LeCroy

TF-DSQ

Probe Calibration
And
Deskew Fixture

Operator's Manual

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LeCroy Corporation

700 Chestnut Ridge Road
Chestnut Ridge, NY 10977–6499
Tel: (845) 578 6020, Fax: (845) 578 5985

Internet: www.lecroy.com

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TF-DSQ-OM-E Rev B

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Table of Contents

PROBE CALIBRATION WITH THE TF-DSQ FIXTURE

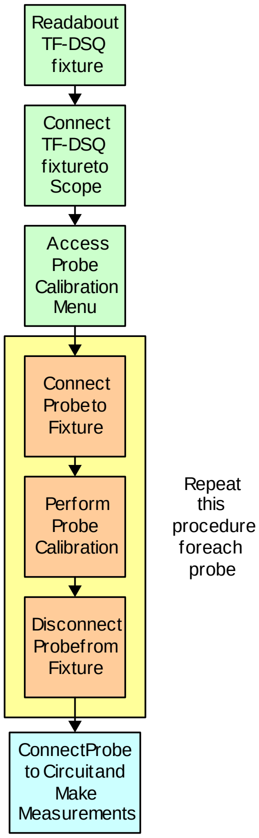
The TF-DSQ fixture is used in conjunction with the scope software to perform probe deskew and DC calibration. It has the following leading features and specifications:

- ***Deskew to +/- 20 ps typical accuracy***
- ***Differential and single-ended drive***
- ***75 ps edge for precise deskewing***
- ***Calibration of DC gain and offset and skew at same probing point***
- ***Accounts for risetime variations***
- ***Accounts for common-mode voltage***
- ***DC gain calibration accounts for probe loading effects***
- ***Integrated operation with scope for fully automatic calibration***

Specifications

Scope Compatibility (requires software version 3.6.0 or later)	**WaveMaster Scopes:** 8300, 8300A, 8500, 8500A, 8600A, and 8620A including all WaveMaster XXL models. **Serial Data Analyzers:** SDA 3000, 3000A, 5000, 5000A, 6000, 6000A, and 6020 including all SDA XXL models. **Disk Drive Analyzers:** DDA 5005A and 5005A XXL
Scope Connection	**ProLink**
Probes Supported	**D600, D600A, D300, and D200 with all probing accessories** **AP020, AP033, AP034** **HFP1000, 1500, 2500, and 3500** **PP005 and PP005A**
DC range	**± 5 V single-ended, ±10 V differential**
DC accuracy	**± (1% + 600 µV)**
Edge Risetime	**75 ps (typical) < 95 ps (guaranteed)**
Edge Amplitude and Rep Rate	**Approximately 800 mV @ 10 MHz**
Deskew Accuracy	**± 20 ps (typical)**

TF-DSQ PROBE CALIBRATION & DESKEW FIXTURE



Probe calibration is accomplished with the TF-DSQ fixture by following the basic steps in the flowchart at left. It is recommended that you read the instructions presented here in their entirety to familiarize yourself with the advanced features of the TF-DSQ fixture.

The combination of TF-DSQ fixture and scope software is designed with an important use model. Connecting probes to the circuit under test can be a difficult procedure. LeCroy's system, therefore, is designed in a manner that allows you to set up the probe calibration fixture, calibrate each individual probe once, connect your probes to the circuit, and disconnect the fixture. Once your probes are in the circuit, there is no need to revisit the fixture until the next calibration interval.

You should familiarize yourself with the following topics:

TF-DSQ fixture overview

TF-DSQ Scope connection

Probe Calibration Menu access

Probe connection to fixture

Calibrating probes

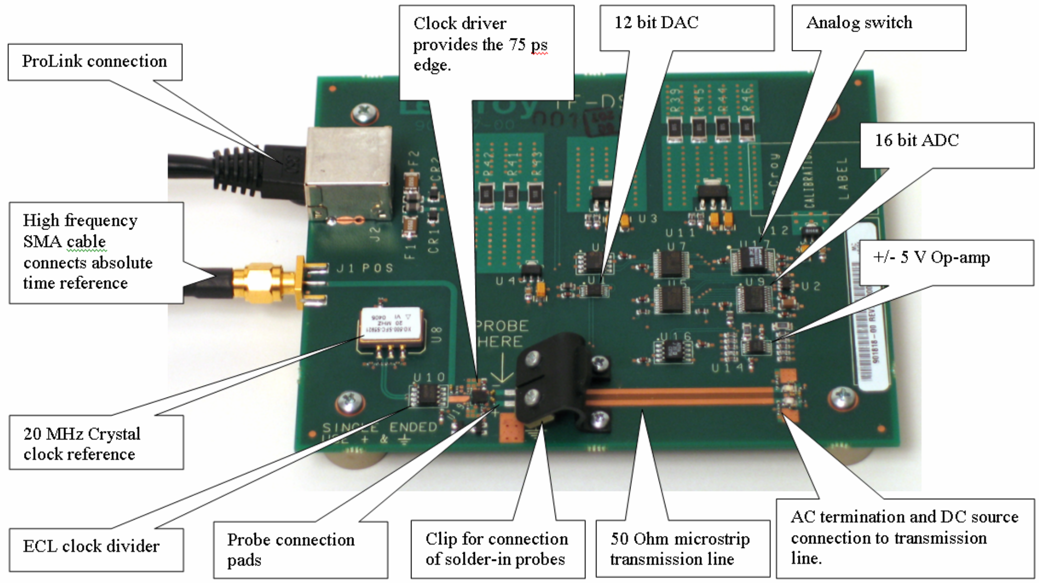
TF-DSQ FIXTURE OVERVIEW

The TF-DSQ fixture comes in a soft case containing the following components:

- The TF-DSQ fixture
- A 50-ohm cable
- A ProLink extender
- A CD containing PDF files of manuals for several scope options, including the TF-DSQ fixture

TF-DSQ Components

Major components of the TF-DSQ fixture are shown in the following figure:



TF-DSQ Fixture Elements

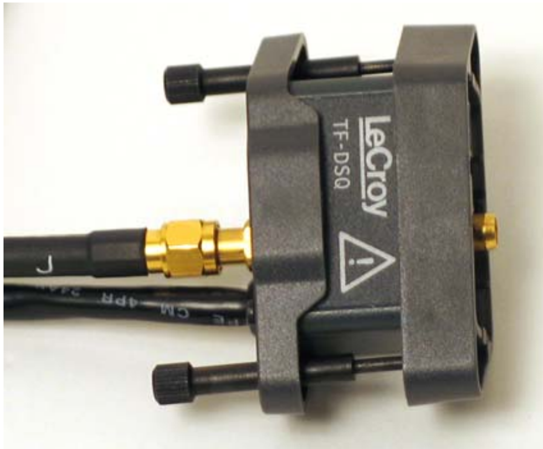
ASSEMBLING THE TF-DSQ FIXTURE

See the fixture overview to identify individual components.

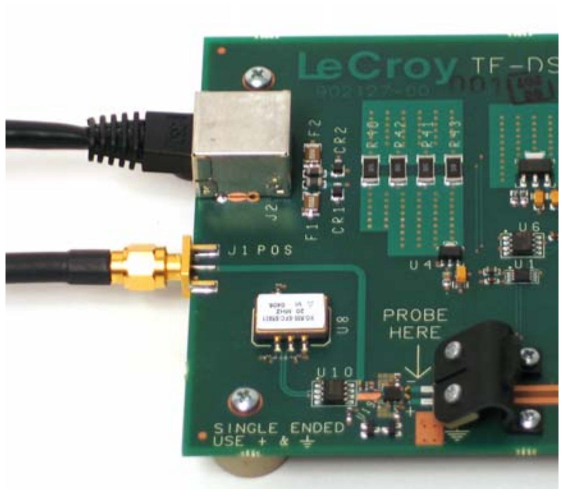
System assembly is accomplished in the following steps:

1. Connect one end of the 50-ohm cable to the ProLink extender (this comes normally connected)
2. Connect the other end of the 50-ohm cable to the SMA connector on the TF-DSQ fixture.
3. Connect the ProLink cable from the extender to the TF-DSQ fixture.

The 50-ohm connection should be torqued with an RF torque wrench and must be properly tightened.



ProLink Extender with ProLink Cable and SMA



TF-DSQ with ProLink Cable and SMA

TF-DSQ SCOPE CONNECTION

The TF-DSQ fixture is connected to either an unused scope channel or the external ("Aux In" on WaveMaster scopes) input, if one exists. In other words, any scope channel or scope input with a ProLink connector. The TF-DSQ fixture can be used only on scopes with blind mating adaptor (BMA) inputs.

Scope Auxiliary Input with ProLink and BMA Connector

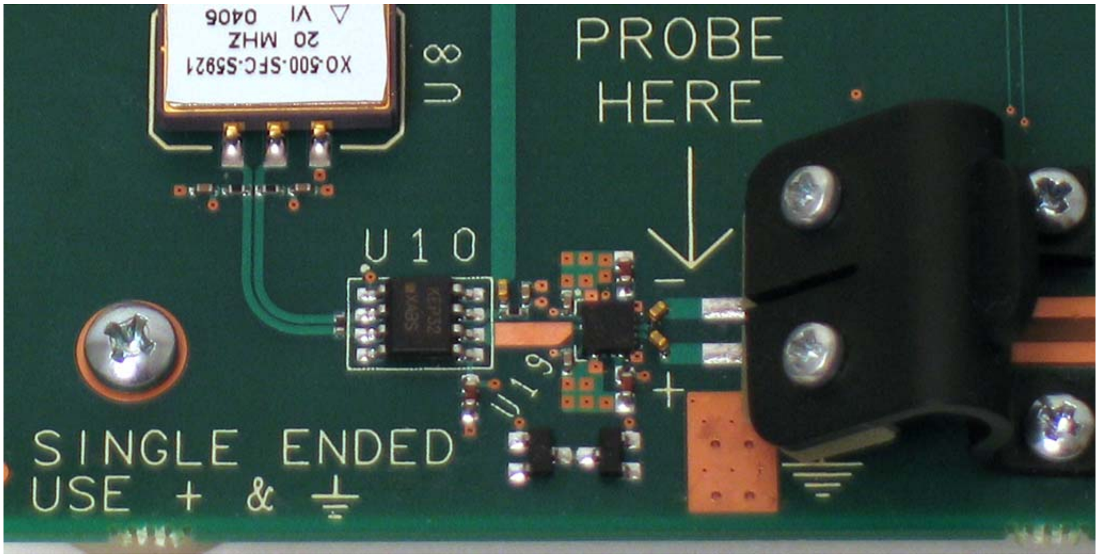
Connection of the TF-DSQ Fixture to the Scope Input

We recommend connecting to the external trigger input on a WaveMaster scope, or to an unused scope channel in the case of an Serial Data Analyzer with the "A" model suffix (these scopes replace the external trigger input with a clock recovery module).

To verify proper operation, you will see the TF-DSQ fixture called out as the probe calibration source in the probe calibration menu.

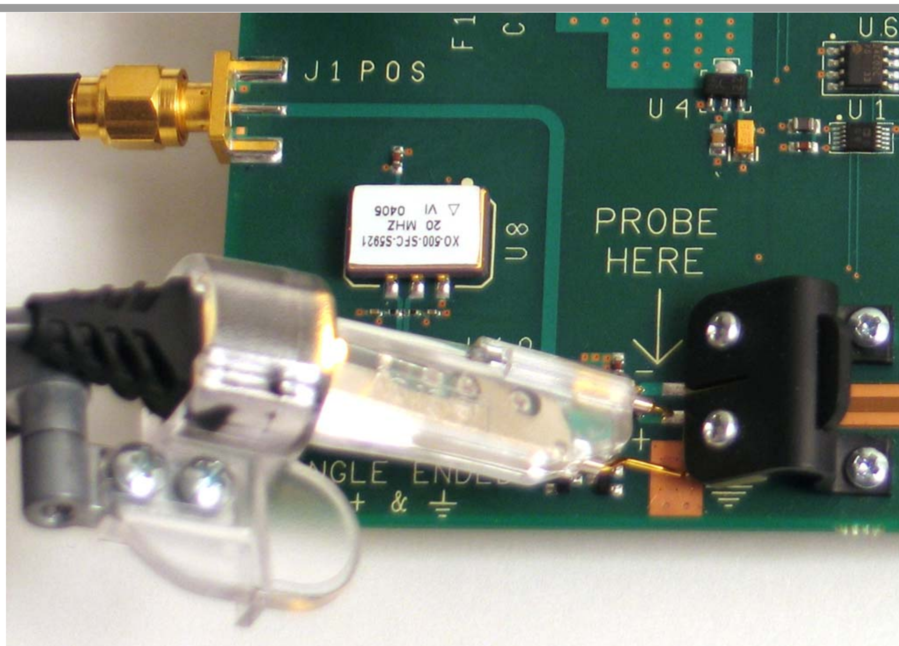
PROBE CONNECTION TO TF-DSQ

The TF-DSQ provides multiple probe connectors for various kinds of probes. Probes are connected electrically in either a single-ended or differential arrangement, depending on the type of probe. Probes are connected mechanically using either the probing pads, or a probing clip provided for solder-in probing solutions.

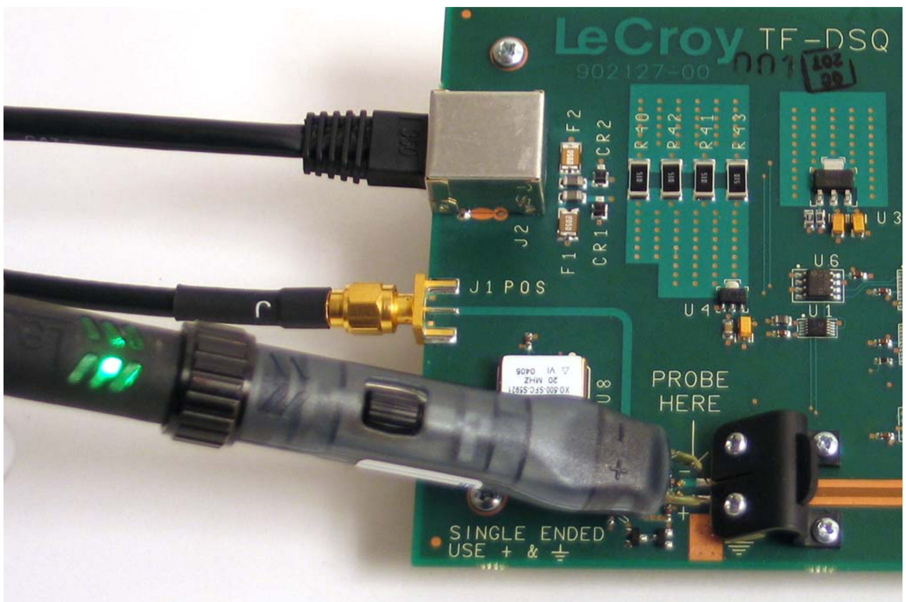


Probe Connection Points and the Clip

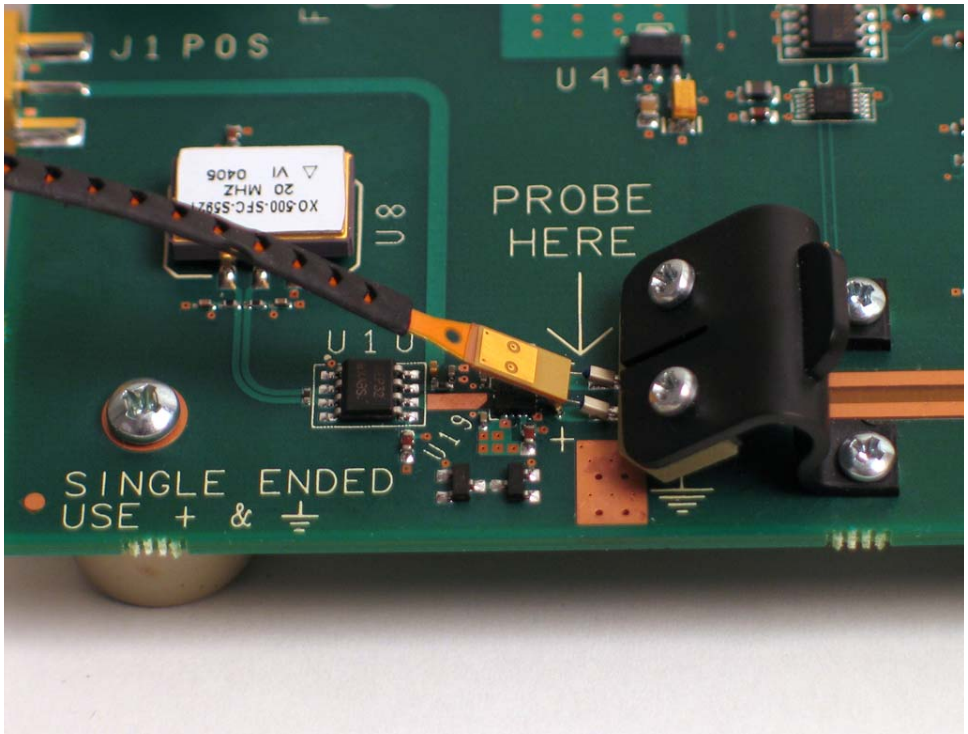
Differential probes are connected with the tip designated V+ mated to the "+" pad on the fixture, and the tip designated V- to the "-" pad on the fixture. Single-ended probes are connected with the probe tip connected to the V+ pad only, and the ground lead optionally connected to ground. Solder-in probes have their appropriate tips held down to the microstrip transmission line by the clip. Simply push down on the clip with your thumb, insert the probe connection leads under the clip and release. Make sure that V+ and V- are connected properly.



Single-ended Probe Properly Connected to the Fixture



Differential Probe Properly Connected to the Fixture (Browsing Configuration)

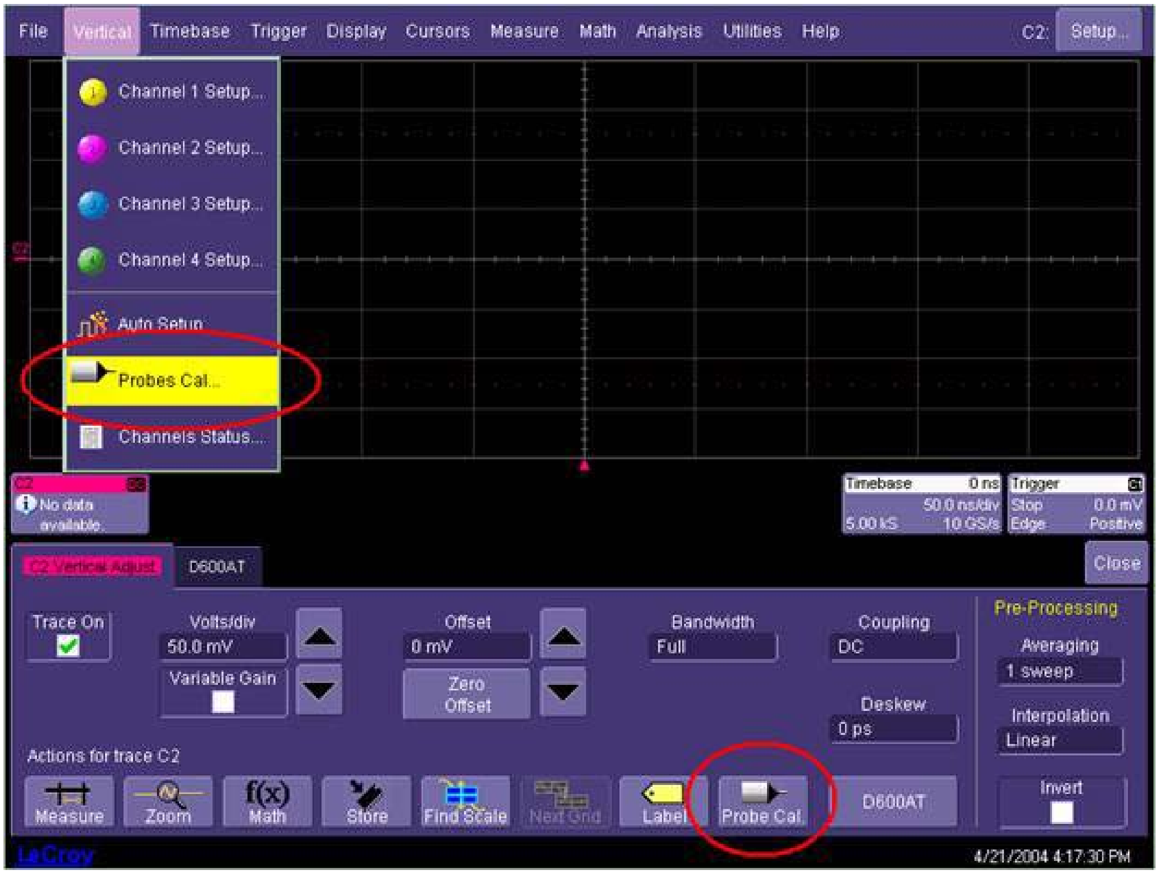


Differential Probe Properly Connected to the Fixture (Solder-in Configuration)

PROBE CALIBRATION MENU

Accessing the Probe Calibration Menu

The probe calibration menu can be accessed from the **Vertical** drop-down menu or from the channel "Vertical Adjust" dialog:



Probe Calibration Menu Description

Probe Calibration Information and Controls

The information in the probe calibration menu is organized such that each row represents the information for a given channel, and each column represents the calibration information or control for that channel. For each channel, the information and control provided includes:

- The channel number in the colored button icon and the probe type that is installed
- A **Full Calibration** button, which starts the calibration
- DC correction information including both gain and offset correction
- The skew correction
- A **Clear** button

Probe Channel and Type Identification

This area shows the type of probe connected to the channel. All other information shown in a given row is associated with that probe.

Full Calibration Button

This button causes the scope to automatically perform a full DC and deskew calibration. See details of probe DC calibration or probe deskew calibration.

Probe DC Information

Shows the gain and offset applied to the probe. If the probe measures a voltage of V, the new, calibrated voltage is:

$$V_{calibrated} = V \cdot Gain + Offset$$

Note that the offset is in Volts, and the gain is unitless.

The probe DC calibration information can be entered either manually or as the result of an automatic calibration. In the case of automatic calibration, it can be part of the full calibration or it can be a standalone DC calibration executed in advanced mode. When the DC calibration information is a result of an automatic calibration utilizing the TF-DSQ fixture, the information shown is the gain and offset utilized for the currently configured channel sensitivity (volt/division setting; see details of DC calibration). In this case, when the channel sensitivity is altered, you will notice that these values will change. **When the DC calibration information is entered manually, it will clear any automatic results and replace them globally with the newly entered values. This means that if new gain and offset numbers are entered manually, these values will apply across all sensitivity settings of the scope.**

The gain is limited to between 0.8 and 1.2, but the offset is not limited.

Note: It is important to note that some passive probes, and any user-designed probes, do not provide proper probe identification information to the scope. In these cases, the scope may not be able to determine the proper attenuation values. In this situation, you should make sure that the proper attenuation is entered in the channel "Vertical" setup dialog. Furthermore, the gain entered should be the gain *correction* applied to the system with the correctly entered attenuation.

Probe Deskew Information

The probe deskew information contains the measured skew between the probe in the specified channel and the reference channel. It can be entered manually or as the result of an automatic calibration. In the case of automatic calibration, it can be the result of a portion of the full calibration or it can be the result of a standalone deskew calibration. Even after the deskew has been performed automatically, the deskew correction can be tweaked manually.

Clear

All probe calibrations can be cleared by pressing this button corresponding to a probe.

Probe Calibration Source

This specifies the signal source used for DC and skew calibrations. When the TF-DSQ fixture is plugged into a scope input, the scope will automatically specify this fixture as the calibration source.

Skew Reference

This specifies the channel or external input where the skew reference is supplied. The skew reference is the absolute time reference to which all deskew measurements are made. When the TF-DSQ fixture is plugged into a scope input, the scope will detect this and automatically show the front panel connection of the fixture.

Recall Calibration

Whenever a probe calibration is applied, the scope saves the information in a file on the disk. If the scope must be rebooted for any reason, the probe calibration information is always cleared, but can be manually recalled by pressing this button.

Advanced Mode Checkbox

When the **Advanced Mode** checkbox is unchecked, you have access to the basic probe calibration menu. The basic probe calibration menu shows you only what is absolutely needed to perform a simple calibration of the probes. In other words, it shows you the calibration information and provides the capability to calibrate the probe with a single button press, clear the calibration information, and manually reload the calibration information following a scope reboot. When the advanced mode button is checked, you have access to the advanced mode probe calibration menu.

BASIC PROBE CALIBRATION

The TF-DSQ fixture is used to calibrate probes. Prior to beginning your measurements

- Assemble the TF-DSQ fixture
- Attach the fixture, ideally to the Auxiliary Input or an unused scope channel
- Access the Probe Calibration Menu

Follow the instructions for each probe used:

- Connect the probe to the scope channel
- Attach the probe to the TF-DSQ fixture
- Press the **Full Calibration** button in the Probe Calibration Menu.
- Wait a few seconds as the probe is calibrated (calibration wizard closes at end of calibration).
- When the calibration completes, remove the probe from the TF-DSQ fixture

Now you are ready to probe the circuit and perform your measurements. If power is interrupted during your measurements, reboot the scope and manually recall your settings.

ADVANCED MODE PROBE CALIBRATION MENU

The advanced mode is entered by checking the advanced mode box in the basic probe calibration menu.

Checking this box allows:

- Calibration of gain/offset only
- Calibration of deskew only
- Access to the advanced menu (shown as a tab behind the "Probes Cal" dialog)

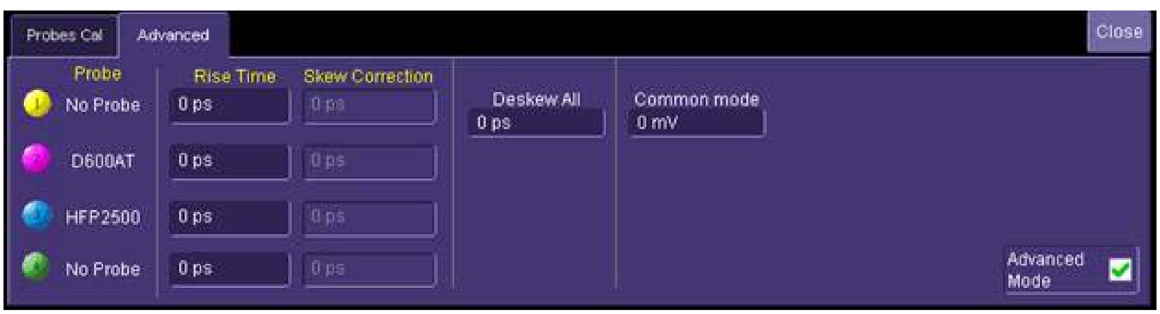
Gain/Offset Only Calibration

Pressing this button performs only the DC calibration of the probe on the specified channel. See details of Probe DC Calibration.

Deskew Only

Pressing this button performs only the deskew calibration of the probe on the specified channel. See details Probe Deskew Calibration.

The Advanced Menu



The Advanced Menu contains information and functionality useful to the advanced user of the TF-DSQ fixture. These include:

- Risetime Skew Correction

- Deskew All (or common deskew capability)
- Common mode voltage settings for DC calibration

Rise Time Skew Correction

This field shows the signal risetime and the corresponding skew correction based on the signal risetime.

When probes are deskewed, the risetime measurement of the edge used for deskewing is displayed in the **Rise Time** field corresponding to the probe and probe channel, and an additional skew correction of zero is applied.

The measured risetime of the signals encountered can be entered into the **Rise Time** field, and the scope will automatically calculate and apply a new skew correction value to be utilized in addition to the deskew amount calculated during the deskew calibration procedure. With this use, a finer deskew calibration is performed because the risetimes of the signals measured are accounted for. See details of risetime correction.

Deskew All (or Common Skew)

This is the deskew amount applied to all channels. The time entered in this field is the absolute time by which all waveforms displayed by the scope are delayed in time. This value effectively adjusts the zero time reference of the system. See Probe Deskew Calibration for details.

Common Mode Voltage Selection

The TF-DSQ fixture will calibrate probes differentially or in single-ended mode depending on the type of probe. Differential probes allow the common mode voltage component to be applied during the DC calibration for improved calibration accuracy in situations where probe gain or offset correction depends on common mode components. See Probe DC Calibration or Differential and Single-ended Probe Basics for details.

ADVANCED PROBE CALIBRATION

When the **Advanced Mode** checkbox is checked, you can perform the DC calibration and the deskew calibration separately by pressing **Gain/Offset Only** or **Deskew Only**.

When performing DC calibration, you have the option to apply a common mode component to the differential DC levels applied to the probe during calibration. See Probe DC Calibration or Differential and Single-ended Probe Basics for details..

After performing the deskew calibration, you have the option to apply a common skew value to all channels to adjust the zero time reference of the system.

If you know the risetime of the signals being measured, you can enter the measured risetime of the signals in the **Rise Time** field to obtain a further skew correction that accounts for the risetime. If the risetime entered is less than the risetime measured during the calibration, no correction is applied; otherwise, the system will calculate a correction to account for the signal risetime. It is important to enter the measured risetime. That is the risetime of the signal that the scope measures (or will measure). See details of risetime correction.

DESKEW THEORY OF OPERATION

Deskewing is an adjustment of the times of waveform data points on the screen. Deskewing is an operation to correct the times that waveforms are displayed on the screen, mainly to account for propagation delays through probes and cables.

When considering skew, there are two important things to consider:

- The relative skew between two channels
- The absolute skew from the zero time reference (i.e., the trigger point)

Two channels are properly deskewed relative to each other when the difference between the deskew values entered for each channel aligns an edge occurring at the same time and applied to both channels. A channel is properly deskewed in an absolute sense when an edge is applied to that channel, the scope is triggered on that edge, and that edge appears such that the trigger threshold crossing appears at the trigger delay, which is the zero time reference on the scope screen.

Probes are deskewed one at a time relative to a reference such that the resulting calibration will deskew each probe relative to every other probe.

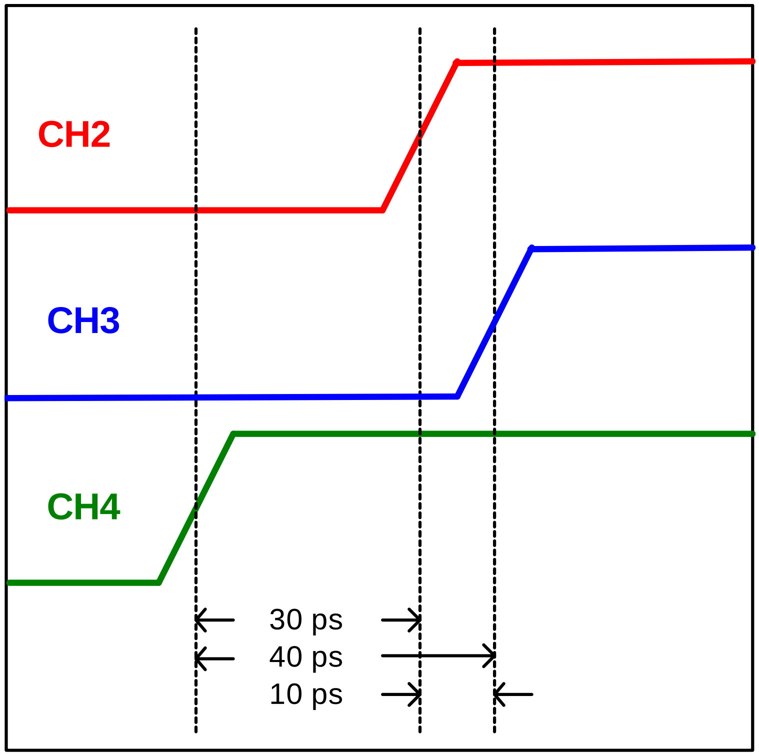
The TF-DSQ fixture has a built-in step generator. The edge generated is driven out of a cable into a scope channel or external input where the fixture is connected. The edge is simultaneously driven onto a transmission line containing the probing pads. When a probe is connected to the probing pads, the edge appears at the fixture connection to the scope and on the channel where the probe is connected. Generally, there is a difference in time between the edges due to propagation delay variations between the fixture cabling and the probe.

During the deskew procedure, the scope triggers on the channel or external input used for the fixture connection and the time from this trigger to the edge on the probe channel being deskewed is calculated. This time becomes the skew time for the probe. This process is repeated for all of the other probes being utilized.

During scope operation, there is a small dilemma. Each probe that is deskewed causes the waveform to be delayed or advanced due to the deskew time calculated for the channel. This causes the trigger to be misaligned because the trigger point is where the edge reaches the internal scope trigger circuitry, not when the edge appears at the probe tips. The scope accounts for this by subtracting the deskew correction for the channel used as the trigger source from the deskew correction on all channels. In essence, the channel used as the trigger source has zero deskew correction applied, while the relative deskew difference between all channels is maintained. This trigger compensation is hidden from the user. If better trigger alignment is desired or if there is some need to shift all of the waveforms, the **Deskew All** value in the "Advanced" menu is utilized to shift all traces together.

A simple example illustrates this:

Two probes are used in a system. They are connected to channels 2 and 3. The TF-DSQ fixture is connected to channel 4. When the scope is triggered on channel 4, you observe the following edges:



When the probes are deskewed, the relative time between channel 4 (where the TF-DSQ fixture is connected) and channel 2 is calculated as 30 ps, and **-30 ps** is entered in channel two's skew entry. Similarly, the time between channel 4 and channel 3 is calculated as 40 ps and **-40 ps** is entered in channel 4's skew entry. When triggering on channel 4, channel 2 is advanced 30 ps in time and channel 3 is advanced 40 ps in time such that all of the edges are aligned with each other and with the trigger point.

When triggering on channel 2, these times are adjusted by a common 30 ps. So, 30 ps is added to channel 2 to cause 0 deskew amount, and 30 ps is added to channel 4 to cause -10 ps deskew. Without this common addition (or delay) of all waveforms by 30 ps, all edges would remain aligned, but channel 2's trigger position would be off by 30 ps. So, you can see that this 30 ps commonly, added to all waveforms, keeps the trigger points aligned.

DESKEW RISETIME ADJUSTMENT THEORY OF OPERATION

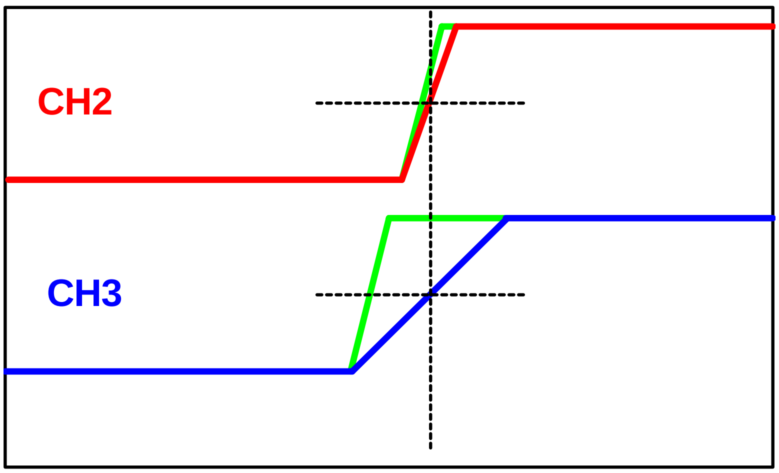
There are two situations that require adjustment of the deskew values to account for risetime:

- Two probes are used for relative time measurements, but each *probe* has a different risetime.
- Two probes are used for relative time measurements, but each *signal* has a different risetime.

The first case will be explained with obvious analogy to the second case.

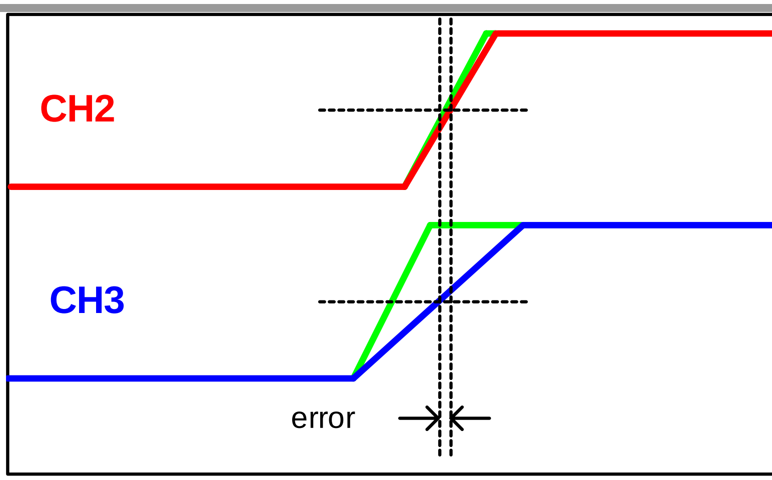
Often, two probes are utilized for measurements where each probe has a different risetime. This might occur because you are making a measurement where a reasonably low bandwidth probe can be used, but you do not have two of them, so you substitute a higher speed probe.

When the probes are deskewed, the high-speed edge from the TF-DSQ fixture is utilized. The deskewed probes might show signals that look as follows when the high-speed edge supplied by the TF-DSQ fixture is observed:



In the above picture, the green trace edge is the edge actually supplied by the TF-DSQ fixture, but because of risetime limitations of the probe and channel, the edges appear as the red and blue traces. These traces are shown aligned at the 50% crossing point at the end of the deskew calibration.

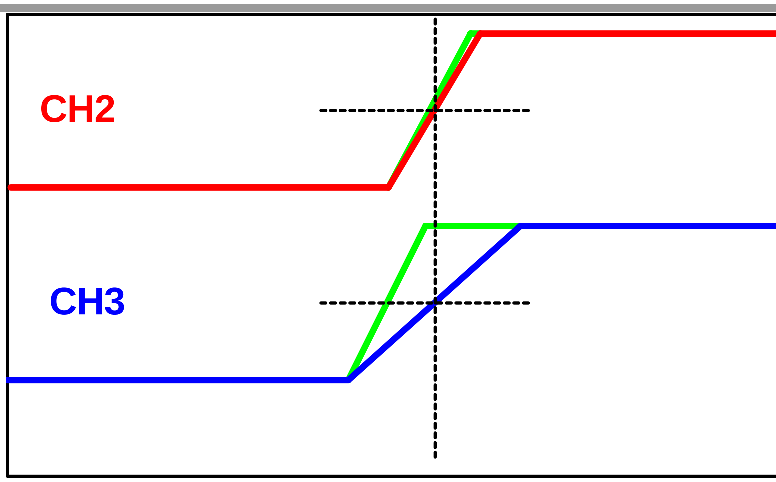
Now, lets assume that these probes are applied to signals with the same risetime, but different from the risetime applied by the deskew fixture:



In this example, you can see that the application of signals with the same risetime, but different from that applied by the deskew fixture produces a deskew error, unless compensated. In the above figure, the green trace is the actual signal applied to the probes that has a risetime of twice that employed by the fixture. The red and blue traces represent the trace acquired through the probes and channel due to this edge. Because of the different risetime applied, there is a small error.

A possible solution to this would be to vary the risetime of the edge applied to the probe by the fixture, a very difficult design. But even despite this difficulty, with a variable risetime solution, you would be required to know ahead of time what the measured risetimes would be, or to measure the risetimes first.

The TF-DSQ fixture, in accordance with the philosophy of requiring only one calibration in the fixture, handles this in a special manner. The user simply enters the measured risetime of the signals after the probe is connected to the circuit. Since the scope software saves the edge acquired during the deskew calibration process, it applies this saved edge to a variable filter using digital signal processing until the measured risetime is arrived at. At that point, the software calculates the difference in the time of the 50% crossing and calculates an additional skew correction to be applied. In this manner, the risetime is compensated for in the deskew calibration without the requirement of recalibration.



The above figure shows the traces realigned as a result of the skew correction applied after the measured risetime has been entered.

DC CALIBRATION THEORY OF OPERATION

DC calibration involves the calculation of two constants to be applied to waveforms to correct for voltage measurement inaccuracy. The two constants are the gain, applied multiplicatively, and the offset, applied additively. It is important to distinguish the gain and offset *correction* from the channel gain determined by the sensitivity control (volts/division selection) or the offset control. The sensitivity and offset controls change the absolute gain and offset of the front end amplifier, but cannot correct for inaccuracy. This is true also with the vertical gain and offset controls in zooms. The way to visualize this is to place a cursor at a point on a waveform and read the voltage. Adjusting volts/div or offset, or adjusting the gain or offset of a zoom, will affect the size of the waveform on the screen, but will not affect the voltage measured at the cursor position. The gain and offset correction applied during DC calibration will affect the voltage measured according to the following formula:

$$V_{calibrated} = V \cdot Gain + Offset$$

where V is the voltage measured prior to calibration.

Probes are calibrated for each fixed gain setting of the scope, meaning they are calibrated at 10, 20, 50, 100, 200, 500 mV and 1V per division. A unique gain and offset calculation is made for each range.

The calibration of the probe is performed utilizing 5 DC levels. The DC levels are applied such that the voltages ideally appear on the scope screen at -3, -1.5, 0, 1.5 and 3 vertical divisions. The best fit line is calculated, and the appropriate gain and offset that would make the line fit the actual voltages applied is also calculated. The gain and offset for each range is the gain and offset correction displayed in the gain and offset fields.

In all cases, the DC levels applied to the probe are measured by an ADC on the fixture placed near the probing points. In this way, the absolute voltage at the probe tips are known precisely and any DC probe loading effects are accounted for.

In the case of single-ended probes, the DC levels applied to the V+ probing pad are the same as the voltages that appear at the appropriate grid locations on the scope screen. Differential probes are handled slightly differently. In their case, the voltage applied to the V+ tip is the voltage specified in the **Common mode** voltage field, plus half the voltage desired on the scope screen. The voltage applied to the V- tip is the common mode voltage minus half the voltage desired. In this way, the probe experiences the specified common mode voltage, and the differential voltage measured by the probe is calibrated for common mode voltage effects.

DIFFERENTIAL AND SINGLE ENDED PROBE BASICS

Differential and single-ended probe discussions are a sometimes confusing subject. There are aspects of operation that must be known in order to understand their calibration.

A single-ended probe exposes a probing tip and a ground connection lead. Typically, the ground lead is connected to the outer conductor in a coaxial cable, which is connected directly to the scope's ground. The probing point is typically connected to the center conductor. Typically, the ground connection represents an essentially zero-ohm connection to scope ground, and the probe tip is a specified impedance to that ground. Other than probes, a 50-ohm cable is often used for single-ended measurements. In this case, the outer conductor connects the scope's ground to the circuit's ground, and the cable is terminated with 50 ohms at the scope, such that the conductor looks like 50 ohms looking into it at all frequencies.

In the case of single-ended measurements, the scope is measuring the difference between the probe tip and ground. Since ground is considered to be zero volts, one can say that the voltage measured at the probe tip is the absolute voltage.

A differential probe, in contrast, exposes two probing tips with an optional ground connection lead. Often, the ground connection lead is left unconnected (more on this later). Each of the probe tips are connected to two different signals in a circuit. The probe measures only the difference between the two probing points with no actual notion of the absolute voltages present. In practice, differential probes have limitations not only on the difference allowed between the two probing tips, but also the absolute voltage allowed. This absolute voltage is referenced to the scope's ground. For this reason, the probe ground lead is sometimes connected to ground in the circuit to make scope ground and circuit ground the same. This is often done only when the circuit is floating, which means that the circuit's ground is free to move to any voltage, depending on its ground connections.

Despite the fact that the differential probe only measures the difference between the voltages at its probe tips, its accuracy is sometimes affected by the absolute voltages present.

Differential signaling is used commonly for high-speed signals. In a differential system, two wires are used to transmit the signal. Often the signals are the direct opposite of each other, with both swinging across zero volts. Frequently, these signals have a common offset or bias applied to them. In this case, the common offset applied to each signal is called the common mode signal component, and the difference between each signal is called the differential mode signal component. Typically, the differential signal is the actual information signal being transmitted, with the common mode signal being present for other physical reasons, such as the biasing of an ECL gate. An ideal differential probe receives only the differential mode signal. Practical probes reject the common mode signal to a large extent. The ability of a differential probe to reject the common mode signal is stipulated by the common mode rejection ratio (CMRR).

Despite the fact that differential probes measure differentially, they can be used to measure common mode signals. In this case, the V- tip is connected to ground, and the probe continues to measure the difference between the tips. This is a useful configuration for identifying ground problems.

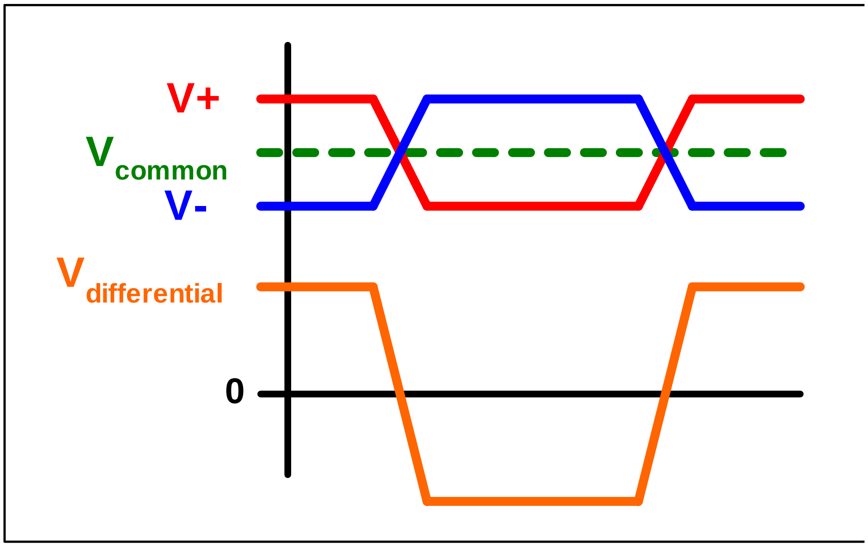
The voltages in differential systems can be described by the following diagram and equations:

$$V_{differential} = V_{+} - V_{-}$$

$$V_{common} = \frac{V_{+} + V_{-}}{2}$$

$$V_{+} = V_{common} + \frac{V_{differential}}{2}$$

$$V_{-} = V_{common} - \frac{V_{differential}}{2}$$



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