Oscilloscope Triggering with High Speed Comparators

Jaskaran Atwal, Analog Signal Chain

The oscilloscope is one of the most useful test and measurement tools for electronic engineers. Oscilloscopes are used to analyze electrical signals for the purposes of testing, debugging, and troubleshooting electronic circuits. Without this tool many technological developments would not be possible. Oscilloscopes have come a long way from when they were first invented before WWII. The original analog oscilloscopes have been replaced in the majority of applications by digital oscilloscopes.

Over the years, many advancements have been made to oscilloscopes with the continuing development of software and analog and digital devices, but the basic functionality has remained the same. The oscilloscope operates by taking an electrical signal as an input and displaying this waveform on a screen. To display a repeating waveform, a trigger is required. Without this trigger, multiple copies of the repeating waveform would be drawn all over the display. This would lead to a jumble rather than a clean centered display of the waveform. An example block diagram of the triggering circuit is shown in Figure 1.

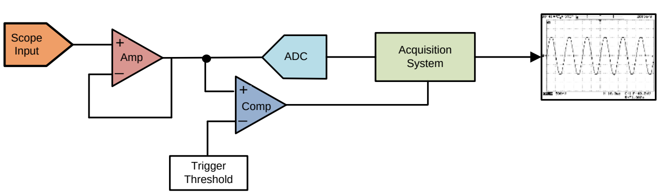

Figure 1. Oscilloscope Triggering Block Diagram

Now that we have introduced the importance of triggering in oscilloscopes, let's discuss how the triggering function is designed in oscilloscopes. The triggering function tells the oscilloscope what data from the input waveform it needs to care about and when the Acquisition System must start processing and displaying this data. The point at which the oscilloscope triggers, or the Trigger Threshold, is configurable by the user and typically based on a falling or rising edge and voltage level of the input waveform.

The trigger system can be implemented in software or hardware. An analog trigger system typically works by monitoring the input waveform with an amplifier and passing this input to a high speed comparator to detect if the trigger threshold set by the user has been reached. The comparator will fire and alert the Acquisition System when the trigger threshold has been met. Only now will the data from the output of the ADC be processed by the Acquisition System and be displayed on the screen.

To properly detect and trigger at any input signal, the comparator must be high speed. High speed is important when the input signal may contain a glitch or very small pulse width. Without a high speed comparator, the system may not be able to trigger on this input signal. The propagation delay of the comparator is part of what makes this triggering possible, but the specific comparator parameters to look for are toggle rate and pulse width. Toggle rate and pulse width for comparators can be compared to the bandwidth parameter for amplifiers. Along with that, it is important that the trigger system is immune to noise to prevent any false triggering. Hysteresis is a key feature that can help comparators with minimizing the effects of noise. The LMH7322 is a good fit for this application with its extremely small pulse width of 260 ps, toggle rate of 3.9 Gb/s, and 75 mV of programmable hysteresis. Size constraints of the overall system can also be important when selecting components for this application. The LMH7322 is available in a small 24-pin WQFN package.

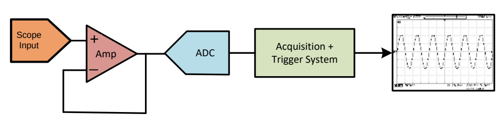

Figure 2. Software Trigger Block Diagram

Software triggers on the other hand work by constantly sampling data from the ADC and determining when the trigger threshold has been reached. The input signal is not split into parallel paths as shown in Figure 2. Once the ADC and software determines the threshold has been reached, the waveform is processed and displayed on the screen.

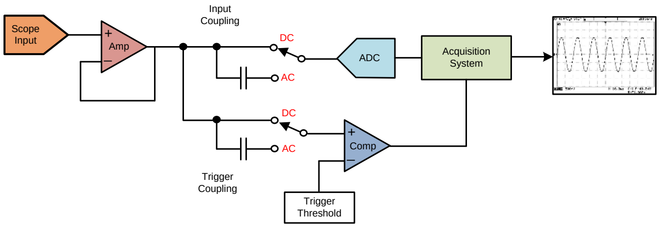

Figure 3. Input and Trigger Coupling Block Diagram

The introduction of analog and software based trigger systems give us the opportunity to discuss why one could be preferred over the other. The AC and DC coupling options on the inputs of the oscilloscope are well known, but less known are the coupling options on the trigger shown in Figure 4. As the software implementation of the trigger does not split up the input signal, the trigger does not have the option to be AC or DC coupled. The trigger instead relies on the input coupling and triggers based on this coupled signal. The downside to this is that you cannot display the DC coupled input waveform while triggering on the AC coupled input waveform.

One example of this drawback is shown when analyzing a spike or glitch on a power line. In this scenario you may want to see both the DC component of the signal and the spike or glitch on top. The resolution of the ADC can be taken up by the DC component of this input signal. The software trigger, without AC coupling, may not have enough remaining resolution to detect the spike or glitch and display the full input signal. On the other hand, Analog trigger systems split up the input of the oscilloscope as shown in Figure 3. This allows for the freedom to have input coupling and trigger coupling independent from each other and avoid the drawback described.

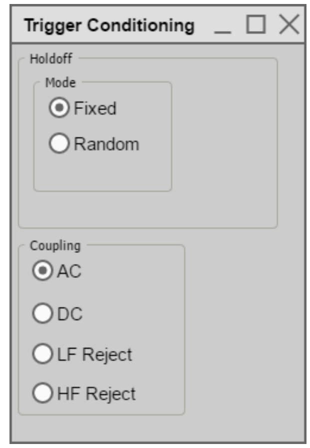

Figure 4. Trigger Coupling Options

As discussed, the triggering system is essential to properly display an electrical signal on an oscilloscope. An analog trigger system however can offer the most freedom in these applications. High speed comparators are at the center of these analog trigger systems. The LMH7322 is a high speed comparator that is a good fit for this application with its small pulse width, high toggle rate, programmable hysteresis, and small size package.

Table 1. Device Recommendations

Device	Toggle Rate	Min Pulse Width	Hysteresis	Supply
LMH7322	3.9 Gb/s	260 ps	75 mV	2.7 V - 12 V
LMH7324	3.72 Gb/s	290 ps	22.5 mV	5 V - 12 V
LMV7220	1.8 Gb/s	-	External	2.7 V - 12 V

Table 2. Other High Speed Comparators

Device	Propagation Delay	Hysteresis	Supply
TIV3501	4.5 ns	6 mV	2.7 V - 5.5 V
LMV7219	7 ns	7 mV	2.7 V - 5 V
TL3016	7.6 ns	External	± 5 V

IMPORTANT NOTICE FOR TI DESIGN INFORMATION AND RESOURCES

Texas Instruments Incorporated ('TI") technical, application or other design advice, services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, "TI Resources") are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using any particular TI Resource in any way, you (individually or, if you are acting on behalf of a company, your company) agree to use it solely for this purpose and subject to the terms of this Notice.

TI's provision of TI Resources does not expand or otherwise alter TI's applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources.

You understand and agree that you remain responsible for using your independent analysis, evaluation and judgment in designing your applications and that you have full and exclusive responsibility to assure the safety of your applications and compliance of your applications (and of all TI products used in or for your applications) with all applicable regulations, laws and other applicable requirements. You represent that, with respect to your applications, you have all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. You agree that prior to using or distributing any applications that include TI products, you will thoroughly test such applications and the functionality of such TI products as used in such applications. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

You are authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI RESOURCES ARE PROVIDED "AS IS" AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING TI RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY YOU AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

You agree to fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of your non-compliance with the terms and provisions of this Notice.

This Notice applies to TI Resources. Additional terms apply to the use and purchase of certain types of materials, TI products and services. These include; without limitation, TI's standard terms for semiconductor products http://www.ti.com/sc/docs/stdterms.htm), evaluation modules, and samples (http://www.ti.com/sc/docs/sampterms.htm).

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265