



## Dual Scope Synchronization

*Our thanks to Tektronix for allowing us to reprint the following article.*

### Introduction

The Tektronix DPO/DSA/MSO70000 models above 12GHz in bandwidth provide 50 GS/s sampling rate on each of 4 channels simultaneously, or 100 GS/s sampling rate on 2 channels in interleaved mode. With interleaved operation comes the opportunity for using two instruments, synchronized together, to get 4 channels sampling at 100 GS/s.

The 100 GS/s operation is facilitated by interleave circuitry which is integrated into the acquisition system internal to the scope. Switching from non-interleaved to interleaved operation only requires changing the sampling resolution through the front panel control (the resolution knob) or through the programmable interface.

Why go to the expense and trouble of synchronizing two instruments? For some applications, such as coherent signal analysis of complex modulated optical signaling, the 20% noise reduction achieved with oversampling results in critical improvement in bit error ratio performance in challenging low level signal environments.

There are several ways to configure a two-scope system for synchronized acquisition, with varying levels of alignment accuracy. This application note describes the most precise method to align acquisitions between two scopes.

### Methods of Synchronization

*Channel sample synchronization (alignment of time related events across two instruments) consists of three elements: channel skew, acquisition sample alignment, and trigger alignment. Deskew adjustment to individual channels will address the channel skew. Sample alignment can be attained using an external reference clock. Trigger alignment is achieved by carefully applying the same trigger signal to each matched-length path. Sample, and Trigger alignment are both subject to jitter that is random in nature, and difficult to remove from the acquisition.*

### Synchronization

To facilitate using 2 scopes to achieve 4 channels at 100 GS/s, the new Tektronix DPO/DSA/MSO70000C models

include enhancements to the system clock to provide tight timing synchronization between the two instruments. In interleave mode, using a 10 MHz external reference clock, the enhanced system clock provides acquisition sampling that is synchronized to +/- 500 fs RMS for single acquisitions from minimum acquisition time to 10 us, across two instruments. The synchronization is maintained to  $\leq 3$  ps RMS from 100 us up to the maximum acquisition time of the instruments (increases somewhat linearly between 10 us and 10 ms, and then levels off at approximately 3 ps).

### Deskew

The synchronized start of acquisition (triggering) of two scopes is affected by two aspects of operation.

First, it is necessary to deskew the channels. Coarse synchronization of the triggering events is attained by physically matching path lengths from the trigger source (e.g. external trigger signal) using matched cable lengths and power splitter. The fine control of synchronization is achieved using the deskew feature for each of the scope channels. The interleaved channels on a single scope can be deskewed to each other. In addition, using the standard deskew control, the two scopes can also be deskewed to remove minor differences in propagation through the trigger channels. The deskew alignment can be performed to 1 ps using these controls.

Trigger synchronization is also affected by trigger jitter in each system. The trigger jitter is dependent on the frequency of the signal applied to the instrument. For example, a PRBS signal of 12 Gbps may have up to 2.6 ps RMS of jitter. When using two scopes, this value would add together for a total of 5.2 ps RMS worst case separation of triggering events between the two instruments. Using the enhanced trigger feature on the scope can result in trigger jitter as low as 100 fs RMS per instrument.

### Preliminary Setup Considerations

#### Recommended Equipment

The following list shows the equipment that was used in the test setup for synchronization. There are also recommendations on other equipment for accomplishing the same outcome.

- Two (2) MSO72004C Real Time Oscilloscopes
- One (1) 10-100 MHz external reference source (e.g. AWG7122B)
  - Used for alignment edge, external time base reference and external trigger source
  - One of the scopes in the setup can also be used as the time base reference for the second instrument.
- One (1) 36 inch pair of delay matched cables
- Three (3) 12 inch pairs of delay matched cables
- Four (4) three-way SMA power splitters/dividers
  - Could also use one four way splitter, and one two way splitter
- Nine (9) SMA F-F Barrel connectors
- Six (6) TCA-292MM TekConnect adapters
- Three (3) 36 inch BNC cables
- One (1) BNC T adapter F-F-F

### Signal Path Calibration (SPC)

Use the following procedure to compensate the internal signal acquisition path. Perform this procedure if the ambient temperature has changed more than 5 °C (9 °F) since you performed the last signal path compensation. Perform the signal path compensation once a week. Failure to do so may result in the instrument not meeting warranted performance levels.

1. Power on and warm up the instrument for 20 minutes before continuing with this procedure.
2. Disconnect any probes you have connected to the input channels.
3. Set the instrument to Menu mode.
4. Select Instrument Calibration from the Utilities menu.
5. Note any instructions that appear under Calibration Instructions in the resulting control window.
6. Click Calibrate to begin the procedure. The procedure may take several minutes to complete.

### External Reference Source

Use the rear-panel external reference input (Ext Ref) to synchronize the oscilloscope time base to an external 9.8 MHz to 10.2 MHz reference frequency source. The reference input voltage range is 200 mVp-p to 7 Vp-p.

**NOTE. You must perform signal path compensation whenever you change the reference.**

To minimize jitter when using an external reference clock input (available on ≥4 GHz instruments only):

- Select the Low (Stable) option when using a stable low-jitter clock source.

- Select the High (Tracking) option when the oscilloscope needs to track the external clock to minimize jitter.

The performance of internal reference can be approached using a clean reference signal with input slew rate exceeding 1.5V/ns. This is most easily achieved either with a square wave meeting that slew rate or use a 100 MHz sinewave (~2V pk-pk). This will be required for the best possible performance in synchronous sampling applications.

### External Trigger source

Optimal trigger jitter performance is attained by using one of the analog channels as a trigger source. If your application utilizes 100 GS/s sampling, you can use one of the disabled channels (e.g. CH2 and CH4 when using CH1 and CH3 as the data inputs) as a trigger source without disturbing the 100 GS/s operation. Any of the PinPoint trigger features can be used in this configuration.

### Connector torque

To ensure the best signal fidelity, all connectors should be tightened to 5 inch lbs using any commonly available torque wrench sized to SMA dimensions.

### Equipment Setup

#### Parent and Child Scope Connections

In the setup and subsequent procedure that follows, the terms “Parent” and “Child” are used to differentiate between the instrument that is the reference for acquisition alignment (the Parent), and the instrument that receives the alignment reference (the Child). The oscilloscopes used in synchronization will not be connected directly to one another; they will be linked together through the use of an external trigger source, and an external reference source.

#### Instrument Configuration

The Parent scope and Child scope have identical connections, depending on the configuration you are running. One of several possible configurations will be discussed in this document; This configuration uses an External Trigger Source and External Clock Reference, both of which are split and fed via matched path lengths into the two instruments separately.

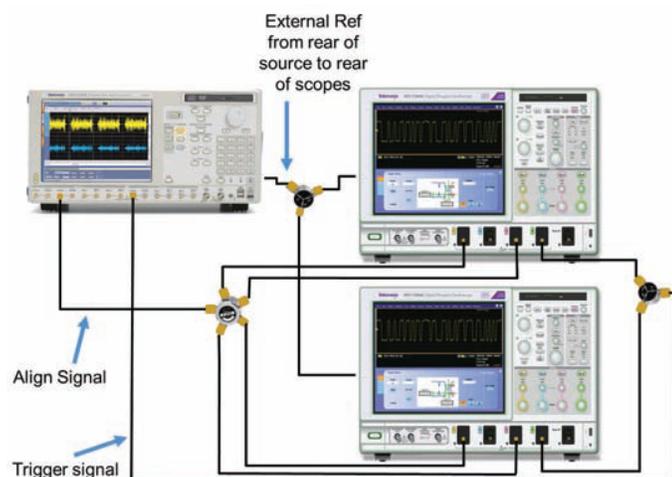
The scopes can be setup in a number of ways, which will deliver varying degrees of performance with respect to jitter and reference clock timing variation. The method described here gives the best performance using the equipment specified.

## External Trigger Source

In the setup described here, one of the analog channels on the Parent and Child is used as the source for the edge trigger used in the oscilloscope; using one of the analog channels provides the least trigger jitter, thereby ensuring that the signals are more tightly aligned in time. A Tektronix AWG7122 is used as our external trigger source, and that signal is split and then connected to the Channel 4 input of the Parent and Child scopes.

## External Reference Clock Source

To minimize any differences that may exist between the sampling clocks of the two instruments operating independently, an external reference clock is fed to both Parent and Child scopes. The AWG7122 “Reference Out” is split between the Parent and Child, and connected to the “Ref In” found on the back of the oscilloscopes. It bears mentioning here that although the AWG7122B was used as the clock reference for the scopes in this setup, any 10 MHz external clock generator with high slew rate, good frequency stability, and low noise can be used.



**Figure 1. Connection of Signal Source and Oscilloscopes for Dual-Scope Synchronization**

### Connection Procedure:

1. Attach one 36" BNC cable to “Reference Out” of AWG, or other suitable time base reference, and use a BNC “T” adapter to split the signal into two 36" BNC cables.
2. Attach the two split time base signals connected in step 1 to the “Ref In” on the Parent and Child scopes.
3. Connect one 36" SMA cable to CH1 Analog out of AWG, or other suitable signal source that can output a simple step with a rising edge greater than ~60 ps, connect the end of this cable to one four-way SMA signal splitter and connect two pairs of 12" matched

delay SMA cables to the four open connectors on the four-way splitter.

4. Using the ends of the two pairs of 12" matched SMA cables (the split CH1 Analog out of AWG), connect one pair to Channels 1 and 3 of the Parent scope, and the second matched pair to Channels 1 and 3 of the Child scope.
5. Connect one 36" SMA cable to CH2 Analog out of AWG, or other suitable signal that can be used as the trigger source for the acquisition. Attach a two-way SMA splitter to the other end of this SMA cable, and then attach one pair of 12" matched delay SMA cables to the two open connections on the two-way splitter. Ideally, the 36" cable we attached to CH2 of the AWG would be the second leg of a matched SMA set, with the first leg being the 36" SMA cable referred to in Step 3.
6. The ends of the 12" matched pair that are connected to CH2 of the AWG will serve as the trigger source for Parent and Child scopes. Connect one end of the 12" SMA cable pair to Channel 4 on the Parent scope, and the other end to Channel 4 on the Child Scope.
7. On both the Parent and Child scopes, you will need to change the reference that is used for the timebase to an external source. Change the reference to external in the TekScope application by going to “Utilities”>“Instrument Calibration”, and selecting “External” as the reference source.
8. Next, in the TekScope application on the Parent and Child Scopes, you will need to choose a common trigger source for both instruments to trigger on. In our setup, we’ve used Channel 4 from both instruments as the common trigger...you may have chosen differently, so assign the source accordingly.

Refer to Figure 1 for a visual reference of how the equipment was connected in this document.

After steps 1-6 above have been accomplished, you’re ready to perform the next important part of the synchronization of two instruments: Deskew.

### Deskew Procedure

Deskewing the two instruments ensures that the synchronization of  $\leq 2$  ps RMS can be attained between channels on both instruments. Oscilloscopes are aligned to a common point in time (in our case, the trigger source of the Parent scope) by applying a small skew (as needed, typically a few picoseconds) to each channel on the Parent and Child scopes, so that the acquisitions are more closely aligned in time than they would be if we were just to use the hardware setup alone. This manual deskew procedure is necessary as part of a full synchronization operation, and should be performed if your setup has changed in any way; if in

doubt, start from the beginning of the connection procedure and work your way through deskew.

### Steps to deskew:

1. Press "Default Setup" front panel button on both Parent and Child scopes.
2. Perform SPC calibration as described on page three of this document (ensure that the signal generator output is turned off).
3. Ensure that the oscilloscope settings (Vertical, Horizontal, Sample Rate...etc.) are set up as they would be for the actual signals you intend to measure. This might require you to consider a different source for deskew alignment, so use an alignment signal that would be appropriate for your specific needs.
4. With your instruments setup as described in the 'Parent and Child' connections section earlier, you are ready to start deskewing the instruments.
5. On both the Parent and Child scope, set the instrument into average acquisitions mode by going into "Horiz/Acq"> "Horizontal/Acquisition Setup" and selecting the "Acquisition" tab. Enable averaging by pressing the "Average" button and select the number of averages you wish to perform. In our setup, we used 512 averaged acquisitions to smooth out our waveform, and give more repeatable measurement results when determining skew variation. You may or may not choose to average the alignment signal, though not doing so may affect the performance of the alignment, depending on the input you use for alignment.
6. In the TekScope application on both Parent and Child scopes, go into "Trigger">"A Event (Main) Trigger Setup" and select the "Mode" tab from the user interface. Ensure that the "Enhanced Triggering" option is unchecked.
7. Set your signal source to manually allow you to force a trigger event, and then press the "Single" button on the front of the Parent and Child scopes. Ensure that neither of the scopes actually takes an acquisition, by making sure your signal source is waiting for you to force the trigger event.
8. Now, turn on your signal generator or force the trigger event on your signal source, and check to see that both oscilloscopes have taken an acquisition.
9. If 100 GS/s operation is required, then you will need to deskew the channels in a particular order that ensures you can acquire at 100 GS/s; you can only acquire at 100 GS/s (on a 70000C series instrument) on two channels at a time. You can use channels 1&3, 1&4, 2&4, or 2&3 when running in 100 GS/s.
10. You should now have two acquisitions on screen, on both the Parent and Child scopes; we will use this acquisition to measure, and then apply deskew to both instruments as needed.
11. Using the onscreen cursors and the zoom features of the instrument, you will measure the distance (in time) that the midpoint from the Slave scopes' CH1 is from its own trigger point. Then, apply that difference in time as the value for deskew on CH1. You will repeat this for all of the remaining channels on the Child scope.
12. On the Parent scope, you will use the same procedure described in step 11 above to deskew all the channels on the Parent to a common trigger reference.

### Conclusion

Once you've completed the actions discussed in this document, you will have two instruments that are synchronized in time, to within approximately 1 – 2 ps RMS between scope channels on the two instruments. The procedure and setup described here can be configured in a number of ways that will provide varied levels of performance. The synchronization of two instruments can also be simplified by automating the deskew and subsequent alignment process using programmatic control of the instruments.

