. For instance, if Channel 2 is configured for the  $\pm 2$  Volt input range and is selected as the trigger source, a trigger level of  $+25\%$  corresponds to a 0.5 Volt trigger level. Alternatively, if the external source is selected, then the percentage is with respect to the external trigger input range.

A common CompuScope triggering problem is sometimes encountered by users who wish to trigger off of a uni-polar signal. Typically using a 0 to 5 Volt digital signal as an external trigger source, users mistakenly set the trigger level to 0%, which corresponds to a 0 Volt trigger level. Since, however, the digital signal may not actually fall all the way to 0 Volts, the trigger level is not actually crossed by the signal and the CompuScope does not trigger. Simply raising the Trigger Level to 1 or 2 Volts resolves the problem.

All CompuScope models use some non-zero value for the Trigger Sensitivity. This value specifies the minimum amount by which the trigger signal must swing through the trigger level in order to cause a trigger event. For

instance, if the CompuScope Trigger Sensitivity is specified as  $\pm 10\%$  and if the trigger source uses an input range of  $\pm 2$  V, then the trigger signal must pass from a voltage that is 200 mV below the trigger level through a voltage that is 200 mV above the trigger level in order to cause a trigger event. Signals with amplitudes of less than 400 mV peak-to-peak, therefore, cannot cause a trigger event on the  $\pm 2$  V input range, in this example. Without a non-zero Trigger Sensitivity, a CompuScope would trigger falsely on small amplitude noise components of a signal, which is catastrophic in many applications.

Correct usage of CompuScope Trigger functionality requires an understanding of the concept of a Trigger Timeout. This value specifies the amount of time that CompuScope hardware will wait for a trigger event before the driver forces a trigger event to occur. Users should choose a Trigger Timeout value that exceeds the maximum amount of time in which a trigger event is expected. This way, if the a trigger event does not occur in the expected amount of time, the CompuScope hardware will not wait forever for a trigger that may never come but will instead force a trigger event so that the user can take corrective action. For instance, if a user is triggering off of the zero-crossing point of a 100 Hz sine wave, then the user may safely set the Trigger Timeout value to 1 second, since presumably if a trigger has not occurred in that time, it never will. Alternatively, if a user wants to trigger off of a lightning event, which may take weeks to occur, the user would want to use an infinite Timeout value. GageScope allows selection of the Trigger Timeout value in AUTO mode and uses an infinite Timeout value in NORMAL mode. Many CompuScope users have experienced triggering problems that resulted from not setting a sufficiently large Trigger Timeout value.

Some users do not wish to trigger off some feature within an electrical signal but rather wish to trigger when some software event occurs or simply to trigger as soon as possible. These users should disable the trigger source and then issue a Force Trigger event from software or from a GUI when triggering is desired. For instance, a user studying transmission of Ethernet data packets may want to force a trigger event on a CompuScope at the moment their software application has transmitted a data packet.

## Complex Triggering

In addition to simple triggering, a variety of complex triggering configurations are possible on CompuScope hardware. These configurations make use of the multiple trigger engines available on a single CompuScope card, as well as trigger signal interconnections between CompuScope cards within a Master/Slave CompuScope system. We have continuously improved CompuScope trigger engine architecture in order to allow a wider range of triggering possibilities.

In order to provide comprehensive and uniform control of complex triggering on different CompuScope models, we have presented the triggering controls in terms of logical trigger engines, which are distinct from the physical trigger engines on the CompuScope hardware.

Complex triggering configurations are implemented by setting the configuration for each logical trigger engine. The outputs of each logical triggering engine are Boolean ORed together to create the overall triggering signal. The number of available logical triggering engines may be obtained from the drivers. The software does not inhibit any source being selected for logical triggering engines, however, invalid selections will cause an error.

Trigger configurations for each logical triggering engine require three specifications: the engine's Source, the engine's trigger Level and the engine's trigger Conditions. As in simple triggering, the trigger level is specified as a percentage of the input range of the trigger source. The currently available triggering Conditions are Edge-Positive and Edge-Negative. The selection specifies whether the engine will trigger on a Positive (Rising) or Negative (falling) slope of the trigger signal. In future, more Conditions may be available in order to allow control of triggering capabilities other than edge triggering.

From the point of view of trigger engine architecture, CompuScope models may be divided into three classes, which are listed below.

The CompuScope model of Triggering Class I have 1 or 2 on-board triggering engines, whose outputs are Boolean ORed to create the final triggering signal. CompuScope models in this class include the CS8500, CS82G, CS14100, CS12100, CS12400, BASE-8, and all Octopus CompuScope digitizers. These boards, however, do not have bidirectional trigger bus connections implemented for a Master/Slave multi-card system. For CompuScope models in this class, the logical trigger engines must always be on the Master CompuScope card in a Master/Slave system. A Master/Slave system composed of CompuScope cards from this class will have a number of logical triggering engines that is equal to the number of triggering engines on a single CompuScope card. Further, valid selections for the trigger sources must be on the Master CompuScope, including all input channels and its External Trigger input. For Triggering Class I CompuScope cards, therefore, the logical triggering engines are equivalent to the physical triggering engines on the Master CompuScope.

The CompuScope models of Triggering Class II have 1 or 2 on-board triggering engines but also include a connection to a bidirectional trigger bus within a Master/Slave multi-card CompuScope system. CompuScope models in this class include the Cobra, CS1610, CS1602 and CS1220. Bidirectional trigger bus connections within a Master/Slave system allow for more complex triggering possibilities. The outputs of the triggering engines from all CompuScope cards in a Master/Slave system of this class are Boolean ORed together in order to produce the final trigger signal. A Master/Slave system composed of CompuScope cards from this class, therefore, will have a number of logical triggering engines that is equal to the number of triggering engines on a single CompuScope card multiplied by the number of CompuScope cards in the system. Logical Triggering engines, therefore, are equivalent to physical triggering engines, for this class of CompuScope. Valid sources for each engine, therefore, are the source on which the physical engines are located. As an example, consider a 4-board Master/Slave CS1602 system, each card of which has 2 input channels and 2 trigger engines. Physical (and therefore logical) triggering Engine #5 resides on CS1602 #3 (the second Slave CompuScope). Valid sources for triggering Engine #5 are therefore Channel 5, Channel 6 and the external trigger input on CS1602 #3.

The CompuScope models of Triggering Class III have 1 or more on-board triggering engines and do not include a connection to a bidirectional trigger bus within a Master/Slave multi-card CompuScope system. These models have triggering functionality called Flexible Triggering. Triggering Class III CompuScope cards include the CS14200 and CS14105. Without usage of a bidirectional trigger bus, flexible triggering allows triggering from a CompuScope other than the Master CompuScope in a Master/Slave multi-card CompuScope system. A Master/Slave system composed of CompuScope cards from this class will have a number of logical triggering engines that is equal to the number of triggering engines on a single CompuScope card. However, the source of a logical trigger engine may be channels that reside on CompuScope cards other than the Master CompuScope. Unlike for other classes, logical triggering engines for Class III CompuScope cards may not be identified with physical triggering engines. Once the source of a logical triggering engine is selected to be an input from a given CompuScope within a Master/Slave system, all subsequent logical engines must use sources from this same card. As an example, consider a 4-board Master/Slave CS14200 system, each card of which has 2 input channels and 3 triggering channels. Assume that the source of logical triggering Engine #1 is selected as channel #5. Channel #5 resides on CS14200 #3 (the second Slave CompuScope). Valid sources for triggering Engine #2 and #3 are therefore Channel #5, Channel #6 and the external trigger input on CS14200 #3.

Octopus CompuScope digitizers are distinct in that they provide a number of triggering engines that is greater than the number of inputs. For instance an 8-channel Octopus CompuScope has 17 trigger engines. On Octopus CompuScope cards, two physical Triggering engines are available for each input channel and one for the external trigger input. Logical triggering engines are assigned as they are used and the driver takes care of mapping logical to physical engines. For instance, on an 8-channel Octopus CompuScope, we may select channel #5 as the source to logical triggering Engine #1. We may then select any channel or external as the source for logical Engine #2 or other engines. However, any input channel may only be selected a maximum of two times. The External Trigger Input may only be selected once. Invalid selections will cause an error condition to be returned by the software.

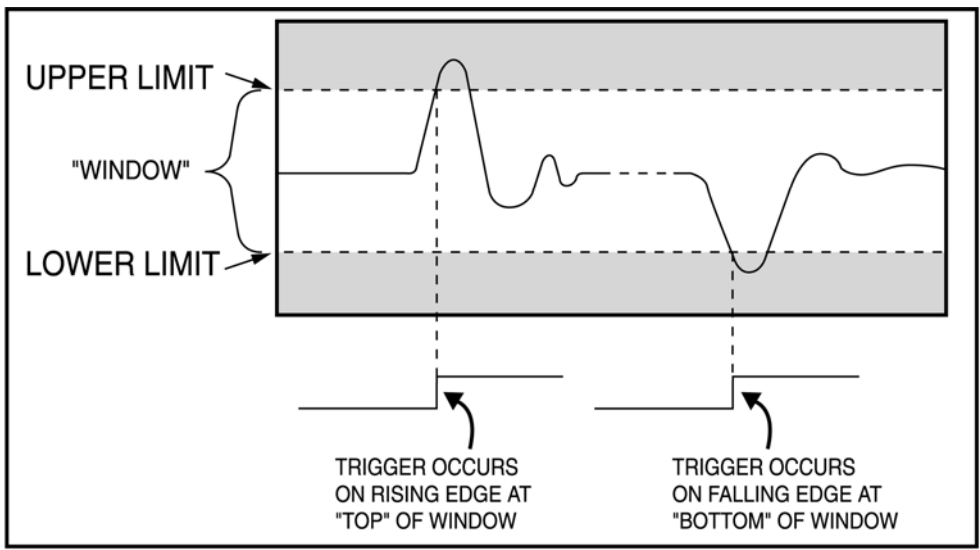
The table below lists all current CompuScope models, their Triggering Class and a number of the triggering attributes discussed above.

CompuScope Model	Triggering Class	Trigger from all Channels?	External Trigger?	Number of Physical Triggering Engines	Bidirectional Trigger Bus for Master/Slave System?
2-Channel Octopus	I	YES	YES	5	N/A
4-Channel Octopus	I	YES	YES	9	N/A
8-Channel Octopus	I	YES	YES	17	N/A
BASE-8	I	YES	YES	1	N/A
CS82G	I	YES	YES	1	NO
CS8500	I	YES	YES	1	NO
CS12100	I	YES	YES	2	NO
CS12400	I	YES	YES	3	NO
CS14100	I	YES	YES	2	NO
Cobra	II	YES	YES	2	YES
CS1610	II	YES	YES	2	YES
CS1602	II	YES	YES	2	YES
CS1220	II	YES	YES	2	YES
CS14200	III	YES	YES	2	NO
CS14105	III	YES	YES	2	NO

Usage of complex triggering allows a number of useful triggering functionalities to be implemented. Two illustrative examples are Windowed Triggering and multi-channel Boolean ORed triggering.

### Windowed Triggering

Windowed Triggering uses two trigger engines in such a way that a trigger event occurs if the signal voltage leaves a range of voltages specified by an Upper Limit and a Lower Limit, as illustrated below.



### ***Figure 2: Windowed triggering***

Windowed triggering is implemented by selecting the same input channel as the trigger source for two trigger engines. The levels for the two engines are then selected as the Upper and Lower Limit with positive and negative slopes, respectively. In this way, if the signal voltage rises above the Upper Limit, the first engine triggers and if the signal voltage falls below the Lower Limit, the second engine triggers. Since the outputs of both trigger engines are Boolean ORed together, a trigger on either engine will cause a global trigger event to occur. A special case of Windowed trigger is Absolute Value Triggering, where the Upper and Lower Limit are made equal and opposite so that a trigger event occurs if the absolute value of the voltage signal exceeds the selected level.

### **Multi-channel Boolean ORed Triggering**

Multi-channel Boolean ORed triggering is very useful for particle counting applications, such as particle physics experiments. Here, multiple particle detectors are configured to produce short voltage pulses as particles arrive into them. Multiple Detectors may be arranged at different angles in order to detect particles traveling in different directions from the source. In these applications, users typically want to trigger their digitizers when a particle pulse is produced by any one of the detectors. Setting up the triggering conditions is easy using the intrinsic Boolean ORing of CompuScope multiple Triggering engines. A 4-channel Octopus CompuScope, for instance, may be configured to trigger on any channel simply by setting the source to logical trigger engines #1, #2, #3 and #4 to Channels #1, #2, #3, and #4. For a 2-card Master/Slave CS1610 system, the logical trigger engines source settings would be exactly the same.