

Instruction Manual

Tektronix

**CT-6
High Frequency AC Current Probe**

071-0453-00

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Table of Contents

General Safety Summary	v
Contacting Tektronix	vii
Getting Started	1
Accessories and Options	2
Standard Accessories	2
Options	2
Optional Accessories	2
Installation	3
Probe Holder	7
Evaluation Board (Optional)	8
Operating Basics	9
Interpreting the Current and Voltage Ratings	9
Matching Impedances	10
Measuring Current	11
Injecting Current Signals	12
Optimizing Performance at High Frequencies	13
Circuit Equivalent	13
Selecting the Wire Size and Length	14
Positioning the Probe	14
Ground Side and Signal Side Measurements	16
Using the Optional Evaluation Board	17
Calibration Lines	18
Evaluation Lines	18
Probe Holder	18
Specifications	21
Performance Verification	25
Equipment Required	25
Preparation	26
Mount the Current Probe on the Evaluation Board	26
Frequency Response and Sensitivity	27
Set up the Signal Generator with the Digital Oscilloscope ..	27
Measure Output and Calculate Sensitivity	27
Measure Low End Frequency Response	27
Measure High End Frequency Response	28
CT-6 Test Record	29

Table of Contents

Frequency Response and Sensitivity – Alternate Procedure . . .	30
Set up the Network Analyzer	30
Calibrate Network Analyzer with Evaluation Board	31
Calibrate out Line Losses	31
Remove Delay	31
Verify Frequency Response and Sensitivity	32
CT-6 Test Record – Alternate Procedure	33

List of Figures

Figure 1: CT-6 current probe with probe holder and BNC-SMA adapter	1
Figure 2: Using a single wire	5
Figure 3: Using two wires to measure differential current	6
Figure 4: Using a square pin and jumper	6
Figure 5: Securing the CT-6 probe head to a test fixture board	7
Figure 6: Signal measurement	11
Figure 7: Signal injection	12
Figure 8: Circuit equivalent of added inductance and capacitance	13
Figure 9: Positioning for best HF response (20–25 gauge)	15
Figure 10: Coupling the probe to signal side or ground side	16
Figure 11: Test Fixture board for the CT-6 current probe	17
Figure 12: Securing the CT-6 probe head to the test fixture board	19
Figure 13: Typical frequency response (Bode plot)	22
Figure 14: Typical group delay ($d\phi/df$)	22
Figure 15: Securing the current probe to the evaluation board	26

Table of Contents



General Safety Summary

Review the following safety precautions to avoid injury and prevent damage to this product or any products connected to it. To avoid potential hazards, use this product only as specified.

Only qualified personnel should perform service procedures.

To Avoid Fire or Personal Injury

Connect and Disconnect Properly. Do not connect or disconnect probes or test leads while they are connected to a voltage source.

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

Do Not Operate Without Covers. Do not operate this product with covers or panels removed.

Do Not Operate With Suspected Failures. If you suspect there is damage to this product, have it inspected by qualified service personnel.

Do Not Operate in Wet/Damp Conditions.

Do Not Operate in an Explosive Atmosphere.

Keep Product Surfaces Clean and Dry.

Safety Terms and Symbols

Terms in This 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. These symbols may appear on the product:



CAUTION
Refer to Manual



Double
Insulated



Protective Ground
(Earth) Terminal



Contacting Tektronix

Product Support	<p>For application-oriented questions about a Tektronix measurement product, call toll free in North America: 1-800-TEK-WIDE (1-800-835-9433 ext. 2400) 6:00 a.m. – 5:00 p.m. Pacific time</p> <p>Or contact us by e-mail: tm_app_supp@tektronix.com</p> <p>For product support outside of North America, contact your local Tektronix distributor or sales office.</p>
Service Support	<p>Contact your local Tektronix distributor or sales office. Or visit our web site for a listing of worldwide service locations.</p> <p>http://www.tektronix.com</p>
For other information	<p>In North America: 1-800-TEK-WIDE (1-800-835-9433) An operator will direct your call.</p>
To write us	<p>Tektronix, Inc. P.O. Box 500 Beaverton, OR 97077</p>

Getting Started

The CT-6 is a miniature AC current probe suited for probing low-voltage, high-frequency circuits. Performance highlights include the following:

- 250 kHz to 2 GHz typical bandwidth
- 5 mV/mA sensitivity
- low insertion impedance
- inductive pick up or injection of signals

For a complete list of specifications, see page 21.

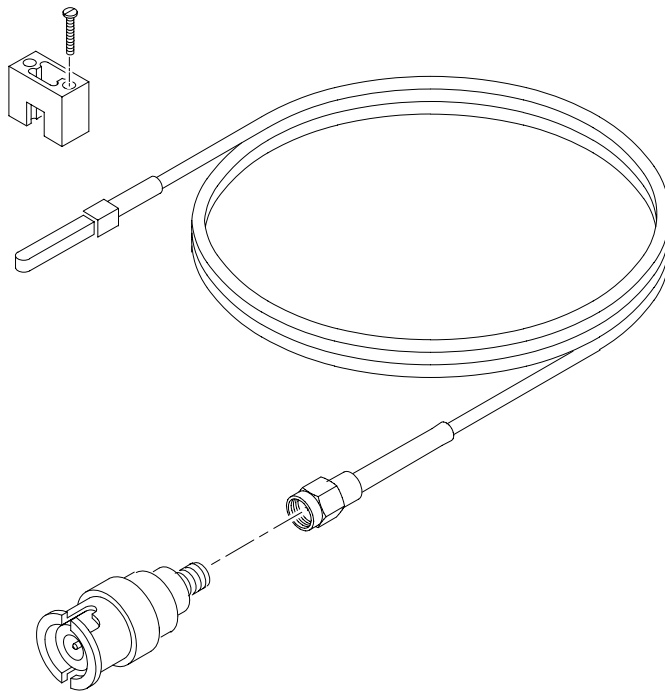


Figure 1: CT-6 current probe with probe holder and BNC-SMA adapter

Accessories and Options

Standard accessories accompany every CT-6 current probe. Both standard and optional accessories may be ordered separately. Options must be ordered at the time of purchase.

Standard Accessories

The following accessories ship with every CT-6 current probe:

- Instruction Manual (071-0453-00)
- BNC-SMA adapter (015-0572-00)
- Probe holder (015-0682-00) with 2-56 screws (211-0034-00)
- Marker bands for identifying multiple probes on the inputs of a test instrument (016-1315-00)
- Certificate of traceable calibration

Options

The following CT-6 options are available at the time of purchase:

- Option C3 (three years calibration services)
- Option D1 (calibration data)
- Option D3 (three years calibration data)
- Option R3 (extended 3-year repair/service contract)
- Option TF (evaluation board included with the current probe)

Optional Accessories

The following optional accessories are recommended for the CT-6 current probe:

- Evaluation board without the current probe (067-0349-00)
- SMA–SMA barrel adapter (015-1012-00)

Installation

Install the probe on the measurement instrument and in the circuit as detailed in this section.

To measure or inject a signal using the CT-6 current probe, do these steps:

1. Connect the SMA output connector of the CT-6 current probe to the measurement instrument, or to the signal generator if injecting a signal. Use the SMA-BNC adapter if necessary. Make sure the instrument or signal generator has a 50 Ω impedance.



WARNING. *To avoid personal injury, use the probe on grounded systems only. To avoid RF burn hazard, apply stimulus signal only after connecting the probe to the circuit.*

2. Power off the circuit under test.
3. Choose the point in the circuit where you are going to measure current or inject a signal.



WARNING. *To avoid personal injury or fire, do not exceed the maximum bare wire voltage of 30 V. Avoid using the probe in circuits where voltages exceed 30 V.*

Maintain adequate spacing between the housing on the probe head and other exposed circuit connections. The hole in the probe head is insulated, but the painted housing on the probe head is at ground potential.

4. Interrupt the circuit under test and route a conductor through the hole in the probe head in one of the following ways:
 - a. For the best overall signal fidelity, use a short wire with a small diameter. (See Figure 2.)
 - b. For convenience in measuring signals below 1 GHz you can use a square pin and jumper. (See Figure 4.)

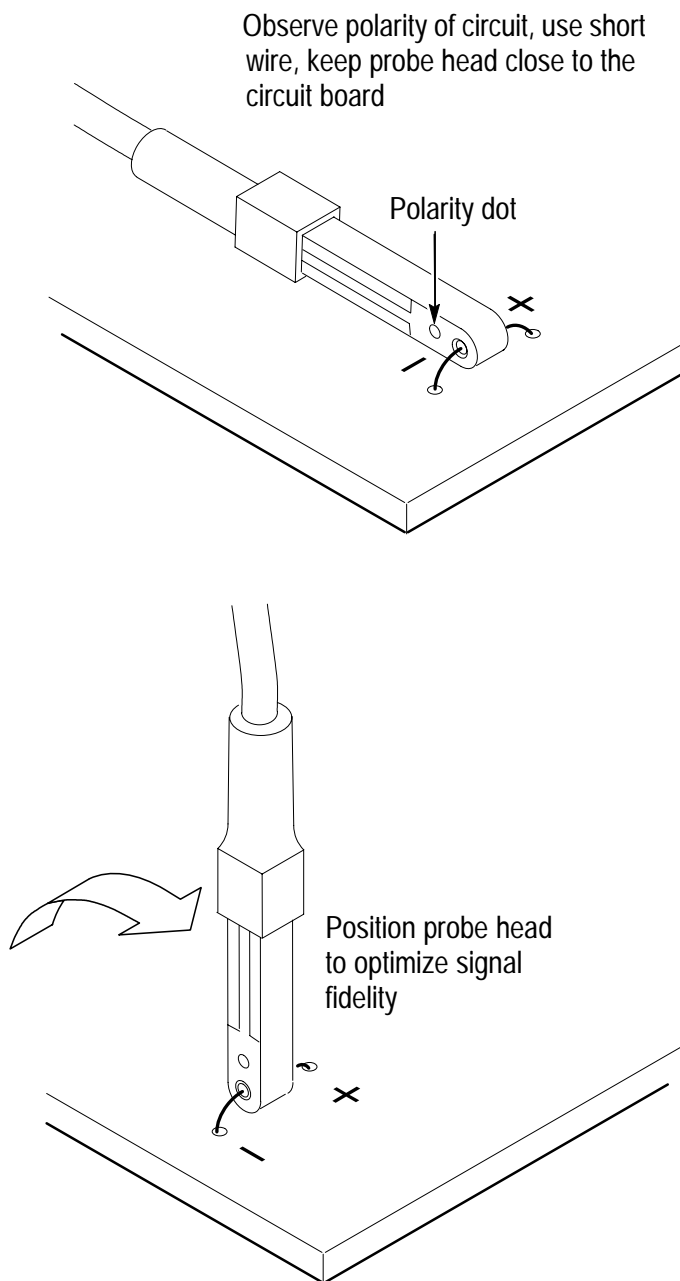


Figure 2: Using a single wire

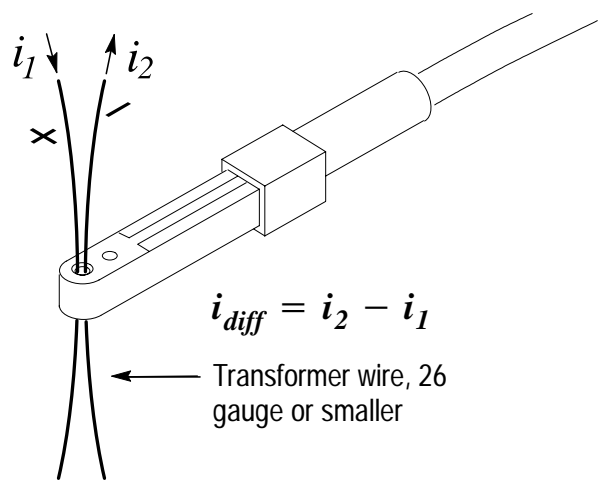


Figure 3: Using two wires to measure differential current

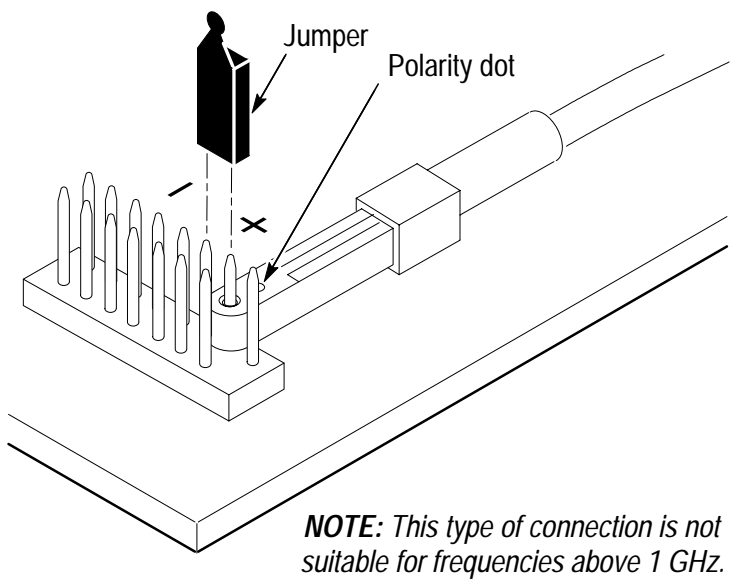


Figure 4: Using a square pin and jumper

Probe Holder

To help stabilize the probe, you can use the probe holder provided to secure the probe to a test fixture or prototype circuit board. See Figure 5.

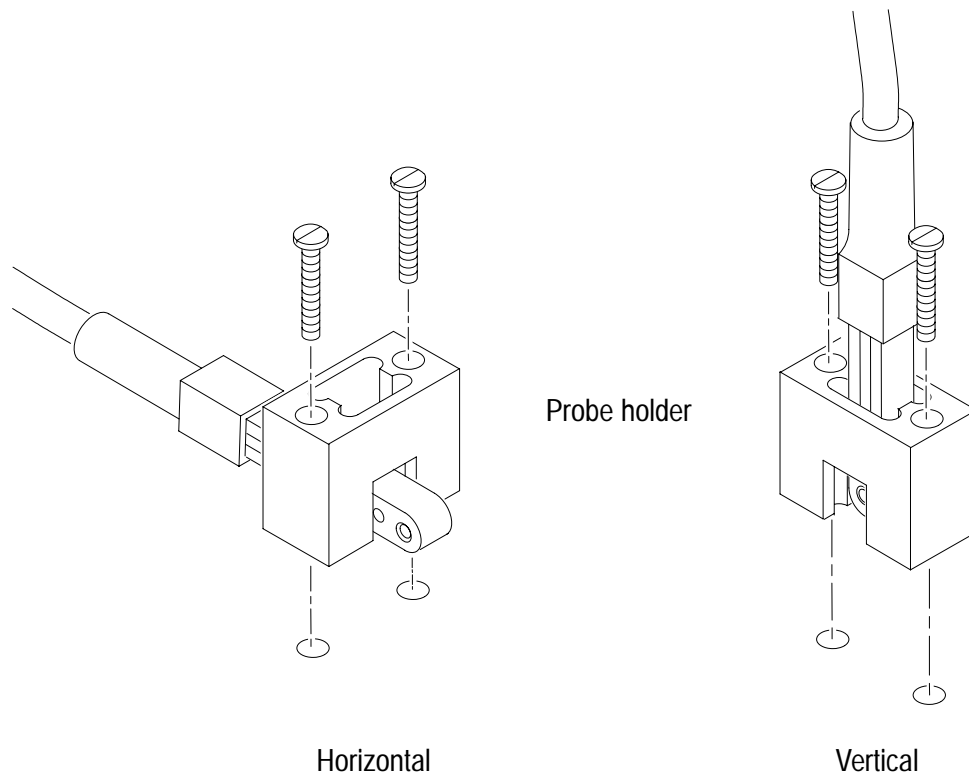


Figure 5: Securing the CT-6 probe head to a test fixture board

To mount the probe holder, do these steps:

1. Temporarily place the probe and probe holder in the position you intend to mount them.
2. Use the probe holder to mark holes on the test fixture or prototype board.
3. Drill holes that are the appropriate diameter for the mounting hardware you intend to use. The 2-56 screws and probe holder supplied with the current probe are designed to mount in plated

circuit board holes that are 0.080 inches in diameter and 0.360 inches center to center.

Evaluation Board (Optional)

Prepare the optional evaluation board for use by installing the five rubber feet with the screws provided; install one foot at each corner of the board and one in the middle.

Operating Basics

For accurate measurements, it is important to understand the electrical characteristics of the CT-6 current probe and how these characteristics affect the way you use the probe. The following topics are discussed in this section:

- Interpreting Current and Voltage Ratings
- Matching Impedances
- Measuring Current
- Injecting Signals
- Optimizing Signal Fidelity at High Frequencies
- Making Ground Side and Signal Side Measurements
- Using the Test Fixture Board

Interpreting the Current and Voltage Ratings

Refer to the specifications on page 21 for the current ratings and safety ratings of the probe. Definitions of the current ratings are as follows:

- Maximum continuous current refers to the maximum RMS current that the current probe can continuously measure.
- Maximum pulsed current refers to the maximum peak value of a pulse the current probe can measure, regardless of the pulse duration or frequency.
- Ampere-second product refers to the maximum allowable pulse duration for a given amplitude. For example, with a rating of 0.25 ampere-microsecond, a 250 mA peak pulse is allowed for 1 μ s and a 125 mA peak pulse is allowed for 2 μ s.

- Effect of DC current refers to the amount of DC current that can pass through the current probe before the low frequency cutoff point doubles. High amounts of DC current also degrade the ampere-second product for low frequency signals.

Stay within the safety rating for maximum bare-wire voltage regardless of the amount of current you are measuring. Note the following warning:



WARNING. *To avoid personal injury or fire, do not exceed the maximum bare wire voltage of 30 V. Avoid using the probe in circuits where voltages exceed 30 V.*

Maintain adequate spacing between the housing on the probe head and other exposed circuit connections. The hole in the probe head is insulated, but the painted housing on the probe head is at ground potential.

Matching Impedances

The probe is designed to work with 50 Ω impedance on the input of the measurement instrument (or output of a signal generator) as well as in the circuit under test. Even though the current probe can measure signals from (or inject signals to) circuits with varying impedances, the ideal impedance match is 50 Ω . Improperly matched impedances can cause aberrations and affect the probe sensitivity.

Measuring Current

Electrically, the current probe acts like a transformer. When measuring the AC current through a single conductor, the conductor acts as the primary winding and the current probe acts as the secondary winding. See Figure 6.

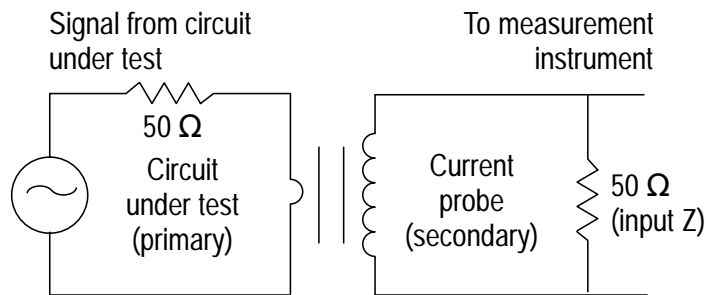


Figure 6: Signal measurement

The probe converts current in the circuit under test (primary) to a measurable voltage on the output (secondary). With matching 50Ω impedances, the sensitivity of the probe is 5 mV/mA .

To calculate the current in the circuit, divide the units of voltage measured on the probe output by 5. For example, if you measure a 50 MHz signal that is $200\text{ mV}_{\text{P-P}}$, the actual current in the circuit is $200 \div 5 = 40\text{ mA}_{\text{P-P}}$.

Injecting Current Signals

When injecting AC current into a single conductor, the current probe acts as the primary winding and the conductor acts as the secondary winding of a transformer. See Figure 7.

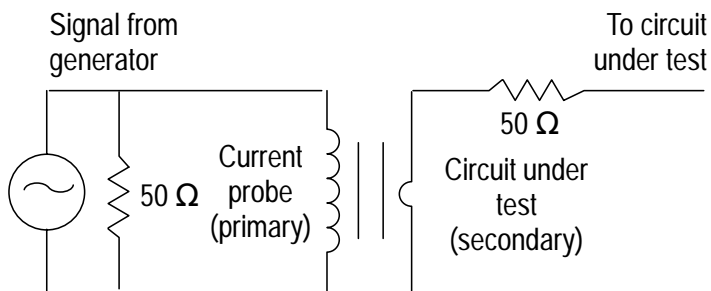


Figure 7: Signal injection

The probe converts a voltage signal (primary) to a current signal in the circuit under test (secondary). With matching 50Ω impedances, the sensitivity of the probe is 5 mV/mA.

To calculate how much voltage to apply to the probe to inject a desired amount of current, multiply the units of desired current by 5. For example, if you want to inject a 50 MHz signal that is 30 mA_{P-P}, the amount of voltage to apply is $30 \times 5 = 150 \text{ mV}_{P-P}$.



WARNING. To avoid personal injury, use the probe on grounded systems only. To avoid RF burn hazard, apply stimulus signal only after connecting the probe to the circuit.

Optimizing Performance at High Frequencies

The CT-6 current probe preserves the fidelity of the signal without the effects caused by the resistive elements of conventional passive probes. This is because the current probe couples signals magnetically rather than electrically to the measurement instrument or from the signal source.

At the high end of the current probe's frequency range, however, the added inductance of the current probe and the stray inductance and capacitance of the coupling may, in some cases, affect the fidelity of the signal.

The information and techniques presented in this section will help you to understand and minimize inductive and capacitive effects at high frequencies and optimize the performance of the probe.

Circuit Equivalent

The series equivalent of the current probe when placed in the circuit with a 27 gauge wire is shown in Figure 8.

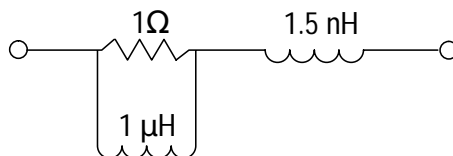


Figure 8: Circuit equivalent of added inductance and capacitance

The higher the frequency of signal you are measuring, the more you may want to consider this added inductance and capacitance and any effect it has on the circuit under test.

Selecting the Wire Size and Length

The gauge and length of wire used to route the test current through the probe may affect the amount of stray capacitance and inductance.

- The longer the wire, the more stray inductance there is and the greater the impedance the probe adds to the circuit at higher frequencies. Because of this effect, it is best to use the shortest wire possible. A 1 cm long wire is ideal.
- The larger the gauge of wire, the more stray capacitance there is between the wire and the current probe. Stray capacitance affects the circuit at high frequencies and adds aberrations to high-frequency signals. Because of these effects, it is best to use the smallest diameter wire possible. A 20-gauge bare wire is the largest wire that the 0.032-inch opening in the probe can accommodate.

Positioning the Probe

There is also stray capacitance associated with the case that surrounds the head of the current probe when there is a relatively large diameter wire in the probe (approximately 20 to 25 gauge). When measuring high-frequency signals with larger diameter wire, it is generally best to position the probe head perpendicular to the circuit board under test. See Figure 9.

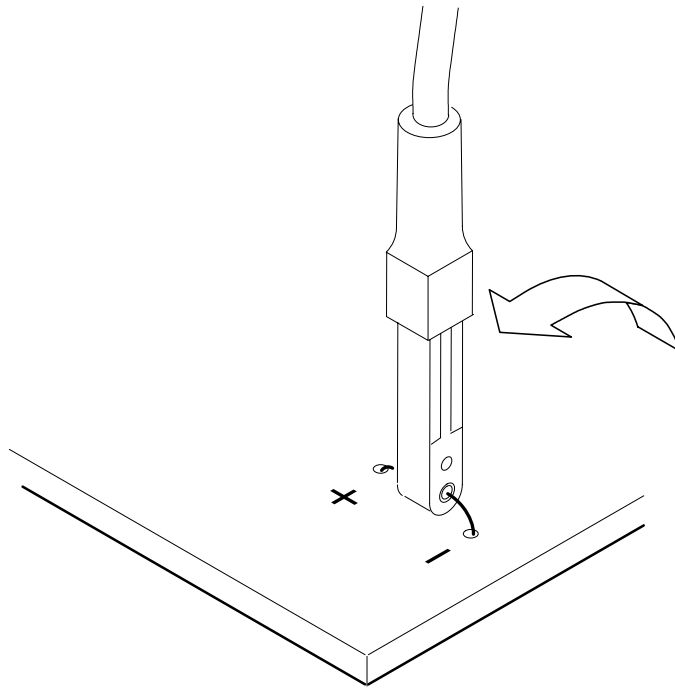


Figure 9: Positioning for best HF response (20–25 gauge)

Ground Side and Signal Side Measurements

For the most accurate measurements, couple the probe to either the signal side of a $50\ \Omega$ load or the ground side of a low impedance load.

- For the best impedance match with the probe output, take current measurements on the signal side of the $50\ \Omega$ circuit load.
- If coupling to the signal side of a $50\ \Omega$ load is impractical, take current measurements on the ground side of a load that has a low enough impedance to allow measurable signal current to pass through the probe.

Figure 10 shows the signal and ground side points.

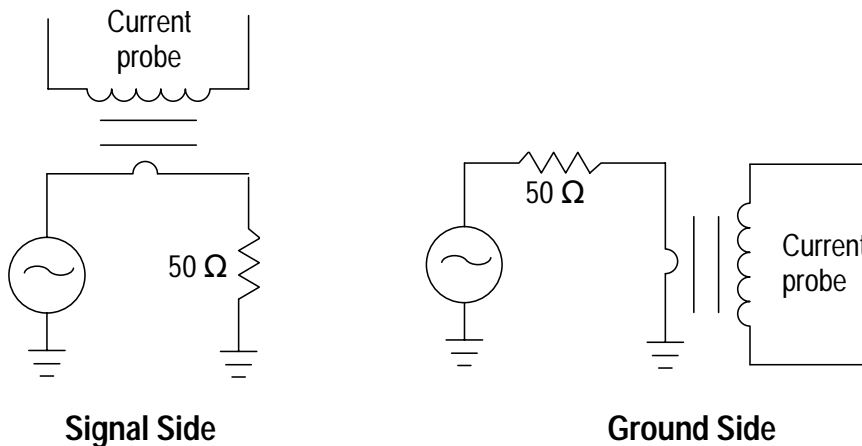


Figure 10: Coupling the probe to signal side or ground side

The optional evaluation board has separate signal side and ground side connections to help assess the effects of these two techniques on signal measurements.

Using the Optional Evaluation Board

The evaluation board for the CT-6 current probe (Figure 11) is available as a purchase option or optional accessory. This fixture simplifies testing the probe for purposes of characterization or verification.

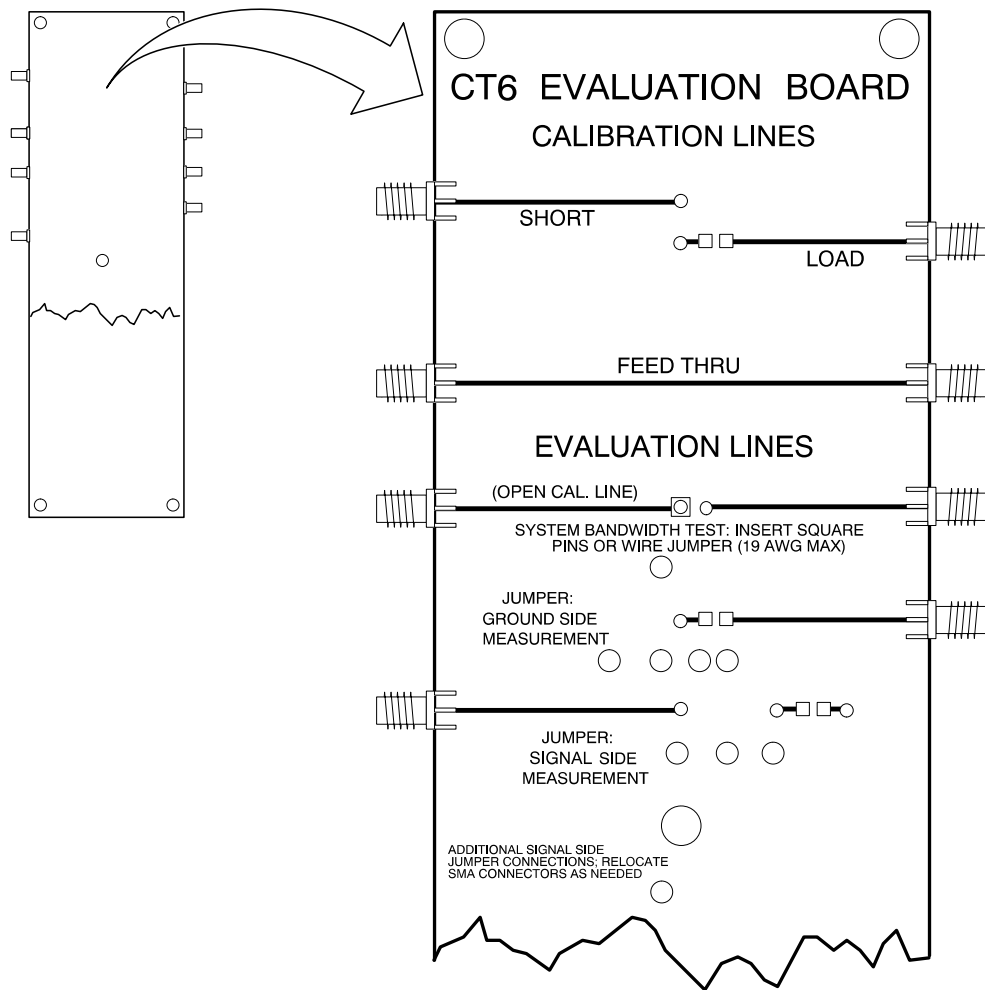


Figure 11: Test Fixture board for the CT-6 current probe

Calibration Lines

The Short, Load, and Feed Thru calibration lines (and Open Cal evaluation line) are used in setting up the network analyzer used in the procedures for *Performance Verification* on page 25.

Evaluation Lines

Evaluation lines enable you to connect and measure your test signals. The fixture helps to isolate and characterize probe performance and signal characteristics for open, ground side, and signal side connections.

System Bandwidth Line (or Open Cal). The system bandwidth line allows you to test the system bandwidth and to isolate and evaluate the fidelity of the test signal through the particular square pins or wire jumper you intend use.

Without a wire jumper or set of pins in place, you can use the line for the “open” calibration of a network analyzer.

Ground side. The ground side line is for evaluating the performance of the current probe with the test signal on the ground side of a 50 Ω load. (See Figure 10 on page 16.)

Signal side. The signal side line is for evaluating the performance of the current probe with the test signal on the signal side of a 50 Ω load. Because the signal side technique is commonly used, additional lines are provided in case the circuit board pads are damaged by the repetitive soldering and unsoldering of signal jumpers.

To prepare a signal side line for use, unsolder the connector located on the edge of the board and solder it to the pads at the next location.

Without a wire jumper in place, you can use a signal side line for the “open” calibration of a network analyzer.

Probe Holder

For the ground side and signal side lines, the probe holder is included to stabilize the probe head and increase the repeatability of measurements. Figure 12 demonstrates how to use a probe holder to secure the probe in two different ways. The holder uses two 2-56 screws in .080 inch diameter holes spaced 0.360 inches apart center to center.

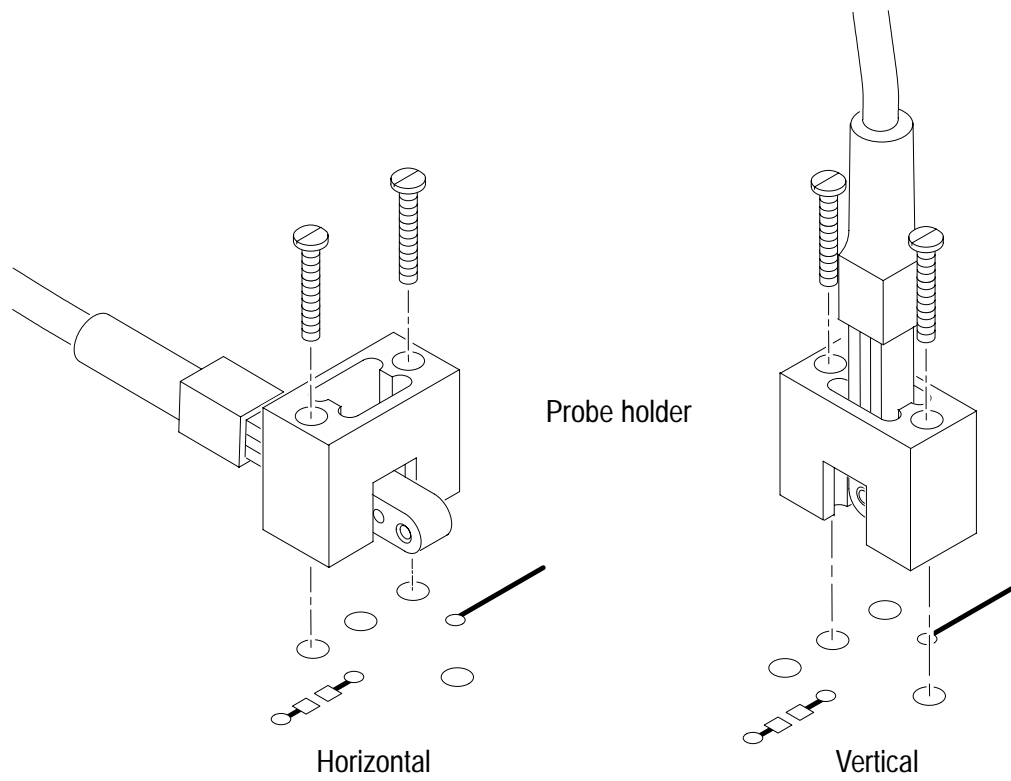


Figure 12: Securing the CT-6 probe head to the test fixture board

Specifications

Tables 1 and 2 list the specifications for the CT-6 current probe. All specifications are guaranteed unless noted as “typical.” Typical specifications are provided for your convenience but are not guaranteed. Specifications marked with the ✓ symbol have corresponding checks in the *Performance Verification* section on page 25.

Table 1: General specifications

Maximum bare wire voltage	30 V
Maximum continuous current (RMS)	120 mA
Maximum peak pulse current	6 A
Effect of direct current, typical	200 mA
Amp-second product, typical	0.25 amp- μ s into 50 Ω
✓ Sensitivity	5 mV/mA \pm 3% into 50 Ω load at 50 MHz (-20 dB \pm 0.27 dB)
✓ Frequency response	250 kHz to 1.5 GHz
Frequency response, typical	250 kHz to 2 GHz (See Figure 13)
Rise time, calculated	< 233 ps, 10% to 90%
Rise time, calculated typical	< 175 ps, 10% to 90%
Aberrations, typical	< 6% for 5 ns
Group delay, typical	5.2 ns for > 10 MHz (See Figure 14)
L/R time constant (droop), typical	< 0.4 μ s
Insertion impedance, typical	1.1 Ω at 10 MHz ¹ 1.3 Ω at 100 MHz ¹
Characteristic line impedance of optional evaluation board	50 Ω \pm 5%

¹ Requires matching 50 Ω termination on probe input and output

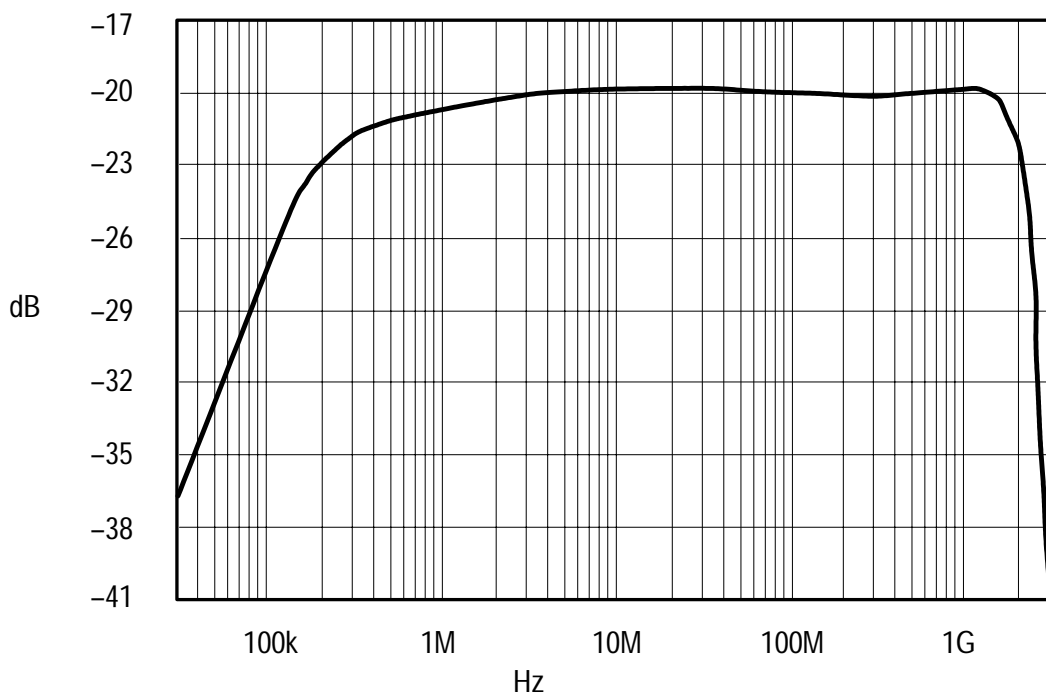


Figure 13: Typical frequency response (Bode plot)

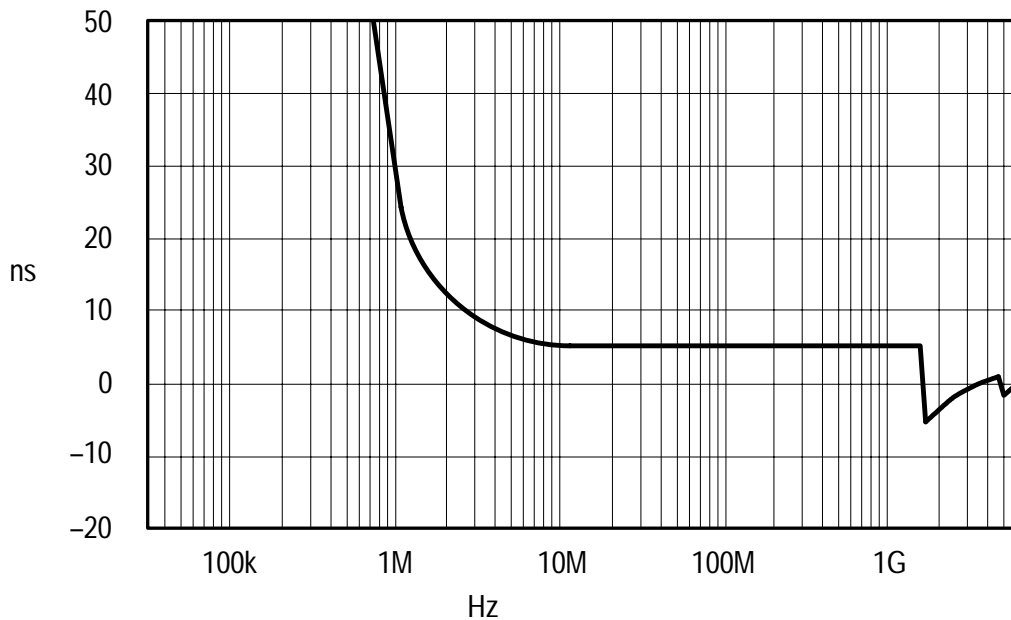


Figure 14: Typical group delay ($d\phi/df$)

Table 2: Environmental and mechanical specifications

Temperature	Operating: 0°C to +50°C Non-operating: -55°C to +75°C
Humidity	Operating: 0°C to +50°C at 0 to 90% relative humidity Non-operating: 0°C to +60°C at 0 to 90% relative humidity
Altitude	Operating: 4,572 m Non-operating: 15,240 m
Weight	17 g, stand alone 322 g , when packaged for domestic shipment 381 g, when packaged for domestic shipment with Option TF
Probe head (case) dimensions	Height: 4.3 mm Width: 4.3 mm Depth: 17.8 mm
Cable length	1 m

Performance Verification

Use the procedures in this section to verify the performance of the CT-6 current probe to the following warranted specifications:

- Sensitivity
- Frequency Response

Before beginning these procedures, photocopy the test record on page 29 (or page 33 if using a network analyzer) and use it to record test results. The recommended verification interval is one year.

Equipment Required

Table 3 lists the equipment required to perform these procedures. The types and quantities of connectors may vary depending on the specific equipment you use. For an alternate procedure that uses a network analyzer, see page 30.

Table 3: Test equipment

Description	Minimum requirements	Example product
Digital sampling oscilloscope	> 8 GHz bandwidth	Tektronix 11801B with SD24 sampling head
Signal Generator	250 kHz to 2.1 GHz	Marconi 2024 Gigatronix 6062A
SMA cable	3.5 mm, 1 meter	Tektronix 012-0649-00
Bare wire	20 gauge, 1 cm long	As per description
Evaluation Board with probe holder	–	Tektronix 067-0349-00 ¹

¹ The evaluation board comes with the current probe when ordered as Option TF.

Preparation

Turn on all test equipment and allow a 20-minute warm up period.

Mount the Current Probe on the Evaluation Board

1. Solder one end of a 1 cm, 20 gauge bare wire to a signal side line on the evaluation board.
2. Slide the probe holder over the end of the current probe.
3. Turn the current probe so the polarity dot faces the circuit load.
4. Insert the bare wire through the hole in the current probe.
5. Secure the probe holder to the board with two 2–56 screws.
6. Carefully solder the bare wire to the evaluation board.

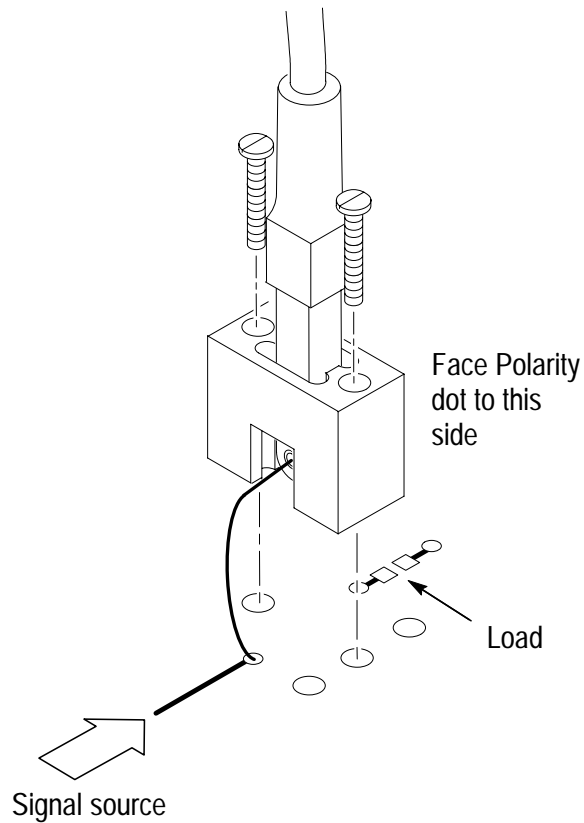


Figure 15: Securing the current probe to the evaluation board

Frequency Response and Sensitivity

Use the following procedures to verify performance with a digital oscilloscope and signal generator.

Set up the Signal Generator with the Digital Oscilloscope

1. Connect the output of the signal generator directly to the signal input of the sampling head on the digital oscilloscope with an SMA cable.
2. Connect a trigger signal to the oscilloscope from the generator.
3. Set the output frequency to 50 MHz and the output amplitude to 0.0 dBm.
4. Set time per division to 5 ns and volts per division to 100 mV per division and trigger on the signal or use the AutoSet function to automatically set up the oscilloscope.
5. Measure the the output of the signal generator on the oscilloscope and save or record the value.

Measure Output and Calculate Sensitivity

1. Connect the SMA output of the CT-6 current probe to the signal input of the digital oscilloscope.
2. Connect the output of the signal generator to the SMA connector on the evaluation board.
3. Set time per division to 5 ns and volts per division to 10 mV per division and turn averaging on.
4. Measure the probe output and calculate the sensitivity:

$$\text{Sensitivity at 50 MHz} = 20 \log (\text{Probe Output} / \text{Probe Input})$$

Measure Low End Frequency Response

1. Connect the output of the signal generator directly to the signal input of the digital oscilloscope with an SMA cable.
2. Set the output frequency to 250 kHz and the output amplitude to 0.0 dBm.

3. Set the oscilloscope attenuation to 100 mV/div and time base to 1 μ s/div (or press AutoSet).
4. Measure the the output of the signal generator on the oscilloscope and save or record the value.
5. Connect the SMA output of the CT-6 current probe to the signal input of the digital oscilloscope.
6. Connect the output of the signal generator to the SMA connector on the evaluation board.
7. Measure the probe output and calculate the sensitivity:
Sensitivity at 250 kHz = 20 log (Probe Output/ Probe Input)
8. Calculate the frequency response at 250 kHz and record results on the test record:
(sensitivity at 50 MHz) – (sensitivity at 250 kHz) \geq –3 dB.

Measure High End Frequency Response

1. Connect the output of the signal generator directly to the signal input of the digital oscilloscope with an SMA cable.
2. Set the output frequency to 1.5 GHz and the output amplitude to 0.00 dB.
3. Set the oscilloscope attenuation to 100 mV/div and time base to 200 ps/div (or press AutoSet).
4. Measure the the output of the signal generator on the oscilloscope and save or record the value.
5. Connect the SMA output of the CT-6 current probe to the signal input of the digital oscilloscope.
6. Connect the output of the signal generator to the SMA connector on the evaluation board.
7. Measure the probe output and calculate the sensitivity:
Sensitivity at 1.5 GHz = 20 log (Probe Output/ Probe Input)
8. Calculate the frequency response at 1.5 GHz and record results on the test record:
(sensitivity at 50 MHz) – (sensitivity at 1.5 GHz) \geq –3 dB.

CT-6 Test Record

Identification Number	Procedure performed by	Date

Tests		Low limit	Test Result	High limit
Sensitivity @ 50 MHz		-20.27 dB		-19.73 dB
Frequency response	@250 kHz	-3 dB		N/A
	@1.5 GHz	-3 dB		N/A

Frequency Response and Sensitivity – Alternate Procedure

To verify the performance of the probe using a network analyzer, use the alternate procedure in this section.

Not all network analyzers are identical. This procedure uses the network analyzer identified in Table 4. Adapt this procedure as necessary to suit your particular analyzer. The types and quantities of connectors may vary depending on the specific equipment you use.

Table 4: Test equipment required for alternative procedure

Description	Minimum requirements	Example product
Network analyzer	100 kHz to 3 GHz range	Hewlett-Packard HP8753D with female SMA connectors
SMA cables (2)	3.5 mm, 1 meter	Tektronix 012-0649-00
SMA–SMA barrel adapter	Female-female, 3.5 mm	Tektronix 015-1012-00
Bare wire	20 gauge, 1 cm long	As per description
Evaluation Board with probe holder	–	Tektronix 067-0349-00 ¹

¹ The evaluation board comes with the current probe when ordered as Option TF.

Set up the Network Analyzer

1. Preset the network analyzer to the factory default setting.
2. Set frequency range (100 kHz to 3 GHz minimum span).
3. Set frequency to log scale if desired.
4. Set for 3.5 mm diameter cables and select full two-port operation.
5. Connect one SMA cable to Port 1 of the network analyzer and the other cable to Port 2.

Calibrate Network Analyzer with Evaluation Board

1. Connect the SMA cable from Port 1 to the open line. Calibrate forward reflection with Port 1 connected to the open, short, and load lines in turn.
2. Connect the SMA cable from Port 2 to the open line. Calibrate reverse reflection with Port 2 connected to the open, short, and load lines in turn.
3. Compute list of calibration constants.

Calibrate out Line Losses

NOTE. Since the feedthrough line is slightly longer than the line extending the SMA cable from Port 1, this calibration will not be exact; however, up to frequencies around 2 GHz, the difference is negligible.

1. Calibrate forward and reverse transmission and forward and reverse matching with Port 1 and Port 2 connected to the Feedthrough line on the evaluation board.
2. Select Omit Isolation and Done Cal functions (or equivalent) to complete the forward and reverse calibrations.

Remove Delay

1. Display the Smith chart.
2. Look at S11 parameter.
3. Calibrate the port extensions on the short and open lines for Port 1, and then repeat for Port 2.
4. Connect Port 1 and Port 2 to the feedthrough line and check for a flat line.
5. Move zero reference to about 3 divisions from the top graticule line.
6. Save the file.

Verify Frequency Response and Sensitivity

1. Connect Port 1 to a signal side connector on the evaluation board.
2. Connect the male SMA connector of the current probe to the SMA cable on Port 2 of the network analyzer using the Female-female SMA adapter.
3. Connect the current probe to a signal side line on the evaluation with a probe holder and a 1 cm, 20 gauge bare wire. Install the current probe so that it is perpendicular to the evaluation board.
4. Set reference value to -20 dB.
5. Make a Bode plot of the S_{21} parameter.
6. Place markers at the following points on the curve
 - a. -3 dB at the low end of the frequency range
 - b. 50 MHz
 - c. -3 dB at the high end of the frequency range
7. Note the frequencies measured at the -3 dB points at the high and low frequencies and record them on the test record.
8. Record the sensitivity (in dB) at 50 MHz on the test record.

CT-6 Test Record – Alternate Procedure

Identification Number	Procedure performed by	Date

Tests		Low limit	Test Result	High limit
Frequency response (-3 dB point)	low frequency	< 250 kHz		250 kHz
	high frequency	1.5 GHz		> 1.5 GHz
Sensitivity (-dB)	@50 MHz	-20.27 dB		-19.73 dB

