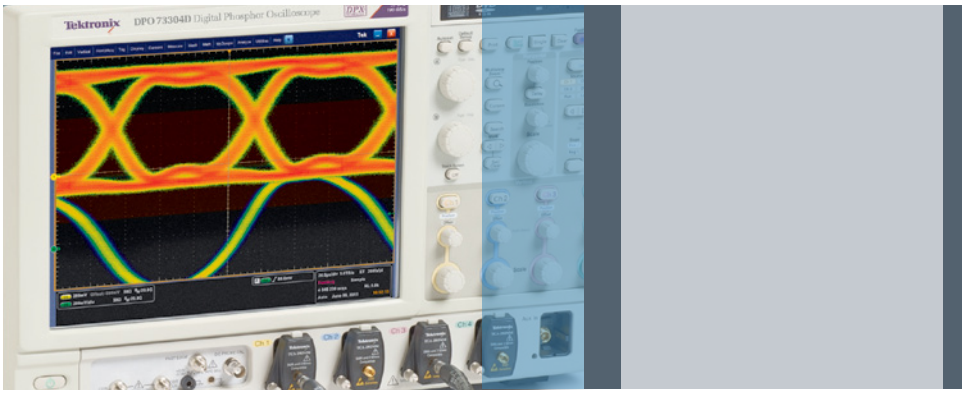

Dual Scope Synchronization

Application Note

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.

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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 Tektronix DPO/DSA70000D and 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 <= 2 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 2 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 automated deskew function in Tektronix' Dual Scope Synchronization application or the 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

Tektronix' DPOACQSYNC kit provides a complete set of cables and accessories for running two 70000 series scopes in a synchronized manner. As part of this kit multiple matched length cables are provided. In addition, a fast edge source for aligning the acquisitions is included. More details on this kit are listed below.

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) DPO/DSA7000D or DPO/DSA/MSO72004C Real Time Oscilloscopes
- One (1) 10-100 MHz external reference source (e.g. AWG7122)
  - Used for 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.

Figure 1.

DPOACQSYNC Kit Contents:

- Fast Edge Source
- 2.92 mm coaxial cable set of 4 matched to 1 ps
- 2.92 mm coaxial cable set of 2 matched to 1 ps
- 2 additional 2.92 mm coaxial cables
- 4-way, 50 Ohm Power Divider
- 2-way, 50 Ohm Power Divider
- Torque wrench for RF cabling
- Teklink cable
- Other assorted cables and adapters

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. If the Tekscope UI is in Buttons mode, set the instrument UI 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 will 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 mV_{p-p} to 7 V_{p-p}.

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

To minimize jitter when using an external reference clock input:

- 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 best performance of the reference clock can be achieved 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.

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 unused 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.

Connector torque

To ensure the best signal fidelity, all connectors should be tightened to 8 inch lbs using a tourque 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).

Instrument Configuration

The Parent scope and Child scope could have identical connections, depending on the configuration you are running. The recommended configuration will be discussed in this document; This configuration uses an External Trigger Source 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, the analog channels on the Parent and Child are used as the source for the oscilloscopes' trigger. Using the analog channels provides the least trigger jitter, thereby ensuring that the signals are more tightly aligned in time. One of the fast edge source outputs is used as the trigger source for alignment of the two scopes.

External Reference 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. Refer to the sidebar for detailed requirements of the external clock reference. The scopes in this setup can be connected to any 10 MHz or 100 MHz external clock generator source.

Connection Procedure:

1. Using the set of four 18" (46 cm) **matched** SMA cables, connect one cable to CH1 of the Parent, and the other end to an open port on your 4-way power splitter. Use one of the other open cables in this set to connect from CH3 on the Parent to an open port on the 4-way splitter.
2. Connect one of the remaining unattached cables of the set of four 18" **matched** SMA cables to CH1 of the Child, and the other end to an open port on your 4-way power splitter. The remaining cable in this set of four will connect from CH3 on the Child, to an open port on the 4-way splitter.
3. Using the pair of 18" **matched** SMA cables, connect one cable to CH2 of Parent, and the other end to an open port of your 2-way power splitter. The other cable in this pair will connect from CH2 on the Child, to an open port the 2-way splitter.
4. Using one cable of the pair of 18" **unmatched** SMA cables, connect the last open port on your 2-way splitter to one of the negative outputs on the Fast Edge Source/ Deskew Fixture.
5. Connect the remaining cable on the pair of 18" **unmatched** SMA cables with the last open port on your 4-way power splitter and attach the other end to the second negative output on the Fast Edge Source.
6. Connect an external trigger signal (from the AWG7122 in this case) to CH4 of the Parent. If no external trigger source is available, the Fast Edge output from the front of the Parent can be connected to CH4 for deskew operations.
7. Attach one end of your 20" (51 cm) BNC cable to the REF IN on the Parent, and the opposite end to the BNC T adapter. Connect another BNC cable to the REF IN on the Child and the opposite end to the BNC T adapter. Connect the a 20" BNC cable to the 10 MHz Reference Output of the AWG7122 and the opposite end of the cable to the BNC T adapter.
8. Attach the SMA-BNC adapter to AUX OUT of the Parent; connect one end of the 60" (152 cm) SMA cable to adapter, and connect opposite end of the cable to the trigger input on front of the Fast Edge Source.
9. Connect the USB cable from any open USB type A port on the Parent, and the type B connector to the Fast Edge Source's power input.

After steps 1-9 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 <=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 point of the Parent scope) by applying a small skew (as needed, typically a few picoseconds) to each channel on the Parent and Child scopes. Using this deskew procedure, the acquisitions are more closely aligned in time than they would be if we were just to use the hardware setup alone. Two methods to deskew the scopes are possible, one is automated using a Tektronix supplied application. The other is a manual procedure. The deskew procedures are 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.

Deskew Procedure (Automated):

1. If your scopes are not already connected to a network, connect them to each other via Ethernet cables.
2. Open “Dual Scope Synchronization” application located at “Start > All Programs > Tektronix”
3. In the "Instrument Connections" section (Figure 2) of the "Configure" tab:
    a. Get the IP addresses for both the Parent and the Child and enter the addresses in the text boxes on the left side of the application window.
        1. The scope that you run the application on becomes the Parent. The application will connect through the Virtual GPIB connection to the scope software on the Parent.
        2. To easily get the IP addresses of the instruments, you can hover-over the LAN Server Control icon in the system tray (Shown in Figure 3) and see the current IP address of the scope as assigned by the network.
    b. Press "Connect"
        1. The scopes should both connect and report back with identity information in the console readout at the bottom of the application.

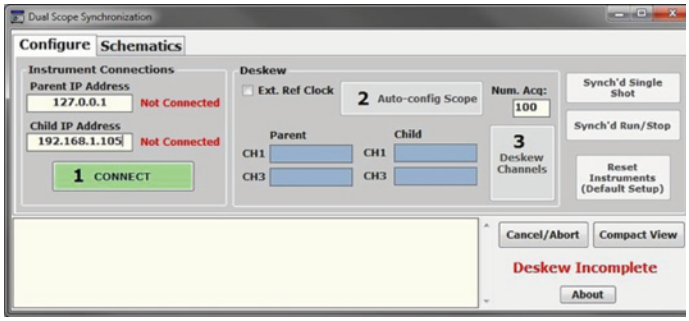

Figure 2. Configure Tab view upon initial application startup.

Figure 3. Easily find IP address of the scope from the LAN Server Control icon in system tray.

4. The source of the scopes’ external reference clocks is configurable in this application via the “Ext. Ref Clock” check box.
    a. This check box allows the user to decide whether the scope is configured so that:
        1. The Parent external reference out is connected to the Child external reference in (check box unchecked, default condition).
        2. Both the Parent and Child scopes are receiving a reference clock from an external source, that is split and connected to the reference in on both scopes (check box checked). If you are using the AWG7122's external reference output, this box should be checked.

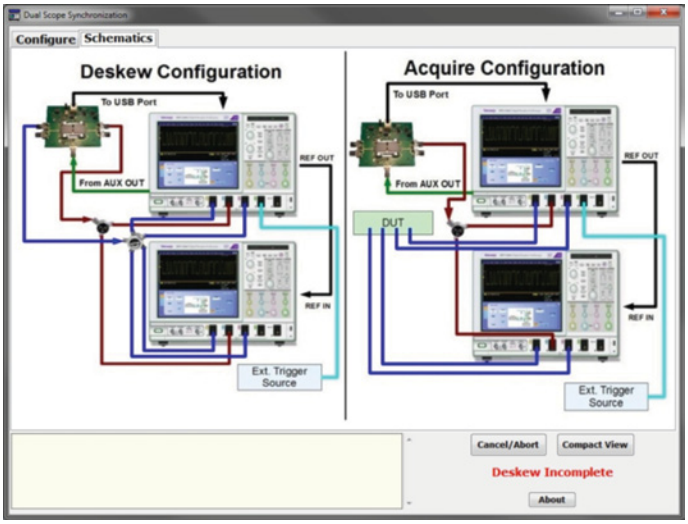

Figure 4. Schematic Tab, showing instrument connections for Deskew and Acquire operations.

5. Once the scopes are connected, press "Auto-Config Scope" button to put both instruments in a configuration that will be used during the automated deskew routine.
   a. The auto-config routine will setup the scopes with instrument settings based on the Deskew configuration shown in the "Schematics" tab (Figure 4).
   b. When this setup is complete, you will see an “Autoscale Complete” message in the console window at the bottom of the application.
6. When the automated configuration completes, you are now ready to run the deskew routine.
   a. The “Num. Acq” text box allows you to control how many acquisitions are taken. These acquisitions are used as a statistical basis for the deskew values that are applied to the Parent and Child inputs.
   b. The recommended minimum for “Num. Acq” is 100. Note: Tests have shown negligible improvement with a setting beyond 200 acquisitions.
   c. Pressing the “Deskew Channels” button will begin the deskew operation.

Figure 5. Minimized application window.

7. During the deskew operation, you will see a message displayed on both instruments indicating the operation’s progress.
8. When deskew completes, you will see the “Deskew Incomplete” message in the lower right-hand side of the application change to “Deskew Complete.”
9. After deskew is applied to the system, you can disconnect the 4-way splitter from the system, and apply your data signals to the scopes as shown in the “Acquire Configuration” under the “Schematics” tab.
10. The vertical and horizontal scaling on the instruments can be adjusted as needed, within the following guidelines:
    a. The sample rate of the instruments must not be changed after the deskew operation has been performed. This application automatically sets the scopes to acquire at 100GS/s, and cannot be changed.
    b. All vertical and horizontal scales must be set to the same values on both instruments.
11. To control the acquisition state of both instruments, the user only needs to use the Parent front panel.
    a. The Child unit will be left in “Run” mode, and will respond accordingly to the Parent “Run/Stop” and “Single” buttons
12. The application has a “minimized” interface, that allows the user to better see the scope graticule, and still perform most of the functions available in the program
    a. Pressing the “Compact View” button in the main window will minimize the application as shown in Figure 5.
    b. The “Restore View” button will return the application to the original (default) size.

Deskew Procedure (Manual):

Configure scope settings:

1. Vertical
    a. Set the Vertical Scale of CH1 and CH3 on both Parent and Child to 20mV/div. and adjust the Position to 4 div using the position selection just above the scale setting.
    b. Set the scale of CH2 on the Parent and the Child to 40mV/div and adjust the Position to 4 div using the position selection just above the scale setting. Turn off CH2 on the Parent and the Child after setting their vertical settings.
2. Horizontal
    a. Set 100GS/s sampling rate on the Parent and the Child.
        1. Go into the "Horiz/Acq" menu, and select "Horizontal/Acquisition Setup."
        2. Set "Horizontal Mode" to “manual.”
        3. Set “Sample Rate” to “100GS/s.”
        4. Repeat for the Child.
3. Trigger
    a. Setup the A Trigger on the Parent to "Edge" type and set the trigger source to "CH4."
        1. Press the "Set to 50%" button.
    b. In the "A>B Seq" tab, select the "Trig on nth Event" button, and then set the "B Event" field value to "1"
    c. Setup the B Trigger on the Parent
        1. Turn on CH2
        2. Go to the tab labeled "B Event" and select "Edge" for the Trigger Type, and "CH2" for the source. Adjust B Event trigger level to mid-point of the signal present on CH2, which should be approximately -160mV.
    d. Select the "Options" tab and ensure "Normal" button is active under the "Trigger Mode" heading. Uncheck "Enhanced Triggering" from the section labeled "Trigger Position." Now, select the "Time" button in the section labeled "Holdoff", adjusting the "Trig. Holdoff" field to 50ms
    e. Set the Child instrument to an Edge trigger type for the A Event with CH2 as the source.
        1. Set the trigger level to -160mV.
    f. Select the "Options" tab and ensure "Normal" button is active under the "Trigger Mode" heading, and then uncheck "Enhanced Triggering" from the section labeled "Trigger Position.”
    g. Turn off CH2 on the Parent and the Child after setting up their triggers.

4. External Signals
    a. Configure the Parent and the Child to accept an external reference
        1. Select "Utilities" from the top menu, then "External Signals."
        2. Choose "External" for the reference source.
        3. Set PLL Loop Bandwidth setting to "High (Tracking)."
    b. Configure "AUX OUT" on the Parent scope.
        1. Select "Utilities" from the top menu, then "External Signals."
        2. Set the "AUX OUT" to "A Trig."
        3. Set polarity to "Neg."
5. Display
    a. Turn on Zoom for both Parent and Child.
        1. In the "Horiz/Acq" menu, select "Zoom Controls" and then select the button labeled "Display."
        2. Adjust the horizontal position of the zoom window to 50% (middle of acquisition).
        3. Set the zoom factor to "100."
    b. Turn on infinite persistence for the Parent and the Child.
        1. Go into the "Display" menu and select "Display Setup"
        2. Under the “Intensity” section of the “Appearance” tab, adjust the “Record View” value to 35-40%.
        3. In the “Colors” tab, select “Temp” from the “Record View Palette” section.

Apply Deskew to Channels

1. Adjust Deskew for both Parent and Child.
    a. In the "Vertical" menu, select "Deskew" from the menu listing.
    b. In the window that pops up on screen, select CH1 and adjust deskew until you reach the point where the center of the persisted waveform trace is lined up with the horizontal trigger position; this is indicated by the orange triangle at the top edge of the waveform display area.
    c. Apply deskew for CH3 on the Parent, and CH1 and CH3 on the Child in the same way as you did for CH1 of the Parent

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 synchronization of two instruments can also be simplified by using the automatic deskew and alignment application.

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