Tektronix®

TDP7700 Series TriMode™ Probes

Technical Reference

077-1427-00

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TriMode™ Probes
Technical Reference

Revision A

www.tek.com
077-1427-00

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- In North America, call 1-800-833-9200.
- Worldwide, visit *www.tek.com* to find contacts in your area.

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Important safety information

This manual contains information and warnings that must be followed by the user for safe operation and to keep the product in a safe condition.

General safety summary

Use the product only as specified. Review the following safety precautions to avoid injury and prevent damage to this product or any products connected to it. Carefully read all instructions. Retain these instructions for future reference.

This product is not intended for detection of hazardous voltages.

To avoid fire or personal injury

Observe all terminal ratings. To avoid fire or shock hazard, observe all rating and markings on the product. Consult the product manual for further ratings information before making connections to the product.

Do not apply a potential to any terminal, including the common terminal, that exceeds the maximum rating of that terminal.

Do not operate without covers. Do not operate this product with covers or panels removed, or with the case open. Hazardous voltage exposure is possible.

Avoid exposed circuitry. Do not touch exposed connections and components when power is present.

Do not operate in wet/damp conditions. Be aware that condensation may occur if a unit is moved from a cold to a warm environment.

Do not operate in an explosive atmosphere.

Keep product surfaces clean and dry. Remove the input signals before you clean the product.

Provide proper ventilation. Refer to the installation instructions in the manual for details on installing the product so it has proper ventilation.

Slots and openings are provided for ventilation and should never be covered or otherwise obstructed. Do not push objects into any of the openings.

Probes and test leads

Remove all probes, test leads and accessories that are not in use.

Inspect the probe and accessories. Before each use, inspect probe and accessories for damage (cuts, tears, or defects in the probe body, accessories, or cable jacket). Do not use if damaged.

Use only specified replacement parts.

Terms in the manual

These terms may appear in this manual:

WARNING. *Warning statements identify conditions or practices that could result in injury or loss of life.*

CAUTION. *Caution statements identify conditions or practices that could result in damage to this product or other property.*

Terms on the product

These terms may appear on the product:

- DANGER indicates an injury hazard immediately accessible as you read the marking.
- WARNING indicates an injury hazard not immediately accessible as you read the marking.
- CAUTION indicates a hazard to property including the product.

Symbols on the product

The following symbols may appear on the product:

Theory of operation

Introduction

The TDP7700 Series TriMode Probes are designed for use with 6 Series MSO and newer oscilloscopes. Three TDP7700 Series TriMode Probe models are available with bandwidths from 4 GHz to 8 GHz. 6 Series MSO oscilloscope models are available at comparable bandwidths. These probe and oscilloscope models feature the high performance TekVPI intelligent probe interface. Several TekFlex tip models are available to support different application requirements.

The TDP7700 Series probes and probe tips contain device-specific S-parameter data that, when transferred to the host oscilloscope after the initial connection is made, create unique system DSP filters. These DSP filters optimize high frequency performance of the probe and probe tip signal path.

The TekFlex connector allows for quickly changing tip accessories with a simple pinch to open operation. Accessories include small solder-in tips for accessing high speed signals in tight spaces, a 2.92 mm adapter for connecting to fixtures and pre installed test points and a high bandwidth adjustable browser for debugging and non permanent connections.

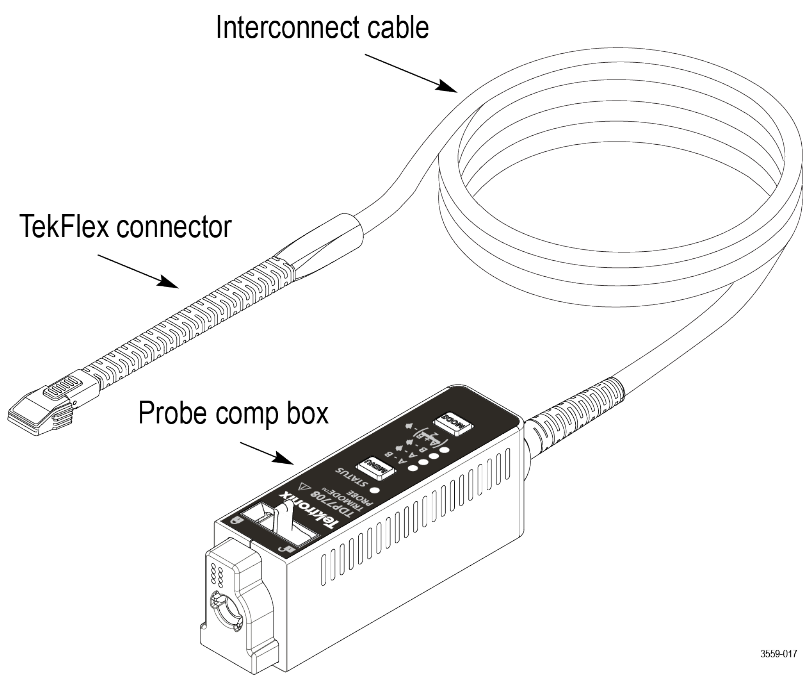


Figure 1: TDP7700 Series TriMode probe components

Probe components

TDP7700 Series probes are comprised of a probe compensation box (comp box), a TekFlex connector for attaching probe tips, and an interconnect cable that transfers measured signals, power, and control signals between the probe comp box and the TekFlex connector probe head. A TekFlex probe tip must be inserted into the TekFlex connector probe head to make the final connection to the DUT (device under test).

Probe compensation box. The probe compensation box assembly mates to the host instrument through an intelligent FlexChannel probe interface. Power, control signals, and the signal measured by the probe are transferred to and from the oscilloscope through the FlexChannel interface. The comp box includes a button to select the TriMode input mode for probe tips that support TriMode functionality: (For more information see *TriMode operation* on page 10.)

- Differential (A–B)
- A input (single-ended to ground)
- B input (single-ended to ground)
- Common-mode ((A+B)/2 to ground)

The probe input mode can also be selected using the oscilloscope Probe Setup configuration menu. The Probe Setup configuration menu is also used to adjust the probe Differential offset, Common mode offset, A side offset and, B side offset voltage settings. All other TDP7700 Series probe internal controls, such as vertical scaling, are handled automatically through communication between the probe and oscilloscope.

CAUTION. *To prevent damage to the probe, use care when handling the probe. Rough or careless use can damage the probe.*

LED indicators. There is a Status indicator LED located on the top plate of the probe comp box. This LED is normally green, but turns red when any of the following conditions exist and remains red until the problem condition is cleared:

- Probe power-on self-test failure (clear by disconnecting and reconnecting the probe)
- Probe over-temperature detected (clear by disconnecting and reconnecting the probe, allowing time for probe to cool)
- Probe input over-voltage detected (reduce input over-voltage to clear)
- Probe over current detected (adjust V_{term} or remove input signal to clear)

If the LED is red, disconnect and reconnect the probe to restart the power-on diagnostic sequence. If the symptoms continue, connect the probe to another oscilloscope channel or oscilloscope. If the symptoms remain, return the probe to Tektronix for repair.

Main interconnect cable. This cable assembly consists of a pair of matched, low-loss coaxial signal cables that carry the acquired signal from the probe head to the probe comp box. The cable assembly includes an 8-conductor bundle of wires that supply probe tip head power and control signals from the probe comp box through the TekFlex connector interface. Some of the wires carry bidirectional data, such as queries and responses about the type of probe tip attached to the TekFlex connector, and other probe tip-specific information.

TekFlex™ connector. The new TekFlex connector technology combines a high speed signal path with low speed control signaling in a single, easy to connect accessory connector. The TekFlex connector has a pinch-to-open design that when open requires minimal force to attach an accessory tip. When the TekFlex connector is closed, it provides a secure connection to the accessory to avoid accidental disconnections.

The connector provides a light-weight electrical and mechanical interface between a TDP7700 Series probe and a TekFlex active probe tip. It contains a spring-loaded set of electrical contacts that connect between the main cable wiring and contact patterns on the attached probe tip. There is a differential, high-frequency contact pattern on the top of the probe tip that connects the probe tip dual signal inputs and grounds to the probe main cable coaxial pair. There is also an eight-finger contact pattern on the bottom of the probe tip that connects the probe tip power and control signals to a ribbon wire in the main cable. The TekFlex connector provides mechanical alignment between a keyed hole pattern on the probe tip and a pair of pins inside the spring loaded connector housing.

With the TekFlex connector, the TDP7700 series probes offer a set of active probe tips with the probe's buffer amplifier only millimeters from the input connections. The short signal path enabled with the active tips provides high fidelity and a high impedance input. It minimizes signal loss, capacitance, and additive noise.

Probe tips

The probe tips are automatically detected and displayed in the Probe Setup configuration menu.

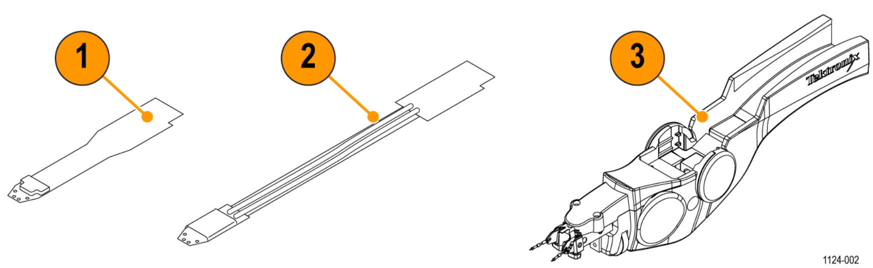


Figure 2: TekFlex active probe tips

TekFlex solder-in tips. These tips use flex circuit material and provide soldered, multi-point connections. They support full TriMode measurement capabilities and full probe bandwidth. If care is taken during the soldering process, these probe tips can be reused through multiple soldering operations. The small size and low cost design are good for high interconnect density measurements.

Both P77STFLXA Flex circuit based solder tips and P77STFLXB Flex circuit based DDR memory solder tips are available.

The first time the probe tip is detected, S-parameter data for the probe tip is sent to the oscilloscope, and probe-tip specific DSP filters are generated. These filters improve the measurement accuracy of high-frequency measurements.

P77STCABL. This optional tip provides a soldered, multi-point connection that supports full TriMode measurement capabilities at full probe bandwidth. If care is taken during the soldering process, this probe tip can be reused through multiple soldering operations. In some applications the robust mechanical design of the tip and flexible cable construction provides better usability, compared to the lower cost flex circuit tips. The first time the probe tip is detected, S-parameter data for the probe tip is sent to the oscilloscope, and probe-tip specific DSP filters are generated.

P77BRWSR. The optional browser connects to the circuit using two input contacts with very fine point tips. These tips have built-in compliance 0.02 in (0.5 mm) and adjustable spacing 0.008 in to 0.210 in (0.2 mm – 5.3 mm). The input contacts include an embedded damping resistor for optimum measurement performance.

The browser tip can be held in place or can be used to make hands-free connections to the DUT when using the Browser Tri-Pod accessory, or a probe positioner, such as the Tektronix PPM203B. The browser includes multiple sets of S-parameters based on the spacing of the tips. The spacing is monitored and the correct set of S-parameters are automatically used.

P77C292MM adapter. Use the P77C292MM, 2.92 mm adapter to connect a TDP7700 series probe to a DUT with 50 Ω test point connectors. 2.92 mm connectors are mechanically compatible with SMA connectors.

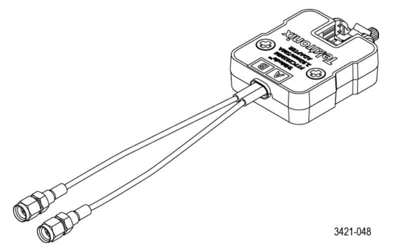


Figure 3: P77C292MM adapter

The adapter supports testing of serial standards such as HDMI, MIPI M-PHY, and DisplayPort; cables and retainer are included.

After connecting the adapter to the flex cable, use the retainer to provide a secure connection to the flex cable to minimize movement or to attach the adapter to the hand's free tripod.

For stacking more than one adapter, use the linkage adapter accessories to secure the P77C292MM adapters together.

Probe input architecture

Input architecture

TDP7700 Series probes feature a new probe architecture that addresses the need for high frequency response with decreased probe loading for high-speed, low power applications such as MIPI® and LPDDR. High performance probes with multi-GHz bandwidth have evolved in recent years, starting from traditional designs with metal pin tips attached to a probe head amplifier located at the end of a coaxial cable. As the probe bandwidth extended to 10 GHz and above, probe designs migrated to connectorized amplifier input structures that supported a variety of high frequency passive probe tips, including solderable tip designs. These probe tips typically provide a passive input attenuator network at the probe tip followed by a long cable attached to the probe amplifier connection socket. Although these passive tip, probe designs enable good, high frequency performance, they show higher probe loading in the frequency band below 1 GHz than earlier traditional designs with an amplifier closer to the probe tip. A probe with this higher loading characteristic below 1 GHz has problems when taking measurements of signals such as MIPI that can be switched to an unterminated, high impedance mode for low power operation. The TDP7700 Series probe solves this loading problem by introducing an active probe tip design with a tiny buffer amplifier located near the tip inputs. By locating an amplifier with a high impedance attenuator network at the probe tip inputs, the probe tip parasitic capacitance can be kept much lower than passive cable tip designs, thus reducing probe loading in the low power signaling frequency band used by serial data standards such as MIPI.

The following figure shows a simplified diagram of the TekFlex active probe tip architecture.

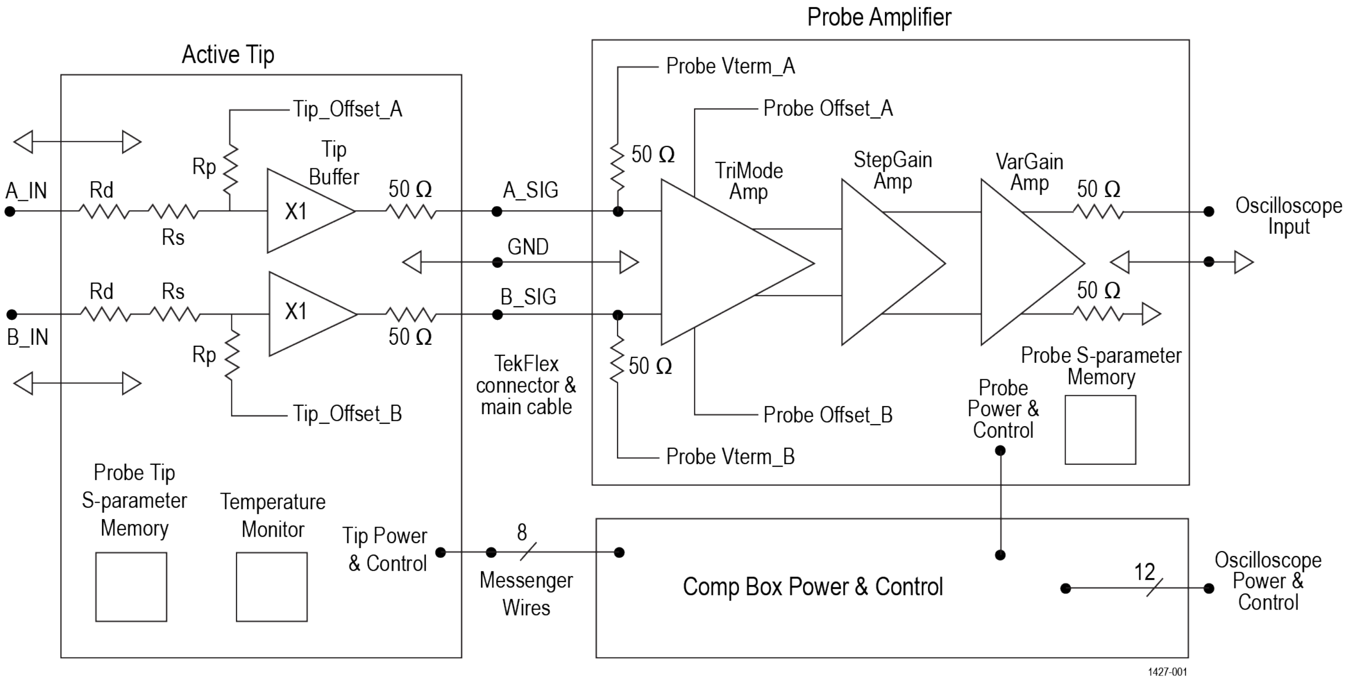


Figure 4: TDP7700 Series TriMode probe input architecture

The TekFlex active probe tip has two inputs, A_IN and B_IN, which can, depending on the tip design, support TriMode measurements. With a TriMode tip, such as a TekFlex solder-in tip, it is possible to make differential, single-ended A, single-ended B, and common-mode measurements, all from a single soldered differential signal connection to a DUT. The soldered wire connections between the two probe tip input signal vias and DUT differential signal nodes should be kept as short as possible (as should the ground via connections if single-ended measurements will be made). The A and B input signals on the probe tip pass to a matched pair of damping resistors, Rd, that isolate the probe connection to the DUT. The damping resistor value of approximately 100 Ω also serves to tune the probe tip high frequency response. Following each input damping resistor is a pair of attenuation resistors, Rs and Rp. The attenuation resistor values depend on the specific probe tip attenuation factor design. There are currently two attenuation factors available as shown in the following table with approximate attenuation resistor values. The probe tip attenuation factor in the table includes an additional 2X factor due to attenuation from the 50 Ω tip buffer output impedance and the 50 Ω probe amplifier termination impedance.

Table 1: Probe tip attenuation factors

Attenuation factor	Rs	Rp	Dynamic range	Offset voltage range
4x	25 kΩ	25 kΩ	2.5 V_{pp}	±4.0 V
10x	60 kΩ	15 kΩ	6.0 V_{pp}	±10.0 V

The input attenuation resistors serve three major functions for the dual input tip buffer:

- The high resistance of the attenuation resistors provides very light loading on the probe input signals.
- The probe tip attenuation factor expands the linear dynamic range of the probe tip inputs.
- The probe tip attenuation network provides a resistive summing junction for injecting an offset voltage signal to extend the probe tip operating voltage window.

TekFlex active tips contain a pair of unity gain amplifiers that buffer the DUT differential input signal. These buffer amplifiers provide an impedance conversion for the input signals from the high impedance input attenuator at the tip input to the 50 Ω output drive at the tip output. The buffer amplifier 50 Ω output impedance is needed to drive the probe TekFlex connector and meter-long main cable transmission lines with good high frequency fidelity. The new TekFlex interface to which TekFlex probe tips are attached includes both a dual high frequency connection for the probe tip signals as well as a low frequency connection for eight messenger wires that provide power and control for the active probe tips.

The control features of the new TekFlex interface include two analog tip offset voltage signals and a pair of digital communication signals for accessing the probe tip S-parameter memory.

The probe tip S-parameter memory contains characterization data for use with DSP correction filters that are unique to the probe tip. The S-parameter memory includes a unique data header used in automatically identifying the probe tip type and serial number. The A and B signal outputs from the probe tip are connected by high frequency spring contacts in the TekFlex connector to a pair of delay-matched coaxial cables that carry the input signals through the main cable and into the comp box. These signals terminate to a pair of 50 Ω termination resistors at the probe amplifier in the comp box. The termination resistors have an adjustable termination voltage connection for optimal loading of the probe tip output signals. The TekFlex interface messenger wires are routed as a small gauge ribbon cable, along with the delay-matched coaxial cables, inside a shielded main cable assembly.

The TDP7700 Series probe amplifier has several cascaded amplifier stages that condition the probe tip differential signal for precision measurement fidelity. The complex input stage of the probe amplifier selects the desired TriMode input mode.

This input stage of the probe amplifier includes connections for injecting a pair of adjustable probe offset voltages for precision control of the probe output zero voltage, which is a measure of the output signal with volts at both probe tip inputs.

The next stage in the probe amplifier is the step gain stage. The step gain stage provides several switchable, coarse gain steps, that extend the sensitivity range of the probe measurement down to the millivolt level with good noise performance. The step gain stage is automatically switched to its optimum setting by the oscilloscope as the oscilloscope vertical channel sensitivity is adjusted by the user.

The final stage of the probe amplifier is the variable gain stage. The variable gain stage is used for fine tune adjustment of the gain of the probe and probe tip to its calibrated value. The calibrated gain setting is determined from calibration constants characterized during manufacturing testing of the probe and probe tip and includes compensation for probe temperature variation. Although the signal that passes through the probe amplifier is processed as a differential signal through the internal amplifier stages, it is routed to the oscilloscope's TekVPI interface as a single-ended output.

The ground path for high frequency signal return currents is shown in the probe architecture figure. (See *Figure 4: TDP7700 Series TriMode probe input architecture* on page 6.) The probe ground path is continuous and along the following path:

- Extends from the DUT ground vias connections at the probe tip input
- Through the probe tip ground path
- Through the TekFlex connector ground spring contacts
- Along the main cable coaxial shields into the probe comp box
- Through the probe amplifier circuit board ground plane inside the probe comp box, and
- Through the TekVPI interface to the host oscilloscope ground

A TriMode tip requires a short DUT ground reference for making low noise single-ended probe measurements.

Although two ground via connections are available on the probe tip input, a single ground via wire connection is usually adequate for making single-ended measurements of both the A and B input signals or a common-mode measurement, all of which are ground referenced.

If only one single ended signal will be connected to the probe, the user has the choice of connecting the A input to the signal and the B input to ground, or connecting the A input to the signal and the ground input of the probe to the ground input of the DUT. In this situation, Tektronix recommends using A-B mode with the B input connected to ground. Reasons for this recommendation include that with the B input left disconnected, there is a possibility of an interfering signal coupling into the input of the probe and distorting the measured signal acquired on the A side.

A second reason for using A-B vs. A-ground is that it is often more convenient to connect the differential inputs of the probe to a device and keep the wire lengths short. The ground connections of the probe are set back from the tip and may not be as convenient to connect to a DUT with tightly spaced test points.

The optional accessory P77BRWSR is a variable-spacing probe tip which operates in Differential Input mode only. The P77BRWSR Browser probe tip does not have a physical ground connection at the probe tip; but the differential measurement process itself provides a high frequency virtual ground connection between the A and B signal input pins. A low frequency ground connection is optionally available at a square-pin socket on the browser probe tip housing.

The comp box receives power and control signals from the oscilloscope through the TekVPI interface. The TekVPI interface is an intelligent probe connection that includes many automated and manual control features. For example, there is a probe S-parameter memory in the comp box that stores high frequency characterization data for the probe signal path.

The downloaded S-parameter data for a probe and attached probe tip is used by the oscilloscope to generate a DSP correction filter for optimum measurement fidelity. Because this S-parameter data is unique and serialized for each probe and probe tip, it only needs to be downloaded once to an oscilloscope.

Automatic probe tip type identification is another example of the intelligent operation of the TDP7700 Series probes. When no probe tip is attached to the TekFlex connector of a TDP7700 Series probe, the TekFlex probe tip interface power is disabled. When a probe tip is attached to the TekFlex connector, the attachment is detected by the probe and the probe queries the probe tip memory to check for a valid identification header. If a valid probe tip type is verified by this TekFlex data interface query, the probe tip power is enabled until the probe tip detachment is detected.

When probe tip power is enabled, an LED is activated on the probe tip, indicating that the TekFlex interface and attached probe tip appear to be operating properly. If the probe tip type attached to the TekFlex connector is a browser probe tip, the probe tip automatically detects the current tip spacing and communicates that information to the oscilloscope.

There are several calibrated tip spacing regions defined for the browser tip, which affect the frequency response of the browser tip signal. Wider tip spacing tends to degrade the browser tip frequency response. The oscilloscope uses the current tip spacing region information to select the optimum DSP correction filter for use with the browser tip measurements.

Input architecture with the P77C292MM SMA adapter

The P77C292MM adapter is a passive probe adapter; there are no active components within the adapter. It is intended to connect the TDP7700 series probes to 50 Ω RF test points.

The following figure shows the simplified diagram of the TDP7700 Series TriMode probe input architecture with the P77C292MM SMA adapter. Because there are no active components within the adapter the A and B inputs are passed through directly to the probe amplifier.

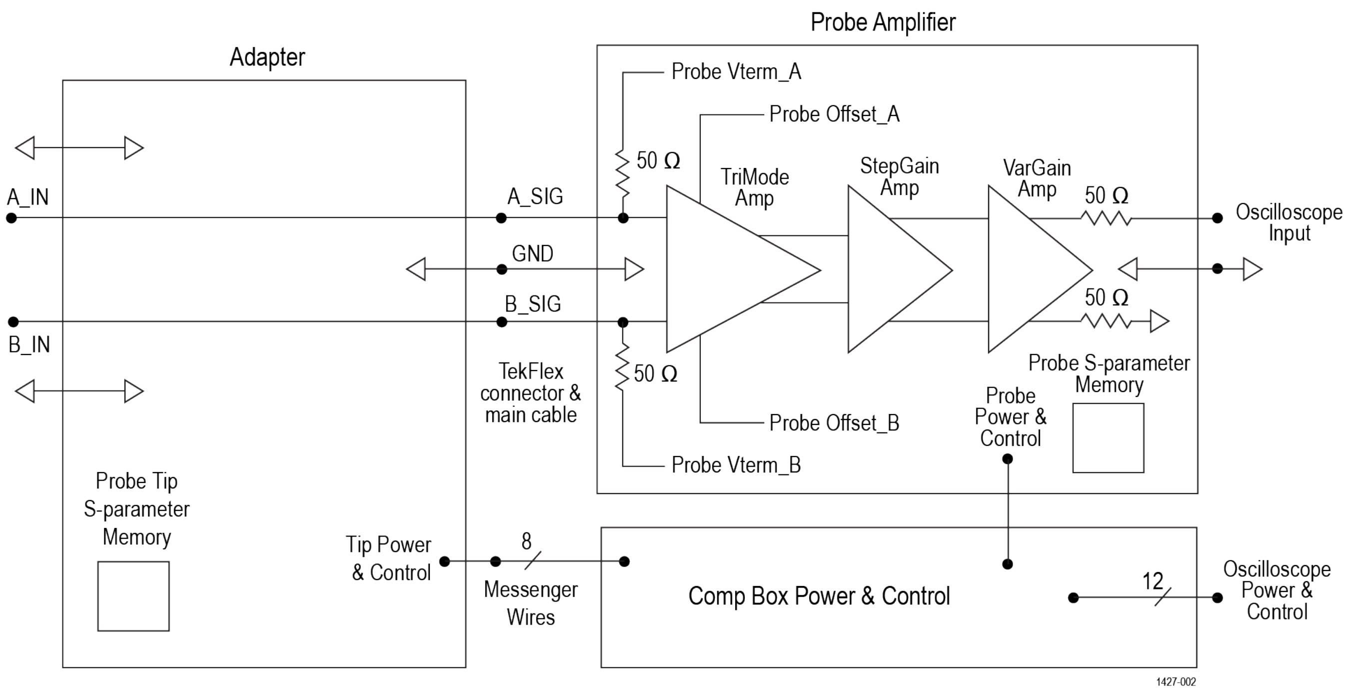


Figure 5: TDP7700 Series TriMode probe input architecture with the P77C292MM SMA adapter

TriMode operation

The TriMode feature of the TDP7700 Series probes is designed for improved convenience and enhanced capability in measuring differential signal quality. Because a differential signal is composed of two complementary single-ended signals, full characterization of a differential signal requires more than a simple differential measurement.

A TriMode probe features four input modes that allow a differential signal to be fully characterized with four measurements:

- Differential
- Positive polarity, single-ended
- Negative polarity, single-ended
- Common mode

A TriMode probe provides improved efficiency and convenience by enabling full differential signal characterization from a single soldered connection.

TekFlex active probe solder tips support the TriMode functionality of a TDP7700 Series probe by buffering a matched pair of input signals from a DUT differential signal connection. These active solder tips support the transmission of high-frequency return currents through a probe tip ground path referenced to the DUT ground connection.

Using any of the TekFlex solder-in tips, probe connections are made to the two complementary signals (the A signal and the B signal) and a ground reference. From this single DUT connection, the internal electronic switching control of the TriMode probe allows any one of the four probe input modes to be selected at a time. The TriMode probe inputs are routed to an ASIC (application-specific integrated circuit) inside the probe to a set of four independent input amplifiers that perform the following signal calculations:

- A – B (for differential signal measurement)
- A – GND (for A input single-ended measurement)
- B – GND (for B input single-ended measurement)
- [A+B]/2 - GND (for common mode measurement)

NOTE. *In the B – GND Mode, the negative polarity B input is not inverted.*

The four input amplifiers are multiplexed together and only the selected input mode function is sent to the connected oscilloscope. The following figure shows a conceptual view of the TriMode probe input structure, where the C input provides the probe ground reference and is connected to the probe tip ground interconnect using the probe's cable coaxial shields.

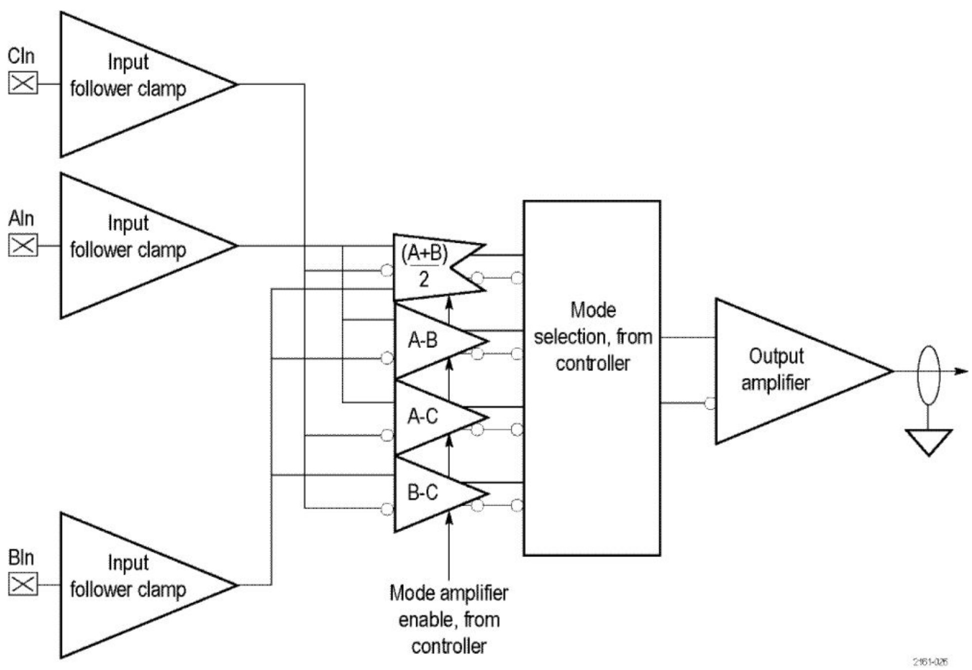


Figure 6: TriMode input structure

Operating voltages

The TDP7700 Series probes are designed to probe high-frequency, low-voltage circuits. Before probing a circuit, take into account the limits for the operating voltages discussed in this section.

- Max non-destruct input voltage
- Input signal dynamic range
- Offset voltage
- Operating voltage window

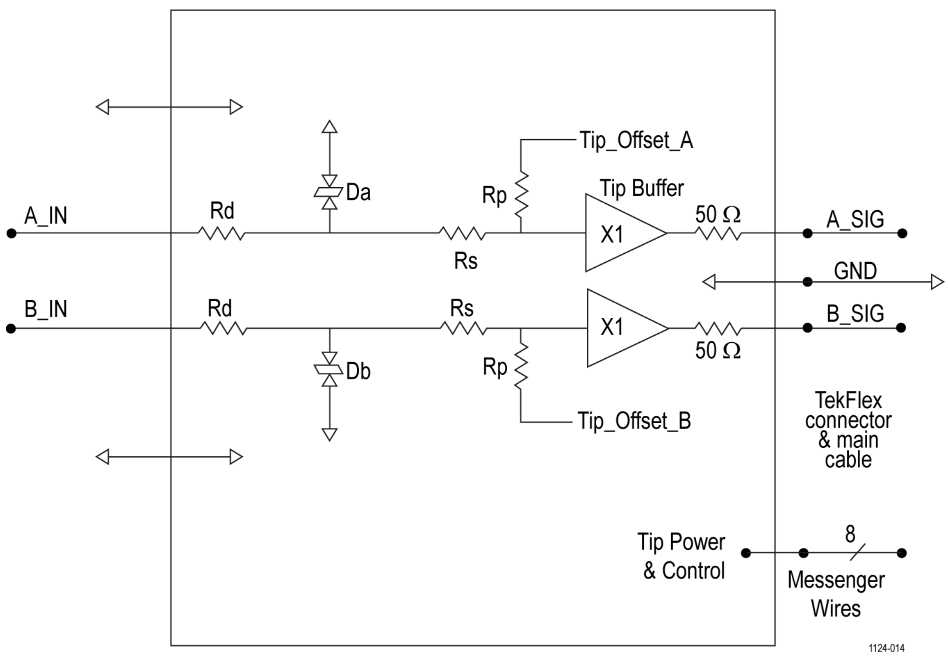


Figure 7: TekFlex probe tip inputs

Max non-desctruct input voltage

The maximum input voltage is the maximum voltage to ground that the inputs can withstand without damaging the probe input circuitry. The TekFlex active probe tips include some over-voltage protection circuitry at the probe tip signal inputs. (See *Figure 7: TekFlex probe tip inputs* on page 12.) Transient voltage suppression diodes, Da and Db, provide bidirectional voltage clamping of signals applied to the probe tip inputs. These TVS diodes limit potential ESD damage as well as signal over-voltage damage to the active tip buffer amplifier device.

CAUTION. *To avoid damaging the inputs of the probe, do not apply more than ±15 V (DC + peak AC) between either probe input and ground.*

⚠ ***CAUTION.*** *To avoid ESD damage to the probe, always use an antistatic wrist strap (provided with your probe), and work at a static-approved workstation when handling the probe.*

Input signal dynamic range

The input signal dynamic range is bound by the maximum voltage difference between either the A and B input of the probe tip and the probe tip ground reference that the probe can accept without distorting the signal. Outside of the input signal dynamic range, gain compression will result in increased linearity error and clipping. The DC specifications of the probe are valid only over the input signal dynamic range. The dynamic range is not a hard limit for signal distortion; probe tip input voltages can slightly exceed the dynamic range limit if a slightly higher linearity error is determined to be acceptable.

The differential and common-mode dynamic ranges for TekFlex probe tips are derived from the single-ended dynamic range. The maximum differential signal can be twice the single ended range since the A side can be at the positive dynamic range limit and the B side can be at the negative dynamic range limit (or vice versa). The maximum common-mode signal is the same as the single-ended dynamic range limits. With the probe tip A and B offset voltages both set to 0 V, the dynamic range will be symmetrical around that 0 V level. In this case, the dynamic range can be considered to equal ±(dynamic range ÷ 2). If the oscilloscope vertical scale factor is set high enough to display the full dynamic range, the oscilloscope will momentarily add dynamic range limit annunciation lines. These dynamic range annunciation lines can be refreshed by adjusting one of the vertical channel knobs, such as position or scale factor.

Offset voltage

The offset voltage control sums an adjustable DC voltage with the probe signal input. It is commonly used to nullify an input DC bias voltage to center the input signal swing within the linear dynamic range of the probe input. The A and B probe inputs both have an independent offset voltage control when used in A mode or B mode respectively. The following figure shows a simplified diagram of a TekFlex probe tip input network.

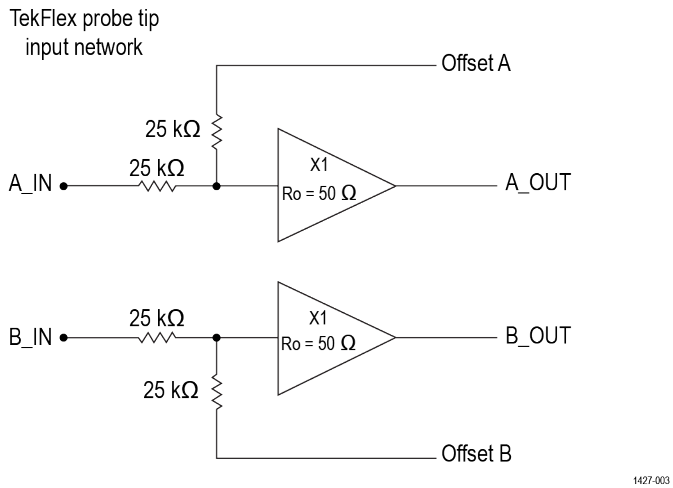


Figure 8: Simplified diagram of the TekFlex probe tip input network

The offset voltage affects the probe tip buffer's measured signal through a resistive summer configuration that forms the buffer's input attenuator network. The high value resistors used in the input attenuator result in an interaction between the input signal and the offset voltage DC level.

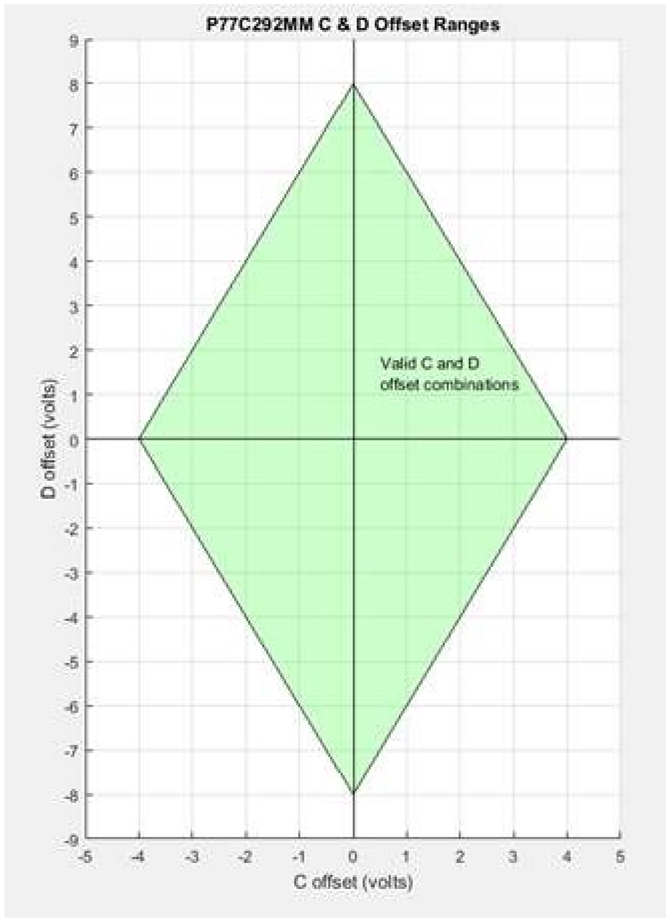
Calibrated offset voltage performance requires both the input signal and the offset voltage generator in the probe have a source resistance that is very small compared to the 25 kΩ attenuator resistors. The source resistance (R_S)of the offset voltage generator in the probe is less than 1 Ω and measured DUT signals typically have R_S << 25 kΩ. If a probe tip is attached to a probe TekFlex connector with its probe tip inputs open, the input signal source resistance is much larger than the 25 kΩ attenuator resistors. As a result, the offset voltage control is no longer calibrated and will have twice the calibrated effect on the measured probe output.

The offset voltage control, accessible from the attached oscilloscope front-panel control and the on-screen user interface, allows the probe dynamic range to be effectively moved up and down within the limits of the offset voltage range and the operating voltage window. When the offset voltage is set to zero volts and the input signal is zero volts (inputs shorted to ground, not open), the displayed signal should be zero volts. If a noticeable zero volt offset is present under the above conditions, an oscilloscope SPC and an autozero operation should be performed.

In A or B mode, the single-ended offset can be controlled through the probe menu. In C or D mode, both the differential or common-mode offsets can be controlled through the probe menu. The single-ended offsets are related to the differential/common-mode offsets by the following relationships:

- Differential = (A - B)
- Common = (A + B)/2
- A = Common + (Differential/2)
- B = Common - (Differential/2)

The offset range limits apply to each side of the single-ended inputs. Due to this, the common-mode and differential offset ranges are limited to the area shown in the diamond-shaped graph below. When the maximum differential offset is applied, the common-mode offset is restricted to 0V. Similarly, with the maximum common-mode offset applied, the differential offset is constrained to 0V.



It is additionally possible to turn on an Autotracking function. In C-mode, the autotracking function adjusts the offsets to null out the low-frequency differential input seen by the probe amplifier, maximizing the common-mode dynamic range. In D mode, the autotracking function adjusts the offsets to null out the low-frequency common-mode input seen by the probe amplifier, maximizing the differential dynamic range.

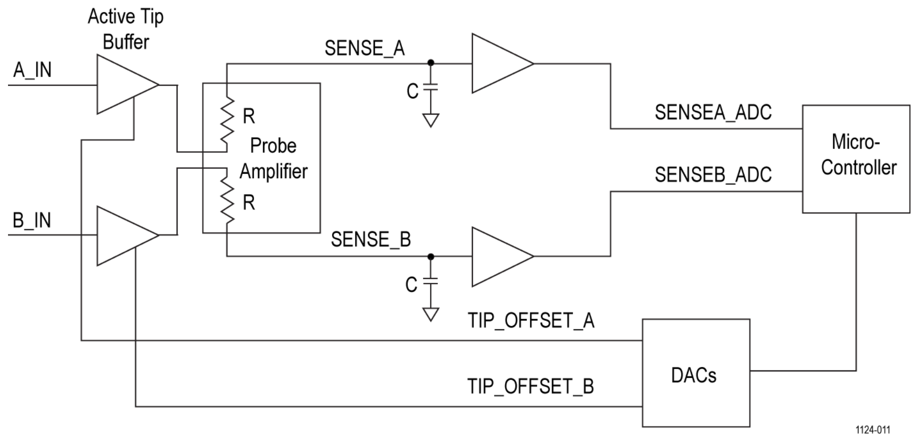


Figure 9: Simplified Auto Tracking circuitry

The A and B input signals are buffered by the active probe tip buffer amplifier and passed down the probe main cable assembly into the comp box probe amplifier input pins. The A and B input signals are picked off inside the probe amplifier with large value resistors and output to an averaging filter capacitor as Sense_A and Sense_B signals. These sense signals are buffered by a pair of unity gain amplifiers and passed to the comp box microcontroller ADC conversion inputs. The converted sense signals are transmitted to the oscilloscope when requested by an Auto Offset cycle, where they are processed by the oscilloscope according to the selected Auto Offset mode. The processed mean value or individual A and B offset values are sent back to the probe microcontroller, which drives the tip offset DAC signals accordingly.

Operating voltage window

Voltage window. The operating voltage window defines the input signal voltage range within which probe measurements can be made with good fidelity. The operating voltage window limits is a function of input dynamic range, offset and, in the case of the P77C292MM adapter, V_{term}. In the figures below, the grey area demonstrates the range of signals that can be measured by a tip. The smaller green box illustrates the dynamic range considering specific offset levels. The dynamic range square can be moved around within the operating window by adjusting the A and B offset settings.

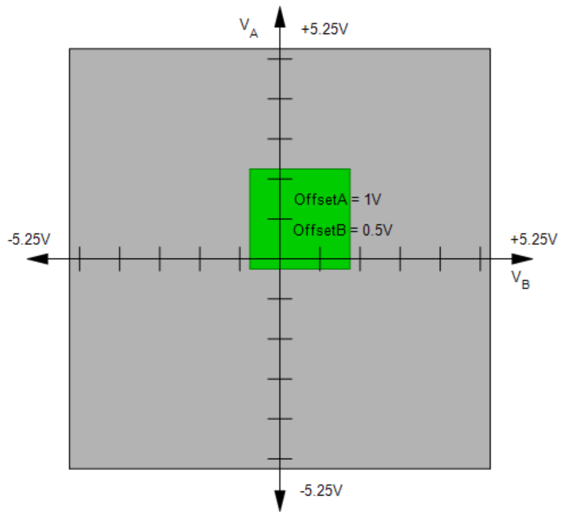


Figure 10: Operating voltage window (TekFlex solder-in tips)

The A operating voltage window range of ±5.25 V is shown on the vertical axis and the B operating voltage window range of ±5.25 V is shown on the horizontal axis. The dynamic range is also shown on the figure as the smaller green square. The TekFlex solder tip single-ended dynamic range for both the A and B inputs is 2.5 V_{p-p}. Differentially, the solder tip dynamic range is 5 V_{p-p}.

Because there are several step gain values available within the TDP7700 Series Probe Amplifier, the actual size of the dynamic range square depends upon the oscilloscope vertical scale factor setting. The vertical scale factor determines the required probe amplifier step gain setting, which is automatically set to the proper value under the oscilloscope control.

The dynamic range square is set to its full-size 2.5 V_{p-p} setting when the vertical scale factor is set to large enough V/div settings that a 2.5 V_{p-p} signal can be fully displayed on the oscilloscope. As the vertical scale factor is set to lower V/div settings, the probe amplifier step gain threshold will eventually be reached and the step gain value will be increased by one step. In C and D mode, only common-mode and differential offset adjustments are possible. For active tips, this is represented by the one-dimensional figures below.

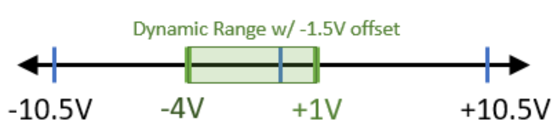


Figure 11: Operating voltage window (diferential mode, flex tip)

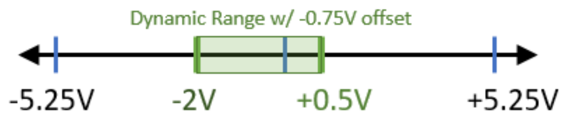


Figure 12: Operating voltage window (common mode, flex tip)

Voltage window with P77C292MM SMA adapter. The P77C292MM adapter operating voltage window is shown in the following figure.

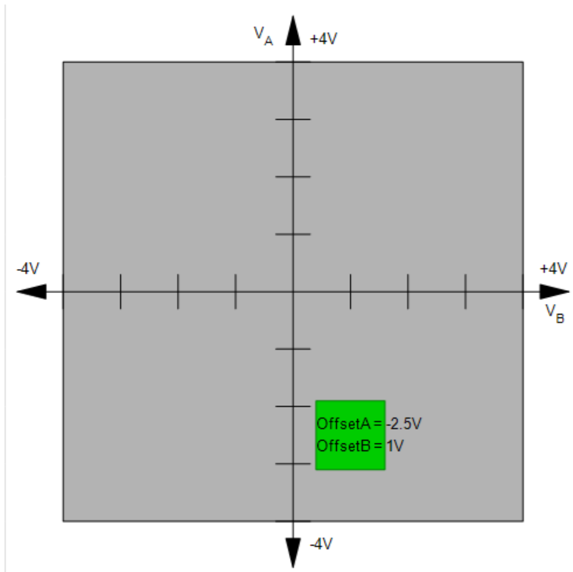


Figure 13: Operating voltage window (P77C292MM SMA adapter)

The A operating voltage window range for the adapter of ±4.0 V is shown on the vertical axis and the B operating voltage window range of ±4.0 V is shown on the horizontal axis. The dynamic range is also shown on the figure as the smaller green square.

Similar to the operating voltage for the TekFlex solder-in tips, the dynamic range square labeled Small Signal AC can be moved around within the limits of the operating voltage window by adjusting the A and B offset voltage settings. The A and B offset voltage values determine the location of the center of the dynamic range square in the operating voltage window plot. In C and D mode, only the common-mode and differential offsets are available. These operating windows are illustrated by the figures below.

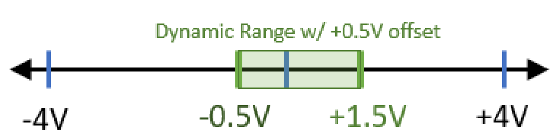


Figure 14: Operating voltage window (differential mode, P77C292MM adapter)

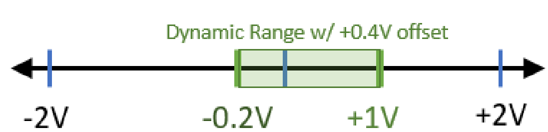


Figure 15: Operating voltage window (common mode, P77C292MM adapter)

The P77C292MM adapter has a further dimension that effects the operating window. The V_{term} setting influences the dynamic range. A plot of V_{term} and valid input voltages is shown in the Overload Specification section.

Improving measurement accuracy

DSP correction filtering

TDP7700 Series probes and probe tips use DSP correction filtering to optimize probe measurement fidelity. High frequency time domain measurement performance characteristics such as rise time, aberrations, and pulse flatness are improved by DSP correction filtering. Similarly, frequency domain performance characteristics such as bandwidth, frequency response flatness, and differential signal coupling are improved by DSP correction filtering. DSP correction filtering is performed automatically by the oscilloscope using S-parameter characterization data downloaded from probe and probe tip storage memories. This S-parameter data is unique for each probe and probe tip, rather than the nominal response data that was used in some previous generation probe families.

Distinct S-parameter data sets are stored in probe memory for each probe input mode and step gain setting combination. Every different input mode and step gain combination has a slightly different amplifier signal path, which requires different signal response correction. Since the solder tip buffers do not have complex mode switching, only one S-parameter data set is stored in the probe tip storage memory. The high frequency signal performance of the P77BRWSR browser tip changes slightly as the tip spacing is adjusted. Several S-parameter data sets are stored in the browser tip memory and automatically switched to the optimum data set, under control of the browser tip spacing position detection circuitry.

S-parameter characterization data are measured for each probe and probe tip as part of the manufacturing test process. TDP7700 Series probe signal performance is measured using a 3-port VNA measurement configuration with a 2-port TekFlex connector input and a 1-port TekVPI interface output. Custom test fixtures have been developed for making VNA port connections to the probe TekFlex connector input and TekVPI interface output. Test fixtures designed for connecting to the probe input and output signal ports are de-embedded to remove interconnect losses and signal path imperfections.

TekFlex probe tip signal performance is measured using a 4-port VNA measurement configuration with 2-port input and output connections. Because the TekFlex probe tips do not have standard RF connectors at their inputs or outputs, the custom test fixtures inject and receive VNA port signals. Custom calibration standards were developed to support de-embedding these probe tip manufacturing test fixtures.

Solder-in tip connection wire length

There are four via locations for soldering wire connections between the probe tip and the measurement DUT.

The via connections include the probe tip A and B inputs for a differential signal and two ground connections for best performance and flexibility in connecting to a close DUT ground. In general, the probe tip soldered wire connection length should be kept as short as possible. In addition, the probe tip A and B input wires should be matched in length for best differential mode measurement performance.

The differential input mode does not require a ground reference wire connection, since the differential measurement process provides its own virtual ground. The single-ended input modes, which include A-GND mode, B-GND mode, and common mode, all require at least one ground wire connection.

While only connecting the differential inputs of the probe is required and is most convenient, if there is room for another connection and a circuit ground near the probe tip, connecting to a ground connection is recommended. Connecting the ground can help avoid a situation where a large potential on the ground of the DUT causes the test signal to drift outside of the linear range of the input amplifier of the probe. Ideally, it is a good idea to connect the differential inputs and the ground to avoid clipping of the signal in the probe amplifier.

The measurement performance of all input modes is affected by the length of the input wire connection, with high frequency performance degradation increasing with increased wire length.

The measurement performance of the single-ended input modes is affected by the length of the ground wire connection, with high frequency performance degradation also increasing with increased ground wire length. The TekFlex solder-in probe tip performance is specified using a test fixture built with a probe tip having a signal wire length of 10 mils (.25 mm) and a ground wire length of 66 mils (1.7 mm).

The typical pulse waveforms in the following figures show the effect of input wire length variation on measured responses. Note that these measurements, in these images, were made using a 20 Ghz P7720 probe.

Figure 16: P77STFLXA solder tip attached with 10 mils (0.250 mm) wires (rise time = 30.5 ps)

Figure 17: P77STFLXA solder tip attached with 75 mils (1.90 mm) wires (rise time = 27.9 ps)

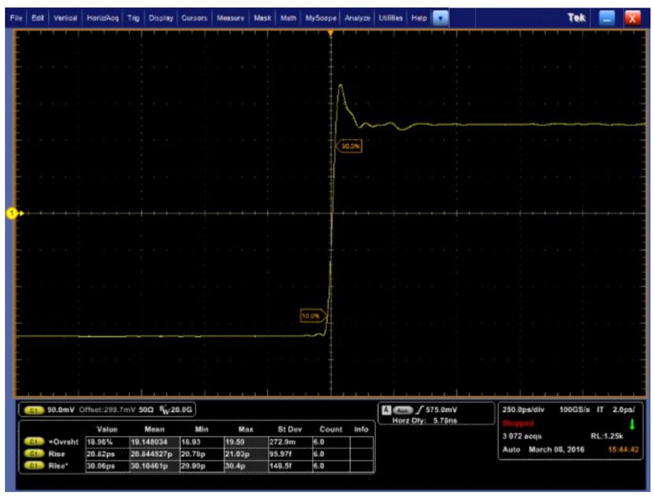


Figure 18: P77STFLXA solder tip attached with 120 mils (3.05 mm) wires (rise time = 30.1 ps)

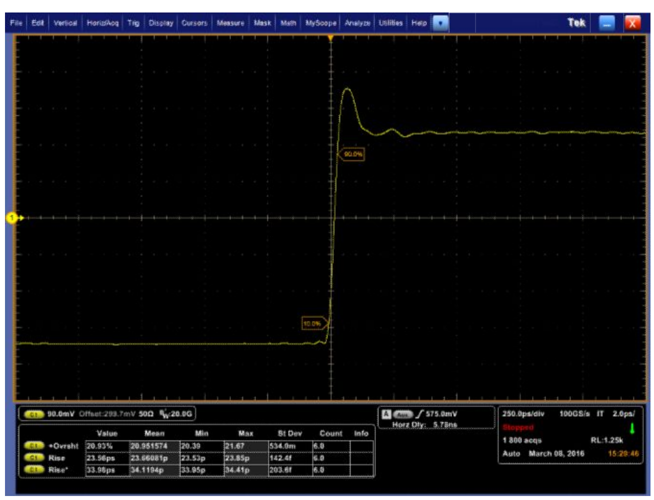


Figure 19: P77STFLXA solder tip attached with 200 mils (5.08 mm) wires (rise time = 34 ps)

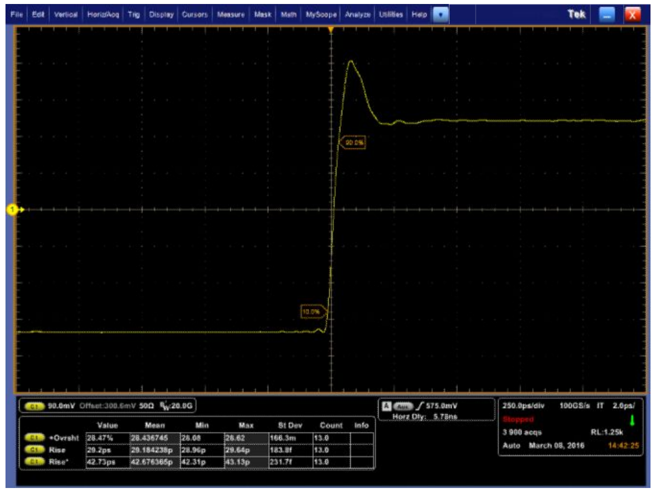


Figure 20: P77STFLXA solder tip attached with 300 mils (7.62 mm) wires (rise time = 42.8 ps)

The following table shows the rise time and overshoot degradation versus lead length.

Table 2: Rise time and overshoot degradation versus lead length

Signal wire lead length	10 - 90 Rise time	20 - 80 Rise time	Effective bandwidth
0.25 mm	30.5 ps	21 ps	20 GHz
1.90 mm	27.9 ps	19.3 ps	20 GHz
3.05 mm	30.1 ps	20.9 ps	20 GHz
5.08 mm	34 ps	23.6	17 GHz
7.62 mm	42.8 ps	29.2	14 GHz

Using offset voltage to extend TekFlex® solder-in tip input voltage range

The single-ended linear dynamic range of the TekFlex solder-in tip inputs is specified to be 2.5 V_{p-p}, which is a range from -1.25 V to +1.25 V with zero volt offset. The dynamic range of buffers is limited by the input attenuation factor, which is 2X for the solder-in probe tips as shown in the following simplified figure. A 2X attenuation factor was selected for the probe tips to optimize dynamic range and noise, since a higher attenuation factor would have increased probe noise. Although the dynamic range of the probe tip buffer cannot be extended, it is possible to extend the range over which the tip dynamic range window can be moved by adjusting the probe offset voltage. The offset voltage range of the TekFlex solder-in tips is -4 V to +4 V, which is adjusted using the Probe Setup screen of the oscilloscope or the offset knobs on the oscilloscope front panel. Using the offset voltage controls, it is possible to make measurements within any 2.5 V_{p-p} window between -5.25 V and +5.25 V. As an example, by setting the offset voltage to +3.0 V, it is possible to measure an HDMI signal, which has a signal swing between about +2.8 V and +3.3 V.

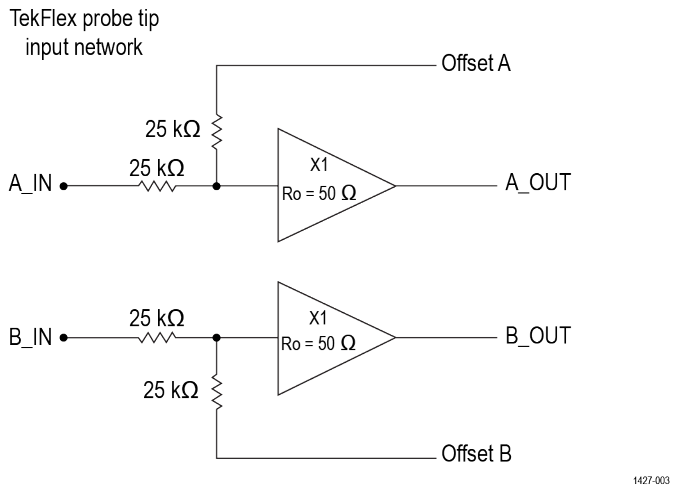


Figure 21: Simplified diagram of the TekFlex probe tip input network

The offset voltage affects the probe tip buffer's measured signal through a resistive summer configuration that forms the buffer's input attenuator network. The high value resistors used in the buffer's input attenuator result in an interaction between the input signal and the offset voltage DC level.

Calibrated offset voltage performance requires that both the input signal and the offset voltage generator in the probe have a source resistance that is very small compared to the 25 kΩ attenuator resistors. The source resistance of the offset voltage generator in the probe is less than 1 Ω. Typically, when the probe and tip are connected to a DUT, the DUT signals have a source resistance R_S much less than 25 kΩ.

If a probe tip is attached to a probe but not soldered to anything, the inputs will be open which effectively makes the source resistance look much larger than the 25 kΩ attenuator resistors. As a result, the offset voltage control is no longer calibrated and will have 2X the calibrated effect on the measured probe output. This effect can be helpful in troubleshooting connection issues with the tips. If a probe tip has been soldered to a DUT and adjusting the offset voltage causes the offset to move 2X the adjustment, it could indicate a broken solder joint that has left the probe tip input open.

Making single ended measurements using the P77BRWSR differential probe tip

A TriMode tip provides solder connections for a DUT ground reference for both the A and B probe inputs making single-ended measurements with a TriMode probe tip straightforward. Although the differential input mode of the probe is normally used to make a differential signal measurement, single-ended measurements can be made using Differential Input mode when the probe input connections and offset voltage controls are configured properly, This single-ended configuration process is particularly important to understand when using the tip, since this variable-spacing Browser tip operates only in Differential Input mode. Differential Input mode provides a measurement of the difference (A – B) between the A and B input signals. If the probe tip B input is connected to a DUT ground, the resulting Differential Input mode measurement (A – 0 V) results in a display of the single-ended A input signal response.

When making differential signal measurements, the P77BRWSR Offset Voltage control is normally set to the Common-mode (CM) Tracking mode. With CM tracking mode active, the A and B input signals are monitored and the Offset A and Offset B settings are both adjusted to match the DC common-mode voltage of the A and B input signals [(A + B)/2]. The differential Offset voltage should be set manually to the center of the signal voltage swing. The common mode offset should be set to 1/4 of the signal swing. For a +5 V CMOS logic signal; for example, the differential offset voltage should be set to +2.5 V and the common mode offset should be set +1.25V. The A signal input voltage should then range from +5 V to 0 V, which is within the 6 Vp-p dynamic range of the Browser tip as long as the offset voltage is set near the center of its expected voltage swing. These offset settings maximize the dynamic range of single ended measurements for the differential browser.

Temperature compensation

The TDP7700 Series probes employ temperature compensation to optimize measurement accuracy.

Active tip measurement configuration

In many of the high-frequency signaling standards that the TDP7700 Series probes are designed for, a 50 Ω termination at the transmitter is in parallel with another 50 Ω termination at the end of the transmission line path, effectively making a 25 Ω signal source impedance. In this application, the solder tip or browser tip measurement configuration is designed to pick off the transmitted signal at a location in the signal transmission path.

The input impedance for a solder tip, Z probe, varies with frequency. For a TekFlex solder tip the DC input resistance is about 50 kΩ and decreases with frequency above about 10 MHz to about 100 Ω above 10 GHz. Refer to the graphs later in this document for input impedance information. See page *Impedance graphs* on page 36.

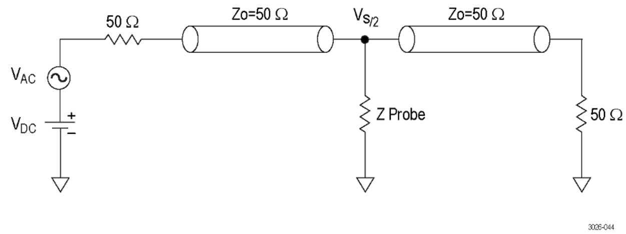


Figure 22: Active tip measurement configuration

Skew measurements of differential signals

Differential signals are composed of two complementary single-ended signals that generally swing around a common bias voltage. An example of an LVDS differential signal is shown in the following figure.

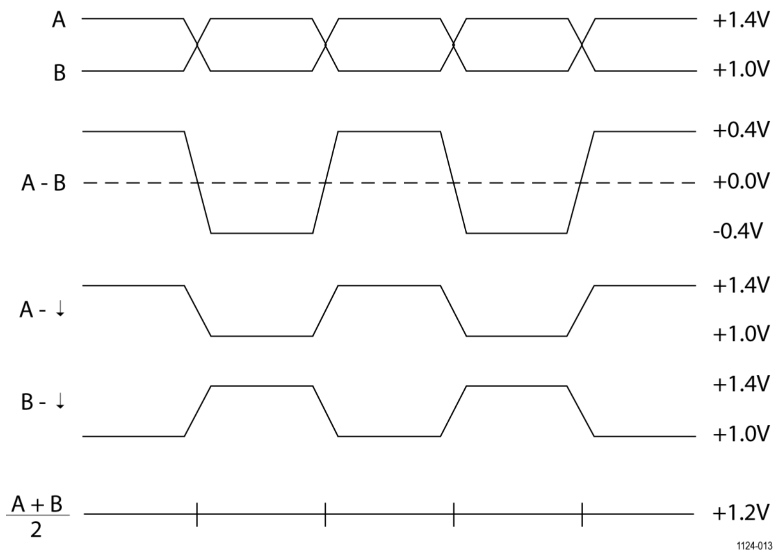


Figure 23: Example of LVDS differential signal

The complementary single-ended signals labeled A and B in the previous figure must have well matched signal timing (for example, low skew) to function as a useful differential signal. If the signal skew becomes comparable in size to the rise time of the complementary signals, then the rise time of the resulting differential signal will be slower than expected. Skew is a measure of the time delay mismatch between two supposedly matched signals.

Although very accurate low skew measurements usually require TDR or VNA measurement equipment, it is possible to make relatively accurate skew measurements of a differential signal pair using a TDP7700 Series probe and a TekFlex probe tip. A flex circuit based solder tip should first be soldered to the DUT differential signal, taking care to match the A and B input wire lengths, because the wiring length mismatch will contribute to the skew measurement error. A DUT ground reference connection should also be made to one of the TekFlex tip ground vias using a wire length as short as possible.

At first it might seem reasonable to try to make a skew measurement by directly comparing the A and B signal timing. Although it is possible to display both the single-ended A and B signals that make up the differential signal using the TriMode measurement selection function, both signals cannot be displayed with a single signal acquisition of the oscilloscope. Even though it is possible to capture the A signal and store it as a reference waveform for comparison with a follow-on B signal acquisition, the trigger timing uncertainty between acquisitions might make this a less than accurate, if not impossible approach.

A more indirect, but more accurate, skew measurement is possible by switching the probe input mode to the common mode setting. Because the common mode setting for a TekFlex probe tip features full probe bandwidth, the response should be fast enough to display the relative skew performance. The common mode response for a perfectly matched, zero skew, complementary signal pair should be a flat trace at the common DC bias voltage level. As the skew of the signal pair increases, the common mode waveform begins to show narrow pulses at the signal logic transitions. The pulse width of these narrow transition pulses is a relative measure of the skew.

Reference

This section defines common terms used to specify the instrument.

Differential measurements

A differential probe is optimized to measure high speed differential signals. Differential signals are formed from two complementary signals with a common reference voltage. (See *Figure 24: Simplified model of a differential amplifier* on page 29.)

Devices designed for differential measurements avoid problems presented by single-ended systems. Differential signal transmission improves signal fidelity by doubling the effective signal amplitude compared to single-ended signal transmission. Differential signaling also improves signal fidelity by removing common mode noise due to the CMRR of the receiver or measurement device.

A differential probe is basically a differential amplifier used to make differential measurements that reject any voltage common to the inputs and amplifies any difference between the inputs. Voltage that is common to both inputs is often referred to as the common-mode voltage (V_{CM}) and voltage that is different as the differential mode voltage (V_{DM}).

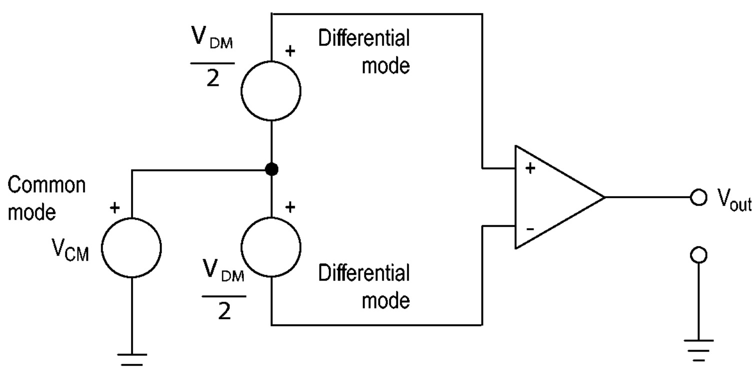


Figure 24: Simplified model of a differential amplifier

Common-mode rejection ratio

Differential amplifiers cannot reject all of the common-mode signal. The ability of a differential amplifier to reject the common-mode signal is expressed as the common-mode rejection ratio (CMRR).

The DC CMRR is the differential-mode gain (A_{DM}) divided by the common-mode gain (A_{CM}). It is expressed either as a ratio or in dB:

$$\text{DC CMMR} = \frac{A_{DM}}{A_{CM}}$$

$$\text{DC CMRR}(dB) - 20\log\left|\frac{A_{DM}}{A_{CM}}\right|$$

AC CMRR for the probe is determined using 3-port, mixed-mode S-parameters for the measured differential mode response, where A input = Port 1, B input = Port 2 and Output = Port 3 is defined as:

$$20\log\left|\frac{S_{SD21}}{S_{SC21}}\right| - 6dB$$

The 6 dB term in the AC CMRR equation gives the voltage-referenced response. CMRR generally is highest (best) at DC and degrades with increasing frequency. A typical CMRR plot for a TDP7700 Series probe and a flex circuit-based solder tip is shown.

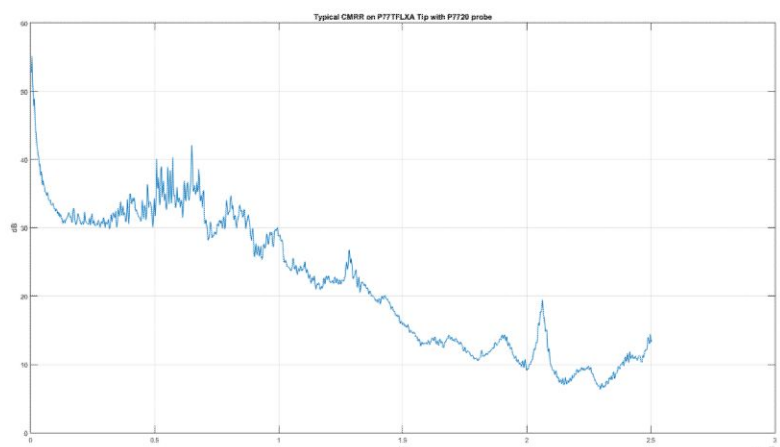


Figure 25: Typical CMRR

Assessing CMRR error

The CMRR of the TDP7700 Series probes is shown in graphs assuming a sinusoidal common-mode signal. A quick way to assess the magnitude of CMRR error when the common-mode signal is not sinusoidal is to connect both leads to the same point in the circuit. The oscilloscope displays only the common-mode component that is not fully rejected by the probe. While this technique might not yield accurate measurements, it allows you to determine if the magnitude of the common-mode error signal is significant. When using the solder-in tips, keep the tip leads the same length to maximize the probe CMRR.

Input impedance effects on CMRR

The lower the input impedance of the probe relative to the source impedance, the lower the CMRR for a given source impedance imbalance. Differences in the source impedance driving the two inputs lowers the CMRR. Note that single-ended measurements generally result in asymmetric source impedances which tend to reduce the differential mode CMRR.

Differential-mode rejection

When making common-mode signal measurements ((A+B)/2 – GND) with the TriMode probe, it is desirable to reject the differential-mode signal present between the two inputs. This rejection is expressed as the Differential-Mode Rejection Ratio (DMRR).

AC DMRR for the probe is defined using 3-port, mixed-mode S-parameters as:

$$20\log\left|\frac{S_{SC21}}{S_{SD21}}\right| + 6dB$$

for the measured common mode response. The 6 dB term in the AC DMRR equation gives the voltage-referenced response.

Channel isolation

Under ideal conditions when taking single-ended measurements with a differential probe, no part of a signal applied to one input of the probe would appear on the other input. In reality some portion of the signal on one input does “bleed” over to the other input, and this effect increases with frequency. Channel isolation is a measure of how much crosstalk occurs between the two probe inputs. The channel isolation is defined with S-parameter measurements below, where:

A input = S1, B input = S2, Output = S3

$A\ ISOLATION = 20\ \log\ (S_{31}/S_{32})\ |\ A\ Mode$

$B\ ISOLATION = 20\ \log\ (S_{32}/S_{31})\ |\ B\ Mode$

A typical isolation plot for the TDP7700 Series probes using a TekFlex solder tip is shown in the following figure. When the probe is used with TekFlex solder tips, note that channel isolation performance is highly dependent on probe tip attachment lead length. Good channel isolation requires keeping the interconnect lead length for both signal and ground connections very short.

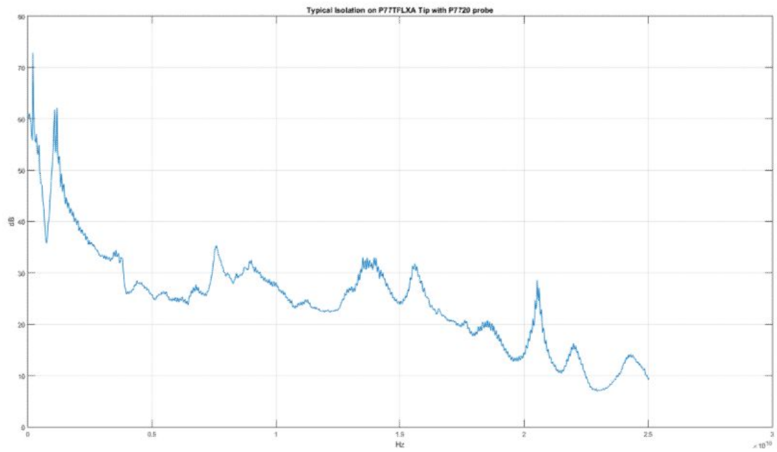
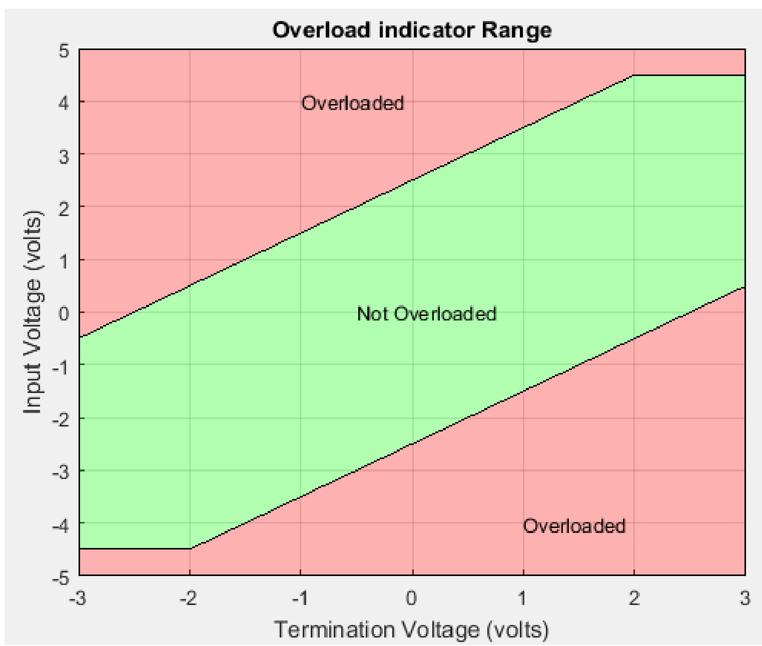


Figure 26: Typical channel isolation

Specifications

These specifications apply to the TDP7700 Series probes when installed on an 6 Series MSO oscilloscope with a bandwidth greater than or equal to 8 GHz. The probe performance may be degraded if a probe is operated using an oscilloscope with bandwidth less than the probe bandwidth. The probe and oscilloscope must have a warm-up period of at least 20 minutes and be in an environment that does not exceed the allowed environmental limits. (See *Environmental* on page 38.)

Output zero, typical	±4 mV
Linearity, typical	±1%
Termination voltage range, typical	± 2.5 mV.
Overload indicator range, typical (P77C292MM tip only)	The Overload indicator is active when the probe input is current limited or when an input overvoltage condition is detected.



CMRR, typical, unfiltered, probe only	
DC-50 MHz	34 dB
50 MHz-800 MHz	24 dB
800 MHz-4 GHz	14 dB
4 GHz-8 GHz	10 dB

DMRR, typical, unfiltered, probe-only

DC-50 MHz	34 dB
50 MHz-800 MHz	24 dB
800 MHz-4 GHz	14 dB
4 GHz-8 GHz	10 dB

Channel isolation, typical

Unfiltered, probe only

DC-50 MHz	50 MHz-800 MHz	800 MHz-4 GHz	4 GHz-8 GHz
>40 dB	>30 dB	>15 dB	>6 dB

Time delay, typical 5.05 ns ± 0.1 ns

Small signal rise time, typical

10% - 90% Rise Time

Probe	Rise time
TDP7708	<55 ps
TDP7706	<65 ps
TDP7704	<100 ps

20% - 80% Rise Time

Probe	Rise time
TDP7708	<38 ps
TDP7706	<46 ps
TDP7704	<72 ps

Small signal frequency response, typical

Probe	Frequency response
TDP7708	≥8 GHz
TDP7706	≥6 GHz
TDP7704	≥4 GHz

Noise

System noise, probe with P77STCABL tip

Probe	Noise
TDP7708	≤4.65 mV_{rms}
TDP7706	≤4.1 mV_{rms}
TDP7704	≤4.1 mV_{rms}

System noise, typical, probe with P77STCABL tip

System Noise

Probe	A, B mode	C mode	D mode
TDP7708	≤3.3 mV_{rms}	≤2.6 mV_{rms}	≤3.8 mV_{rms}
TDP7706	≤3.0 mV_{rms}	≤2.5 mV_{rms}	≤3.7 mV_{rms}
TDP7704	≤2.7 mV_{rms}	≤2.3 mV_{rms}	≤3.2 mV_{rms}

DC input resistance (, typical)

Tips/Adapters	Differential
P77C292MM	100 Ω
P77STFLXA, P77STCABL	100 kΩ
P77BRWSR	144 kΩ ± 20%

Low frequency input capacitance (differential, typical)

Solder-in tips 0.4 pF

Browser 0.23 pF @ 50 mil spacing

0.22 pF @ 200 mil spacing

Operating voltage window, typical

Solder-in tips ±5.25 V

Browser ±10 V

SMA adapter ±4 V

Offset voltage range, typical

Solder-in tips -4 V to +4 V

Browser -10 V to +10 V

SMA adapter -4 V to +4 V

Input range, typical

Solder-in tips

Single-ended	Differential
2.5 V_{pp}	5.0 V_{pp}

Browser

Single-ended	Differential
6.0 V_{pp}	12.0 V_{pp}

SMA adapter

Single-ended	Differential
1.2 V_{pp}	2.0 V_{pp}

Impedance graphs

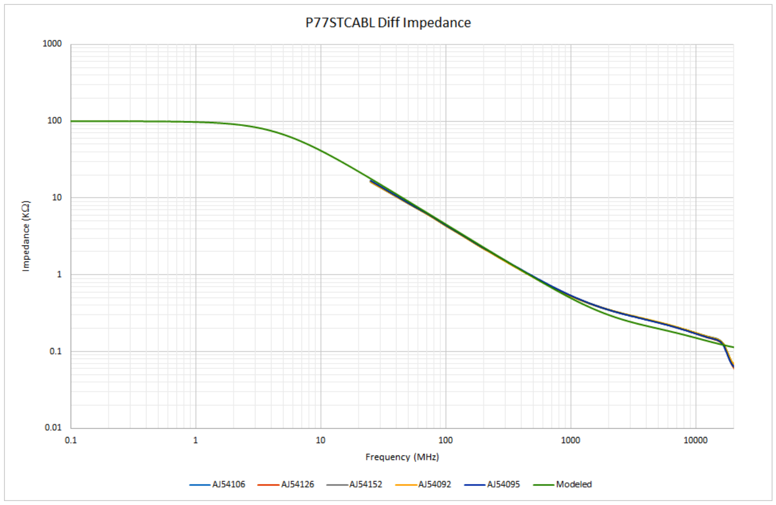


Figure 27: P77STCABL differential impedance

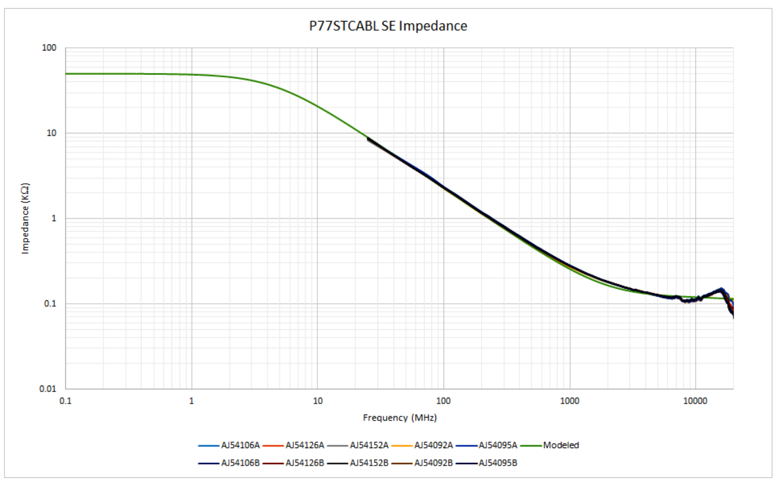


Figure 28: P77STCABL SE impedance

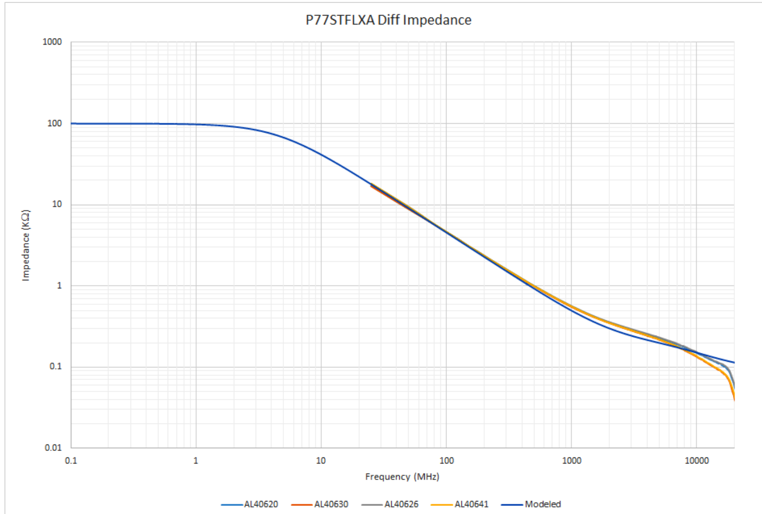


Figure 29: P77STFLXA differential impedance

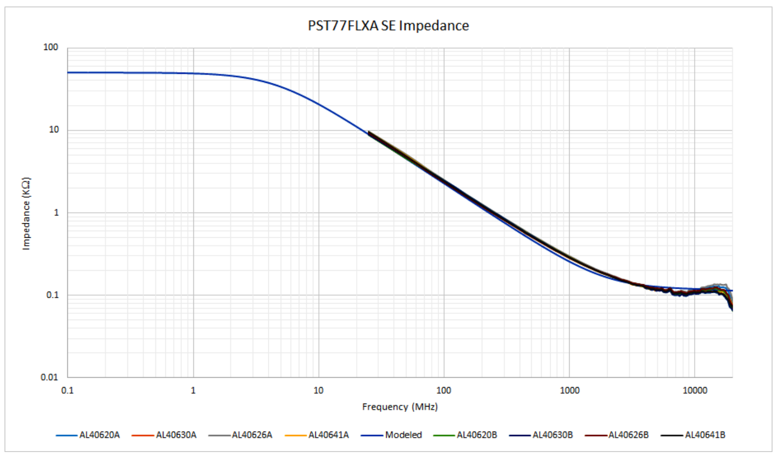


Figure 30: PST77FLXA SE impedance

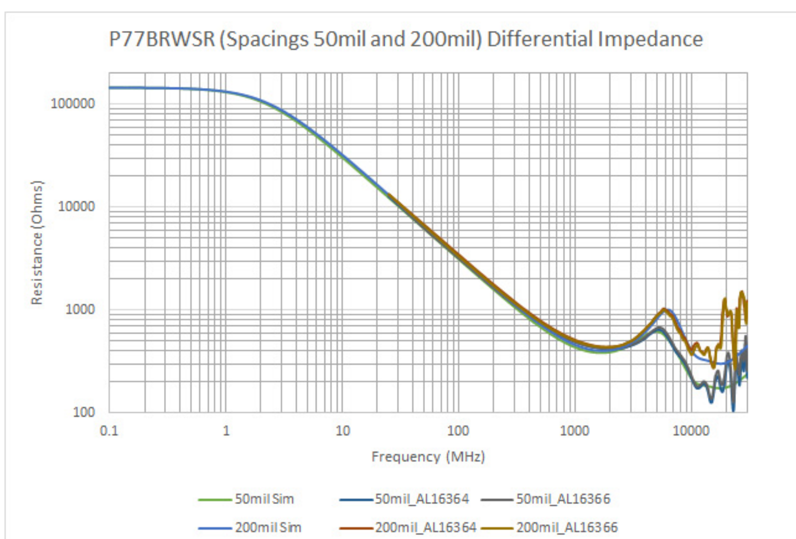


Figure 31: P77BRWSR differential impedance

Nominal characteristics

Weight	
Probe cable and head	3.5 oz
Probe (comp box, cable, head)	9.6 oz
Cable length	1.21 m (4.0 feet)
Oscilloscope interface	FlexChannel
Accessory connector	TekFlex

Environmental

Temperature range	
Compensation box and browser	Operating: 0 °C to +50 °C (32 °F to 122 °F) Non-Operating: -20 °C to +60 °C (-4 °F to 140 °F)
Cable and solder-in tips	Operating: -35 °C to 85 °C (-31 °F to 185 °F) Non-Operating: -35 °C to 85 °C (-31 °F to 185 °F)
SMA adapter	Operating: -35 °C to 85 °C (-31 °F to 185 °F) Non-Operating: -35 °C to 85 °C (-31 °F to 185 °F)
Altitude nonoperating	12,000 meters
Humidity, comp box	
Operating	5% to 90% relative humidity (% RH) at up to +40 °C, 5% to 55% RH above +40 °C up to +50 °C, non-condensing.
Nonoperating	5% to 90% RH (Relative Humidity) at up to +40 °C, 5% to 55% RH above +40 °C up to +60 °C, non-condensing.

Performance verification

Test record

Test record for TDP7700.

Model	Serial #	Procedure performed by	Date

System noise				
Performance checks				
Noise	**Probe**	**Horizontal scale**	**Limit**	**Test result**
P77STCABL or P77STFLXA	TDP7708	4 µs/div	≤ 4.65 mV_{rms}	
	TDP7706	4 µs/div	≤ 4.1 mV_{rms}	
	TDP7704	4 µs/div	≤ 4.1 mV_{rms}	

Check system noise

This test checks the system noise.

This test is valid when used on an MSO6 Series instrument. Use the following steps to check the system noise:

1. Plug a P77STCABL or P77STFLXA into the probe tip and connect the probe to a channel on the oscilloscope. The LED on the tip should light up after loading.
2. Set the probe to **Differential (A-B)** mode.
3. Adjust the vertical resolution so the noise is on the screen and isn't clipping, but still takes up as much of the screen as possible.
4. Adjust the horizontal scale to **4 µs/division**.
5. Add an **AC RMS** measurement for the channel the probe is plugged into:

   a. Tap the **Add New... Measure** button.

   b. Tap the **Amplitude Measurements** panel.

   c. Double-tap the **AC RMS** measurement to add the measurement badge to the Results bar.

   d. Tap outside the menu to close it.
6. Record this measurement in the test record, it should be lower than the system noise specification.

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