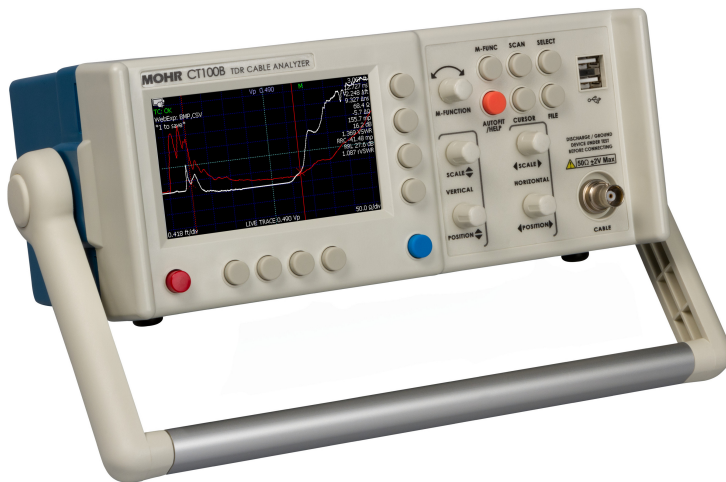




## ***Operator's Manual:***

# CT100B Series TDR Cable Analyzers

## For Software Version 2.25.1



**Part No.: CT100B-M-OM-012**

**CAGE Code: 4JEE1**

**Revision Date: 2023.04.11**



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We at MOHR are always working to improve the written materials we offer to our valued customers. Since our last printing, there may have been minor updates to this manual.

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# 1. General Information

## 1.1. Product Description

The MOHR CT100B TDR Metallic Cable Analyzer uses a form of closed-circuit radar known as time-domain reflectometry (TDR) to test cables for defects or “faults”. The instrument applies a fast rise time broadband step signal to the cable under test and then measures the reflected voltage at very short time intervals. The resultant TDR trace allows the operator to identify changes in impedance along the length of the cable indicating the presence of faults such as opens, shorts, kinks, defects in the shield or conductor, foreign substances such as water, and thermal damage, among others.

The CT100B provides sophisticated signal-processing software that lets users analyze the frequency-domain characteristics of the TDR trace, replacing a handheld vector network analyzer (VNA) or frequency-domain reflectometer (FDR) for many applications. With the CT100B TDR Cable Analyzer a user can detect, localize, and characterize almost any cable fault in both the time and frequency domains.

Please note that with the release of the CT100B, the CT100HF instrument has been updated with the CT100B hardware, firmware, and software improvements. Any reference to the CT100B in this manual also applies to the CT100HF unless specifically stated.

## 1.2. Power Requirements

The CT100B may be operated using either the supplied AC adapter or internal NiMH batteries (for a minimum six hours operating time, typical use). The internal NiMH battery charges under AC during normal operation.

The external AC power adapter (pn: CT100-AC-PS) operates on 100-240 VAC at 50-60 Hz and draws a maximum current of 1.5 A. Use of a grounded AC socket (US 3-prong or EU equivalent) is essential for safe operation of the CT100B with the included AC power adapter. Review the *Safety Summary* section before operating the CT100B.

## 1.3. Options and Accessories

Options and accessories available for the CT100B are described in Appendix C, *Options and Accessories*.

## 1.4. Unpacking and Initial Inspection

Before opening the shipping package containing the CT100B, inspect it for signs of damage. If there is evidence of damage to the shipping package, notify both the shipping carrier and MOHR.

The shipping container should contain the CT100B and standard accessories, including this *Operator's Manual*, front panel cover, external AC adapter and power cord, soft transit case, and calibration fixture(s). If the shipping container is intact but there are missing items or if the CT100B is damaged, defective, or does not meet operational requirements, contact a MOHR-authorized sales representative.

## 1.5. Repacking for Shipment

In the event that the CT100B needs to be shipped to a MOHR-authorized service center for repair, calibration, or other service, contact MOHR for a Return Material Authorization (RMA) number. Affix a label to the outside of the shipping container indicating:

- RMA number
- name, address, phone, and email of the owner
- name of the MOHR service representative who was contacted regarding the shipment
- serial number of the instrument
- description of the problem with the instrument and/or the desired service or maintenance

Optimally, the original shipping carton and packing material should be used to repack the CT100B for shipment. Otherwise, the following steps should be taken:

1. Place the CT100B in an electrostatic discharge (ESD) safe bag.
2. Wrap with 3 in. of antistatic bubble wrap or non-movable foam cushioning. DO NOT USE packaging peanuts.
3. Place in a sturdy cardboard box and fill any additional void with packaging material. DO NOT USE packaging peanuts.
4. Include any Purchase Orders, Work Orders, or special instructions with shipment.
5. Write the RMA number on outside packaging.

## 2. Safety Summary

The safety information presented in this brief summary is only intended for operators of the CT100B. Safety information relating to specific circumstances is present throughout this manual and is not necessarily present in this summary. Please read this manual in its entirety before using the CT100B and take note of safety information not included in this summary.

### 2.1. Terms in the Manual



*WARNING: Refers to conditions or practices that could result in personal injury or loss of life.*



*CAUTION: Refers to conditions or practices that could result in damage to this product or other products and in some cases could void the Warranty.*

### 2.2. Terms on the CT100B

#### 2.2.1. DANGER

Indicates an injury hazard immediately accessible.

#### 2.2.2. WARNING

Indicates an injury hazard not immediately accessible.

#### 2.2.3. CAUTION

Indicates a hazard to property including the product.

## 2.3. Symbols in the Manual



## 2.4. Symbols on the CT100B



## 2.5. Static Charge

Any cable or wire can carry a significant static electric charge that could damage the sensitive internal electronics of the CT100B. For this reason, it is essential to discharge the electrical conductors of any cable or device-under-test (DUT) by shorting them to each other or to earth ground before connection is made to the CT100B's sampling circuitry.

CT100B instruments supplied with a front panel BNC test port are equipped with a built-in internal self-grounding connection that briefly shorts the conductors of the DUT to each other, dissipating stored charge, before completing the connection to the CT100B's sensitive internal sampling circuitry. For this reason, the last cable connection should always be made to the CT100B test port. For example, if the DUT is a cable assembly, all internal connections within the cable assembly should be made before connection is made to the CT100B BNC test port. This ensures that all stored charge in the DUT is discharged during the connection to the CT100B BNC test port.

Sometimes it is convenient to insert a patch cable between the CT100B BNC test port and the DUT. In this case, it is recommended that all cable connections, including the connection of the patch cable to the DUT, be made before connecting the patch cable to the CT100B BNC test port. Otherwise, the BNC test port self-grounding safety feature is circumvented.

If for some reason the last connection cannot be made at the CT100B test port, then the conductors of the DUT should be discharged (shorted) manually using an industry-standard shorting cap termination or equivalent direct electrical connection.

Note that CT100B instruments equipped with SMA or other front panel test ports **do not** have internal self-grounding protection. Therefore, when using these instruments, the conductors of the cable under test/DUT should **always**

be shorted to each other or to earth ground prior to connection to the CT100B's test port.



*CAUTION: Failure to properly ground the cable/device under test prior to connecting it to the front panel connector, either directly or indirectly, could result in damage to the sampling electronics and will void the Warranty.*

## 2.6. Fuses

There are no external fuses or breakers accessible to the user. However, there are two internal automatic thermal breakers that disconnect the power from the charger and battery to the rest of the system. These thermal breakers make an audible click when they actuate, and the CT100B turns off. One of the circuit breakers automatically resets after time. When this breaker cools, the CT100B can be restarted, but the CT100B should be serviced by qualified personnel. There is also an internal breaker on the power board. If tripped, this breaker must be reset manually and the instrument should be serviced by qualified personnel.



*CAUTION: If the thermal breakers trip, the instrument should be evaluated by qualified service personnel for maintenance.*

## 2.7. AC Power Source

The CT100B is intended to operate only from a 120 VAC or 240 VAC RMS power source using the CE- and UL-approved 24 VDC external power supply/adaptor (pn: CT100-AC-PS) provided with the instrument.



*WARNING: Only use the power cord supplied with the instrument, and then only if the cord is in good condition. Refer all maintenance regarding the power supply or power cord to qualified service personnel.*



*CAUTION: Use of any power source other than the supplied external power adapter(s) could damage the instrument and may void the Warranty. Use only MOHR-approved accessories.*



*WARNING: To reduce the risk of electric shock, disconnect all external cables before connecting the 24 VDC external power supply.*

## 2.8. Grounding the CT100B

When the CT100B is connected to the external AC adapter, the CT100B chassis, front panel USB, screen, and controls are grounded through the grounding conductor of the power cord. To avoid electrical shock, it is essential that the protective ground connection is present when operating the unit under AC power. When disconnected from external power, the CT100B is floating relative to earth ground, unless one of the USB ports is connected to a grounded device. In this case, the ground of the USB device is common with the CT100B chassis, screen, and electronic controls.

At all times, the front panel BNC or SMA connector is floating and is isolated by at least 500 VDC from the remainder of the CT100B. This eliminates measurement errors caused by common-mode noise and slight ground-potential differences in the cable/device under test. However, care should be taken with respect to electrical safety, as the front panel BNC or SMA shield is never safely grounded unless connected to a safely grounded cable or device and can be considered a second live conductor if connected to a cable or device carrying a non-zero electrical potential relative to earth ground. This situation carries the risk of electric shock.



*WARNING: The BNC or SMA connector shield represents a floating ground and is never safely grounded even with the use of a properly grounded AC adapter. Never use the CT100B to test any cable or device carrying a non-zero electrical potential relative to earth ground, as this could render an electric shock.*

## 2.9. Danger Arising From Loss of Ground

When disconnected from the AC power adapter, the CT100B is no longer grounded unless connected to a grounded USB device at the front panel host USB port. Because the test port connector shield is floating relative to the remainder of the instrument, the test port connector may be operating at an elevated voltage even when the AC adapter is connected. Therefore, the test port connector should never be used to test any cable or device with an electrical potential relative to earth.



*WARNING: Upon loss of the protective ground connection, all accessible parts, including the screen, knobs, and connectors, can render an electric shock.*

## 2.10. Explosive Atmospheres

Do not operate the CT100B in an explosive atmosphere unless your unit has been specifically certified for that condition. Explosive Atmospheres: MIL-STD 810G, Method 511.5, Procedure I (+55°C, sea level to 4600 m).



## 2.11. Do Not Remove Covers or Panels

To avoid personal injury and risk of electric shock, do not open the CT100B case unless replacing the battery and do not operate unless the case is fully intact.



**WARNING:** Disconnect power, USB, Ethernet, and test cables prior to opening the CT100B case to replace the battery. Failure to do so can render an electric shock.

## 2.12. Connecting Cables to the Test Port

To avoid damage to the CT100B and the very sensitive sampling electronics associated with the front panel BNC or SMA connector, do not connect it to any cable or device that can be driven by active circuitry or is subject to transient voltage spikes.



**WARNING and CAUTION:** The instrument should never be used to test any cable or device carrying live electrical signals, as this carries a risk of electric shock. This could also damage the sampling electronics and will void the Warranty.



**CAUTION:** Always properly ground the conductor(s) of any cable or wiring to remove any static charge prior to connecting it, either directly or indirectly through attachment to another cable, to the CT100B's front panel test port connector. Failure to do so can damage the instrument's sensitive sampling electronics and will void the Warranty.

## 2.13. Battery Replacement and Disposal

The CT100B contains an internal battery pack. The internal battery pack is 2700 mAh, NiMH, 12 AA cells, 14.40 volts, 38.88 Wh. There is also a 120 mAh lithium button cell of 2.8 volts and 0.336 Wh. Depending on the state or local jurisdiction, these batteries may require special disposal and/or recycling. Contact your local authorities for safe disposal in your area, or you may return them to MOHR for recycling.



**WARNING:** The battery pack must be replaced with MOHR pn: CT100-AC-B2700. Use of any other battery pack will damage the instrument and pose a danger of fire.



**CAUTION:** User replacement of components is limited. Multiple Warranty seals are installed on components within the CT100B. Removal or damage of these seals voids Warranty.



## 3. Getting Started

If you would like a detailed explanation of TDR measurement theory and applications before using the CT100B, please read Section 7, *TDR Measurement Theory*.

### 3.1. Handling

The CT100B is designed to meet the rigors associated with normal instrument use both in the field and on the benchtop. Care should be taken to protect it from excessive mechanical shock, vibration, static electrical charges, and water hazards.

The CT100B front panel is protected from impact by a snap-on front cover. The carrying handle rotates 360° and can be used to support the instrument for bench-top use.

The CT100B is not watertight and must be protected against water spray. If the unit is subjected to water spray, first turn off the unit with the battery-disconnect power switch on the rear panel and then drain all of the excess water from the case and allow it to dry completely.

As noted in the *Safety Summary* and elsewhere, the CT100B is sensitive to damage introduced by electrostatic discharge. Always properly ground the conductors of a cable to each other or to earth ground before attaching it, either directly or indirectly, to the front panel BNC, SMA, or other test port. Failure to do so could damage the sampling electronics and void the Warranty.

The CT100B can be stored in temperatures between -20°C to +60°C with or without a battery installed and can be operated from 0°C to +50°C.

### 3.2. Powering the CT100B

The CT100B can be powered through the included 120/240 VAC RMS to 24 VDC external power adapter. This adapter has sufficient capacity to charge the internal battery from a dead battery state while the unit is under operation. The internal battery will allow the unit to operate using power conservation techniques for periods of at least 6 hours under typical use. Automatic power-down occurs after a variable amount of time of inactivity, selectable in software by the user. The screen also can be set to turn off after a set amount of inactivity. A heavily discharged battery will require 4 hours to reach full charge.

Fusing is internal and based on thermal reset switches and a manual-reset breaker. If one of these fuses trips, it may indicate that a hardware malfunction has occurred, and the instrument should be evaluated by qualified personnel.

#### 3.2.1. Caring for the Battery

The CT100B has an intelligent battery-charging circuit that dynamically determines the optimum charge rate and reverts to low-level trickle charge when the battery is fully charged. Charging is automatic and there are no charge-length restrictions.

The battery should be charged between 0°C and +45°C. Battery operation should be limited to between 0°C and +50°C. Batteries should be stored between -20°C and +60°C for no longer than 30 days or between -20°C and +30°C for no longer than one year. If the battery pack is older, it may not show a 100% charge capacity even when the maximum battery charge is obtained.



*CAUTION: Do not attempt to charge the battery pack below 0° C or above +45° C. Batteries should not be stored below -20° C or above +60° C.*

#### 3.2.2. Charging and Power Status

The CT100B operates from a 24 volt power adapter or the internal battery pack.

In the *Power* menu, a submenu of the *Settings* menu, the user can set power save and shutdown timers. Different timeout values can be set for when the CT100B is using the AC/DC converter or batteries. In power save mode, the screen goes blank and only enough power is used to monitor for user input. When input is received, the CT100B resumes normal operation. When the shutdown timer expires, the CT100B will turn off.

A battery indicator can be toggled on or off with the *Power Display* menu option in the *Power* menu. The indicator will show the level of charge in the battery. It will also show if the 24 volt adapter is attached and providing power.

#### 3.2.3. Batteries and Long-Term Storage

The CT100B has NiMH internal batteries. These batteries will drain if the CT100B is left in storage over long periods. To preserve battery charge for as long as possible during storage, make sure the power switch on the back of the CT100B is set to the OFF position. After several months of storage, the internal batteries may be completely drained. Allow up to 4 hours for the first recharge of the CT100B after coming out of long-term storage.

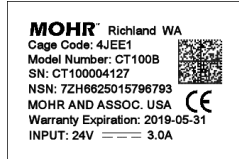
#### 3.2.4. Low Battery

When a low battery condition is first encountered, the CT100B alerts the user. **Internal Battery Low** text appears on-screen in red when the battery percentage left drops below 20 percent.

### 3.3. Labels

#### 3.3.1. Nameplate

The CT100B has a nameplate label affixed on the back of the case. See Figure 3.3 for positioning. The nameplate includes Cage Code, Model Number, Serial Number, NSN, a warranty expiration date, electrical input information, and a 2D barcode containing the identifying information. See Figure 3.1 for an example nameplate label.



**Figure 3.1.** Example nameplate label found on back of a CT100B.

#### 3.3.2. Discharge Warning Label

The CT100B has a warning label above the test port on the front of the instrument. This label warns the user to discharge any cable or device before connecting it to the test port. See Figure 3.2 for location and contents of the label.

### 3.4. License Codes

Each CT100B requires a unique license code to operate. Without the correct code, menus and buttons still function, but there will be no live trace displayed on the screen. The correct code for a particular device can be requested from MOHR. Installation instructions will be included with the license code or can be found in Appendix E.5.

Depending on how it was purchased, the instrument may be supplied with either a 30-day demonstration license or permanent license. Current license information can be found by pushing the blue *MENU* button and navigating to *Settings* → *Info* → *License* → *License Info*. A dialog showing license date and active features will appear. When the CT100B has a permanent license installed, appropriate options will be active. When the instrument has a demonstration license, the dialog will show a future license date and the instrument will provide appropriate warnings to the user as the expiration date gets closer. If your CT100B has a license with pending expiration and you are unsure how to upgrade to a permanent license, please contact MOHR.

### 3.5. Preparing to Use the CT100B

Before using the CT100B, make sure you have read and understand the *Safety Summary* section and the power requirements described in Section 3.2. If you would like a detailed explanation of TDR measurement theory and applications before using the CT100B to test cables, please read Section 7, *TDR Measurement Theory*.

Otherwise, remove the front cover and turn on the power. You are ready to test cables using the most versatile and sophisticated portable TDR instrument on the market.

### 3.6. Front Panel Controls and Connectors

The following numbered items describe the controls and connectors identified in the front panel diagram (Figure 3.2).

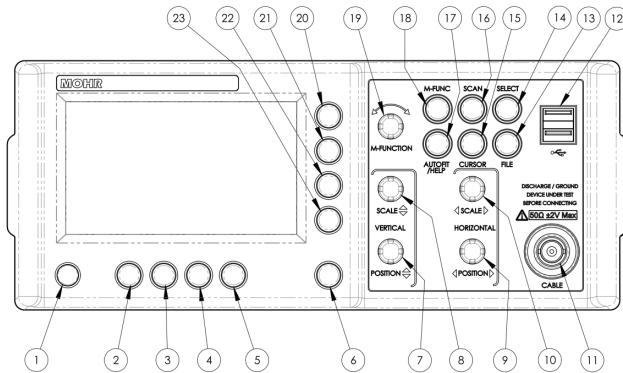


Figure 3.2. Diagram of the CT100B front panel.

1. **POWER (red)** button. Pressing this button turns the instrument on when the main power switch on the rear panel is in the ON position. Pressing the **POWER** button when the unit is on will turn the unit off after verification that you really wish to power down. If the **POWER** button is held in for several seconds, the unit will turn off regardless.
2. **H1** function button. Function depends on menu.
3. **H2** function button. Function depends on menu.
4. **H3** function button. Function depends on menu.
5. **H4** function button. Function depends on menu.
6. **MENU (blue)** button. Push to display the top-level menu screen. If a menu is already on the screen, this button will clear the menu. The previous menu will be displayed. This button also activates on-screen help when held down while pressing other buttons.
7. **VERTICAL POSITION** knob. Controls the vertical position of the currently selected trace. Trace selection is controlled by the **SELECT** button (14).

8. *VERTICAL SCALE* knob. Controls the vertical scale, which is displayed on the bottom of the screen. This control modifies the appearance of the currently selected trace. The scale is expanded about the vertical center of the screen.
9. *HORIZONTAL POSITION* knob. Controls the horizontal position of the active cursor. Displayed trace positions are moved horizontally if the cursor is moved toward the edge of the screen to keep the cursor on-screen.
10. *HORIZONTAL SCALE* knob. Controls the horizontal scale of displayed traces. The scale is expanded about the active cursor.
11. BNC or SMA test port. This connects to the cable to be tested. Be sure to properly ground the cable before connecting it to the test port in order to prevent electrostatic damage to the CT100B's sensitive sampling circuitry.

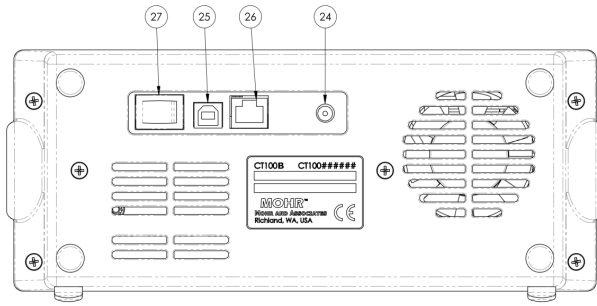


*CAUTION: All static charge must be drained from the cable to be tested prior to connecting to the test port (11). This is done by shorting the cable center conductor to the cable sheath/ground return. If this procedure is not followed, the sampling electronics can be damaged and will void the Warranty.*

12. Host USB port. This USB (V1.1) connection can be used to interface to a client USB device such as a barcode reader, keyboard, or flash drive.
13. *FILE* button. Opens the *File* menu, which contains a database of user configurations, saved cable records (scans), and a Vp database for known cable types.
14. *SELECT* button. Used to select between traces on the screen. It has no effect if there are no other traces. **Note:** While the *SELECT* button is held down, press the *M-FUNC* button. The CT100B will generate a screenshot that can be saved to a USB drive.
15. *CURSOR* button. This button is used to toggle between the two available cursors. Pressing and holding the *CURSOR* button for one second and then releasing the button will bring both cursors onto the screen.
16. *SCAN* button. Opens the *Scan* menu, which lets you scan, save, and hide traces.
17. *AUTOFIT/HELP* (orange) button. Opens the on-screen help library along with *Autofit* soft-menu options.
18. *M-FUNC* (multifunction) button. The function of the *M-FUNCTION* knob (19) is set by this button. The current operation is displayed on the screen (top-center).
19. *M-FUNCTION* (multifunction) knob. This knob adopts the function selected through the use of the *M-FUNC* button (18). It also allows users to scroll through dialog box options.
20. *V1* function button. Function depends on menu.
21. *V2* function button. Function depends on menu.
22. *V3* function button. Function depends on menu.
23. *V4* function button. Function depends on menu.

### 3.7. Rear Panel Connectors and Switches

The following numbered items describe the connectors and switches identified in the rear panel diagram (Figure 3.3).

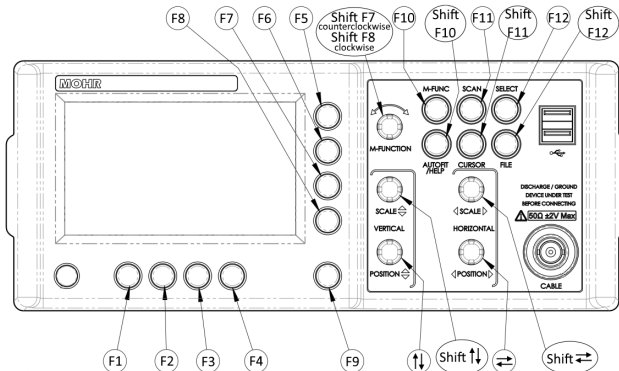


**Figure 3.3.** Diagram of the rear panel of the CT100B/CT100HF.

24. 24 VDC power adapter plug. The provided 24 VDC AC adapter plugs into this port. Only MOHR-approved positive center tip, 24 V adapters may be used.
25. Client USB connection. Allows the CT100B to be connected to a host computer for data transfer and PC control.
26. RJ45 Ethernet port. This is a 10/100 Mb Ethernet port that can be used for data transfer and remote PC control.
27. Power switch. This is a manual ON/OFF power switch that turns the device off and disconnects the power from the internal electronics so that the unit can be stored and/or shipped safely.

### 3.8. Keyboard Alternate Controls

If a keyboard is plugged into the front panel USB port, alternate hotkey controls are available for all front panel buttons and knobs (illustrated in Figure 3.4).



**Figure 3.4.** Keyboard controls for front panel buttons and knobs.

1. F1-F4 map to  $H1-H4$ .



2. F5-F8 map to  $V1-V4$ .
3. F9 maps to the blue *MENU* button.
4. F10-F12 map to the *M-FUNC*, *SCAN*, and *SELECT* buttons.
5. Shift F10-F12 map to the *AUTOFIT/HELP*, *CURSOR*, and *FILE* buttons.
6. Vertical arrow keys adjust the *VERTICAL POSITION* knob.
7. Horizontal arrow keys adjust the *HORIZONTAL POSITION* knob.
8. Shift vertical arrow keys adjust the *VERTICAL SCALE* knob.
9. Shift horizontal arrow keys adjust the *HORIZONTAL SCALE* knob.
10. Shift F7 rotates the *M-FUNCTION* knob counterclockwise.
11. Shift F8 rotates the *M-FUNCTION* knob clockwise.

**Note:** Some functions may require multiple button pushes to take effect.

## 3.9. Menu Selections and Function Buttons

### 3.9.1. M-FUNC Button

The *M-FUNC* button is used to switch between functions *Brightness*, *Shift*, *Smooth*, and *Vp* (and Fine/Coarse *Vp*) shown in the Multifunction indicator at the top of the display screen.

*Brightness* controls how bright the screen display is. When the CT100B is powered on, *Brightness* will always be at 100 percent. Use the *M-FUNCTION* knob to decrease or increase screen brightness.

With *Shift* selected, you can use the *M-FUNCTION* knob to slide the entire displayed scan left and right. If you have a scanned or saved trace selected, *Shift* will move the trace independently of the live trace or other traces on-screen.

*Smooth* controls how many successive scans should be averaged when drawing the displayed trace. This is done to decrease visible noise on the trace. For more information about smoothing, see Section 4.6.

*Vp* or velocity of propagation is the measure of the velocity of an electrical signal within a cable expressed as a fraction of the speed of light. When *Vp* is selected, turning the *M-FUNCTION* knob will adjust the *Vp* value for the displayed cable. For more information about *Vp*, see Section 4.3.

### 3.9.2. SCAN Button and Menu

The *SCAN* button displays menu selections associated with saving and managing TDR traces and cable scan records. *SCAN* menu selections are shown in Table 3.1.

**Table 3.1.** SCAN Button and Menu

Menu Selection	Purpose/Action
Save/Rename	Saves selected trace to internal storage. Renames previously saved traces.

Table 3.1 (Continued) SCAN Button and Menu

Menu Selection	Purpose/Action
Showing Sel. Trace Only/Showing All Traces	Turns all traces invisible except the currently selected trace. Select again to set all traces visible.
Hide All Traces	Hides all traces except the live trace. (If traces were previously saved, they can be recalled from the <i>FILE</i> menu; see Section 3.9.6.)
Hide Selected Trace	Hides the selected trace. (If trace was previously saved, it can be recalled from the <i>FILE</i> menu; see Section 3.9.6.)
Start Scan	Initiates cable scan.
Cursor/Snapshot	Switches between scan modes:
▷ <i>Cursor</i> .....	Creates a new scan of the portion of the trace between cursors using the current resolution and smooth settings.
▷ <i>Snapshot</i> .....	Saves trace as currently displayed on-screen.
Annotations	Adds/removes annotations for a trace.
▷ Create Annotation	Creates a new annotation for the selected trace.
▷ Delete Annotation	Deletes selected annotation from the selected trace.
▷ Modify Annotation	Modifies the text of an existing annotation.
▷ Save Changes	Saves the selected trace with annotations. If the selected trace is already saved, allows user to rename trace.
▷ List Annotations	Creates a scrolling list of the annotations associated with a trace.
▷▷ Delete	Deletes selected annotation from the selected trace.
▷▷ Modify Text	Modifies the text of an existing annotation.
▷▷ View	Shows the details of the selected annotation.
▷▷ Select	Selects the highlighted annotation in the annotation list.
▷▷ Cancel	Exits out of annotation list.
▷ Annotations On/Off	Toggles display of annotations on and off.
▷ Previous	Selects the previous annotation.
▷ Next	Selects the next annotation.
Math	See Table 3.2: Math Menu.

### 3.9.2.1. Math Menu

The *Math* menu is a menu selection under both the *SCAN* button and the blue *MENU* button. *Math* menu selections are shown in Table 3.2.

**Table 3.2. Math Menu**

Menu Selection	Purpose/Action
<b>FFT Tools</b>	
▷ FFT Settings	
▷▷ Window	Sets window type (Hann, Hamming, etc.).
▷▷ size	FFT buffer size.
▷▷ Frequency Cut-Off Range	FFT display frequency cut-off.
▷▷ Hide Selected Trace	Hides the selected trace.
▷ Apply FFT	Creates FFT trace from selected trace data.
▷ View Live FFT	Creates live FFT trace from live TDR trace.
▷ Apply VSWR	Creates VSWR (voltage standing wave ratio) trace from a selected complex division or $S_{11}$ trace.
▷ Set Base	Sets base trace for complex division FFT trace.
▷ Complex Division	Creates complex division FFT: Divides selected FFT by base FFT. Equivalent to uncalibrated $S_{11}$ trace when base FFT is of a shorted test port.
▷ Phase	Creates phase angle trace from selected FFT trace.
▷ Smith Chart	Toggles Smith Chart display for selected complex division FFT or $S_{11}$ trace.
<b>SParam &amp; Normalize Tools</b>	
▷ $S_{11}$ Calibration	Performs Open-Short-Load $S_{11}$ calibration and creates $S_{11}$ trace.
▷ Normalize Pulse Rise Time	Sets the rise time to apply to the selected normalized trace.
▷ $S_{11}$ Options	
▷▷ Pre-Filter Options	Changes the filter options that smooth the aberrations of the base traces.
▷▷ Post-Filter Options	Changes the filter options that limit the noise of the base traces.
▷▷ Other $S_{11}$ Options	

Table 3.2 (Continued) Math Menu

Menu Selection	Purpose/Action
▷▷▷ OSL Bases Visible	When enabled, the Open, Short, and Load traces will appear on-screen. Disabling it removes them from the screen, eliminating excess on-screen clutter.
▷▷▷ Align Base Traces	When enabled, the Open, Short, Load, and DUT traces may be aligned to each other based on the common part of the beginning of the trace.
▷▷ Calibration Standards	Brings up a table of Calibration Standard Kit Coefficients. There is the option to change and apply the standards.
▷▷ S <sub>11</sub> → USB (.csv)	Creates a CSV (Comma Separated Value) file of the selected S <sub>11</sub> trace and outputs that file to a connected USB drive.
▷▷ Phase Corr. Off/On	Toggles the Phase Correction On/Off.
▷▷ Phase Corr. Start	Using the active time-domain cursor, sets a new start point for the Phase Correction.
▷▷ Between Cursor Off/On/Hold	Toggles S <sub>11</sub> Between Cursors mode:
▷▷▷ Off.....	Between Cursors Off.
▷▷▷ On.....	Between Cursors On – the active section will adjust with time-domain cursor movement.
▷▷▷ Hold .....	Between Cursors Hold – the active section will remain regardless of cursor movement.
▷ Hide Selected Trace	Hides the selected trace.
▷ Reapply S <sub>11</sub>	Adjusts the time-domain settings to match those used for the selected live S <sub>11</sub> trace.
▷ Apply Normalization	Creates normalized TDR trace based on the selected S <sub>11</sub> trace.
▷ Cable Loss	Changes selected S <sub>11</sub> trace to Cable Loss (S <sub>21</sub> /insertion loss) trace. Terminate cable with precision short adapter for meaningful results.
▷ Smith Chart	Toggles Smith Chart display for selected complex division FFT or S <sub>11</sub> trace.
Layer Peeling	Creates layer-peeling trace from selected trace. Assumes active cursor (layer peel start) is set at 50 ohms.
Hide Selected Trace	Hides the selected trace.
Set Base	Sets selected trace as the base (denominator) trace for math operations.

Table 3.2 (Continued) Math Menu

Menu Selection	Purpose/Action
Difference	Creates subtraction trace from selected trace and base trace (Difference = Selected – Base).
1st Derivative	Creates first derivative trace from selected trace.
Der. Smooth Off/On	Toggles first derivative trace smoothing.

### 3.9.3. SELECT Button

The *SELECT* button switches which on-screen trace is the active trace. See Section 4.9.1 for more information on selected traces.

When the *SELECT* button is held down, pressing the *M-FUNC* button will generate a screenshot to save on a USB drive.

### 3.9.4. AUTOFIT/HELP Button and Menu

The *AUTOFIT/HELP* button calls up the online help library, *AUTOFIT* soft-menu options, options for resetting the CT100B's configurations that influence trace measurements, and an option to download a PDF of this manual to a USB drive.

For the help library, use the *M-FUNCTION* knob and *Select* menu option to scroll through and select topics.

When you select the *AUTOFIT* menu option, the CT100B looks for the TDR signature of an open- or short-terminated cable and selects appropriate horizontal and vertical scale values to display the entire cable on the screen. By default the cursors are positioned approximately to the beginning and end of the cable. This is the quickest way to find the distance to fault of a broken cable.

If you select *Autofit w/o Cursors*, the entire cable will be displayed on-screen, but the cursor position will not be affected.

If *Vertical Reset* is selected then only vertical scale and position are affected.

Selecting *Reset Options* brings up four different options for changing the settings of the CT100B along with brief descriptions of the options (Figure 3.5). You can reset the basic settings, load a default configuration, load a saved configuration, or reset all device settings to the factory settings. If the CT100B does not have saved default or user configurations, those options will be grayed out.

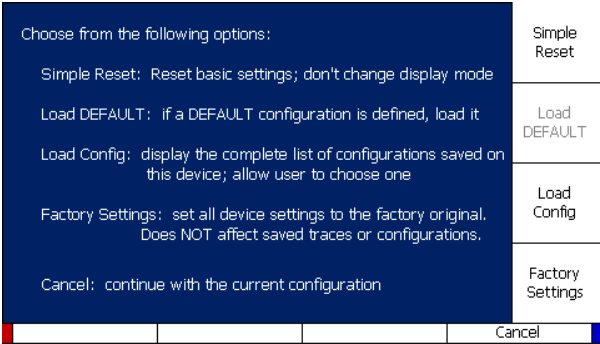


Figure 3.5. The Reset Options menu.

For more information on default and user configurations, see Section 4.10.

The *Reset Options* menu can also be found by briefly pressing the red *POWER* button and choosing *Reset Options* when the shutdown dialog appears. It is also part of the CT100B's startup screens.

*Manual* → *USB* will download a PDF of this manual to a USB drive. Insert a USB drive into the front panel port of the CT100B and select *Manual* → *USB*. A message will appear saying that the PDF has been successfully copied.

3.9.5. CURSOR Button

The *CURSOR* button toggles between cursors, making the active cursor inactive and the inactive cursor active. Pressing and holding the *CURSOR* button for one second then releasing will reposition any cursors not visible on the screen to the screen.

3.9.6. FILE Button and Menu

Use this menu to access the user library of configurations, cable types, and cable records. *FILE* button menu selections are shown in Table 3.3.

Table 3.3. FILE Button and Menu

Menu Selection	Purpose/Action
Custom Cable Types	Use to add, select, edit, or delete an entry from the custom cable type library:
> Add New.....	Enter in new cable type information.
> Edit.....	Modify the selected cable type.
> Delete.....	Delete selected cable type from the library.
> Select.....	Select the highlighted custom cable type.
	Instrument settings change to reflect the cable Vp setting.

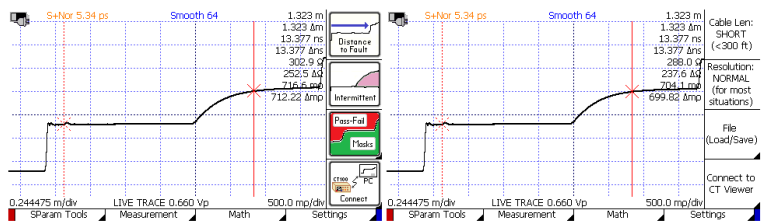
Table 3.3 (Continued) FILE Button and Menu

Menu Selection	Purpose/Action
Reference Cable Types	Use to select a built-in cable type from the standard cable type library. Instrument settings change to reflect the cable Vp setting.
Cable Scan Records	Use to select, delete, or USB save a previously saved TDR trace. (See Section 4.9.4 for more information.)
Config Entries	Use to add, select, or delete an entry from the user configuration library. (See Section 4.10 for more information.)
Export File	Exports selected TDR trace as either a CSV file or a Version 1 file (file compatible with older CT100 models and older CT100B software) to USB drive. Math traces cannot be exported as Version 1 files.
Save Scan	Saves selected trace to internal storage.
<b>Masks</b>	
▷ Create Mask From Trace	Generates mask or test limit based on the selected trace.
▷ Change Vertical Margin	Adjusts the vertical pass/fail criteria of the mask.
▷ Change Horizontal Margin	Adjusts the horizontal pass/fail criteria of the mask.
▷ Clear Mask	Removes the current mask from the display.
▷ Load/Save Mask	Use to add, select, or delete a mask from the mask library.
Print	Prints directly to a PCL3 compatible printer via USB.

### 3.9.7. “Blue” MENU Button and Top-Level Menu

If no menu is displayed, the blue *MENU* button loads the main top-level menu. If the top-level menu is displayed, it closes the menu. If a submenu is displayed, it displays the parent menu.

There are two versions of the main top-level menu. See Figure 3.6. One version, the *Special* menu, contains illustrated depictions of some commonly used features. The other version, the *Standard* menu, shows text selections that help with measuring and scanning cables. The bottom menu selections are the same for both menus. You can toggle between these two versions by going to *MENU* → *Settings* → *Display* → *Special/Standard Menu*.



**Figure 3.6.** The two versions of the Main menu. On the left is the Special menu and on the right is the Standard menu. Note that the menu selections across the bottom are exactly the same for both menus.

Top-level menu selections are listed below in Table 3.4. Holding down the *MENU* button while pressing any button (or turning the *M-FUNCTION* knob) will display a help dialog for that button’s current menu selection (known as “blue button help”).

**Table 3.4.** MENU Button and Menus

Menu Selection	Purpose/Action
Distance to Fault (part of Special Main menu)	<p>The TDR selects appropriate horizontal and vertical scale values to display the entire cable on-screen. The cursors are positioned approximately to the beginning and end of the cable. This is the quickest way to find distance to fault of a broken cable.</p> <p>This function can also be found at <i>AUTOFIT/HELP</i> → <i>AUTOFIT</i>.</p>
Intermittent (part of Special Main menu)	<p>Enables/disables envelope plot mode. Begins capture of trace data to help detect an intermittent fault.</p> <p>Other envelope plot functions can be found at <i>MENU</i> → <i>Measurement</i> → <i>Envelope Plot</i>. See Section 4.12 for more information.</p>
Pass-Fail Masks (part of Special Main Menu)	<p>Use to load a mask from the mask library. This functions as a test limit for the live TDR trace.</p> <p>Other Mask functions, including creating a mask, can be found at <i>FILE</i> → <i>Masks</i>. See Section 4.11 for more information.</p>
CT100 PC Connect (part of Special Main menu)	<p>Loads a menu with options to connect to CT Viewer 2 software running on a Windows PC.</p>



Table 3.4 (Continued) MENU Button and Menus

Menu Selection	Purpose/Action
Cable Len (part of Standard Main menu)	Adjusts the pulse timing for different length cables:
▷ Short.....	For cables of up to approximately* 300 ft. (90 m) long.
▷ Medium.....	For cables up to 1500 ft. (450 m) long.
▷ Long.....	For cables up to 6000 ft. (1800 m) long. [ <b>Note:</b> Access Extra Long Mode in the Measurement submenu. Use Extra Long Mode for cables over a mile (2 km) in length.]
	This menu selection can also be found at <i>MENU → Measurement → Meas. Settings.</i>
	*The exact length will depend on the Vp setting.
Resolution (part of Standard Main menu)	Sets TDR trace horizontal sampling resolution (in picoseconds):
▷ Normal.....	A setting suitable for connector level detail for each of the cable length modes. Short is nominally 5.34 ps (< 1 mm). Medium is nominally 17.5 ps (~2 mm). Long is nominally 49.6 ps (~1/2 inch). Extra Long is nominally 381.5 ps (~2 inches). The actual setting is dependent on horizontal scale, but will be at least as good as the nominal value. If the user adjusts the <i>Horizontal Scale</i> to zoom in to a very short section of cable, the resolution setting will automatically adjust to a finer scale. Multiple measurements may map to a single horizontal offset on the display. This allows you to easily see flaws in the cable or connectors even when looking at long sections (see Figure 3.10).
▷ Fixed.....	Allows user to set a specific value no matter the cable length setting.
▷ Screen.....	Screen resolution (1 sample/pixel) varies dynamically with the current horizontal scale.
	This menu selection can also be found at <i>MENU → Measurement → Meas. Settings.</i>

Table 3.4 (Continued) MENU Button and Menus

Menu Selection	Purpose/Action
File (Load/Save) (part of Standard Main menu)	Calls up the <i>FILE</i> button menu. Use it to add, select, or delete an entry from the cable type, user configuration, and/or cable record libraries. See Table 3.3: FILE Button and Menu.
Connect to CT Viewer (part of Standard Main menu)	
▷ Find CT Viewer	Searches the local area network for running CT Viewer 2 programs. If successful, it establishes a connection.
▷ Manual Connect	A dialog with a list of PCs that have previously been added is displayed.
▷▷ Add PC .....	Enter in new server IP information.
▷▷ Edit .....	If connected to CT Viewer 2, allows user to edit PC name.
▷▷ Delete .....	Deletes selected server from the library.
▷▷ Select .....	Connects to the highlighted server.
▷▷ Cancel .....	Cancels out of the connection menu. See Section 6: <i>CT Viewer</i> for instructions on connecting the CT100B to CT Viewer 2.
▷ Use USB	Go to the PC on which you are running CT Viewer 2 and use that program to connect to the CT100B.
SParam Tools	Tools for creating S-parameter traces and normalized traces. See Return Loss ( $S_{11}$ ) Traces in Section 5.4.
Measurement	
▷ Vert. Ref.	
▷▷ Vert. Ref. Off/On	Toggles VR (Vertical Reference) mode on/off.
▷▷ Set Vert. Ref.	Performs VR calibration using short/open terminators. When setup is complete, a green vertical line indicates start of VR measurements.
▷▷ Vert. Ref. Center Imp.	Adjusts VR calibration to use impedance-matching adapters and baluns.
▷▷ Vert. Ref. Start	Sets start of VR at the position of the active cursor.
▷▷ Vert. Ref. End	Sets end of VR at the position of the active cursor.
▷ Cable Segments	

Table 3.4 (Continued) MENU Button and Menus

Menu Selection	Purpose/Action
▷▷ Add New Segment	Creates a new segment boundary at the active cursor. The selected segment will be split in two, each with the same initial Vp.
▷▷ Delete Segment	Deletes the currently selected segment. The segment will be merged with the segment to the left.
▷▷ Delete All Segments	Deletes all segments. The CT100B will return to normal operation. A single Vp now applies to the entire trace.
▷▷ Prev Segment	Selects the segment to the left of the currently selected segment.
▷▷ Next Segment	Selects the segment to the right of the currently selected segment.
▷▷ Reset All Vp	Resets the Vp of all segments to 1.000.
▷▷ Restore All Vp	Restores Vp of all segments to the previous values.
▷ Extra Long Mode	Extra Long Mode allows the CT100B to obtain traces out to 48,000 ft. (14,600 m) (assumes Vp=0.66). Extra Long Mode is slower than other cable lengths and some instrument features are not available. When in Extra Long Mode, the Cable Length menu option will indicate Extra Long Mode On. Selecting the cable length menu item will switch off Extra Long Mode.
▷ Vert. Units	Selects vertical units for a time-domain trace from reflection coefficient ( $m\rho$ ), impedance ( $\Omega$ ), or voltage standing wave ratio (VSWR).
▷ Envelope Plot	Captures transient cable and connector faults.
▷▷ Envelope Plot Off/On	Enables/disables envelope plot mode. When turned on the CT100B begins capturing trace data and displaying envelope plot information. Envelope plots are useful for detecting and recording transient or intermittent faults.
▷▷ Reset	Deletes/restarts captured TDR trace envelope data.

Table 3.4 (Continued) MENU Button and Menus

Menu Selection	Purpose/Action
▷▷ Fill Mode Off/On	Toggles between fill and frequency density plot mode. Use fill mode to find magnitude of impedance change and highlight fault location. Use frequency density plot mode to find infrequent transient faults.
▷▷ HOLD Off/On	When Hold is on, trace controls are locked for an envelope plot. When Hold is off, trace controls work normally.
▷▷ Save Picture	Saves envelope plot as a screenshot.
▷▷ View Saved	Use to view, delete, or USB save a previously saved envelope plot screenshot.
▷▷ Clear	As trace controls are used to change an envelope plot, the envelope plot preserves a record of the trace from previous positions. Clear erases this history, leaving only the plot from the current position.
▷ Horiz. Units	Toggles through horizontal units (meters, inches, feet, yards, centimeters).
▷ Meas. Settings	
▷▷ Autoset Vp	
▷▷▷ Autoset Vp with Autofit	Set Vp from a cable of known length using Autofit.
▷▷▷ Autoset Vp from Current Cursors	Set Vp from a cable of known length using manual cursor positioning.
▷▷ RRC Classic/1502C Mode (Delta mrho)	Classic: Referenced to amplitude at inactive cursor. 1502C: Referenced to amplitude at test port.
▷▷ Vp 3/6 Sig Figs	Toggles Vp significant digits from 3 to 6 digits.
▷▷ Vert. Units	Selects vertical units for a time-domain trace from reflection coefficient ( $m\rho$ ), impedance ( $\Omega$ ), or voltage standing wave ratio (VSWR).
▷▷ Horiz. Units	Toggles through horizontal units (meters, inches, feet, yards, centimeters).
▷▷ Cable Len	Adjusts the pulse timing for different length cables.
▷▷ Resolution	Sets TDR trace horizontal sampling resolution.

Table 3.4 (Continued) MENU Button and Menus

Menu Selection	Purpose/Action
▷ Vertical Correction	
▷▷ Adjust $m\rho$ Offset	Allows manual vertical measurement offset adjustments. This lets advanced users manually calibrate impedance measurements at a particular location to a known value. When activated, the <i>M-FUNCTION</i> knob adjusts the vertical offset. The blue <i>M-FUNC</i> indicator shows the offset in $m\rho$ (millirho).
▷▷ Cancel $m\rho$ Offset	Use this option to cancel a manual $m\rho$ (millirho) correction. Automatic temperature adjustment will resume autocorrection of the vertical measurements.
▷▷ Adjust $\Omega/(\text{unit})$	Use the <i>M-FUNCTION</i> knob to change the ohms per unit distance resistive loss setting until the cable shows no upward or downward trend across its length.
▷▷ $\Omega/(\text{unit})$ Correct. On/Off	Toggles resistive cable loss correction on/off, as described above. If the end point of the correction has not been set, then it will be set to the position of the active cursor.
▷▷ Set $\Omega/(\text{unit})$ Pos.	Sets the position of the ohms/(unit distance) position to that of the active cursor.
▷▷ Clear	Resets all $\Omega/(\text{unit})$ settings.
Math	See Table 3.2: Math Menu.
Settings	
▷ Meas. Settings	See Meas. Settings under Measurement menu above.
▷ Save Trace Default Name	Allows creation of default name for saved traces. When a trace is saved, the dialog box is autofilled with this name. Can also choose to automatically append a revision number or timestamp to default name.
▷ Network Settings	

Table 3.4 (Continued) MENU Button and Menus

Menu Selection	Purpose/Action
▷▷ Static Network Settings	Modifies static network settings (if DHCP inactive):
▷▷▷ IP Address.....	IP address (xxx.xxx.xxx.xxx)
▷▷▷ Netmask.....	Subnet for CT100B
▷▷▷ Gateway (optional)....	Gateway server setting
▷▷▷ Nameserver 1 and 2 (optional).....	Nameserver settings
▷▷ DHCP on/off	Toggles DHCP on/off.
▷▷ Show IP Config.	Displays current Ethernet configuration.
▷▷ Web Server On/Off	Toggles the internal web server on and off. The web server provides .csv format files, screen-capture bitmaps, and the ability to remotely access the device. See Section 4.15 for more details on accessing data using web export. [ <b>Note:</b> See Section 6 for more information on using CT Viewer 2 to acquire TDR traces. See <a href="http://www.mohrtrm.com">www.mohrtrm.com</a> for information on the CT100B Python programming library and binary programming protocol for Ethernet CT100B interface.]
▷▷ Selected .csv Options	Opens a dialog for adding additional data columns in the .csv trace export file.
▷▷ Set Listen Ports	This dialog box allows you to define a different RPC port # and a different Remote Control Port # for use with the CT Viewer 2 application (default 12347).
▷▷ SP232 Protocol On/Off	Toggles SP232 emulation on/off. A USB to serial adapter is required for SP232 emulation. Press this button while emulation is on to switch the baud rate.
▷ Power	
▷▷ DC Power Save	Sets the inactivity timeout for power save mode while the device is running on external DC supply.
▷▷ DC Shutdown	Sets the inactivity timeout for shutdown while the device is running on external DC supply.
▷▷ Battery Power Save	Sets the inactivity timeout for power save mode while the device is running on battery.
▷▷ Battery Shutdown	Sets the inactivity timeout for shutdown while the device is running on battery.

Table 3.4 (Continued) MENU Button and Menus

Menu Selection	Purpose/Action
▷▷ Battery Icon	Toggles battery icon display on/off.
▷▷ Power Display	Toggles the on-screen power status display on/off.
▷ Diagnostics	
▷▷ Analog	Runs automated diagnostics on the analog trace acquisition circuit board. Results are displayed on-screen in a message box.
▷▷ Database	<b>Clean Database: CAUTION!</b> Not for routine use. This option defragments the database, freeing up unused space, then turns off the CT100B. Use this option only when the CT100B is plugged into an external power supply. Do not shutdown the CT100B while the Clean Database command is in progress.
▷▷ Front Panel Check	Opens the front panel button and knob check screen. Hit each button once and turn every knob in each direction. Press the red <i>POWER</i> button to exit when finished.
▷▷ Jitter	Jitter measures signal noise, jitter, rise time, and sampling efficiency of the trace. These values are used as part of the calibration checkout for the CT100B, and results of interest are explained in Appendix B: <i>Operator Performance Checks</i> .
▷ Info	
▷▷ License	
▷▷▷ License Info	Gives information about the license installed on the CT100B.
▷▷▷ License from USB	Use this option to load a license code from a USB flash drive.
▷▷▷ Enter License	Manually load a license code. This is useful for operators who are unable to connect to CT Viewer 2 or use a flash drive.
▷▷ Web Update	When a CT100B is connected to the internet, this item will automatically update the CT100B if newer software is available.
▷▷ Update From USB Drive	Runs an update from the connected USB drive.

Table 3.4 (Continued) MENU Button and Menus

Menu Selection	Purpose/Action
▷▷ Web Update Address	View/set the web address to query for updated software. Normally this setting should not be changed.
▷▷ Processor	Displays CPU information.
▷▷ Contact	Displays contact information for MOHR.
▷▷ Auto Update On/Off	Toggles Auto Update on/off. With Auto Update on, the CT100B will automatically check to see if it is running the current software version and notify the user if a new version exists.
▷▷ Software Version	Displays software and firmware version information. This also serves to verify the communications links between the micro-controllers.
▷▷ Hardware Info	Displays hardware information.
▷▷ Usage	Displays instrument usage in hours.
▷▷ Time	Time and date settings.
▷▷▷ Time/Date	Sets the current date and time.
▷▷▷ Set Time Zone	Changes the time zone.
▷▷▷ Daylight Savings On/Off	Sets adjustment for daylight saving time on/off.
▷ Display	
▷▷ Change Screen Profile	Toggles screen background (black, gray, white).
▷▷ Standard/Special Menu	Allows user to toggle between the standard text main menu or a main menu with visual shortcuts to commonly used features.
▷▷ Ohms/Rho	Toggles display of impedance (ohms) and reflection coefficient (millirho) at cursor and between cursors.
▷▷ VSWR	Toggles display of VSWR (voltage standing wave ratio) at cursor.
▷▷ Trace Labels On/Off	Toggles display of the trace labels directly below the traces.
▷▷ Time/Date	Toggles time/date display.
▷▷ Distance/ns	Toggles display of distance and time (ns) at cursor.
▷▷ Temp Comp	Toggles display of Temp Comp autocalibration status.



Table 3.4 (Continued) MENU Button and Menus

Menu Selection	Purpose/Action
▷▷ Min/Max Display	Toggles display of min/max values for high-resolution sampling.
▷▷ Horiz. Vert. Ruler	Toggles display of horizontal and vertical rulers.
▷▷ Noise Value	Toggles display of noise value at cursor for diagnostic purposes.
▷▷ Vert. Shift Correction	Toggles the Vertical Shift Correction option. When on, corrects the vertical shift that can happen when changing the DUT.
▷▷ Time of Flight	Shows Time of Flight time measurements. The standard nanoseconds display shows electrical time for a pulse to reach a point and then return to the CT100B. Time of Flight is exactly half that value. It is the one-way transmission time.
▷▷ Vert Centering On/Off	When on, changes to vertical scale will center on the point where the cursor intersects the selected trace. When off, changes to vertical scale will center on the center of the screen.
▷▷ Draw Internal Cable Bkgnd	Changes the background color of the trace from the start of the trace to the end of the internal cable.
▷▷ Set/Clear Zero Offset	Sets a non-standard zero point to use when displaying horizontal distance. This could be used to exclude a test harness or adapter cable from the starting point.
▷▷ Auto Smooth Reset On/Off	When on, the CT100B will automatically reset smoothing when a change in load is detected by the device.
▷▷ Long Trace Progress On/Off	When on, draws a progress bar when scanning long, slow (high-resolution) traces.
▷▷ Scale	Toggles display of horizontal and vertical scales and Vp.
▷▷ Intersection	Toggles display of cursor-trace intersection.
▷▷ Decibels	Toggles display of decibel (dB) values at cursor.
▷▷ Temperature	Toggles display of instrument internal temperature.

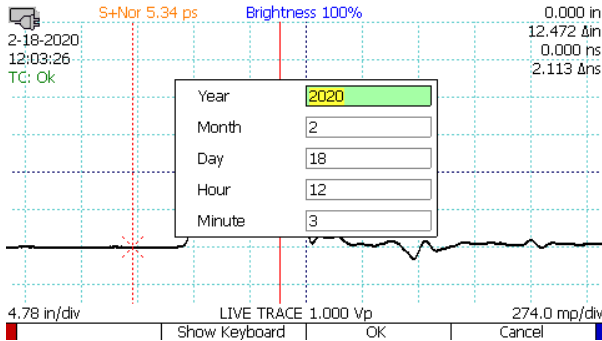
Table 3.4 (Continued) MENU Button and Menus

Menu Selection	Purpose/Action
▷ AutoSmooth On/Off	When on, the CT100B will automatically pick a smoothing value based on the observed noise. When off, the CT100B will use the user-entered smoothed value.

### 3.10. Setting up the CT100B

#### 3.10.1. Navigating Dialog Boxes

Some menu items will bring up dialog boxes with entries that need to be filled in by the user. For an example of a dialog box with multiple entries, press the blue *MENU* button, then *Settings*, then *Info*, then *Time*, and then *Time/Date* (see Figure 3.7).



**Figure 3.7.** An example of a dialog box with entries that need to be filled in by the user.

To fill out the entries, scroll through the different entry boxes with the *M-FUNCTION* knob. With an entry box selected, press the *Show Keyboard* menu option to call up an on-screen keyboard.

With the on-screen keyboard chosen, select the desired characters with the *M-FUNCTION* knob, pressing the *Select Highlighted* menu option after choosing each one. Get more character options by selecting the *Shift* menu option. Delete the character before the cursor with the *Backspace* menu option.

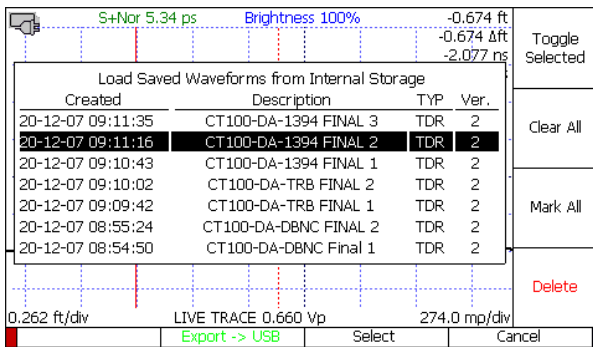
With the keyboard open, accept the current entry with the *Hide Keyboard* menu option or revert to the original entry with the *Cancel* menu option. Both options remove the on-screen keyboard from the screen.

With the keyboard off the screen, select the *OK* menu option to accept all changes to the current dialog box and close the dialog box. Select the *Cancel* menu option to close the dialog box while canceling all changes.

With a USB keyboard attached, entries can be changed directly. Use the Tab key to scroll down through entry boxes and hold down Shift and press Tab to scroll up through entry boxes. Use Backspace to delete the character before the cursor and use the arrow keys to move the cursor left or right. Press Enter for *OK* or Escape for *Cancel*.

### 3.10.1.1. Scrolling Dialog Boxes

Some dialog boxes present a list of items to be selected. For an example of this type of dialog box, press the *FILE* button, and then press *Cable Scan Records* (see Figure 3.8). Use the *M-FUNCTION* knob to highlight individual items for selection, and then use the *Select* option to choose the highlighted item. Where appropriate, multiple items can be marked for selection using the options on the right-side menu: *Toggle Selected*, *Clear All*, and *Mark All*. When an item is marked, it will appear in a different color.



**Figure 3.8.** An example of a dialog box with a list of items that can be scrolled through.

### 3.10.2. Display Features

The CT100B screen provides the operator with numerous features that may be useful in different cable-testing situations. Figure 3.9 shows some of the typical features you will encounter during use. Most of these features can be toggled on or off by pushing the blue *MENU* button and going to *Settings* → *Display*. Many other features are available, however, and most of them are configurable by the user. These features are described in detail throughout this manual.

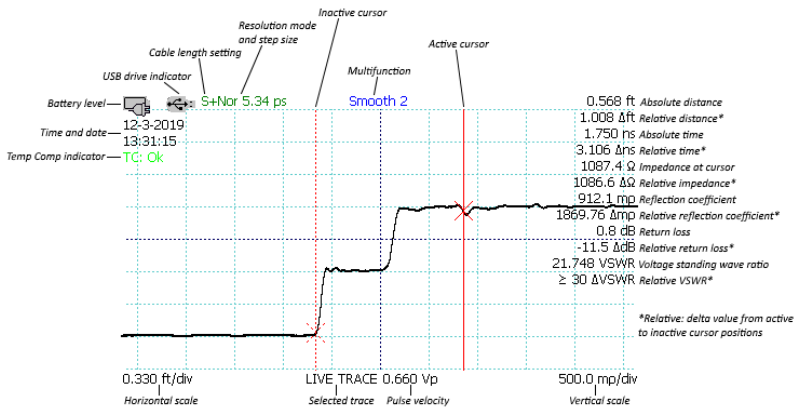


Figure 3.9. Screenshot showing typical features of the CT100B.

### 3.10.3. Setting Date and Time

The date, time, and time zone must be accurately set for saved data in the CT100B to be correctly time-stamped.

1. Change the date and time by pressing the *MENU* button. This calls up the *Main* menu.
2. Select the *Settings* soft-menu option and then select the *Info* menu.
3. Select the *Time* menu option. The *Time* menu appears.
4. Select the *Set Time Zone* menu option. A dialog box listing all time zones appears on the screen.
5. Use the *M-FUNCTION* knob to scroll through the list of time zones. Highlight the correct time zone.
6. Choose the *Select* menu option. The CT100B may prompt you to restart. If so, restart the unit and return to the *Time* menu. The CT100B is now set to the correct time zone.
7. Ensure the menu option for daylight saving is correct for the region you're in. If you observe daylight saving, make sure it reads *Daylight Savings On*, indicating that this setting is on. If the option reads *Daylight Savings Off*, then press the menu button to toggle it on. The CT100B may prompt you to restart. If so, restart the unit and return to the *Time* menu. The CT100B will automatically adjust for daylight savings on the correct dates. If you do not observe daylight saving, make sure it's toggled to *Daylight Savings Off*.
8. Select the *Time/Date* menu option. A dialog box used to set the date and time appears. See Section 3.10.1 for methods of navigating and entering data into a dialog box.
9. Press the *OK* menu option when the correct time and date have been entered.

### 3.10.4. Temperature Correction

The CT100B automatically adjusts for changes in temperature. This eliminates the need for a warm-up period. However, a stable temperature is required for some functions, such as performance checks. To view the internal temperature, go to *MENU* → *Settings* → *Display* and toggle on *Temperature*. In the *Display* submenu you can also toggle on *Temp Comp*. When temperature is displayed on the screen with *Temp Comp* toggled on, a message is shown giving the status of temperature correction. When the CT100B is fully adjusted, the message reads “TC: OK” in green text.

### 3.11. Cable Length Settings

When scanning a cable, the correct cable length needs to be chosen for the most accurate results. If using the *Special Main* menu, press the blue *MENU* button then *Measurement* → *Meas. Settings* and press the *Cable Len* button to toggle through the different lengths. If using the *Standard Main* menu, press the blue *MENU* button and choose a cable length.

- Short: For cables of up to approximately 300 ft. (90 m) long.
- Medium: For cables up to 1500 ft. (450 m) long.
- Long: For cables up to 6000 ft. (1800 m) long.

The exact limit to the cable length setting depends on the Vp setting. All limits given above are based on a Vp of 0.66. Higher Vp cables will have longer length limits and lower Vp cables will have shorter length limits.

To measure cables over a mile (2 km) in length, use Extra Long Mode. Go to *MENU* → *Measurement* to toggle on Extra Long Mode. Extra Long Mode allows the CT100B to obtain traces out to 48,000 ft. (14,600 m), assuming a Vp of 0.66. Extra Long Mode is slower than other cable lengths and some instrument features are not available. When in Extra Long Mode, the *Cable Length* menu option will indicate Extra Long Mode On. Selecting the *Cable Length* menu option will switch off Extra Long Mode.

### 3.12. Sample Resolution

The sample resolution setting establishes the number of sample points per unit of time or distance in the live TDR trace. In general, higher sample resolution sharpens traces at larger horizontal scales by increasing the effective sampling efficiency of the TDR trace (the ratio of sampled vs. actual change in voltage from sample to sample). For larger horizontal scales it also helps ensure that all cable faults are sampled adequately enough to be detected and displayed on the instrument screen. Note that the sample resolution of cable scans can be set separately (see Section 4.8). The following TDR trace sample resolution settings are available in *MENU* → *Measurement* → *Meas. Settings* → *Resolution* (*Special Main* menu) or *MENU* → *Resolution* (*Standard Main* menu):

1. **Screen:** Screen resolution (1 sample/pixel). Fastest trace, adequate for many routine cable-testing tasks. At large horizontal scales, the resolution is low and small faults may be undetectable, or at least underestimated. This is because there may be too few samples in the region of the fault for

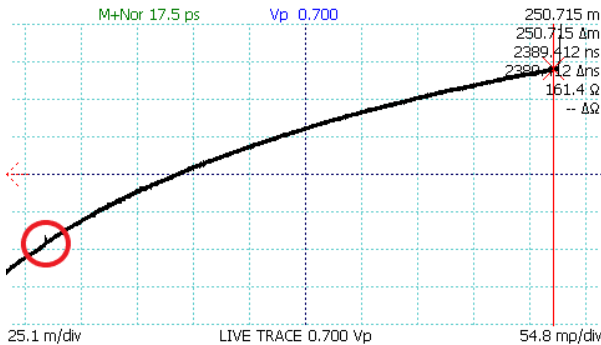
the fault to be reliably identified on the trace. For example, if a thousand foot cable is displayed on the screen, there is only one measurement about every two feet.

2. **Normal:** Sample resolution setting is chosen to match the cable length setting for good compromise of detail and speed. For SHORT length cable settings, the resolution is 5.34 ps (less than a millimeter) or better. For MEDIUM length, the maximum resolution is 17.5 ps (about 2 mm). For LONG length, the maximum resolution is 49.6 ps (about 5 mm). As you zoom in, the CT100B will adjust resolution.
3. **Fixed:** Set a sample resolution manually using *M-FUNCTION* knob; it stays fixed regardless of screen horizontal scale. Useful for enhancing frequency resolution of  $S_{11}$  return loss and cable loss traces that may require sampling at resolutions higher than Normal mode.

Using fine resolution may result in the CT100B buffering. The CT100B will show a scanning progress bar on-screen until buffering is completed.

For larger horizontal scales, the Normal or Fixed sample resolutions provide high-resolution sampling. The trace displayed on the screen at each pixel is a vertical bar that shows the maximum and minimum values sampled within the pixel. **This feature ensures that any detectable TDR cable fault is displayed at least 1 pixel wide regardless of horizontal scale.**

A Normal sample resolution trace of an 800 ft. (250 m) cable is shown in Figure 3.10. In this case the high-resolution sampling of the Normal setting ensures that the small fault from a 50 ohm BNC barrel connector is displayed despite the large horizontal scale. To see this flaw using the Screen sample resolution mode would require the user to “zoom-in” to show the detail of a short section of cable, and then to manually scroll the length of the cable using the *HORIZONTAL POSITION* knob.



**Figure 3.10.** A small fault in a long cable. This fault (red circle) in an approximately 800 ft. (250 m) cable is from a 3 cm barrel connector (0.01% of cable length). The sampling of the Normal sample resolution setting ensures that the cable fault is displayed at this large horizontal scale (~50 cm/pixel).

## 3.13. Measurement Settings

### 3.13.1. Horizontal Units

Horizontal distance measurements can be displayed in meters, inches, feet, yards, or centimeters.

1. Select *MENU* → *Measurement* menu.
2. Select the *Horiz. Units* menu item to switch between the different unit options.

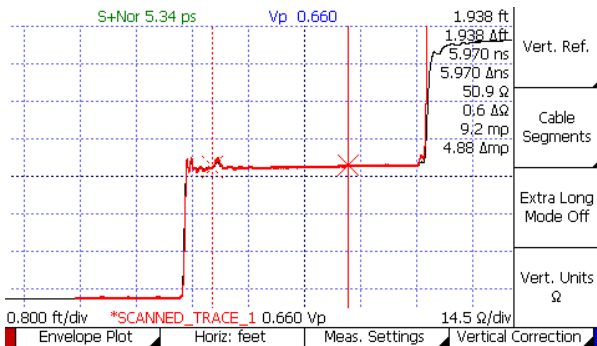
All measurements and all traces are immediately updated to reflect the unit change. Time in nanoseconds (ns) is displayed separately.

### 3.13.2. Vertical Units

The CT100B is able to change vertical units of the live TDR trace so that it is displayed in units of reflection coefficient (millirho), impedance (ohms), or voltage standing wave ratio (VSWR). Changing the vertical units changes the appearance of the selected trace. To change vertical units, use the following procedure:

1. Select *MENU* → *Measurement* menu.
2. Select *Vert. Units* to toggle through the different options.

An example trace with impedance (ohms) as the vertical unit is shown in Figure 3.11. Note that the vertical scale is in ohms and the open fault at the end of the cable on the red (Impedance) trace shows a nonlinear relationship between the reflection coefficient (millirho, shown by the black trace) and the impedance as described in Section 7.6.



**Figure 3.11.** TDR trace with impedance vertical units (red, top) demonstrating vertical scale in ohms and emphasis of the open fault at the end of the cable. The black trace uses reflection coefficient (millirho) as its vertical units.

### 3.13.3. Relative Reflection Coefficient (RRC) Method

The CT100B measures the relative reflection coefficient between cursors. When the two cursors of the CT100B are positioned on either side of a change in impedance, this measurement is the reflection coefficient for that change. The relative reflection coefficient is displayed on-screen with a prefix of  $\Delta mp$ . To view the relative reflection coefficient values, go to *MENU*  $\rightarrow$  *Settings*  $\rightarrow$  *Display* and make sure *Rho* is toggled on. By default, the value is displayed in *Classic* mode, displaying the true reflection coefficient relative to the signal at the input of the reflection. The CT100B can also measure in *1502C* mode, which displays a reflection coefficient relative to the signal at the input of the cable.

1. Select the *MENU*  $\rightarrow$  *Settings*  $\rightarrow$  *Meas. Settings* menu.
2. Select *RRC Classic Mode* from the menu. This will toggle the CT100B between the *Classic RRC* calculation and the *1502C* calculation as displayed on the screen.



## 4. Operating Instructions

If you would like a detailed explanation of TDR measurement theory and applications before using the CT100B to test cables, please read Section 7, *TDR Measurement Theory*, or go to [www.mohrtn.com](http://www.mohrtn.com).

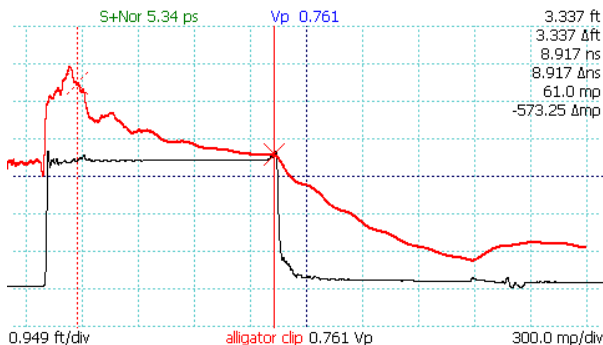
### 4.1. Connecting to the Cable or Device-Under-Test (DUT)

The first and most important decision to make when testing a cable or device-under-test (DUT) is how to connect to the DUT. Because the connection to the DUT acts as a filter for the test signal into and out of the DUT, it is very important that the connection have the highest bandwidth and least aberration possible.

Controlled impedance connections are recommended whenever possible. Controlled impedance connections have conductors with uniform geometry and dielectric properties that do not change significantly during a test session or between test sessions. Examples of controlled impedance connections include coaxial-coaxial adapters, coaxial-twisted-pair adapters, and fixed-pitch TDR probes.

Alligator clip and clip lead adapters with flexible wire test leads should be used only as a last resort. Alligator clip and clip lead adapters are not made for high-frequency operation, are severely bandwidth-limiting, and introduce severe aberration and measurement uncertainty into the TDR trace. Figure 4.1 shows a comparison test of a coaxial cable using clip lead adapters (red, top) and a controlled-impedance adapter (black, bottom). The clip lead adapter TDR trace is severely degraded.

MOHR is able to supply controlled-impedance adapters for almost every type of cable and connector.

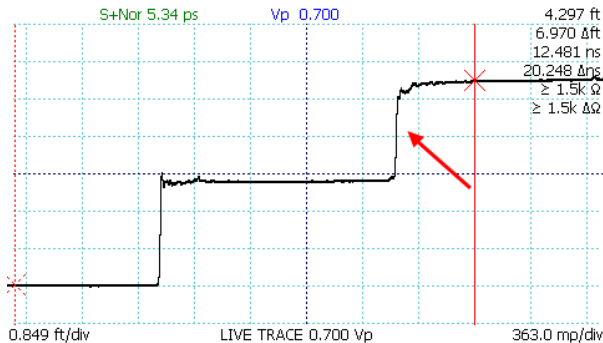


**Figure 4.1.** Clip lead adapter (red, top) and controlled-impedance adapter (black, bottom) testing of 3 ft. coaxial cable with short termination. Active cursor is at the test port. Clip lead adapters introduce severe TDR trace distortion.

## 4.2. Common Types of TDR Cable Faults

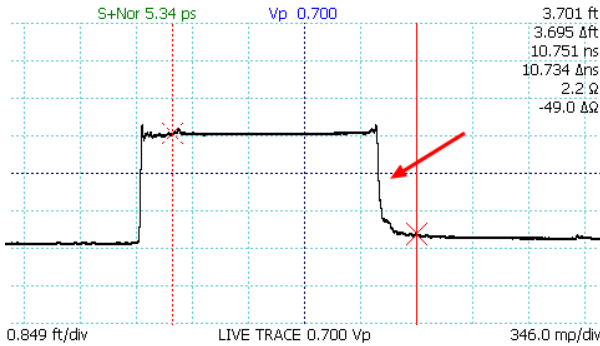
TDR cable faults include opens, shorts, and soft (or partial) faults.

Open faults appear as a pulse upward in the TDR trace (Figure 4.2). These kinds of faults appear naturally when the cable isn't connected to anything and often indicate the end of the cable.



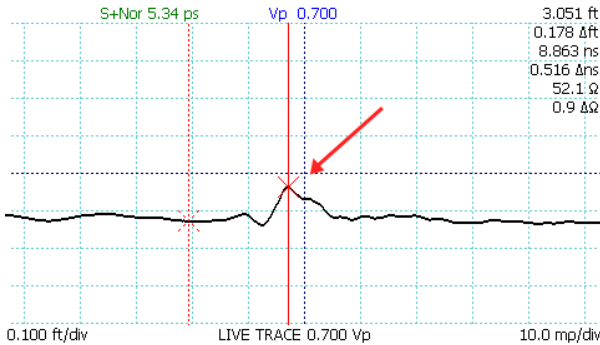
**Figure 4.2.** Open faults appear as a pulse upward in the TDR trace.

Short faults appear as a pulse downward in the TDR trace (Figure 4.3).



**Figure 4.3.** Short faults appear as a pulse downward in the TDR trace.

Short or open faults measured through long lengths of cable (hundreds of feet) will show long, shallow reflections on the TDR trace. Figure 4.4 shows a scan of an SMA interconnect. The trace has a spike at the connection.



**Figure 4.4.** A scan of an SMA connector.

Soft/partial faults, like kinks, dents, or cuts, can appear anywhere along the cable's length. They show up as small bumps on the trace.

Section 7.3 contains additional information on common cable faults.

### 4.3. Change Velocity of Propagation (Vp)

Vp is expressed as a fraction of the speed of light. See Section 7.4 *Velocity of Propagation (VoP, Vp)* for a detailed description of Vp.

The current setting for Vp appears on the lower center of the screen. Press the *M-FUNC* button until the top-center information indicator reads Vp. Turn the *M-FUNCTION* knob and the Vp value will change accordingly. Measurements and traces are automatically updated on the display to reflect the new Vp.

All measurements done by the CT100B are based on time and then converted to distance for display. An accurate Vp is necessary for accurate cable length and Distance-to-Fault calculations. For cables of a known type, the Vp can be approximated by using the nominal Vp for that cable type. The CT100B has a built-in library of cable types and their Vp values (see Section 4.5). You can also measure the Vp by testing a known length of cable that is of the same type as the one you want to test. The method is described in Section 4.4.

### 4.3.1. Fine Vp Control

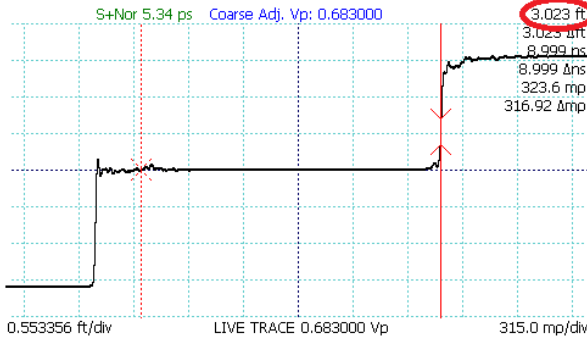
By default, the CT100B displays three decimal places for Vp; however, the CT100B can display six decimal places for Vp when very precise distance measurements are needed.

1. Select the *MENU* → *Settings* → *Meas. Settings* menu.
2. Select *Vp 3 Sig Figs* from the menu to toggle the option to *Vp 6 Sig Figs*. The CT100B will display six decimal places for the Vp readout on the screen when *Vp 6 Sig Figs* is shown on the menu.
3. When the CT100B is in *Vp 6 Sig Figs* mode, a new function, *Fine Adj. Vp*, is added to the *M-FUNC* button. When the *M-FUNC* button is set to *Fine Adj. Vp*, turning the *M-FUNCTION* knob will change the Vp value of the last three significant digits. The Vp value of the first three significant digits can be changed by setting the *M-FUNC* button to the *Coarse Adj. Vp* function.

## 4.4. Find an Unknown Velocity of Propagation (Vp)

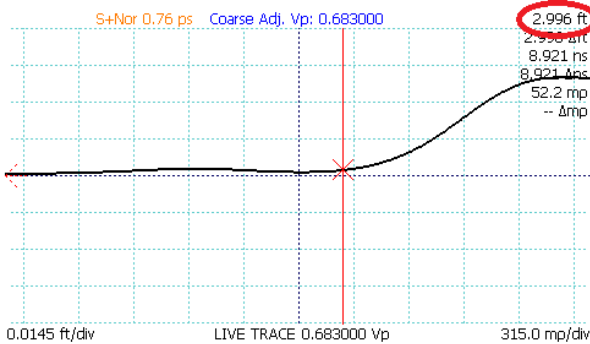
This method is used to find the Vp for cables under test where the Vp is unknown. It requires a sample cable of the same type that can be measured physically.

1. Measure the physical length of the test cable. Make sure the test cable is of the same type for which you need to find Vp. The accuracy of the Vp is dictated by the accuracy of the physical measurement. If the cables are terminated, they can be included in the measurement to find a combined Vp. The physical length measurement should not include any adapters necessary for connecting the cable to the CT100B.
2. Attach the test cable to the CT100B. For the example illustrated in this manual, the test cable is 3.0 feet long.
3. If using the *Special Main* menu, press the *MENU* button then *Distance to Fault*. If using the *Standard Main* menu, press the *AUTOFIT/HELP* button, then select the *AUTOFIT* menu item. The CT100B will display a trace that includes the beginning and the end of the test cable. The cursors will be moved to an area approximate to the cable ends. Figure 4.5 shows an AUTOFIT result. The cable end, in this case an open termination, has been found at 3.023 feet and the whole cable trace is displayed on the screen.



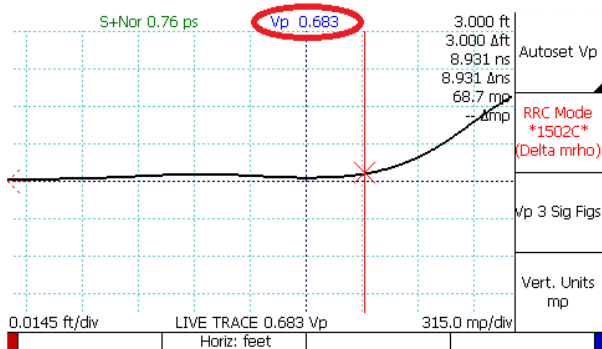
**Figure 4.5.** Screenshot showing AUTOFIT result.

4. Accurately position the cursors to bracket the area of the trace associated with the test cable. Using the scale and position knobs, move the ending cursor so that it is just aligned with the “toe” of the open or shorted fault at the end of the cable (Figure 4.6). If an adapter is used, position the starting cursor at the end of the adapter. The accuracy of cursor placement affects the accuracy of the Vp measurement.



**Figure 4.6.** Use of the HORIZONTAL SCALE knob to improve Vp accuracy.

5. Press the *M-FUNC* button to set the *M-FUNCTION* to Vp, and adjust Vp using the *M-FUNCTION* knob until the CT100B distance measurement to the active cursor equals the physical measurement. The final Vp value is the true Vp value of the cable (Figure 4.7). Note that in the *Measurement* → *Meas. Settings* menu there is an option to set Vp to six significant digits.



**Figure 4.7.** Final Vp of the cable.

The cable Vp can be saved to a table of custom Vp values. See Section 4.5.

## 4.5. Cable Type Library

The CT100B has a library of common cable types and associated velocities of propagation. Vp for these cable types can be loaded from the library. The user can add custom cable types to the CT100B as well. The user-added cable types are stored and accessed separately from the standard cable types.

### 4.5.1. Load a Cable Type's Vp

To load a cable type, follow this procedure:

1. Press the *FILE* button. The *File* menu appears.
2. Select *Reference Cable Types* or *Custom Cable Types* from the menu. An interface appears that allows you to scroll through the cable types with the *M-FUNCTION* knob.
3. Highlight the desired cable type and press *Select*. Vp is now set to the value for that cable type.

### 4.5.2. Custom Cable Types

The CT100B is able to save custom cable types. Use the following procedure to save a custom cable type:

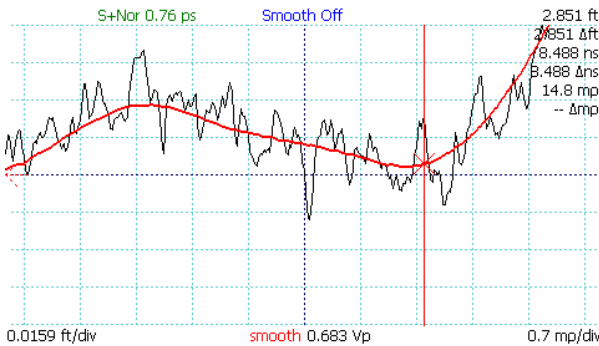
1. Press the *FILE* button. The *File* menu appears.
2. Select the *Custom Cable Types* menu option to access user-editable cable types with menu options *Add New* and *Select*.
3. When *Add New* is chosen, a window appears for entering a cable type name, a Vp for velocity of propagation, and an expected characteristic impedance for the cable. When the window first appears, Vp will be set to the current system Vp, while impedance defaults to 50 ohms.

## 4.6. Smooth Settings

The CT100B smoothing feature performs temporal averaging to decrease visible noise on the live TDR trace and improve signal-to-noise ratio (SNR) for first derivative,  $S_{11}$  return loss, and other mathematical operations. When you acquire baseline TDR scans of cable assemblies meant for archiving and future comparison use, it is recommended that at least a moderate level of smoothing be used so that the vertical resolution of the instrument is used to the fullest extent possible. The effect of smoothing is most apparent at very small vertical scale settings (that is, when the trace is zoomed-in vertically). To change TDR trace smoothing:

1. Press the *M-FUNC* button until *Smooth* shows up in the upper middle of the screen.
2. Rotate the *M-FUNCTION* knob until the desired level of trace smoothing is obtained.

A comparison of a smoothed (1,024 trace average) TDR trace to an unsmoothed TDR trace at 0.7 *mp* (millirho) per vertical division is shown in Figure 4.8.

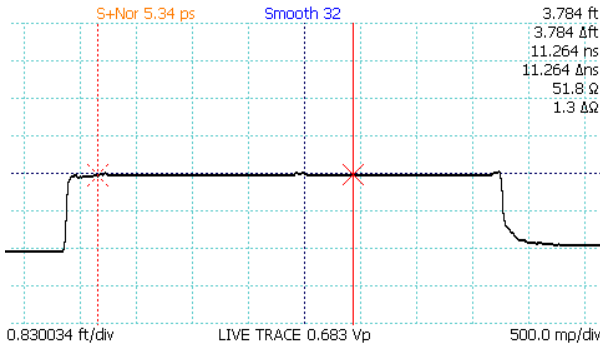


**Figure 4.8.** Smoothed vs. unsmoothed traces at very small vertical scales (0.7 *mp* per vertical division).

## 4.7. Distance-to-Fault

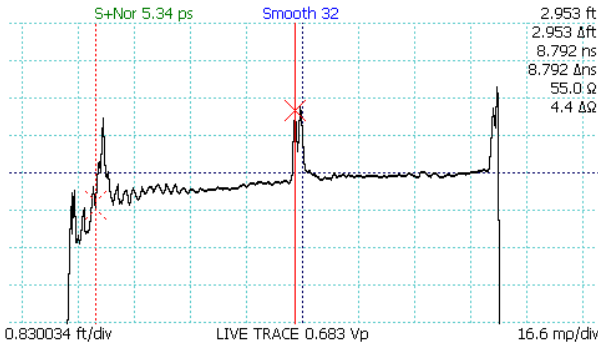
### 4.7.1. Measure Distance-to-Fault (DTF)

1. Attach the cable to the test port.
2. Set  $V_p$  to match the  $V_p$  of the attached cable or select an appropriate cable from the cable type library. See Section 4.5 Cable Type Library for instructions on using the cable type library.
3. Depending on the *Main* menu being used, either press *MENU* → *Distance to Fault* (*Special Main* menu only) or press the *AUTOFIT/HELP* → *AUTOFIT* menu option. The CT100B trace is now scaled to show the entire cable from beginning to end. See Figure 4.9.



**Figure 4.9.** AUTOFIT cable. The cable termination is a short.

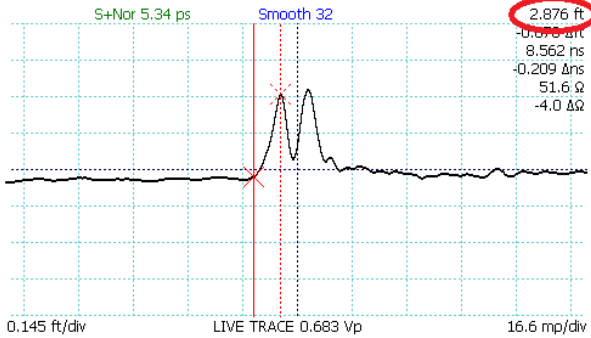
- Note the “bump” in the middle of the cable in Figure 4.9. This is where two short test cables are connected with a BNC barrel connector. Position the active cursor on the reflection caused by this cable fault. Adjusting the vertical scale helps make cable faults more obvious, as in Figure 4.10, which is at the same horizontal scale as Figure 4.9 but zoomed-in vertically. By positioning the inactive cursor just before the connector, we can see the delta value of  $\sim 4.4 \Omega$  impedance change in the connector vs. the impedance of the cable.



**Figure 4.10.** Vertical scale used to emphasize cable fault.

- Use the *HORIZONTAL SCALE* and *VERTICAL SCALE* knobs to further zoom in on the fault to get a more accurate measurement of Distance-to-Fault (DTF). Position the cursor at the “toe” or early rising edge of the fault. The distance measurement shown on the screen for the active cursor is then the Distance-to-Fault. See Figure 4.11.





**Figure 4.11.** A horizontally zoomed-in view of the cable fault with active (solid) cursor at the start of the fault (“toe” region) and inactive (dashed) cursor at the peak of the fault. The DTF measurement is highlighted (red circle).

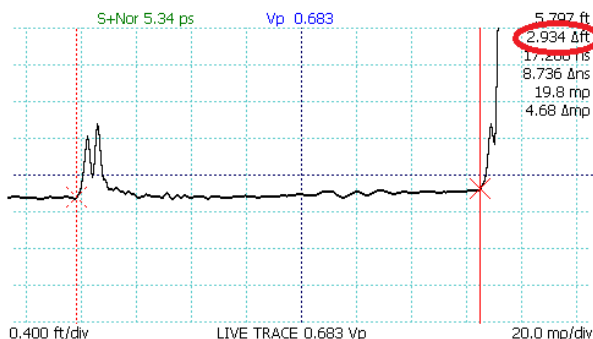
#### 4.7.1.1. Ohms-at-Cursor Measurements

The CT100B can display the impedance in ohms ( $\Omega$ ) at the cursor position. A reading before and after a reflection from a fault shows the impedance mismatch that could cause such a reflection. Impedance measurements at the first fault in a cable are more accurate than impedance measurements at more distant faults.

#### 4.7.2. Relative Distance and DTF Measurements

The CT100B displays the absolute distance from cable start and also the relative distance from the inactive cursor to the active cursor. Note that Vp must be set accurately for the section of cable between the cursors for the CT100B to measure relative Distance-to-Fault accurately. The pulse velocity of any part of the cable that is not between the cursors will not affect the relative distance measurement. To measure the relative distance between two points in a cable, do the following:

1. Move the active cursor to the beginning of the section to be measured.
2. Press the *CURSOR* button to switch cursors.
3. Move the newly active cursor to the end of the section to be measured.
4. The CT100B displays the distance measured between the two cursors as a “ $\Delta$ ” value below the absolute distance measurement. Figure 4.12 is a 3 ft. segment of 50 ohm cable marked by small impedance “faults” caused by BNC connectors on both ends.



**Figure 4.12.** Relative distance measurement between two small impedance “faults” caused by BNC connectors.

In general, for the most accurate relative distance or time measurements between two faults, place the cursors on the “toe” region of the faults where the TDR trace is just beginning to rise above or fall below the cable characteristic impedance.

#### 4.7.2.1. Zero Offset

Normally, the horizontal zero point of a trace is the cable connector on the front of the CT100B. If a zero point needs to be set that excludes a test harness or adapter cable, the *Set Zero Offset Position* function can help.

1. Using the *HORIZONTAL POSITION* knob, position the cursor at the end of the adapter cable or test harness.
2. Press the *MENU* button, and go to *Settings* → *Display* → *Set/Clear Zero Offset* (Figure 4.13).
3. The *Zero Offset* menu appears. Note that measurement for the cursor position has not changed yet (Figure 4.14).
4. Press *Set New Position*. The CT100B will “move” the zero position to where the cursor is located on-screen. The background between the real zero point and the offset will be highlighted in orange. See Figure 4.15.

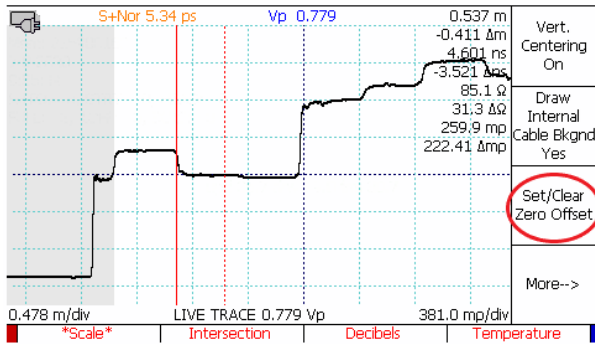


Figure 4.13. The Set/Clear Zero Offset button on the Display menu.

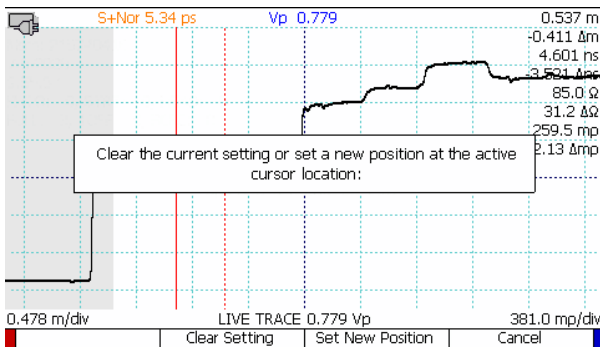


Figure 4.14. The Zero Offset menu. Note that the cursor position is currently at 0.537 m in this example.

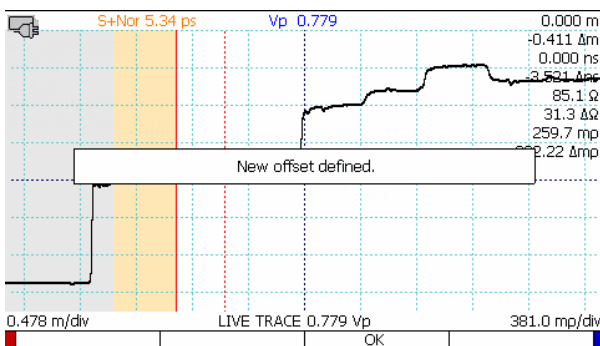


Figure 4.15. After choosing Set New Position, the cursor position is now at 0.000 m.

This setting only affects the on-screen display and measurements of the trace. This will not change a saved trace, and the zero offset cannot be saved.

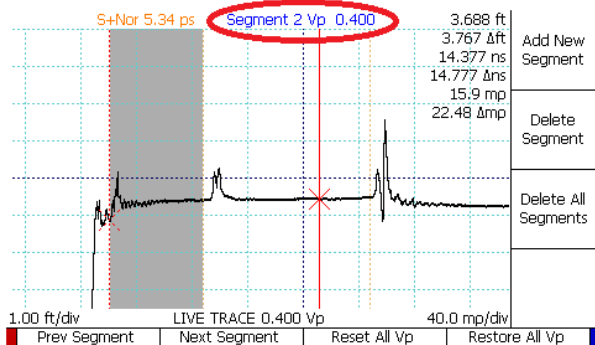
To clear the zero offset, go to *MENU* → *Settings* → *Display* → *Set/Clear Zero Offset* and press *Clear Setting*. The zero point will go back to its normal position.

### 4.7.3. Multi-Segment Cable DTF Measurements

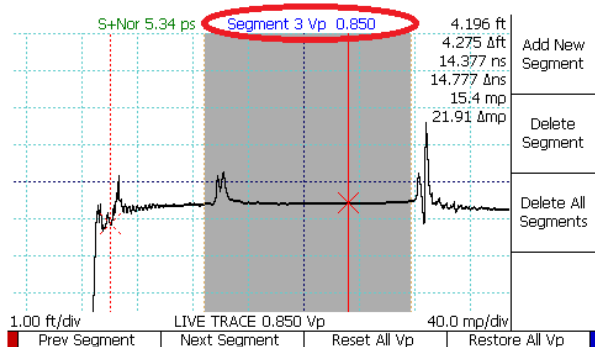
Cable assemblies are sometimes made up from different types of cables in series, each of which may be chosen for unique characteristics such as high-temperature operation or radiation resistance. Such cables frequently have different velocities of propagation ( $V_p$ ), making Distance-to-Fault (DTF) measurements difficult. If the average  $V_p$  of the assembly or the  $V_p$  of any one cable assembly is used, it will result in inaccurate distance measurements along the length of the compound cable.

The CT100B includes multi-segment cable measurement capability designed to improve cable measurement accuracy in the setting of compound, multi-segment cables with differing  $V_p$  values. The CT100B allows the operator to break a TDR trace into cable segments, each of which can have its own  $V_p$ . The Distance-to-Fault calculated from the compound trace shows improved accuracy. The following procedure can be used to perform multi-segment cable measurements:

1. Select the *MENU* → *Measurement* menu.
2. Select the *Cable Segments* submenu.
3. Place the cursor at the start of the cable segment, marked by a connector impedance signature or other demarcation, such as physical distance as calculated using known  $V_p$  for a given cable segment.
4. Select *Add New Segment*.
5. Repeat steps 3 and 4 for each cable segment.
6. Use the *Prev Segment* and *Next Segment* selections to choose each cable segment and use the *M-FUNC*  $V_p$  option to set the given segment's velocity of propagation.
7. The Distance-to-Fault measured by the cursor reflects multi-segment  $V_p$  as shown in Figure 4.16 and Figure 4.17.



**Figure 4.16.** Multi-segment cable segment with  $V_p$  of 0.400 (red circle).

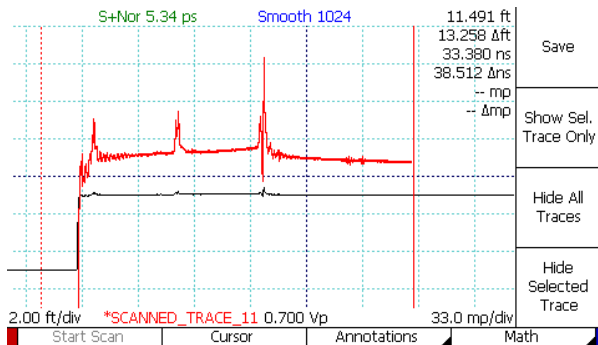


**Figure 4.17.** Multi-segment cable segment with Vp of 0.850 (red circle).

Multi-segment cable measurements can be saved like other traces to the CT100B's internal storage to be retrieved at a later time. See Sections 4.9.3 and 4.9.4 for more information on saving and loading traces.

## 4.8. Scan a Cable

The CT100B can scan a cable with user-defined resolutions. The user can optionally save these records into internal storage. CT100B scans differ from traditional TDR traces because they can be used to save detail at a much higher resolution than displayed on the screen. Cable scans can subsequently be reviewed at different levels of detail and compared to prior scans to identify subtle changes in cable or connector performance. See Figure 4.18. Scans may also be referred to as traces in this manual.



**Figure 4.18.** Scan of a portion of a cable (red), zoomed-in vertically to show additional detail relative to the live trace (black).

Saved scans can be displayed on the screen in addition to the live trace. Pressing the *SELECT* button switches between traces. Vertical position and scale are adjusted for individual traces. Changing these values for one trace won't affect other traces.

There are two types of scans:

1. *Snapshot* scan - Captures the live trace as it appears on the screen. This can work well if using Normal or Fixed resolution mode. If using Screen resolution, the result may be less detailed.
2. *Cursor* scan - Captures the entire trace between the two cursors using the current sample resolution (see Section 3.12). This works even if one or both cursors are off-screen when you begin the scan.

To scan a cable or cable section:

1. Press the *SCAN* button to bring up the *Scan* menu.
2. Select *Snapshot* or *Cursor*.
3. Choose the *Start Scan* option from the menu to begin a cable scan.
4. Select the cable scan (see Section 4.9.1 below) and manipulate as needed.

A scanned trace is created using the smoothing factor that is set at the time of the scan. Because of this, high-resolution or highly smoothed scans may take a long time. During a lengthy scan, a menu will appear with a *Cancel* option. See Figure 4.19. Select *Cancel* to abort the scan.

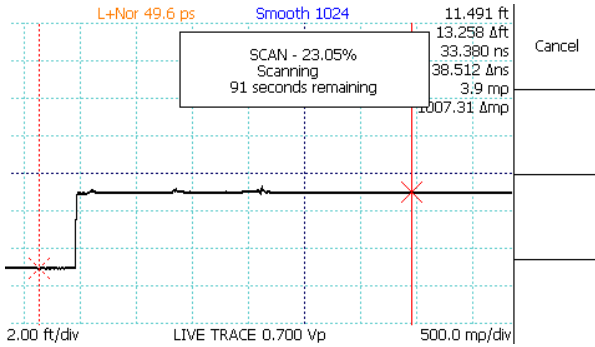


Figure 4.19. Scan progress display with Cancel button.

## 4.9. Working With Traces

### 4.9.1. Select a Trace

The CT100B always shows one trace on the screen in bold. This is the selected or active trace. If it is a live trace, the *VERTICAL POSITION* and *VERTICAL SCALE* knobs can be used on the selected trace, leaving other traces on the screen unchanged. If the selected trace is not a live trace, you can also use the *Save*, *Rename*, and *Hide Selected Trace* options on the *Scan* menu without affecting other on-screen traces. Vertical measurements such as reflection coefficient, return loss, and impedance are always based off of the selected trace and may disappear if the cursor scrolls beyond a scanned boundary or is off-screen.

Press the *SELECT* button to change which trace is active. Figure 4.20 shows a screen with three traces, and the live trace is selected.

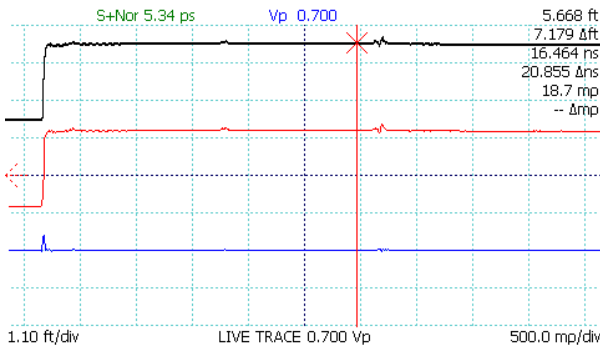
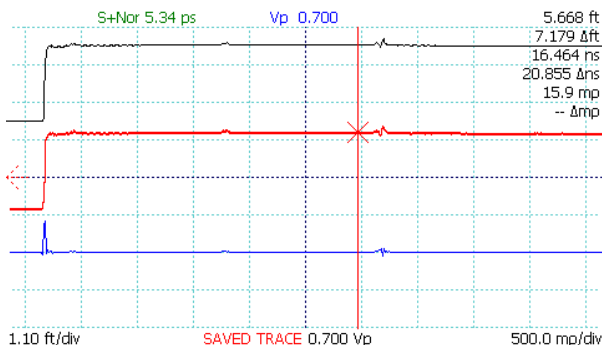


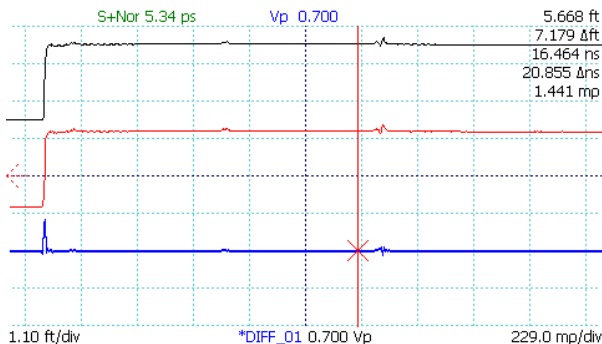
Figure 4.20. Selecting the live trace.

Figure 4.21 shows the same three traces with a saved scan selected. The saved trace has been moved vertically using the *VERTICAL POSITION* knob so that it is easier to see.



**Figure 4.21.** Selecting a scanned trace.

Figure 4.22 shows the same three traces, but now the trace representing the difference between the live trace and the saved trace is selected.



**Figure 4.22.** Selecting a difference trace.

### 4.9.2. Annotate a Trace

Entire traces, individual points on a trace, or a range of points on a trace can be annotated. If an individual point on a trace needs to be annotated, move the active cursor to that point. If a range of points on a trace needs to be annotated, move the active and inactive cursors to the starting and ending points of the range. To create an annotation:

1. Press the *SCAN* button. The *Scan* menu appears.
2. Select *Annotations*. See Figure 4.23. The *Annotations* menu appears. See Figure 4.24.
3. Press *Create Annotation*.



4. A dialog box appears. Press the *Show Keyboard* menu option to display the on-screen keyboard, or use a USB keyboard to enter the text that needs to be annotated to the trace. See Section 3.10.1 for more information on the on-screen keyboard and navigating dialog boxes.
5. Notate a specific point along a trace by toggling on *Set Start Point*. See Figure 4.25. The start point will be set to the active cursor. Toggle on both *Set Start Point* and *Set End Point* to apply an annotation to the range of points on a trace between the active and inactive cursors. See Figure 4.26. If both the start and end points are toggled off, then the annotation applies to the entire trace.
6. Press the *OK* button to finish creating the annotation.

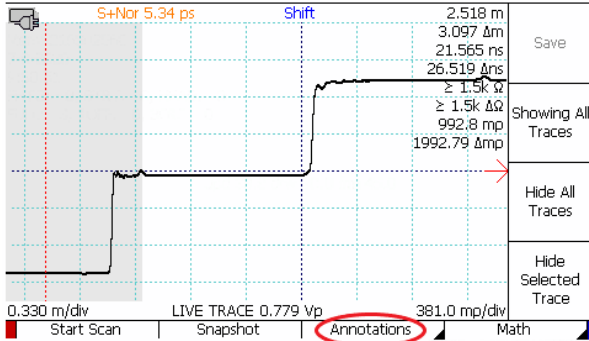


Figure 4.23. The Annotations selection in the Scan menu.



Figure 4.24. The Annotations menu.

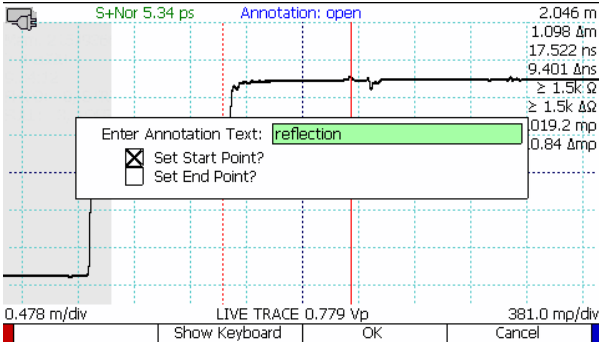


Figure 4.25. Use Set Start Point to annotate a specific point on a trace.

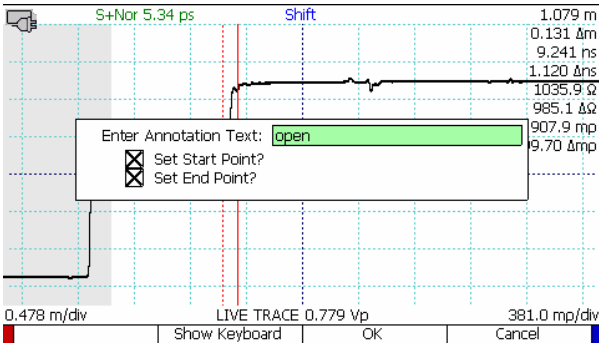
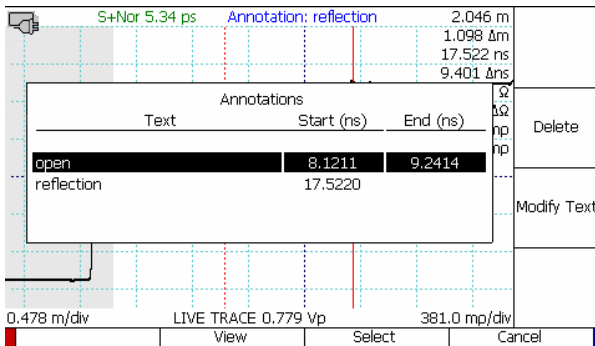


Figure 4.26. Use Set Start Point and Set End Point to annotate a range of points on a trace.

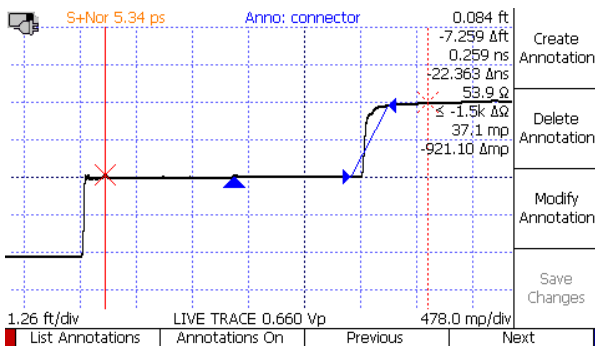
To view a list of all annotations attached to a trace, go to *SCAN* → *Annotations* → *List Annotations*. A scrolling dialog appears that lists the annotation text and any start and end points. See Figure 4.27.



**Figure 4.27.** The List Annotations selection brings up a list of annotations associated with a trace.

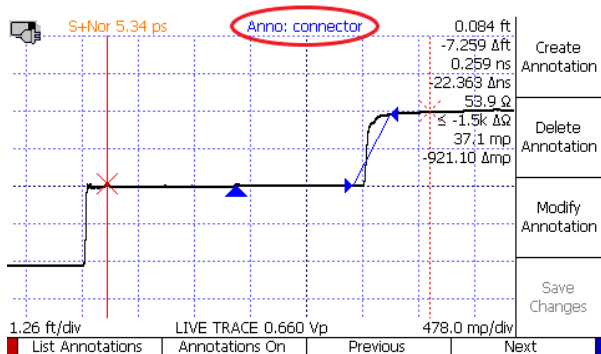
From this box, the annotation text can be viewed or modified or an annotation can be deleted.

An annotation for a specific point will show up as an arrow on the trace at that point. Annotations for a range of points show up as arrows at the starting and ending points of the range, connected by a line. See Figure 4.28.



**Figure 4.28.** A trace with annotations for a specific point and a range of values. These show up as arrows on the trace.

When an annotation is created, the multifunction indicator at the top of the screen will automatically change to show the name of the currently selected annotation (Figure 4.29). Use the *M-FUNCTION* knob to select the next or previous annotation.



**Figure 4.29.** After an annotation is created, the multifunction indicator at the top of the screen displays the name of the currently selected annotation.

To save annotations, go to *SCAN* → *Annotations* → *Save Changes*. If annotations were made to an unsaved trace, a prompt for a name to save the trace with will appear and the trace will be saved with the annotations. If annotations were made to a previously saved trace, *Save Changes* will save the annotations to the trace file.

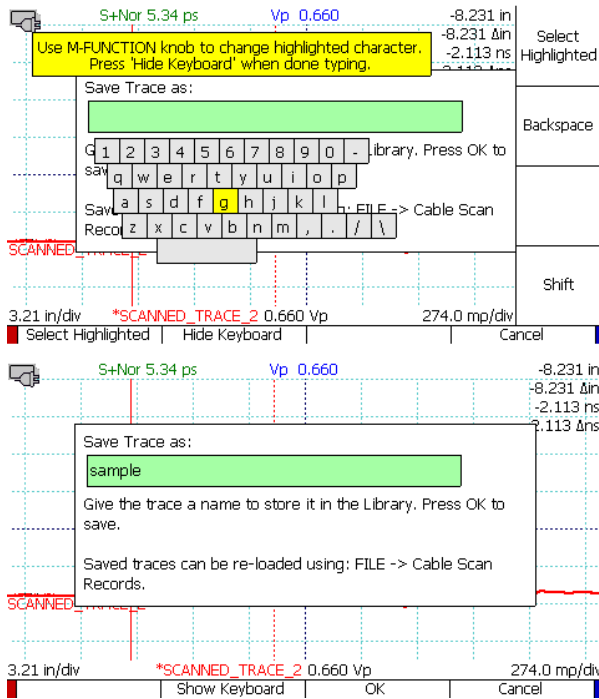
Stored traces with annotations applied can be loaded back on-screen like any other saved trace. See Section 4.9.4 for information on loading traces.

To toggle off annotations on-screen, go to *SCAN* → *Annotations* and press *Annotations On* so that it now says *Annotations Off*.

### 4.9.3. Store a Trace

A scanned trace can be stored for later recall:

1. Press the *SCAN* button. The *Scan* menu appears.
2. Press the *SELECT* button until the scanned trace to be stored is selected.
3. Select the *Save* option from the menu.
4. The CT100B requires a name for storage and will prompt for one with a dialog box.
5. A dialog menu appears. Press the *Show Keyboard* menu option to display the on-screen keyboard, or use a USB keyboard.
6. When using the on-screen keyboard use the *M-FUNCTION* knob to highlight characters. See Figure 4.30. Review Section 3.10.1 for more information on using the *Keyboard* menu. Press the *Select Highlighted* option to enter the highlighted letter into the name.



**Figure 4.30.** Using the on-screen keyboard. Choose Hide Keyboard when finished. Then choose OK to save the trace with the name you entered.

7. Select the *Hide Keyboard* option on the menu when finished. Then choose *OK* to save the trace with the name you entered.

The trace is now stored, and can be recalled later by name under *FILE* → *Cable Scan Records*. Other trace types, such as difference traces, derivative traces, and frequency-domain traces (such as FFTs) can also be stored with the same process.

#### 4.9.3.1. Save Trace Default Name

Users of the CT100B can specify a default name to use for saved traces. When *SCAN* → *Save* is selected, the dialog box is prefilled with that name. The user can edit the name before saving.

To set a default saved trace name:

1. Press the blue *MENU* button. The *Main* menu appears.
2. Choose *Settings* → *Save Trace Default Name*.
3. A dialog box appears. See Figure 4.31. Press the *Show Keyboard* menu option to display the on-screen keyboard, or use a USB keyboard.
4. Enter the default name to use for saved traces.

- There are also options in this dialog box to automatically append either a revision number (e.g., save\_001, save\_002) or a timestamp to the default name.
- Select *OK* to save the default name.

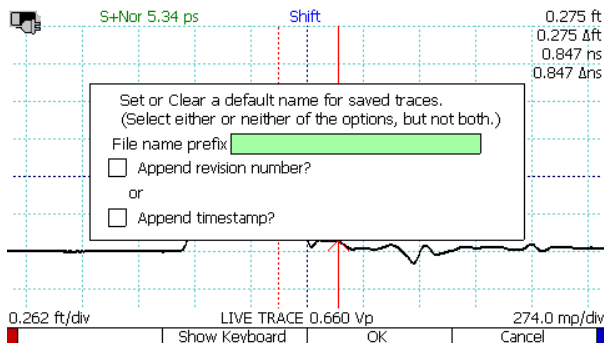


Figure 4.31. The save trace default dialog box.

#### 4.9.4. Load a Trace (Cable Records)

A stored trace can be loaded back to the screen:

- Press the *FILE* button. The *File* menu appears.
- Select the *Cable Scan Records* option. A scrolling dialog box (see Section 3.10.1.1) appears for the selection of a stored trace.
- Use the *M-FUNCTION* knob to highlight the trace you wish to load.
- Press the *Select* menu option to load the trace.

The stored trace now appears on the screen. It can be selected and manipulated the same as any scanned trace. See Figure 4.32 in which the loaded trace (red, top) has been translated slightly upward using the *VERTICAL POSITION* knob in order to improve visualization.

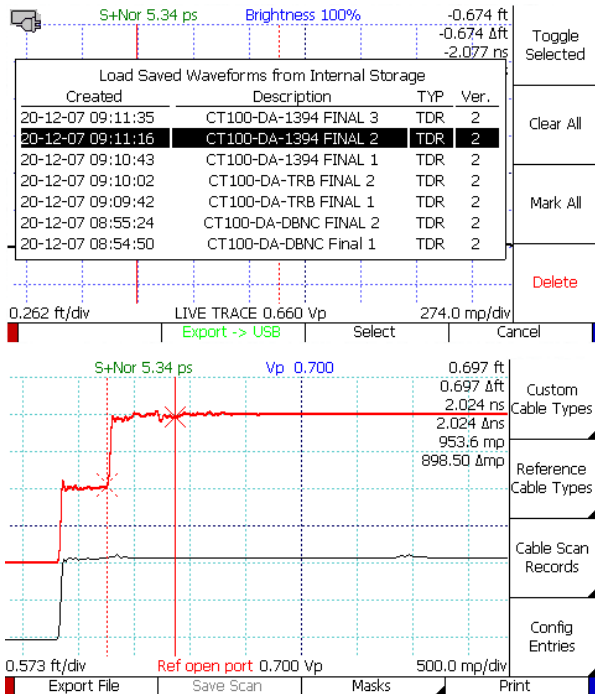


Figure 4.32. Loading a trace.

Some stored traces, such as FFT traces, require some re-calculation to fully load. This calculation is done automatically, but it may take several seconds.

#### 4.9.5. Transfer and Delete Traces

The CT100B has a large storage space, capable of holding thousands of scans. However, with continued use, CT100B storage will eventually fill up. Periodically, an effort should be made to clear stored traces from the device and free up storage space.

##### 4.9.5.1. Transfer Traces

The CT100B ships with an installation DVD for the CT Viewer™ (Version 2) software for Windows. Using either a USB or an Ethernet connection, the CT100B can transfer stored scans to CT Viewer 2. These scans are then stored in the Windows computer for later retrieval, review, email, and analysis. See Section 6: *CT Viewer™* and/or the *CT Viewer™ 2 Quick User Guide* for details on transferring traces to a computer using CT Viewer 2.

**4.9.5.1.1. Export Trace to File** Traces can also be exported to a USB drive for storage, or to transfer to CT Viewer 2 or to another CT100B. To export one or more traces to USB:

1. Insert a USB drive into the front panel port of the CT100B.
2. Press the *FILE* button and then press the *Cable Scan Records* menu option.
3. Mark specific traces for transfer using the *Toggle Selected* option or select them all with the *Mark All* option.
4. Press the *Export* → *USB* menu option. A message should appear after a short time confirming that the traces were transferred.

**4.9.5.1.2. Export Trace to CSV or Version 1** The active trace can be exported as a .csv file or a Version 1 file (a file compatible with older CT100 models and older CT100B software) to an attached thumb drive. To do this:

1. Insert a USB drive into the front panel port of the CT100B.
2. Select the desired trace to export using the *SELECT* button.
3. Press the *FILE* button to open the *File* menu.
4. Press the *Export File* menu option. When prompted, choose *CSV* or *Version 1*, depending on the desired file format. A dialog box will appear displaying the name of the file to be used.
5. Change the file name to the desired name by pressing the *Show Keyboard* menu option to display the on-screen keyboard or by using a USB keyboard.
6. Press the *OK* menu option. A message should appear after a short time that confirms the trace was exported.

### 4.9.5.2. Delete Traces

Once scans are backed up to a computer, they can be deleted from the CT100B either through the CT Viewer 2 software or directly as follows:

1. Press the *FILE* button to open the *File* menu.
2. Select *Cable Scan Records*. A scroll dialog appears, showing all saved trace scans.
3. Mark specific traces for deletion using the *Toggle Selected* option or select them all with the *Mark All* option.
4. Select the *Delete* option. You will have to confirm the deletion.

## 4.10. User Configurations

The CT100B allows the user to save individually named instrument configurations. A saved configuration stores the values of all instrument settings that can influence trace measurements. A configuration can be called up by its name, restoring all settings to the values saved in that configuration.

User Configurations can reduce operator error when configuring the TDR to make important measurements. For this reason it is recommended that User Configurations be used when setting up the CT100B for important measurements, such as quality-control checks on a cable manufacturing line.



If a configuration named *DEFAULT* is saved, that configuration can be easily loaded from the startup screens.

### 4.10.1. Save Configurations

1. Press the *FILE* button. The *File* menu appears.
2. Select the *Config Entries* menu item. The *User Configurations* library is displayed.
3. Select *Add New* to add a new User Configuration. The CT100B will prompt you for a configuration name and will save the current instrument configuration when you press *OK*. See Section 3.10.1 for information on using the *Keyboard* menu.

**Note:** If planning on using a barcode reader to load configurations, avoid using any punctuation or special characters such as ! @ # \$ % ^ & \* () in configuration names. Keep configuration names to one or two words.

### 4.10.2. Load Configurations

1. Press the *FILE* button. The *File* menu appears.
2. Select the *Config Entries* menu item. The *User Configurations* library is displayed.
3. Scroll through saved configurations with the *M-FUNCTION* knob.
4. Press *Select* to load the highlighted configuration. All settings saved in that configuration are automatically restored. Measurements and traces are updated to reflect the new Vp, cursor position, and other applicable settings.

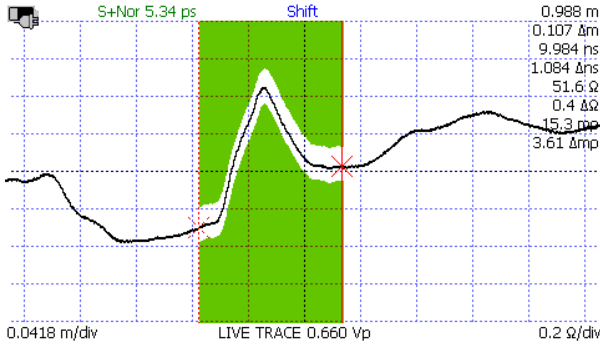
Configurations can also be loaded or reset by pressing the *AUTOFIT/HELP* button, choosing *Reset Options*, and selecting one of the choices listed. See Section 3.9.4 for more information on the *Reset Options* menu.

#### 4.10.2.1. Load Configurations With a Barcode Reader

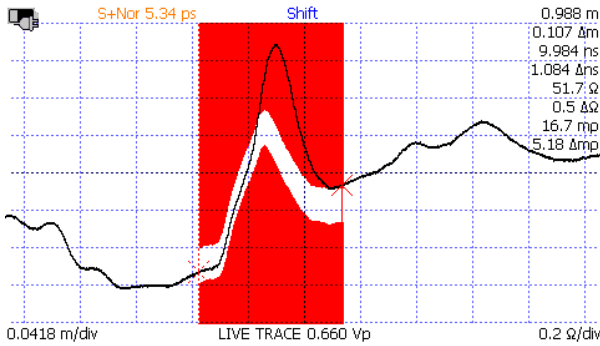
Configurations can be loaded using a barcode reader. Create a barcode that begins with a back quote character ( ` ) then the name of the configuration followed by the tilde character ( ~ ). For example, `standard~ would be the barcode for a configuration named *standard* on the CT100B.

## 4.11. Mask Testing

The CT100B is capable of performing mask testing on the currently displayed live TDR trace. The mask creates an area around a scanned trace that functions as a test limit for the live TDR trace. Any point of the trace that extends into the masked area will cause the background to turn red. This can be used for creating acceptance criteria for cables and connectors. See Figure 4.33 and Figure 4.34 for examples of traces passing and failing a mask test.



**Figure 4.33.** A trace that passes the mask test.



**Figure 4.34.** A trace that fails the mask test.

To create a mask, use the following procedure:

1. Create a cable scan or load a scan from internal storage that will be used to generate a mask.
2. Select *FILE* → *Masks* menu.
3. With the desired cable scan selected, choose *Create Mask From Trace*.
4. The CT100B will generate a mask using the selected cable scan and display it on the screen. If the live TDR trace fits within the mask, it will appear with a green background.
5. Use *Change Vertical Margin* and *Change Horizontal Margin* to adjust the mask boundaries around the trace.

#### 4.11.1. Storing a Mask

The CT100B is capable of storing thousands of masks. To do this:

1. With a mask already displayed select *FILE* → *Masks* menu.

2. Select *Load/Save Mask*. This will open a dialog for saving, exporting, loading, and deleting masks.
3. Select *Add New*.
4. The CT100B requires a name for storage and will prompt for one with a dialog box.
5. A dialog menu appears. Press the *Show Keyboard* menu option to display the on-screen keyboard, or use a USB keyboard.
6. When using the on-screen keyboard, use the *M-FUNCTION* knob to highlight characters. See Figure 4.30 for more information on using the *Keyboard* menu. Press the *Select Highlighted* option to enter the highlighted letter into the name. Press *Hide Keyboard* to accept the name.
7. Press the *OK* menu option when finished.

The mask is now stored and can be recalled later by name under *FILE* → *Masks* → *Load/Save Mask* or, if using the *Special Main* menu, *MENU* → *Pass-Fail Masks*.

### 4.11.2. Loading a Mask

To load a saved mask from storage, use the following process:

1. Press the *FILE* button. The *File* menu appears.
2. Press the *Masks* option to enter into the *Masks* menu.
3. Press the *Load/Save Mask* option to enter into the mask storage dialog.
4. Use the *M-FUNCTION* knob to highlight the mask you wish to load.
5. Press the *Select* menu option to load the mask.

The stored mask will now appear on-screen after a brief loading time.

If using the *Special Main* menu, the mask can also be loaded by pressing *MENU* → *Pass-Fail Masks* then using the *M-FUNCTION* knob and the *Select* menu option to choose a mask.

### 4.11.3. Saving and Loading a Mask as Part of a Configuration

If a mask is active it is stored in a configuration file and will be restored when that configuration file is loaded. This can be especially convenient when using a barcode reader. **Note:** The mask must have already been saved and must be loaded on-screen when saving it as a configuration. See Section 4.10 for information on saving and loading configurations.

### 4.11.4. Exporting/Importing a Mask

Masks can be exported to and imported from a USB drive in order to replicate mask testing on multiple CT100Bs. To export a mask:

1. Insert a USB drive into the front panel port of the CT100B.
2. Press the *FILE* button. The *File* menu appears.
3. Press the *Masks* option to enter into the *Masks* menu.
4. Select the *Load/Save Mask* option. A scroll dialog appears, showing all saved masks.
5. Use the *M-FUNCTION* knob to highlight the mask you wish to export.

6. Press the *Export* → *USB* option.
7. The mask will be copied to the USB drive.

To import a mask to the CT100B, do the following:

1. Insert the USB drive with the mask into the front panel port of the CT100B.
2. Press the *FILE* button. The *File* menu appears.
3. Press the *Masks* option to enter into the *Masks* menu.
4. Select the *Load/Save Mask* option. A scroll dialog appears, showing all saved masks.
5. Use the *M-FUNCTION* knob to highlight BROWSE USB.
6. Press the *Select* option. This will navigate to the attached USB drive.
7. Use the *M-FUNCTION* knob to highlight the mask to be imported.
8. Press the *Import* → *Internal* option.
9. The mask will be copied to internal storage of the CT100B.

#### 4.11.5. Deleting a Mask

Once masks are backed up to a computer, they can be deleted from the CT100B as follows:

1. Press the *FILE* button to open the *File* menu.
2. Press the *Masks* option to enter into the *Masks* menu.
3. Select the *Load/Save Mask* option. A scroll dialog appears, showing all saved masks.
4. Mark specific masks for deletion using the *Toggle Selected* option or select them all with the *Mark All* option.
5. Select the *Delete* option. You will have to confirm the deletion.

### 4.12. Envelope Plot (Transient/Intermittent Fault Detection)

Cable system troubleshooting frequently involves detecting and localizing transient or intermittent faults, such as a twisted-pair cable with frayed insulation that briefly shorts its conductors when mechanically disturbed, or a coaxial connector that reflects an open when shaken. The CT100B's *Envelope Plot* mode simplifies characterization of these types of intermittent faults. There are two ways to create an Envelope Plot.

Using the *Special Main* menu:

1. Position the TDR trace such that the area of interest is located on the screen at a satisfactory horizontal and vertical scale. Resolution from previous measurement will be preserved.
2. Select *MENU* → *Intermittent*. *Intermittent* will toggle the Envelope Plot on and off. **Note:** This menu option does not access the other Envelope Plot features described below.

Using the *Envelope Plot* menu:

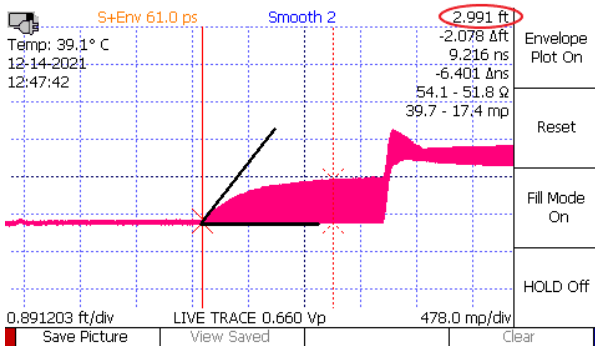
1. Position the TDR trace such that the area of interest is located on the screen at a satisfactory horizontal and vertical scale. Resolution from previous measurement will be preserved.

2. Select *MENU* → *Measurement* menu.
3. Select *Envelope Plot* submenu.
4. Toggle *Envelope Plot* to *On*.
5. Use the *Fill Mode On/Off* option to toggle between *Fill Mode* and *Frequency Density* display mode.

The CT100B can monitor a trace for extended periods of time with appropriate power management settings.

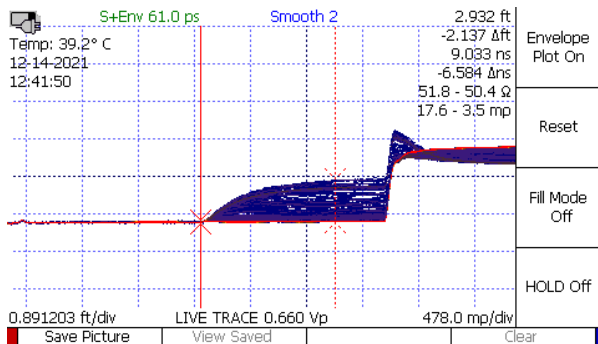
Sometimes manipulation of the cable and/or connectors of interest during Envelope Plot monitoring will provoke an intermittent TDR fault.

*Fill Mode* fills in an area plot between the maximum and minimum impedance values. This is useful to highlight the location of the fault because the fault typically creates an “arrow” that points to the location of the fault as shown in Figure 4.35.

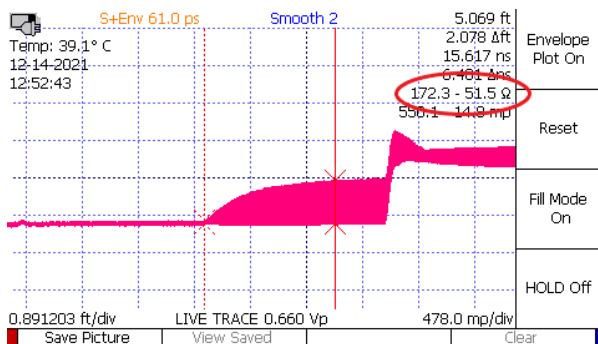


**Figure 4.35.** Envelope Plot with Fill Mode, with the active cursor positioned at the fault location (red circle). Note that the black lines shown here to emphasize the “virtual arrow” do not actually appear on the instrument screen.

*Frequency Density* mode shows the underlying TDR traces, which can be useful to determine the fault mechanism and likelihood of occurrence as shown in Figure 4.36. Both modes provide the range of impedance values at cursor, as shown in Figure 4.37.



**Figure 4.36.** Envelope Plot with Frequency Density display.



**Figure 4.37.** Envelope Plot with Fill Mode, showing the range of impedance values at the cursor position (51.5–172.3 ohms, red circle).

Envelope Plots can be saved as screenshots:

1. With an Envelope Plot on-screen, select *Save Picture*.
2. A dialog box appears. Press the *Show Keyboard* menu option to display the on-screen keyboard, or use a USB keyboard.
3. Enter a name for the screenshot and select *OK* to save the screenshot.

To view saved Envelope Plot screenshots:

1. Make sure *Envelope Plot* is toggled to *Off*.
2. Select *View Saved*. A scrolling dialog box appears.
3. Use the *M-FUNCTION* knob to highlight the screenshot you wish to load.
4. Press the *Select* button to load the screenshot.
5. After the screenshot has loaded, pressing the *OK* or *Cancel* button will remove the screenshot from the screen.

Screenshots can also be exported to a USB drive for storage or to transfer to CT Viewer 2 or another CT100B. To export one or more screenshots:

1. Insert a USB drive into the front panel port of the CT100B.
2. Go to *MENU* → *Measurement* → *Envelope Plot*.
3. Make sure *Envelope Plot* is toggled to *Off*.
4. Select *View Saved*.
5. Use the *M-FUNCTION* knob to scroll through the list of screenshots. Mark specific screenshots for transfer using the *Toggle Selected* option or select them all with the *Mark All* option.
6. Press the *Export* → *USB* menu option. Press *OK* to confirm the export. A message should appear after a short time confirming that screenshots were transferred.

The screenshots will be saved on the USB as an .env file, which can be opened by CT Viewer 2 or viewed with any program that can display .bmp files.

## 4.13. Improving Measurements

### 4.13.1. Vertical Reference (Vert. Ref.) Calibration

Use the vertical reference (Vert. Ref.) system to increase the accuracy of vertical measurements, including impedance, reflection coefficient, and return loss. The *Vert. Ref.* feature can be used with a direct connection, through impedance matching adapters, and using baluns. To calibrate with the *Vert. Ref.* feature, use the following procedure:

1. Go to the *MENU* → *Measurement* menu.
2. Select the option for *Vert. Ref.* to display the *Vert. Ref.* menu.
3. Position the active cursor at the leftmost position where the *Vert. Ref.* should apply. Typically, this will be the position where you will apply the open and short attachments in step five. This position can be changed after the setup.
4. Select the *Set Vert. Ref* option.
5. A set of terminators, both open and short, are included with the CT100B for calibration purposes. Attach these terminators to the CT100B when prompted to do so (pn: CT100-AC-ISS, CT100-AC-ISMM, CT100-AC-IBS, CT100-AC-IBMM).

When the reference measurement is finished, cursor measurements will now appear in blue at the right side of the screen, and the notification *using vert. ref.* will appear underneath.

A green line will appear at the position of the active cursor (see step 3 above). Vertical reference is applied to all points to the right of the green line. Standard vertical measurements are used for all points to the left of the green line. The position of this line can be changed with the *Vert. Ref Start* menu option.

By default, the impedance value at 0 m $\rho$  (millirho) is taken to be 50  $\Omega$ . This value can be changed with the *Vert. Ref. Center Imp.* menu option. If you are using an impedance matcher or balun adapter, the center impedance should be changed to the value of the impedance of the adapter. For instance, if you are using a 100 ohm differential pulse splitter balun to measure differential impedance of twisted-pair cable, then the center impedance should be changed to 100  $\Omega$ .

The CT100B is now configured for enhanced accuracy impedance measurements across a wide range of impedances.

The *Vert. Ref. On/Off* menu option can be used to toggle the vertical reference on and off as needed for a given cable length setting.

### 4.13.2. Cable Resistive Loss Correction

The CT100B has a system for correcting for resistive loss (“dribble up”) in cables. This allows the operator to measure impedance more accurately through long and/or lossy cables.

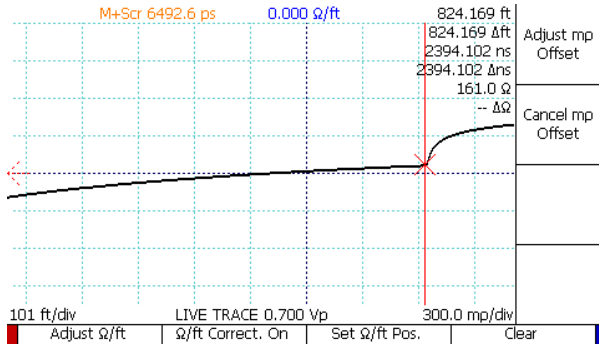
Under the *Measurement* menu, there is an item to set ohms per unit length and another item to toggle the correction on and off. The calculations of this feature assume a linear serial resistance to an attached cable and no other loss. The procedure for performing resistive cable loss correction is as follows:

1. Select the *MENU* → *Measurement* menu.
2. Select the *Vertical Correction* submenu.
3. Adjust the trace of interest so that it fits on the screen, and position the active cursor to the right of the trace you wish to correct.
4. Select *Adjust  $\Omega/\text{ft}$* . (**Note:** This menu option will show the horizontal units set in *MENU* → *Settings* → *Meas. Settings* → *Horiz. Units* [see Section 3.13.1]; i.e., if set to meters, the menu option will read *Adjust  $\Omega/\text{m}$*  instead. This is true for all steps in this section.)
5. Toggle  *$\Omega/\text{ft}$  Correct.* to *On* to turn on the correction, then press *Set  $\Omega/\text{ft}$  Pos.* to set the correction endpoint. The endpoint will appear as a dotted orange vertical line.
6. Rotate the *M-FUNCTION* knob to change the ohms per unit distance correction setting. Use the  *$\Omega/\text{ft}$  Correct. On* toggle menu option to turn the correction on or off.

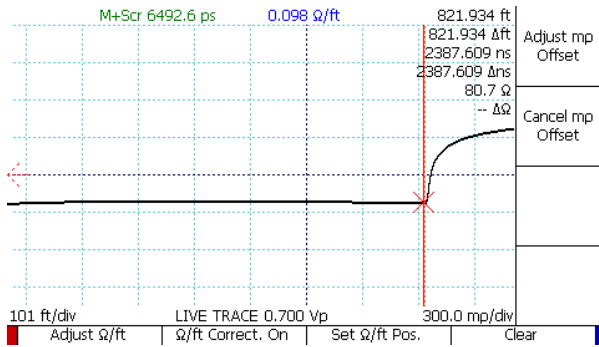
Changing the ohms per unit length setting will modify the slope of the cable’s trace as the resistive loss is subtracted, and consequently the impedance readings for all points on the cable’s trace and beyond. The effect and accuracy of the ohms per unit length value is dependent on the value for pulse velocity. The effect of resistive cable loss correction on a relatively lossy 72 ohm RG-59 cable is shown in Figure 4.38 and Figure 4.39.

Use this correction to make more accurate impedance measurements on a length of cable. Since uniform cables tend to have a characteristic resistive loss per unit length or “dribble up”, one technique is to adjust the correction until the cable is as flat as possible. Another technique is to attach a known impedance reference, such as a resistive terminator, to the cable and adjust the ohms per unit length correction until the measured impedance reads the correct value.





**Figure 4.38.** Resistive cable loss correction, before. Note that the trace slowly rises.



**Figure 4.39.** Resistive cable loss correction, after. Note that the trace is nearly horizontal.

#### 4.14. Take a Screenshot

To save a screenshot, first insert a USB drive into the CT100B. Then hold down the *SELECT* button and press the *M-FUNC* button to trigger the screenshot.

A dialog will appear asking for a name for the screenshot. When *OK* is pressed on the dialog, the screenshot will be saved to the root directory of the USB drive.

Alternatively, pressing the *Print Screen* button on an attached USB keyboard will also trigger a screenshot.

## 4.15. Web Server

The CT100B is able to export raw data and images in real time over Ethernet. To enable this feature, follow this procedure:

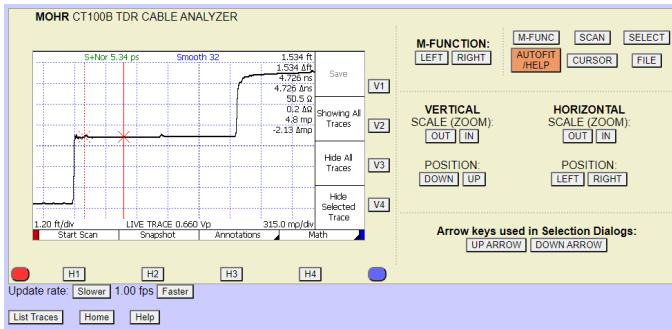
1. Select *MENU* → *Settings* → *Network Settings*.
2. Toggle *Web Server* to *On*.
3. Press *Show IP Config*, and note the IPV4 address.
4. Using a web browser, navigate to <http://xxx.xxx.xxx.xxx/>, where the xxx.xxx.xxx.xxx is the IPV4 address you noted in step 3.

This web page (Figure 4.40) gives you the following options to choose from:



**Figure 4.40.** The web server web page.

1. [screenshot.bmp](#). This displays a current snapshot of the screen, ready to download.
2. [Live Stream](#). This displays a live view of the screen, updated multiple times a second.
3. [Live Control](#). This displays the live, updating view of the screen and also allows remote control of the front panel controls. See Figure 4.41. There is a virtual button on the screen for each physical button on the front panel of a CT100B, and two virtual buttons for each knob to simulate turning the knob clockwise and counterclockwise. The computer mouse can be used to click on these buttons or on virtual “hot spots” like menu options or the multifunction indicator at the top of the screen. There are two extra buttons, an up arrow and a down arrow, that can make scrolling through lists easier on the live control.



**Figure 4.41.** The live control display on the CT100B web page. Each button and knob on the front panel of the CT100B maps to buttons on this page, which can be used to control the CT100B remotely.

4. Download/Upload Traces. This displays a list of the traces stored on the CT100B and allows transfer of traces to and from the PC.
5. trace.csv. This downloads a .csv text file with m vs. millirho and ns vs. millirho columns.
6. selected.csv. This downloads a .csv text file with user-selected columns (these can be chosen at *MENU* → *Settings* → *Network Settings* → *selected.csv Options*).
7. PDF and HTML versions of the CT100B Operator's Manual.

## 4.16. Remote Control

Using the accompanying CT Viewer™ 2 software, the CT100B can be operated by remote control. The remote control system allows the operator to manipulate traces and store movies of traces over time. Remote control only functions over Ethernet connections. It does not work when the CT100B is connected by USB only.

Refer to Section 6.1.3 Send Saved Traces Using Ethernet and Section 6.2 Using Remote Control for instructions on connecting CT Viewer 2 to the CT100B and enabling remote control. Please consult the *CT Viewer 2 Quick User Guide* for more information about using remote control and manipulating a remote TDR trace.



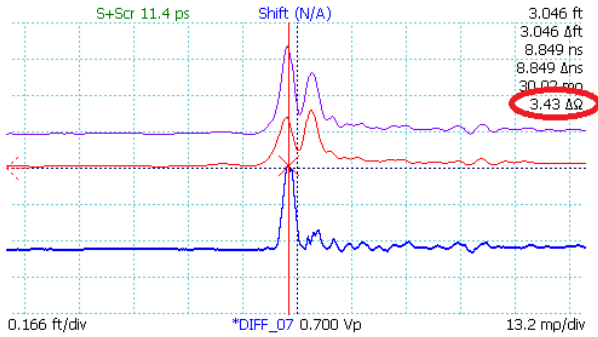
## 5. Math Functions

The CT100B includes various math functions that can help highlight cable issues, measure impedance change, or otherwise help with cable analysis. The following sections explain how to perform those functions.

### 5.1. Difference (Subtraction) Traces

Difference traces are traces calculated from the subtraction of one trace from another trace. A difference trace can allow the operator to identify subtle changes in cable or connector performance. It is recommended that for any important cable and connector assembly, the as-manufactured or known-good configuration of the assembly be scanned and archived on the CT100B and/or a host PC running CT Viewer 2. Later, these archived traces can be used to create difference traces from current data to highlight changes in cable assembly impedance. To create a difference trace, use the following procedure:

1. Press the *SCAN* button. The *Scan* menu appears.
2. Press the *SELECT* button until the first trace of interest is selected.
3. Select the *Math* option from the *Scan* menu and choose *Set Base*. The selected trace will turn purple and is now a base trace for further *Math* functions.
4. Press the *SELECT* button again until the second trace is selected.
5. Select *Difference* from the *Math* menu. A new blue trace is created that displays the difference between the base trace and the selected trace. See Figure 5.1, which shows 3.43 ohm excess impedance due to a slightly loosened BNC barrel adapter. The bottom bold trace is created by subtracting the top (live) trace from the middle (scanned) trace and adjusting the vertical scale to emphasize trace detail.

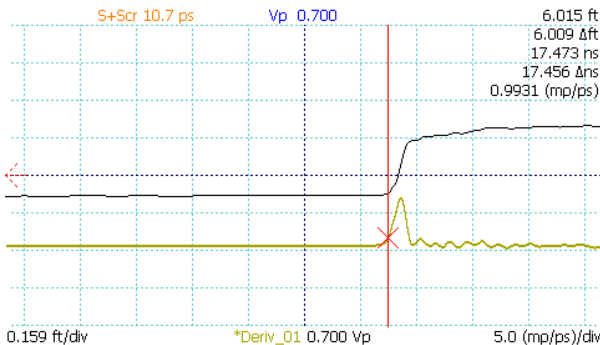


**Figure 5.1.** Difference trace. Live (base trace, purple, top), comparison scan (red, middle), difference (blue, bottom) traces show 3.43 ohm excess impedance (red circle) on the live trace due to a loosened BNC connector.

## 5.2. First Derivative (Slope) Traces

The first derivative trace can be used for two main purposes. First, the first derivative trace can be used to emulate the trace of a pulse-type TDR. Second, it may be used to remove the baseline deviation of long or lossy cables caused by resistive loss, so that vertical gain can be used to emphasize cable faults. To create a first derivative trace, use the following procedure:

1. Press the *SCAN* button. The *Scan* menu appears.
2. Press the *SELECT* button until the trace of interest is selected.
3. Select the *Math* option from the *Scan* menu. The *Math* menu will appear.
4. Select *1st Derivative* from the menu.
5. A new trace is created that displays the first derivative of the base trace. See Figure 5.2.



**Figure 5.2.** First derivative trace (yellow, bottom).

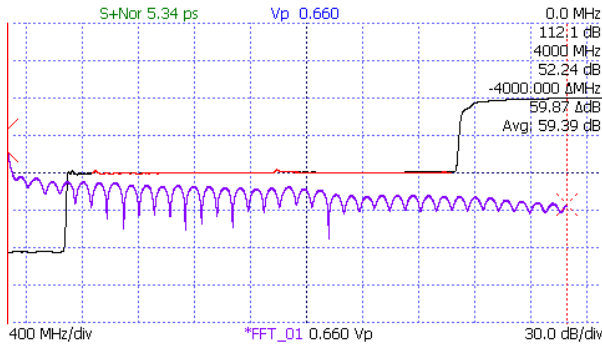
### 5.2.1. Second and Higher Order Derivative Traces

The *1st Derivative* function can be applied to First Derivative traces to create second (and higher) order derivatives.

## 5.3. Fast Fourier Transform (FFT) Traces

The CT100B can calculate FFT frequency-domain information from live and scanned TDR traces. FFT traces can be used to show the frequency-domain content of a trace or portion of a trace between cursors, and comparisons of FFT traces can be used to demonstrate differences and/or changes in frequency content, such as between different types of connectors or cable faults. To create an FFT trace, use the following procedure:

1. Select the live trace with the *SELECT* button.
2. Use the *CURSOR* button and the *HORIZONTAL POSITION* knob to set the boundaries for the FFT with a cursor at either end.
3. Press the *SCAN* button, and then select *Math* → *FFT Tools*.
4. Select *Apply FFT*. The CT100B will now take a high-resolution scan of the live trace between the cursors, and then convert the scan into an FFT plot. See Figure 5.3.



**Figure 5.3.** FFT trace (blue). The FFT plot was created from the section of the black live trace that is currently red.

FFT traces can be stored, reloaded, and transferred to CT Viewer 2 just like normal scanned traces.

## 5.4. Return Loss ( $S_{11}$ ) Traces

This feature uses precision open, short, and 50 ohm load (OSL) calibration standard measurements to correct for systematic errors in the pulsing and sampling electronics, producing a more accurate  $S_{11}$  result on the Device Under Test (DUT). The procedure for creating an  $S_{11}$  return loss plot is as follows:

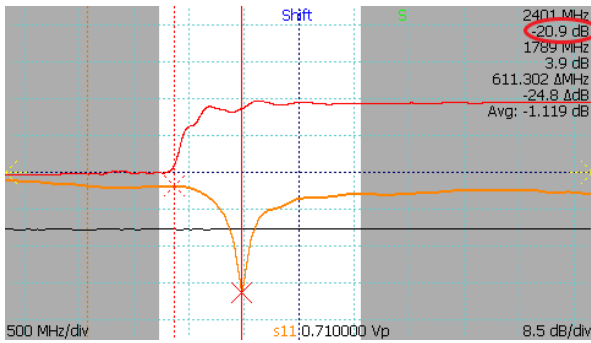
1. Prepare the CT100B by setting the trace resolution as desired by going to *Resolution*  $\rightarrow$  *Fixed* and using the *M-FUNCTION* knob. In general, a resolution of 1-2 ps is adequate to take advantage of the full bandwidth and frequency resolution of the instrument. Larger sample intervals can result in lower bandwidth resolution. Smaller sample intervals have higher frequency resolution but increase sampling time.
2. Use the *M-FUNCTION* knob to set the smoothing factor to an acceptable level, usually in the range of 64 to 256 depending on the application. Use higher smoothing factors for higher bandwidth, lower noise measurements. Higher levels of smoothing improve the signal-to-noise ratio (SNR).
3. **With the DUT detached**, place the **leftmost** cursor just to the **left** of the **test plane** (the location where the calibration standards will be applied). This is usually just to the left of the open at the test port or alternatively at the end of the phase stable cable.
4. **Attach the DUT** to determine the **region of interest** and place the **rightmost** cursor just to the right of the region of interest. This is usually where steady state TDR trace amplitude has been restored. Detach the DUT to continue calibration.
5. Select the *SCAN*  $\rightarrow$  *Math* menu option to open the *Math* menu.
6. Select *SParam & Normalize Tools*. This will open the *SParam & Normalize Tools* menu.
7. Select *S<sub>11</sub> Calibration*. After going through an informational message box, the *S<sub>11</sub> Calibration* menu will appear and the CT100B will ask for the open terminator. Attach the open terminator and press *Scan Open*, or alternatively press *Use Selected* to use the currently selected trace as the open calibration standard. For the best results when using type SMA terminators, use a calibrated 3.5 in.-lb. (0.4 Nm) torque wrench (pn: CT100-TL-TORX7) to tighten the test standards as well as the DUT.
8. Follow the same process as instructed to scan or use the selected trace for the short and 50 ohm load calibration standards.
9. The instrument will now ask for the Measured "Device Under Test" (DUT). Press *Use Live* to create a live *S<sub>11</sub>* trace, *Use Selected* to create a static *S<sub>11</sub>* trace from the currently selected trace, or *Scan Measured* to scan the current live TDR trace.
10. Select the *S<sub>11</sub>* return loss trace. Use the cursors to measure return loss at cursor and average return loss between cursors.

Figure 5.4 shows an *S<sub>11</sub>* return loss plot and TDR trace for a 2.4 GHz WiFi antenna. The return loss at 2.4 GHz (2400 MHz) is 20.9 dB.

## 5.5. Return Loss (*S<sub>11</sub>*) Options

There are several mathematical transforms to apply to the *S<sub>11</sub>* trace and its input traces that can, in some cases, help reduce irregularities in the final Return Loss plot. These options can be found under *SCAN*  $\rightarrow$  *Math*  $\rightarrow$  *SParam & Normalize Tools*  $\rightarrow$  *S<sub>11</sub> Options*. If the options are changed when no *S<sub>11</sub>* traces exist, then they will be applied to the next *S<sub>11</sub>* trace created. Otherwise, they are applied to the last *S<sub>11</sub>* trace that was selected using the *SELECT* button. The options can be combined as necessary, and will change the last selected *S<sub>11</sub>* trace in real time.





**Figure 5.4.**  $S_{11}$  return loss plot (orange) and TDR trace (red) of a 2.4 GHz WiFi antenna. The return loss is calculated on the portion of the TDR trace between the cursors.

### 5.5.1. Return Loss ( $S_{11}$ ) Pre-Filter

The Pre-Filter can reduce aberrations in the  $S_{11}$  trace. This can be combined with a Common Mode Subtraction (CMS) transform on the input traces. To enable or disable these settings, do the following:

1. Create an  $S_{11}$  return loss plot using the procedure as described in Section 5.4.
2. Select the  $S_{11}$  Options menu, then *Pre-Filter Options*.
3. Toggle *Use this filter* to apply filter to the  $S_{11}$  trace.
4. Toggle *Common Mode Subtraction (CMS)* to apply this option to the  $S_{11}$  trace.
5. *Filter/CMS Offset Ratio* is the start of the Aberration Filter and/or Common Mode Subtraction relative to the  $S_{11}$  trace test plane. The default value is 1.66, and is ideal in most cases.
6. *Frequency (MHz)* is the aberration filter frequency. The default value is 200, and is ideal in most cases.
7. Press *OK* to change the settings to those set above. The  $S_{11}$  trace will update using the new settings.

### 5.5.2. Return Loss ( $S_{11}$ ) Post-Filter

The Post-Filter can reduce excess noise in the  $S_{11}$  trace. To enable or disable the setting, do the following:

1. Create an  $S_{11}$  return loss plot using the procedure as described in Section 5.4.
2. Select the  $S_{11}$  Options menu, then *Post-Filter Options*.
3. Toggle *Use this filter* to apply filter to the  $S_{11}$  trace.
4. *Frequency (MHz)* is the noise filter frequency. The default value is 20,000 (20 GHz), and is ideal in most cases.
5. Toggle *Apply Hanning* to apply a Hanning Window to the filter.

6. Press *OK* to change the settings to those set above. The  $S_{11}$  trace will update, although it might not look visually different, depending on the settings.

### 5.5.3. Return Loss ( $S_{11}$ ) Phase Correction

Phase Correction reduces phase error oscillation in the  $S_{11}$  trace. To enable or disable the setting, do the following:

1. Create an  $S_{11}$  return loss plot using the procedure as described in Section 5.4.
2. Select the  $S_{11}$  *Options* menu, then toggle *Phase Corr.* to *On*. The  $S_{11}$  trace will update, although it might not look visually different, depending on the settings.

Phase Correction typically works best when started at the  $S_{11}$  trace test plane. To choose a different starting point:

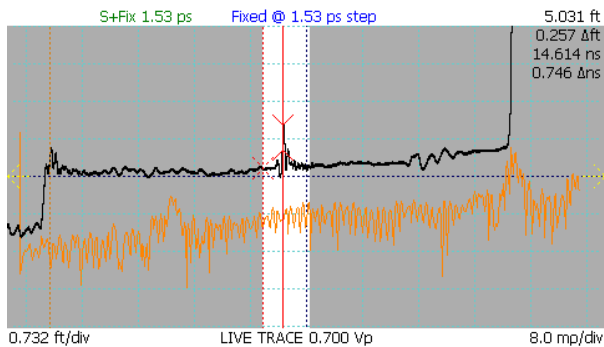
3. Use the *SELECT* button to select a TDR trace, position the active cursor where desired, then press *Phase Corr. Start*. The Phase Correction starting point will go to the active cursor position, and the  $S_{11}$  trace will update, although it might not look visually different, depending on the settings.

### 5.5.4. Time-Domain Gating, or Return Loss ( $S_{11}$ ) Between Cursors

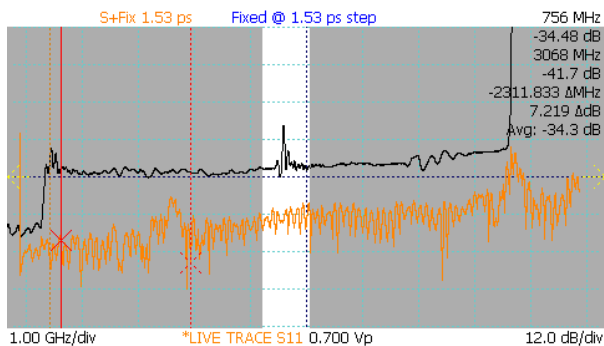
The CT100B is able to use time-domain gating (also called time windowing) to isolate features in the time-domain trace for analysis in the frequency domain using the  $S_{11}$  *Between Cursors* feature. All other time-domain features are excluded from the analysis so that only the feature of interest is analyzed. To perform *Between Cursors* return loss, use the following procedure:

1. Create an  $S_{11}$  return loss plot using the procedure as described in Section 5.4.
2. Use the *SELECT* button to select a TDR trace.
3. Position the cursors around the feature of interest (e.g., a fault or connector).
4. Select the  $S_{11}$  *Options* menu, then toggle *Between Cursors* to *On*. The  $S_{11}$  trace may change to reflect just the features in the highlighted time-domain cursor interval.
5. Pressing the *Between Cursors On* menu option again will change it to *Between Cursors Hold*, which will keep the time-domain region fixed while moving the time-domain cursors. Otherwise, you may select the  $S_{11}$  trace to make frequency-domain measurements using the cursors without changing the time-domain windowing.

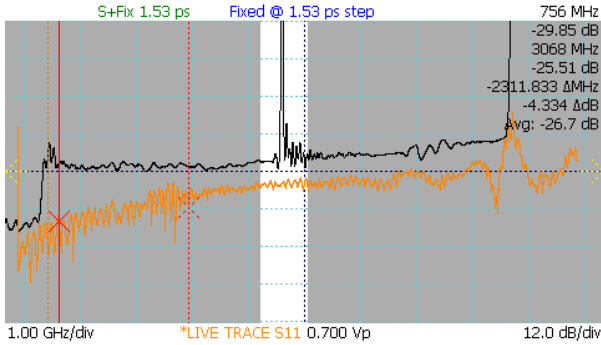
See Figure 5.5 through Figure 5.7 for an example of an  $S_{11}$  return loss plot between cursors. The cursors bracket an SMA barrel adapter between two 3 ft. segments of coaxial cable. The  $S_{11}$  return loss plot shows average 34.3 dB loss across the connector. A loosened connector shows average loss of 26.7 dB across the connector, compatible with 7.7 dB excess return loss compared with the tightened connector.



**Figure 5.5.**  $S_{11}$  between cursors bracketing an SMA barrel adapter on the TDR trace.



**Figure 5.6.**  $S_{11}$  between cursors with tightened connector showing average return loss of -34.3 dB from 756 MHz to 3 GHz.



**Figure 5.7.**  $S_{11}$  between cursors with loosened connector showing average return loss of -26.7 dB from 756 MHz to 3 GHz (7.7 dB excess return loss compared with the tightened connector in Figure 5.6).

### 5.5.5. Return Loss ( $S_{11}$ ) Calibration Standards

Many precision Open, Short, and Load standards have unique offset and coefficient values included with them. By correcting the  $S_{11}$  trace with these values, the error introduced by these terminators can be reduced. To apply or change these standards, do the following:

1. Create an  $S_{11}$  return loss plot using the procedure as described in Section 5.4.
2. Select the  $S_{11}$  *Options* menu, then *Calibration Standards*.
3. Toggle *Use Calibration Kit Standards* to apply offsets and coefficients to the  $S_{11}$  trace.
4. Set the *Characteristic Impedance in Ohms*. This is defaulted to 50.
5. Enter the offsets and coefficient values provided with the Open-Short-Load Calibration Standards. If none are provided, or they are unknown, set these values to 0.
6. Press *OK* to change the settings to those set above. The  $S_{11}$  trace will update, although it might not look visually different, depending on the settings.

If you do not want to use the values set in the table, toggle *Restore Defaults* to disregard the values set in the table and use those loaded from the CT100B internal storage. If this is checked when *OK* is pressed, all former values will be overwritten.

### 5.5.6. Other Return Loss ( $S_{11}$ ) Options

Additional miscellaneous options can be found under *SCAN* → *Math* → *SParam & Normalize Tools* →  *$S_{11}$  Options* → *Other  $S_{11}$  Options*, and then toggle the options desired.

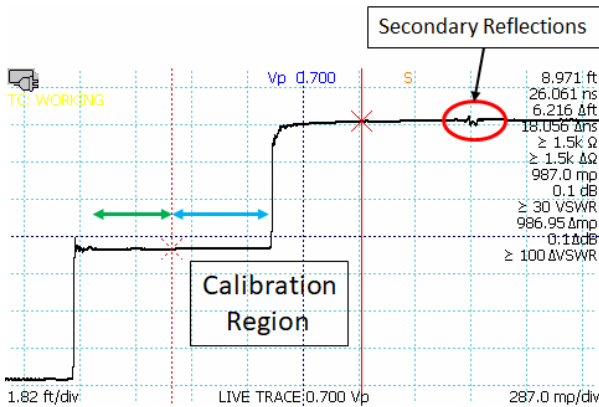
- *OSL Bases Visible*: If not checked, the Open, Short, and Load traces will be hidden after the  $S_{11}$  trace is created. This is to help reduce the visual clutter of the display.

- *Align Base Traces:* If checked, and if the input traces to the  $S_{11}$  trace all include the internal cabling, the input traces are aligned to the common first rise of the internal cable.

## 5.6. Improving S-Parameter Measurements

Note that testing short microwave cables directly from the test port may cause unacceptable noise due to the presence of secondary reflections in the TDR trace. In general, this shows up as excessive spectral noise. In this case, time windowing can be used to restore measurement accuracy:

1. Attach a phase stable cable to the test port of the instrument.
2. Place the leftmost cursor just to the left of the end of the phase stable cable.
3. Identify the start of the multiple reflections on the cable under test and exclude this region with the cursors (see Figure 5.8).



**Figure 5.8.** Using a phase stable cable to improve S-parameter measurements on short microwave cables. Use the phase stable cable (green arrow) and position the rightmost cursor to the left of the secondary reflections (red circle) occurring after the open or short at the end of cable under test (blue arrow) so that they are excluded.

4. Perform SParm calibration as described in Section 5.4.

The time-windowed trace will have substantially reduced noise due to exclusion of the secondary reflections.

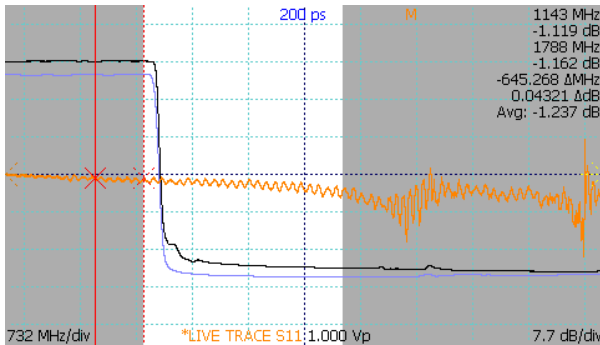
## 5.7. Normalized TDR Traces

This process creates a normalized TDR trace based on a calibrated  $S_{11}$  return loss trace. A normalized TDR trace appears as another trace in the region of  $S_{11}$  calibration. The normalized trace should be cleaner than the Measured DUT trace, with fewer aberrations. The normalized trace also has an adjustable

rise time to help the operator determine what effect a particular cable fault will have on signals with differing rise times. The following procedure creates a normalized TDR trace:

1. Create an  $S_{11}$  return loss plot using the procedure as described in Section 5.4.
2. From the *SParam & Normalize Tools* menu, select *Apply Normalization*.
3. Select *Normalize Pulse Rise Time* and use the *M-FUNCTION* knob to select a suitable rise time for the cable system as applicable. Note that selecting a rise significantly shorter than the native rise time of the TDR instrument will result in a degraded trace.
4. Note that the  $S_{11}$  Options, such as the *Between Cursors On/Off* setting, are used by the TDR normalization process. If *Between Cursors* mode is turned on, the normalized trace information will be taken from the time-windowed  $S_{11}$  trace.

Figure 5.9 shows a normalized TDR trace (blue) with a short fault in a 50 ohm cable. The normalized trace shows reduced aberrations and more accurate relative reflection coefficient and impedance after the fault compared with the live TDR trace.



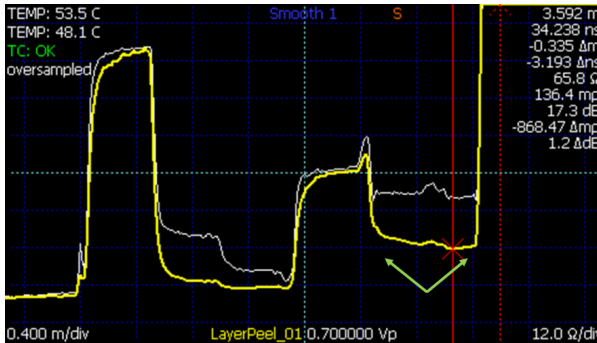
**Figure 5.9.** Normalized trace (blue, bottom) showing short fault in a 50 ohm cable.

## 5.8. Layer-Peeling (Dynamic Deconvolution) Traces

The CT100B includes the capability to perform layer-peeling/dynamic deconvolution. This is a useful technique for improving impedance accuracy by removing the effects of multiple reflections caused by impedance discontinuities along the length of the cable. In general, any impedance discontinuity creates both forward (transmission) and backward (reflection) waves. If reflected off other impedance discontinuities, these reflected waves will constructively or destructively interfere along the length of the TDR trace, leading to impedance measurement errors. The CT100B *Layer Peeling* feature iteratively extracts the underlying reflection coefficients as described in Section 7.13. For a more detailed description of layer peeling, see Section 7.13. To create a layer-peeling trace, use the following procedure:

1. Position the TDR trace on the screen so that the region of interest is visible with a portion of 50 ohm cable visible at the left of the screen (use the CT100B's internal 50 ohm cable if needed).
2. Use the *HORIZONTAL POSITION* knob to place the active cursor on the 50 ohm cable at the left side of the screen. The location of this cursor will define the start of the left side of the layer-peeling trace.
3. Select *Math* menu.
4. Select *Layer Peeling* menu option.

An example of a layer-peeling trace is shown in Figure 5.10. This figure depicts a multi-segment cable of varying impedance (50-125-75-63 ohms) with an open fault at the end. The corrected impedance of the final segment is within 2-3 ohms of the actual value, which represents an ~80% reduction in impedance error when compared with the uncorrected live TDR trace.



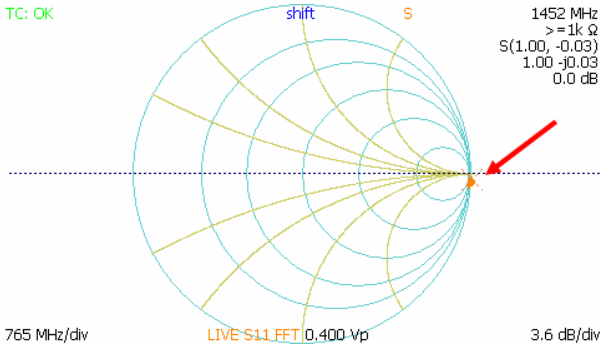
**Figure 5.10.** Example layer-peeling trace (yellow, bottom) versus live TDR trace (white, top). The layer peeled trace reduces the impedance error in the final cable segment (green arrows) by ~80%.

## 5.9. Smith Charts

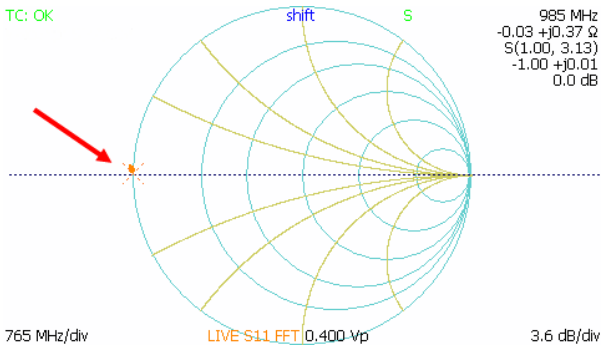
The Smith chart is a useful graphical tool for plotting reflection coefficients and complex impedance values and can be used to simplify impedance matching. For a very brief introduction to Smith charts, see Section 7.14. The CT100B allows the operator to display S-parameter return loss and cable loss traces on a Smith chart. To create a Smith chart, use the following procedure:

1. Create an  $S_{11}$  return loss plot using the procedure as described in Section 5.4.
2. With the  $S_{11}$  trace selected, adjust the cursors to minimum and maximum frequency desired on the Smith chart.
3. Go to *SParam Tools* and select the *Smith Chart* option to toggle the Smith chart display.
4. Use the *HORIZONTAL POSITION* knob to move the cursor along the complex impedance curve.

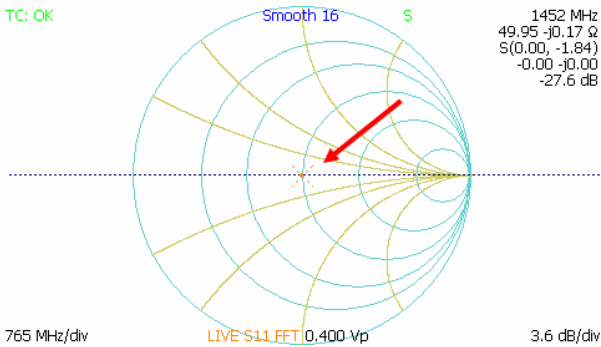
Figures 5.11 - 5.14 show Smith chart representations of an open, short, resistive 50 ohm load, and a reactive 200 ohm load.



**Figure 5.11.** Smith chart representation of open fault (red arrow).

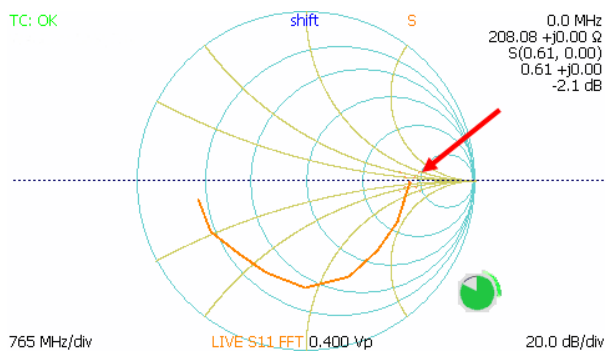


**Figure 5.12.** Smith chart representation of short fault (red arrow).



**Figure 5.13.** Smith chart representation of a 50 ohm resistive load (red arrow).





**Figure 5.14.** Smith chart of reactive 200 ohm load showing effect of reactive impedance at higher frequencies. Cursor (red arrow) shows impedance value calculated at DC (0 MHz).



## 6. CT Viewer

The CT Viewer™ 2 computer software for Windows desktop allows users of the MOHR CT100B TDR Cable Analyzer to transfer, view, and manipulate cable scans that have been saved on their instruments. This software package allows the user to select scans from a stored database that can contain thousands of scans and compare, subtract, or find the first derivative of any of the traces.

This software package will also allow the user to create reports and print plots that can be imported into Microsoft® Word® or other word-processing or report creation software to create files of traces suitable for transfer to others and to load trace files created by others.

This section covers how to transfer saved TDR traces to CT Viewer 2. For more detailed information on installing and using CT Viewer 2, please see the *CT Viewer 2 Quick User Guide*.

### 6.1. Transferring Saved Traces to a Computer

When a scanned trace is saved to the CT100B, it can be sent to a computer that has CT Viewer 2 installed.

#### 6.1.1. Send Saved Traces with a Thumb Drive

1. Insert a USB drive into a USB port on the front of the CT100B. Wait until the USB drive icon appears on-screen.
2. Press the *FILE* button to bring up the *File* menu.
3. Choose the *Cable Scan Records* menu option. A window listing all of the traces saved to the CT100B appears.
4. Use the *M-FUNCTION* knob to select a trace to send to the USB drive. Alternatively use *Toggle Selected* and *Mark All* to select multiple or all traces, respectively.
5. Choose *Export* → *USB* from the menu. The selected trace(s) will now be written to the USB drive.
6. Remove the USB drive for the CT100B and insert the drive into a USB port on the computer.
7. Start CT Viewer 2, and from the *File* menu in CT Viewer 2, select *Open Trace*.
8. Select the scan file name(s) of interest from the thumb drive. The trace(s) will be loaded into CT Viewer 2 and shown on the screen.

## 6.1.2. Send Saved Traces over USB

### 6.1.2.1. Set up USB Drivers on the Host Computer

The USB drivers need to be set up only once for each computer. The USB drivers for the CT100B should have been installed with CT Viewer 2. It is possible to skip this step during the installation. If the drivers aren't installed, Windows will inform the user when the CT100B is connected over USB.

### 6.1.2.2. Send the Traces

1. Start CT Viewer 2 and connect the computer to the CT100B with a standard USB type A to USB type B cable. Connect to the USB type B port on the back of the CT100B.
2. Go to the *File* menu in CT Viewer 2 and select *Open Tester*. A screen will appear that will show the serial number of the connected CT100B and a list of all traces saved on the CT100B.
3. Select a trace to transfer by clicking with the mouse. Select multiple traces by holding down the Shift or Ctrl key while clicking with the mouse.
4. Select the *Transfer To* button to send the traces to CT Viewer 2. The traces will also be loaded on the screen.

## 6.1.3. Send Saved Traces Using Ethernet

### 6.1.3.1. Set up Ethernet

In order to send traces over Ethernet to a computer, both the computer and the CT100B need to be set up for the network. Depending on how your network is configured, the default settings for the CT100B may work. If not, have your network administrator set up the network settings for the CT100B and the computer.

The CT100B network settings are located at *MENU* → *Settings* → *Network Settings*. The CT100B can get a configuration through DHCP, or it can be set up with Static Network Settings (see *Network Settings* in Table 3.4: *MENU Button and Menus*).

### 6.1.3.2. Connect to CT Viewer 2 – First Steps

1. Make sure both the computer and the CT100B are plugged into the network. The CT100B Ethernet plug is found on the back of the CT100B. The light on the CT100B Ethernet port should illuminate.
2. Start CT Viewer 2 on the computer.
3. On the CT100B, navigate to *MENU* → *Connect to CT Viewer*. See Figure 6.1. The *Find CT Viewer* menu button will scan the local network looking for a PC running the CT Viewer 2 program.
4. Or you can use the *Manual Connect* option to reconnect to a server you have used in the past or one that is not on your local network. See Figure 6.2.

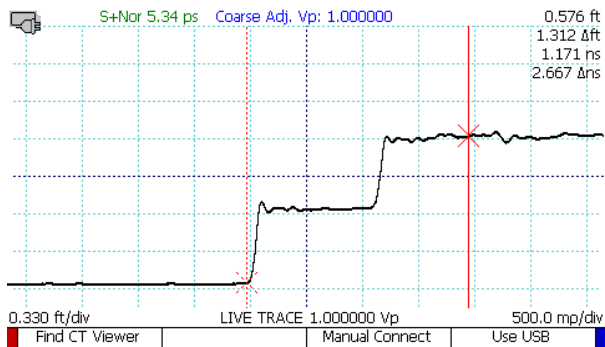


Figure 6.1. Options under the Connect to CT Viewer menu.

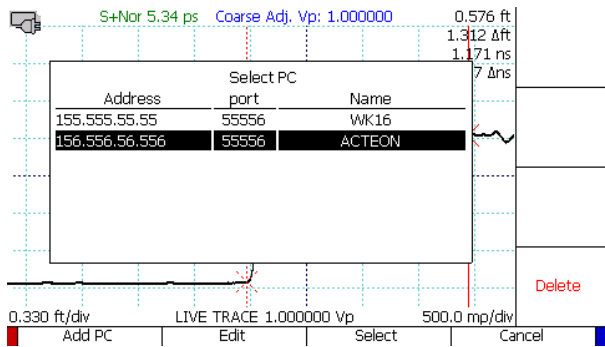


Figure 6.2. Selecting Manual Connect in the Connect to CT Viewer menu will bring up a server menu.

6.1.3.3. Manual Connection the First Time

1. From the server menu, Select *Add PC*. A window with various server settings appears.
2. Use the *M-FUNCTION* knob to move up and down in the window. Use the on-screen keyboard or a USB keyboard to enter values. In *PC Name*, enter a user-friendly name for the computer.
3. In *PC Address*, enter either a network name or an IP address for the computer.
4. Do not change the default port number.
5. Press *OK* to save the server entry, then press *Select* to connect. If the connection is successful, a message will appear on the CT100B and in CT Viewer 2.

#### 6.1.3.4. Connecting After the First Time

1. Navigate to the *MENU* → *Connect to CT Viewer* → *Manual Connect* menu. A window showing all the stored server connections will appear.
2. Use the *M-FUNCTION* knob to highlight the connection for the computer.
3. Press *Select*. The CT100B will try to connect to the server. On success, a message appears on the CT100B and in CT Viewer 2.

#### 6.1.3.5. After Connecting

1. Go to the *File* menu in CT Viewer 2 and select *Open Tester*. A screen then appears that shows the serial number of the connected CT100B and a list of all traces saved on the CT100B.
2. Select a trace to transfer by clicking with the mouse. Select multiple traces by holding down the Shift or Ctrl key while clicking with the mouse.
3. Select the *Transfer To* button to send the traces to CT Viewer 2. A dialog box will appear. Verify that the destination folder is correct and choose *Start Transfer*. The traces will appear on the screen.

## 6.2. Using Remote Control

After the CT100B has connected to a computer over Ethernet using the steps in Section 6.1.3, go to CT Viewer 2 and select *Remote Control* → *Enable Remote Control*.

Once remote control has been established, a new, live trace will appear in CT Viewer 2. This trace will be identical to the trace on the CT100B screen. It can be moved around or scaled just like any other trace in CT Viewer 2.

Normally the CT100B screen goes blank during remote control. To turn on the CT100B screen at the same time as Remote Control, select *Remote Control* → *Assistant Mode* in CT Viewer 2.

### 6.2.1. Record and Playback Real-Time TDR Trace Movies

CT Viewer 2 can record a real-time movie of the TDR trace, useful for detecting and characterizing transient/intermittent faults. To record a real-time movie of the CT100B trace, connect to the CT100B as described in the previous sections, and then select *Remote Control* → *Record to Movie File*. You will be prompted to enter a filename for the recording. Select *Remote Control* → *Stop* to stop the recording. To view the individual TDR traces saved in the movie, go to *File* → *Open Other Files* and locate and select the desired movie (CTM) file. Use the > and < keys to step forward and backward in the file. The time stamp of the trace is shown as part of the trace label.

## 7. TDR Measurement Theory

The purpose of this section is to familiarize the operator with the basic premise of time-domain reflectometry measurement theory as part of using the CT100B instrument.

### 7.1. Time-Domain Reflectometry (TDR)

TDR is a form of closed-circuit radar in which a transient test signal is injected into a device-under-test (DUT) such as a cable, and reflected voltages are measured at precise elapsed times to construct a TDR waveform or “trace”. Assuming a transmission line such as a cable with uniform geometry, the test signal propagates with a characteristic constant velocity and the time can be related to distance. The changes in reflected voltage in a TDR trace with respect to time correspond to distance from the test port to impedance changes.

Cable or connector faults are regions where the measured reflection coefficient and associated impedance are outside of manufactured specification. Cable faults are almost always broadband with preferential attenuation of higher frequencies, and indicate one or more of the following problems:

1. Change in the geometry of the conductors with respect to one another (e.g., a deformed cable),
2. Change in the dielectric properties of the insulator (e.g., moisture in the insulation), and/or
3. Partial or complete interruption in one or both of the signal conductors.

Cable faults are important because they degrade signal quality. Short or open faults completely disrupt signal transmission. In many ways such “hard” faults are helpful because they are easy to diagnose. However, more subtle partial or “soft” faults cause portions of the signal energy to be reflected and/or delayed, contributing to noise. This can show up as reduced bandwidth in microwave/RF cable systems and increased bit error rates in digital cable systems.

Multiple small faults that are individually insignificant with respect to noise may contribute in an additive fashion to exceed the overall “noise budget” of the cable assembly. Because our TDR typically measures the transmission line with more sensitivity than the bit error threshold of most communications systems, it is useful to find these “insignificant” faults and deviations from manufactured specification that may contribute to signal integrity problems.

### 7.2. Reflection Coefficients

The amplitude of reflected voltage at a particular location in a TDR waveform is recorded as the reflection coefficient at that location. The CT100B displays reflection coefficient on the right side of the screen with units of millirho ( $m\rho$ ).

The reflection coefficient is the ratio of the amplitude of the reflected portion of the test signal to the amplitude of the incident test signal. The reflection coefficient (Gamma,  $\Gamma$ ) is related to the impedance change ( $Z$ ) at a given point in a cable according to:

$$\Gamma = \frac{Z_L - Z_S}{Z_L + Z_S}$$

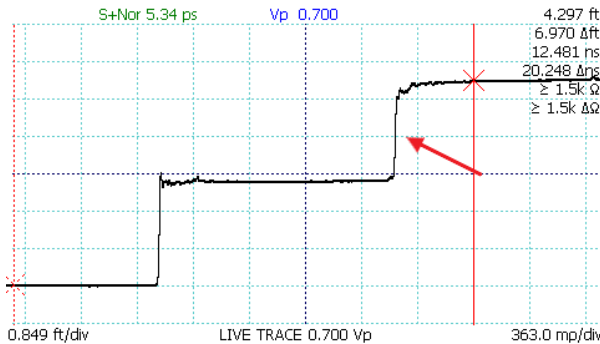
where  $Z_L$  is the impedance of the load (e.g., the device under test [DUT]) and  $Z_S$  is the source impedance of the TDR (typically 50 ohms but potentially other values if an impedance-matching adapter is being used). The reflection coefficient uses units of rho ( $\rho$ ) or millirho ( $m\rho$ ).

Note that the reflection coefficient ( $\Gamma$ ) is a complex variable with unique amplitude and phase for each frequency. However, when measuring reflection coefficient directly from a TDR trace, the measured value is the average reflection coefficient over all frequencies in the incident and reflected test signal.

The CT100B is also able to measure and display frequency-domain complex reflection coefficient values in the context of  $S_{11}$  return loss and cable loss plots such as those produced with Vector Network Analyzer (VNA) and Frequency-Domain Reflectometer (FDR) equipment. This is discussed further in Section 7.11.

### 7.3. Common Types of TDR Cable Faults

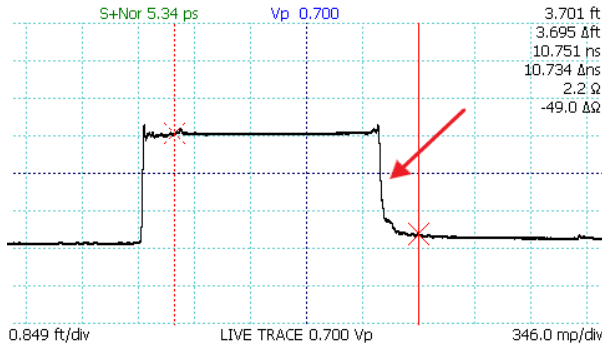
Open faults appear as a pulse upward in the TDR trace (Figure 7.1) because the fault reflects all of the incident step energy in-phase with the test signal.



**Figure 7.1.** An open cable fault shows an upward step edge at the location of the fault.

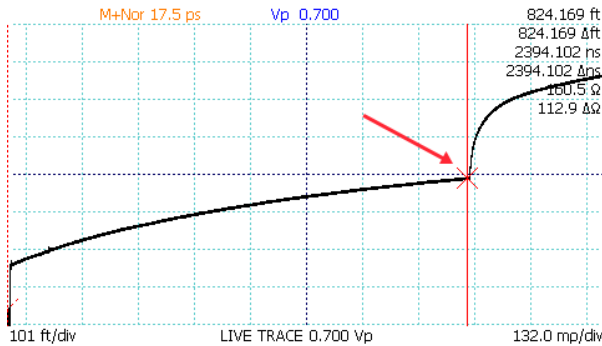
Short faults appear as a pulse downward in the TDR trace because the fault reflects all of the incident step energy  $180^\circ$  out-of-phase with the test signal (Figure 7.2).





**Figure 7.2.** A short cable fault shows a downward step edge at the location of the fault.

Short or open faults measured through long lengths of cable (hundreds of feet) will show long, shallow reflections on the TDR trace because the cable preferentially attenuates higher frequencies in the test signal, degrading the rise or fall time of the reflected fault. Figure 7.3 demonstrates a TDR trace with an open fault at the end of an 824 ft. RG-6 coaxial cable with long, shallow reflected rise caused by cable attenuation of high-frequency components of the step-pulse.

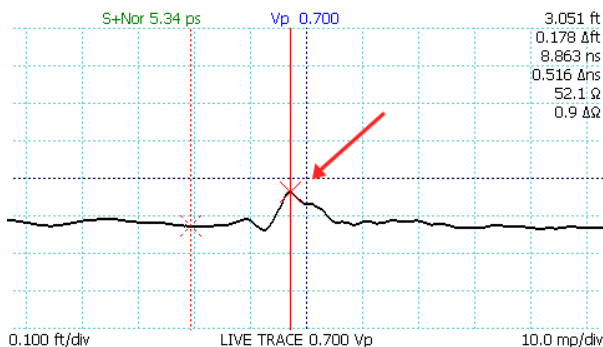


**Figure 7.3.** An open cable fault at 824 ft.

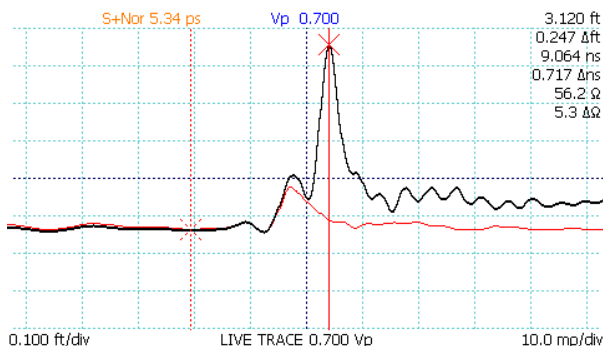
Faults with reactive components such as capacitance and inductance appear as either dips below or bumps above the characteristic impedance of the cable, depending on whether they are in series with the conductor or represent a fault to ground.

Normal connectors will show up as an impedance discontinuity simulating a small fault. Depending on the type and quality of the connectors, the expected impedance variation will differ, as shown in Figure 7.4 and Figure 7.5 for SMA and BNC type connections. Connector damage and corrosion can change the impedance profile of a connector over time, typically increasing the excess

impedance of the connector. Periodic surveillance with TDR can be used to confirm connector performance.



**Figure 7.4.** Normal SMA female barrel interconnect measuring 52.1 ohms.



**Figure 7.5.** Comparison of typical SMA (red trace, bottom) and BNC (black trace, top) coaxial cable interconnects.

Soft/partial faults can appear anywhere along the cable's length.

Any fault has the potential to reduce the incident pulse strength for subsequent cable faults and may change the apparent velocity of propagation. The accuracy of the Distance-to-Fault measurement of a fault that appears beyond another fault is reduced.

## 7.4. Velocity of Propagation (VoP, Vp)

As mentioned in previous sections, a transmission line, such as a coaxial cable, has uniform geometry with a characteristic signal propagation velocity. This velocity of propagation (Vp, VoP, or VP), sometimes also called the velocity factor (VF) or wave propagation speed, is the measure of the velocity of an

electrical signal within a cable expressed as a fraction of the speed of light in a vacuum. With the CT100B,  $V_p$  can be set between 0.250000 and 1.000000.

Nominal  $V_p$  values for most types of cable can be found in the manufacturer's datasheet, and Appendix D: *V<sub>p</sub> of Common Cables* contains nominal values for a variety of commonly used cable types. These values can be a good start for basic cable Distance-to-Fault measurements. However, it is important to be aware that  $V_p$  values for a given cable type may vary from manufacturer to manufacturer and from one manufacturing lot to the next even from the same manufacturer. In addition, cable aging due to temperature, radiation, or other environmental parameters may alter the original characteristic velocity of propagation for a given cable. For this reason, if accuracy is particularly important for a particular cable Distance-to-Fault measurement, it is generally a good idea to establish a known  $V_p$  for a sample of the specific cable under test.

The velocity of propagation ( $V_p$ ) is related to the dielectric constant (relative permittivity,  $\epsilon_r$ ) of the dielectric medium according to:

$$V_p \approx \frac{1}{\sqrt{\epsilon_r}}$$

Velocity of propagation is also related to the distributed inductance ( $L$ ) and shunt capacitance ( $C$ ) of a lossless transmission line according to:

$$V_p = \frac{1}{c\sqrt{LC}}$$

## 7.5. Distance-to-Fault (DTF) and Cable Length

Once the operator identifies an impedance discontinuity such as a cable fault or open or short cable termination, the distance to the fault ( $D$ ) is related to the velocity of propagation ( $V_p$ ), the speed of light ( $c$ ), and the measured round-trip time ( $t$ ) to the fault, according to:

$$D = \frac{V_p \cdot c \cdot t}{2}$$

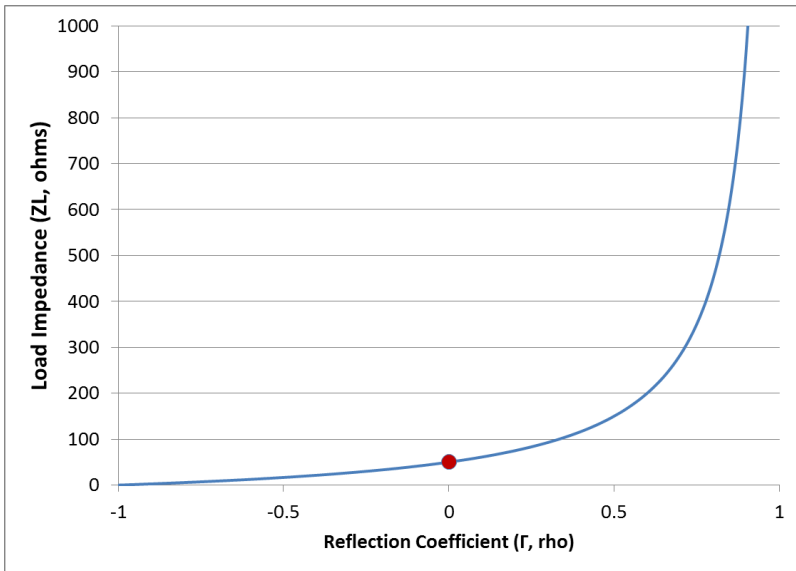
The product is divided by 2 because the CT100B measures the time for the pulse to travel to and from the point of interest.

## 7.6. Impedance

As mentioned previously, TDR instruments measure reflection coefficient directly but must calculate impedance according to:

$$Z(t) = -Z_S \frac{\Gamma(t) + 1}{\Gamma(t) - 1}$$

where  $Z(t)$  is the impedance at time  $t$ ,  $Z_S$  is the source impedance, and  $\Gamma(t)$  is the reflection coefficient at  $t$ . This is the basis for the CT100B ohms-at-cursor measurements. It is important to note that impedance is nonlinear with respect to reflection coefficient, as shown in Figure 7.6.



**Figure 7.6.** Relationship of impedance (ohms) to reflection coefficient (rho) for 50 ohm source impedance (marked by red circle).

Because TDRs measure reflection coefficient, noise and uncertainty on a TDR trace is in units of millirho, not ohms. Given a fixed amount of uncertainty in reflection coefficient, the corresponding impedance uncertainty will be low at impedances less than the TDR source impedance (typically 50 ohms) and increasingly larger and nonlinear for impedance values greater than the TDR source impedance.

The CT100B factory calibration provides typical vertical accuracy of approximately 0.1 ohm near 50 ohms and approximately 10-20 ohms near 1000 ohms for most cable-testing applications. When impedance measurements are very important, accuracy can be improved using Vert. Ref. (Section 4.13.1) and normalized TDR traces (Section 5.7).

## 7.7. Return Loss

Return loss is another way of measuring impedance change in a cable. Return loss is given in decibels (dB) and is always calculated using the relative reflection coefficient. Return loss is related to the reflection coefficient  $\Gamma$  by the formula:

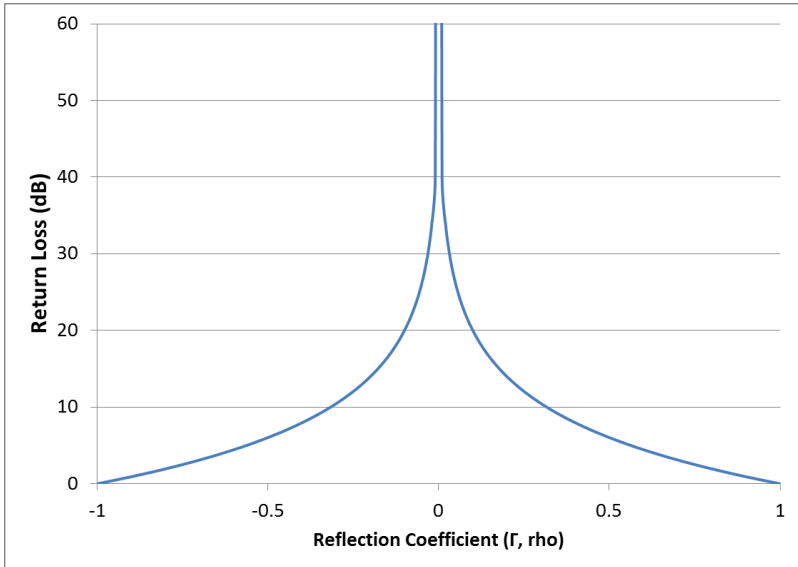
$$\text{Return Loss} = -20 \cdot \log_{10} |\Gamma| \text{dB}$$

The larger the fraction of energy in the reflected signal, the lower the numerical return loss value, so that an open or a short that returns 100% of the signal has a return loss of 0 dB. A very low loss cable will have a large return loss in dB.

Likewise a 50 ohm cable terminated with a perfect 50 ohm load will have very large return loss in dB. This relationship is shown in Figure 7.7.

Return loss measured directly from a CT100B TDR trace represents the average return loss over all frequencies in the step-rise test signal. The CT100B can measure TDR return loss at cursor and relative return loss between cursors and optionally displays these values at the right of the screen in units of dB, with  $\Delta$ dB used for the relative return loss measurement.

The CT100B is also able to measure complex frequency-specific  $S_{11}$  return loss and cable loss values such as those produced with Vector Network Analyzer (VNA) and Frequency-Domain Reflectometer (FDR) equipment. This is discussed in further detail in Section 7.11.



**Figure 7.7.** Relationship of return loss (dB) to reflection coefficient (rho).

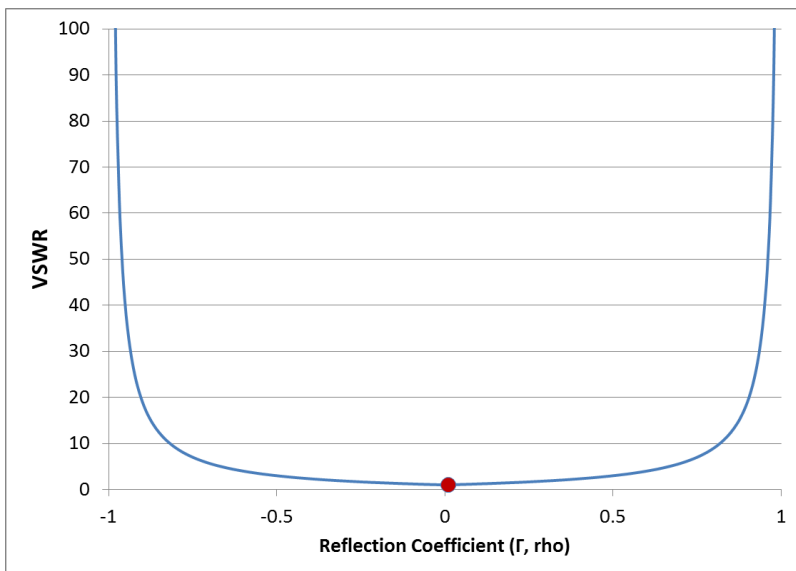
## 7.8. VSWR

Voltage standing wave ratio (VSWR) is a way of displaying reflection coefficient in a nonlinear way that emphasizes changes in cable impedance. VSWR is related to the reflection coefficient  $\Gamma$  according to:

$$\text{VSWR} = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

VSWR measures the ratio of the maximum-over-time amplitude of the nodes and anti-nodes of the standing wave off of a reflection. If there's no reflection (e.g., 50 ohm termination), VSWR will be 1. If all energy is reflected (e.g., short

or open fault), VSWR goes to infinity. This relationship is shown in Figure 7.8. VSWR is a unitless, scalar value.



**Figure 7.8.** Relationship of voltage standing wave ratio (VSWR) to reflection coefficient ( $\rho$ ). VSWR for 50 ohm load is shown by the red circle.

The CT100B displays two different VSWR values at cursor. The first, VSWR, is calculated from the total reflection relative to the CT100B test port source impedance (50 ohms). The second,  $\Delta$ VSWR, is calculated from the reflection between the two cursors. In other words, VSWR is based on the millirho reflection coefficient, while  $\Delta$ VSWR is based on the  $\Delta\rho$ , relative reflection coefficient calculation. There are menu options in the *Display* menu to toggle the display of VSWR and  $\Delta$ VSWR.

VSWR can also be selected as the vertical scale for a trace. From the *Main* menu, go to the *Measurement* menu and select *Vertical Units*.

## 7.9. Rise Time and Spatial Resolution

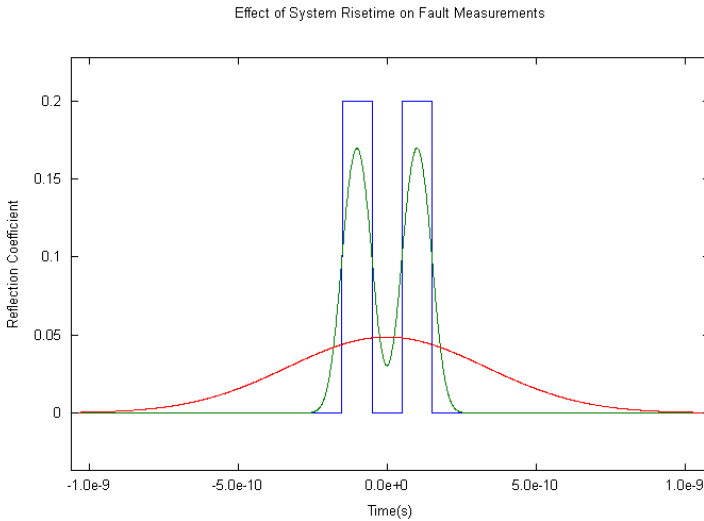
Spatial resolution is defined by the ability of the operator to distinguish the presence of two closely spaced faults on a TDR waveform. An accepted rule of thumb is that the limiting spatial resolution of a TDR instrument is approximately  $\frac{1}{2}$  of the system rise time (10-90%). This is the time required for the step signal reflected from an open or short termination to transition from 10% to 90% of the final step amplitude. The estimated spatial resolution  $R$  is

calculated by the following equation:

$$R \cong \frac{1}{2} \cdot c \cdot V_p \cdot t_r$$

where  $c$  is the speed of light and  $t_r$  is the system rise time. If the velocity of propagation  $V_p$  is taken to be 0.66 and the TDR has a 100 ps system rise time, the calculated resolution is  $\sim 10$  mm.

Faster system rise times allow a given TDR instrument to more faithfully represent partial cable faults such as shield nicks or kinks, as shown in Figure 7.9. This figure depicts a simulation of the difference between a 90 ps rise time TDR and an 800 ps rise time TDR (typical of low-cost TDR instruments) for characterizing two 1 cm long, 75 ohm faults spaced 1 cm apart on a 50 ohm cable. The 800 ps rise time TDR detects only a single fault and grossly underestimates the severity of the fault.



**Figure 7.9.** Simulated comparison of a 90 ps rise time TDR (green) and an 800 ps TDR (red) with respect to the ability to depict two 1 cm long, 75 ohm faults spaced 1 cm apart on a 50 ohm cable. Notice how the faster TDR (90 ps) resolves each fault individually. The blue lines represent a theoretically perfect response.

## 7.10. Timebase/Cursor/Horizontal Resolution

Timebase, cursor, or horizontal resolution refers to the horizontal spacing of samples along the TDR trace. In order to faithfully depict the TDR profile of a connector or cable fault, the cursor resolution should be at least 5 to 10 times higher than the spatial resolution. For the example just shown in Figure 7.9, it is unlikely that the cursor resolution for the slower rise time instrument would be adequate to reliably depict the fault in the first case.

Cursor resolution also comes into play when precise length or phase matching of cables is being carried out, in which the cursor resolution must be sufficient to adequately depict the difference in length between cables. Typically the cursor resolution should be 10 times higher than the intended length accuracy.

With respect to frequency-domain measurements, very high cursor resolution ensures adequate frequency bandwidth because the number of sampled data points in the time domain translates into frequency resolution in the frequency domain.

## 7.11. Frequency-Domain Measurements

### 7.11.1. Scattering Parameters

The scattering parameter or S-parameter approach to describing a device-under-test (DUT) assumes that a DUT is a black box network with N ports. The S-parameter matrix contains the complex reflection and transmission coefficients of the network, describing the amplitude and phase of reflected and transmitted values from each port in response to excitation of one or more of the ports.

According to convention, the scattering parameter  $S_{xy}$  represents the response of the network in terms of reflected and/or transmitted voltages at port x in response to excitation of port y.  $S_{11}$  and  $S_{22}$  are the complex reflection coefficient matrices of port 1 and 2, respectively.  $S_{21}$  and  $S_{12}$  are the forward and reverse complex voltage gain matrices for port 1 and port 2, respectively.

Considering a 2-port network with incident voltage waves  $a_1 = V_1^+$  and  $a_2 = V_2^+$  and reflected waves being  $b_1 = V_1^-$  and  $b_2 = V_2^-$ , the 2-port S-parameter matrix is described by:

$$\begin{pmatrix} b_1 \\ b_2 \end{pmatrix} = \begin{pmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{pmatrix} \begin{pmatrix} a_1 \\ a_2 \end{pmatrix}$$

Solving for  $S_{11}$  gives:

$$S_{11} = \frac{b_1}{a_1} = \frac{V_1^-}{V_1^+}$$

Solving for  $S_{21}$  gives:

$$S_{21} = \frac{b_2}{a_1} = \frac{V_2^-}{V_1^+}$$

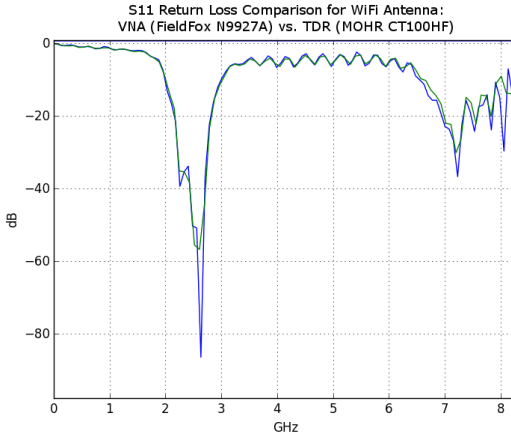
Passive networks like cables, splitters, attenuators, and combiners can be considered reciprocal networks such that  $S_{11} = S_{22}$  and  $S_{21} = S_{12}$ . One-port measurements can be used to characterize the return loss ( $S_{11}/S_{22}$ ) and insertion loss ( $S_{21}/S_{12}$ ) of a variety of 2-port passive networks such as cables. This will be discussed in Cable Loss ( $S_{21}$ ), Section 7.11.4.

You can measure S-parameters directly in the frequency domain using a VNA instrument and indirectly in the time domain using a TDR instrument. The TDR instrument performs a discrete Fourier transform (DFT) operation to decompose a TDR trace into the frequency domain.



When calibration is performed at the test plane using open, short, and 50 ohm load (OSL) terminations, the CT100B is able to mathematically subtract systemic errors in the pulser and sampler electronics from the measured trace, improving S-parameter accuracy.

S-parameters measured with TDR instruments are accurate with sufficient dynamic range for most applications. Figure 7.10 shows a comparison of return loss for a 2.4 GHz WiFi patch antenna measured using a handheld VNA and CT100HF TDR. The TDR-derived return loss measurements show good accuracy from DC to approximately 8.3 GHz. Both spectra clearly show the 2.4 GHz bandpass region expected for a 2.4 GHz WiFi antenna.



**Figure 7.10.** Comparison of  $S_{11}$  return loss of a 2.4 GHz WiFi patch antenna measured using a handheld VNA (Agilent® FieldFox N9927A, green) and TDR (CT100HF, blue), showing good agreement from DC to ~8.3 GHz. Note bandpass in the 2.4 GHz region.

### 7.11.2. Return Loss ( $S_{11}$ )

The complex return loss  $S_{11}$  is expressed as:

$$\text{Return Loss } RL = -20 \cdot \log_{10} |S_{11}| \text{ dB}$$

### 7.11.3. Insertion Loss ( $S_{21}$ )

The complex insertion loss  $S_{21}$  is expressed as:

$$\text{Insertion Loss } IL = -20 \cdot \log_{10} |S_{21}| \text{ dB}$$

True 2-port insertion loss measurements require a 2-port instrument; however the cable loss measurement described below uses the reciprocity feature of passive networks to determine insertion loss from cables and other suitable 2-port networks using a 1-port test instrument.

#### 7.11.4. Cable Loss ( $S_{21}$ )

Cable insertion loss in dB is additive per unit length. Assuming that port 2 of a 2-port DUT (e.g., a coaxial cable) is terminated with a short (or open) adapter such that all (or nearly all) of the incident voltage trace is reflected back to the TDR instrument, insertion loss ( $S_{21}$ ) is half of the corresponding  $S_{11}$  return loss measurement in dB:

$$\text{Cable Loss } CL = \frac{RL}{2} \text{ dB}$$

Again, this relationship is valid if the cable is terminated with a short or open. One drawback to this technique is that the round-trip insertion loss reduces the length of cable that can be tested over a given bandwidth relative to a 2-port measurement because the attenuation of the test signal is doubled. However, for many applications it is adequate.

### 7.12. Normalized TDR Traces

The S-parameter OSL calibration process mathematically models the TDR pulser-sampler system as a two-port error network and subtracts systemic pulser-sampler errors from the  $S_{11}$  matrix. Convolution of the  $S_{11}$  matrix with an idealized Gaussian step or other idealized excitation signal allows the CT100B to create and display a normalized TDR trace. The normalized TDR trace has lower aberration and improved impedance accuracy compared with the original TDR trace.

Although cable fault detection is the most sensitive when using an excitation signal with the fastest rise time possible, by changing the rise time of the Gaussian step, the importance of a given cable or connector fault can be estimated at different signal rise times and bandwidths. For instance if the cable under test is typically used with 1 ns rise time signals, the severity of a cable fault can be determined by using a 1 ns rise time normalized TDR trace. Localized cable faults will always appear less severe when examined using slower rise time excitation signals.

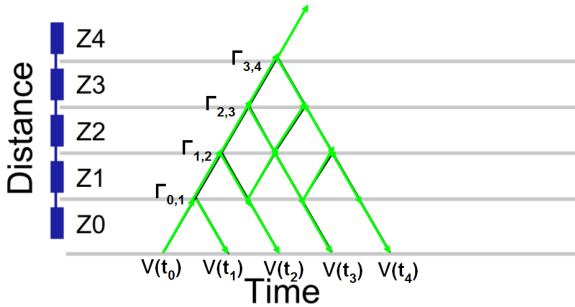
### 7.13. Layer Peeling/Dynamic Deconvolution

Layer peeling (or dynamic deconvolution) is a general method to solve the inverse scattering problem in partially reflective transmission lines such as cables. When applied to TDR traces, this method attempts to extract the underlying real reflection coefficients and impedance in the presence of multiple reflections caused by the presence of impedance discontinuities in the cable assembly under test.

As implemented in the CT100B (see Section 5.8), the layer-peeling method iteratively examines the TDR trace at each time step and attempts to correct for forward and backward signal propagation to extract impedance values at each time step. This is diagrammed in Figure 7.11 showing measured voltages  $V(t)$  taken from the TDR trace and their relationship to actual reflection coefficients ( $\Gamma$ ) at time ( $t$ ) and impedance values ( $Z_x$ ) at different physical distances. The diagram shows that for each time step forward in the TDR trace,

there are increasingly complex contributions from forward and backward reflections as they interact with each new impedance boundary.

For instance, the test signal moving forward from the  $Z_0/Z_1$  impedance boundary is reduced by the energy reflected by the  $Z_0/Z_1$  boundary. Likewise the  $Z_1/Z_2$  impedance boundary is “tested” by the original TDR test signal at time  $t_1$  but also interacts with reflected signals at every subsequent time point due to internal reflections in the cable. The layer-peeled TDR trace partially corrects for the presence of these multiple reflections and provides more accurate impedance values. This effect is most pronounced when there are multiple large impedance transitions in a cable assembly and at short and open faults.



**Figure 7.11.** Layer-peeling scattering diagram relating measured TDR trace ( $V[t]$ ) to actual impedance changes ( $Z[x]$ ) and their associated actual reflection coefficients ( $\Gamma[x, t]$ ).

## 7.14. Smith Charts

The impedance Smith chart is a useful graphical tool for visualizing complex impedances and scattering parameters as shown by Figure 7.12. The CT100B includes Smith chart functionality that can be used to simplify transmission line troubleshooting and impedance matching as described in Section 5.9.

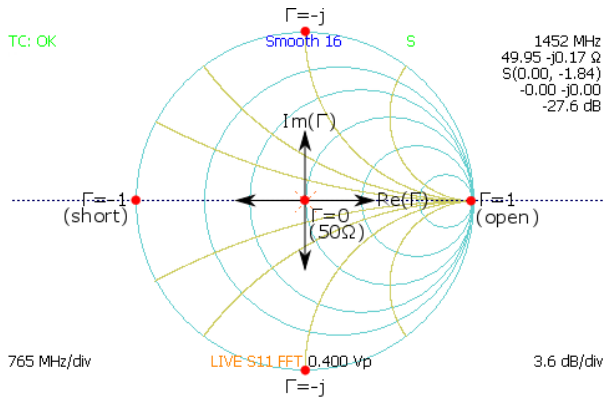


Figure 7.12. Impedance Smith chart relationships.

## A. Specifications

### A.1. Electrical Specifications

Characteristic	Specifications	Notes
Reflected rise time, CT100B 10-90%	150 ps typ, 200 ps max	10 to 90%, into 50 $\Omega$
Reflected rise time, CT100B 20-80%	100 ps typ, 150 ps max	20 to 80%, into 50 $\Omega$
Reflected rise time, CT100HF 10-90%	100 ps typ, 130 ps max	10 to 90%, into 50 $\Omega$
Reflected rise time, CT100HF 20-80%	80 ps typ, 90 ps max	20 to 80%, into 50 $\Omega$
Jitter	15 ps max (peak-to-peak)	< 1 ps rms typ.
Output impedance	50 $\Omega \pm 2\%$	
Pulse amplitude	300 $\pm 10$ mV	Averaged value into 50 $\Omega$
Pulse width	Fixed: 1.000 – 2.000, 5.000 – 6.000, 20.00 – 21.00 $\mu$ s	Averaged values change for short, medium, and long cable length settings, respectively
Pulse repetition time	Fixed: 4.000 $\pm 0.02$ , 20.00 $\pm 0.02$ , 80.00 $\pm 0.02 \mu$ s	Averaged values change for short, medium, and long cable length settings, respectively
Sequential sampling rate	Fixed: 250.0 $\pm 0.2$ , 50.00 $\pm 0.04$ , 12.50 $\pm 0.02$ kHz	Averaged values change for short, medium, and long cable length settings, respectively
Vertical scale	0.5 mV/div	
Vertical accuracy	$\pm 3\%$ full scale	< $\pm 1\%$ of measurement typ.
Vertical position	Any trace point is movable to the center of the screen.	
Sampling efficiency, CT100B	50 to 90%	into 50 $\Omega$

Characteristic	Specifications	Notes
<b>Sampling efficiency, CT100HF</b>	45 to 90%	into 50 $\Omega$
Noise	$\pm 5$ m $\rho$ peak-to-peak	
<b>Input susceptibility</b>	$\pm 1$ A max	into diode clamps
<b>Distance cursor resolution</b>	1/45 of one major division	
<b>Cursor readout resolution</b>	0.001 in. (0.0254 mm)	
<b>Distance measurement accuracy</b>	< 1 cm (0.3 in.) or < 0.5% of measurement plus uncertainty in Vp, whichever is greater	< $\pm 0.05\%$ of measurement typ.
<b>Impedance readout range</b>	< 0.1 $\Omega$ to > 1.5k $\Omega$	
<b>Impedance resolution</b>	3 significant digits	
<b>Impedance accuracy</b>	$\pm 10\%$ , relative measurement $\pm 2\%$	< $\pm 1\%$ typ. (0 to 1k $\Omega$ )
<b>Horizontal scale</b>	0 to 3800 ft./div. (0 to 1158 m/div.) (variable with pulse width)	at Vp of 0.66
<b>Horizontal range</b>	0 to 48,000 ft. (0 to 14,600 m)	at Vp of 0.66
<b>Horizontal position</b>	Any distance to full scale can be moved on the screen.	
<b>Vp range</b>	0.250000 to 1.000000	
<b>Vp default resolution</b>	0.001	
<b>Vp fine resolution</b>	0.000001	
<b>Vp accuracy (coarse)</b>	$\pm 0.1\%$	
<b>Vp accuracy (fine)</b>	$\pm 0.0001\%$	
<b>USB host port</b>	USB 1.1	Front USB host connector is powered (500 mA limit) with 500 VDC isolation from test port.
<b>USB client port</b>	USB 1.1	500 VDC isolation from test port.
<b>Ethernet port</b>	The instrument includes a 10/100 Mbps Ethernet port for network communication.	500 VDC isolation from test port.

Characteristic	Specifications	Notes
DC power supply	24 VDC, 2.5 A, positive tip. Use only the MOHR-approved power supply.	500 VDC isolation from test port.
Battery pack	12 NiMH AA cells, fused at 2.5 A	Pack may wear out over time.
Battery operation time	> 6 hours. Power save options may extend operating time.	18 V full charge down to 12 V battery low, 35% duty cycle.
Battery charge time	Up to 4 hours (2.5 hours typ.) from fully discharged state	
Overcharge protection	Charging discontinues once full charge is attained.	
Discharge protection	Instrument turns off prior to battery damage	Software shutdown when battery is low.
Charge capacity	2.7 Amp-hours (nominal-new)	

## A.2. Environmental Specifications

### A.2.1 Temperature

Operating temperature	0°C to +50°C
Non-operating temperature	-20°C to +60°C

## A.3. Mechanical Specifications

### A.3.1 Weight

Without cover	2150 g (4.740 lb.)
With cover	2323 g (5.121 lb.)

### A.3.2 Dimensions

Height	10.9 cm (4.28 in.)
Width w/ handle	29.2 cm (11.50 in.)
Width w/o handle	26.2 cm (10.30 in.)
Depth w/ cover	17.5 cm (6.90 in.)
Depth, handle extended	27.9 cm (11.00 in.)

## A.4. Certifications and Compliances

### A.4.1 EC

The CT100B and CT100HF comply with all applicable EU directives.

### A.4.2 FCC Compliance

CT100B and CT100HF emissions comply with FCC Code of Federal Regulations 47, Part 15, Subpart B, Class A Limits.

### A.4.3 EMC

CT100B and CT100HF comply with MIL-PRF-28800F, MIL-STD-461F RE102, CE102, and IEC61000.

### A.4.4 Shock and Vibration

CT100B and CT100HF comply with MIL-PRF-28800F (class 3).

### A.4.5 Temperature and Humidity

CT100B and CT100HF comply with MIL-PRF-28800F (class 3).

### A.4.6 Explosive Atmosphere

CT100B and CT100HF comply with MIL-STD-810-G 511.5 Procedure I (+55°C, 0-4600 m).

### A.4.7 US Military Classification

CT100B and CT100HF are class 3 instruments as per MIL-PRF-28800F.

### A.4.8 Air Transport

The CT100B battery is classified as UN3496, Dry Cell, Not Restricted.



# B. Operator Performance Checks

## B.1. General Information

The CT100B Operator Performance Checks are a series of procedures used to verify the calibration of a CT100B TDR. The following series of checks should be performed after a unit has been newly calibrated to verify compliance to published specifications, but may also be performed to determine if calibration is required. It is recommended to perform these checks at least every 6 months. See Section E.4 for more information on calibration.

The following series of steps is designed to allow a CT100B operator to completely verify the properties of an individual CT100B unit to each published specification. Throughout this procedure any references made to the CT100B should be considered applicable to the CT100HF and CT100S.



*NOTE: Operator Performance Checks should not be considered CT100B calibration.*



*NOTE: If a CT100B fails any Operator Performance Check, it should be serviced by a qualified repair facility.*

## B.2. Required Equipment

**Table B.1.** Required Performance Check Equipment for CT100B

Item	MOHR part number
Precision 50 $\Omega$ terminator	CT100-AC-ER50-S
Connector, SMA female to BNC male	CT100-AC-ISFBM
50 $\Omega$ 36 in. reference cable	CT100-AC-W536
Shorting cap	CT100-AC-IBS
BNC male to male adapter	CT100-AC-IBMM

**Table B.2.** Required Performance Check Equipment for CT100HF and CT100B with SMA Option

Item	MOHR part number
Precision 50 $\Omega$ terminator	CT100-AC-ER50-S
Connector, SMA male to BNC female	CT100-AC-ISMBF
Shorting cap	CT100-AC-ISS
50 $\Omega$ 36 in. reference cable	CT100-AC-W536-S

Additionally, a device capable of taking accurate pulse measurements with documented calibration will be required, and, if working with a CT100B [BNC], an open terminator will be needed. Coaxial adapters with low TDR reflections ( $< 5 \Omega$ ) are required in any cases where adapters are used.

### B.3. Getting Ready

Go to *MENU*  $\rightarrow$  *Settings*  $\rightarrow$  *Display* and make sure *Standard Menu* is toggled on. This ensures *Cable Length* can be accessed in the *Main* menu.

Disconnect any cables from the front BNC or SMA connector. Connect the instrument to the external 24 V power supply connected to a standard 3-prong AC source.

Allow the unit to warm up until it displays a steady temperature.

### B.4. Operator Performance Checks

#### B.4.1 Jitter, Noise, Rise Time, and Sampling Efficiency Checks

1. Connect a 50 ohm terminator to the CT100B front panel cable connector.
2. Select the *MENU*  $\rightarrow$  *Settings*  $\rightarrow$  *Diagnostics* menu item to enter the *Diagnostics* submenu.
3. Select *Jitter*. After a moment, a results window appears with a list of measurements.

The value for Jitter used in the specification for a CT100B is Jitter P2P. The value for Noise is Noise P2P.

The value for the 20-80% and 10-90% Reflected Rise Times are both displayed as 20-80 Rise and 10-90 Rise, respectively.

#### B.4.2 Output Impedance Check

1. Disconnect any cables from the CT100B front panel cable connector.
2. Position a cursor before the falling edge of the trace (or before the second rise on an SMA connector).
3. Position the second cursor well to the right of the falling edge (or second rise on an SMA connector).
4. Attach the 50 ohm terminator to the CT100B.

5. The difference in ohms between the two cursors is a measure of the deviation of output impedance from 50 ohms.

### B.4.3 Pulse Amplitude Check

1. Pulse amplitude measurement should be taken with a device that can accurately measure frequency, pulse width, period, and amplitude.
2. Set the device input impedance to 50 ohms.
3. Connect one end of the 36 in. reference cable to a capable pulse measurement device and the other end of the 36 in. reference cable to the CT100B front panel cable connector. A trace should appear on the device display.
4. Switch the CT100B into the Short pulse setting from the *Main* menu *Cable Len* setting.
5. Measure the pulse amplitude coming off the front panel cable connector. The averaged pulse amplitude into 50 ohms should be between 290 mV and 310 mV.
6. Repeat pulse amplitude comparison for Medium and Long settings.

### B.4.4 Pulse Width Check

1. Pulse width measurement should be taken with a device that can accurately measure frequency, pulse width, period, and amplitude.
2. Set the device input impedance to 50 ohms.
3. Connect one end of the 36 in. reference cable to a capable pulse measurement device and the other end of the 36 in. reference cable to the CT100B front panel cable connector. A trace should appear on the device display.
4. Switch the CT100B into the Short pulse setting from the *Main* menu *Cable Len* setting.
5. Measure the pulse width coming off the front panel cable connector. The average pulse width should be between 1.000-2.000  $\mu\text{sec}$  for Short, 5.000-6.000  $\mu\text{sec}$  for Medium, and 20.00-21.00  $\mu\text{sec}$  for Long.
6. Repeat pulse width check for Medium and Long settings.

### B.4.5 Pulse Repetition Period Check

1. Pulse repetition rate measurement should be taken with a device that can accurately measure frequency, pulse width, period, and amplitude.
2. Set the device input impedance to 50 ohms.
3. Connect one end of the 36 in. reference cable to a capable pulse measurement device and the other end of the 36 in. reference cable to the CT100B front panel cable connector. A trace should appear on the device display.
4. Switch the CT100B into the Short pulse setting from the *Main* menu *Cable Len* setting.
5. Measure the pulse repetition rate coming off the front panel cable connector. The average pulse repetition rate should be  $4.000 \pm 0.02 \mu\text{sec}$  for Short,  $20.00 \pm 0.02 \mu\text{sec}$  for Medium, and  $80.00 \pm 0.02 \mu\text{sec}$  for Long.
6. Repeat pulse repetition period check for Medium and Long settings.

### B.4.6 Pulse Frequency Check

1. Pulse frequency measurement should be taken with a device that can accurately measure frequency, pulse width, period, and amplitude.
2. Set the device input impedance to 50 ohms.
3. Connect one end of the 36 in. reference cable to a capable pulse measurement device and the other end of the 36 in. reference cable to the CT100B front panel cable connector. A trace should appear on the device display.
4. Switch the CT100B into the Short pulse setting from the *Main* menu *Cable Len* setting.
5. Measure the pulse frequency coming off the front panel cable connector. The averaged pulse frequency should be  $250.0 \pm 0.2$  kHz for Short,  $50.00 \pm 0.04$  kHz for Medium, and  $12.50 \pm 0.02$  kHz for Long.
6. Repeat pulse frequency check for Medium and Long settings.

### B.4.7 Sequential Sampling Rate Check

The sequential sampling rate is the reciprocal of the pulse repetition time.

### B.4.8 Vertical Scale Check

Twist the *VERTICAL SCALE* knob clockwise. Vertical scale should drop to 0.5 millirho/div and the trace should expand accordingly.

### B.4.9 Vertical Accuracy Check (millirho)

1. Attach an open to the CT100B.
2. Position a cursor on the trace so that it is well after the open.
3. The vertical measurement should be between 940 millirho and 1060 millirho.

### B.4.10 Vertical Position Check

1. Increase vertical scale to 500 m $\rho$ /div by turning the *VERTICAL SCALE* knob counterclockwise.
2. Use the *VERTICAL POSITION* knob to move the live trace completely above the horizontal midline of the screen.
3. Use the *VERTICAL POSITION* knob to move the live trace completely below the horizontal midline of the screen.

A CT100B must succeed at both operations to pass the Vertical Position Check.

### B.4.11 Distance Cursor Resolution Check

Distance cursor resolution is a value determined by a constant. It can be measured by counting distinct locations that a cursor may occupy between two division lines, including one of the division lines.

### B.4.12 Cursor Readout Range Check

1. In the *Measurement* menu, toggle on *Extra Long Mode*.
2. Turn the *HORIZONTAL SCALE* knob counterclockwise until horizontal scale is maximized.
3. Using the *M-FUNC* button and *M-FUNCTION* knob, set  $V_p$  to 1.000.
4. With the *HORIZONTAL SCALE* knob, position a cursor at the most far right position possible.
5. The absolute distance measurement for the cursor is the upper limit for cursor readout range. This number should be larger than 12,000 m or 40,000 ft.
6. Position a cursor at the most far left position.
7. The absolute distance measurement for the cursor is the lower limit for cursor readout range. This number should be less than -1 ft. (-0.3 m).

### B.4.13 Cursor Readout Resolution Check

1. Use the *HORIZONTAL SCALE* knob to set the horizontal scale to 0.00330 ft./div or 0.001 m/div.
2. Position a cursor on the screen and note the absolute distance measurement for the cursor.
3. Move the cursor the smallest possible step using the *HORIZONTAL POSITION* knob. The difference between the new distance measurement and the previous is the minimum cursor readout resolution.

### B.4.14 Distance Measurement Accuracy Check

Accuracy is determined by taking a cable of known length and velocity and comparing the known values against measured values. Accuracy is reported as a percentage. When determining accuracy, ensure that horizontal calibration has been performed accurately.

Accuracy should be checked for Short, Medium, and Long settings.

### B.4.15 Ohm Readout Range Check

1. Connect the 36 in. reference cable to the CT100B.
2. Position a cursor on the trace well beyond the end of the cable. The vertical impedance measurement should read  $\geq 1.5k$  ohms.
3. Position a cursor on the trace well before the leading edge of the pulse. The vertical impedance measurement should read  $\leq 0.1$  ohm.

### B.4.16 Resolution Check

Position a cursor at a point of the trace where the vertical impedance measurement is greater than 0.1 ohm and less than 1500 ohms. The CT100B should display 3 digits for this measurement.

### B.4.17 Vertical Accuracy Check (ohms)

1. Vertical accuracy is checked by comparing CT100B impedance measurements against a load of known impedance. The supplied 50 ohm terminator is required.
2. Within the *Main* → *Settings* → *Display* submenu, select the *Ohms Rho* button until *Ohms* is marked with asterisks. An ohms at cursor reading now appears on the right side of the screen.
3. Connect a 50 ohm terminator onto the front panel cable connector.
4. Move a cursor out to a length greater than 300 ns. Impedance may change a small amount from point to point.
5. Average impedance amongst a number of points along the trace determines vertical accuracy. Impedance at cursor should be between 45 and 55 ohms.
6. Vertical accuracy should be checked for Short, Medium, and Long cable lengths.

### B.4.18 Horizontal Scale Check

1. From the *Main* menu, set *Cable Len* to Long.
2. Using the *M-FUNC* button and *M-FUNCTION* knob, set *Vp* to 1.000.
3. Turn the *HORIZONTAL SCALE* knob counterclockwise. Horizontal scale should increase beyond 61 m/div or 200 ft./div.
4. Turn the *HORIZONTAL SCALE* knob clockwise. Horizontal scale should decrease below 0.01 m/div or 0.03 ft./div.

### B.4.19 Horizontal Range Check

See the cursor readout range instructions in Section B.4. Horizontal range and cursor readout range are always equal.

### B.4.20 Horizontal Position Check

This test is passed implicitly when the Cursor Readout Range and Horizontal Range checks are passed.

## C. Options and Accessories

### C.1. Options

Model CT100B (BNC) – self-grounding BNC test port

Model CT100B (SMA) – stainless-steel SMA test port

Model CT100HF – high-frequency sampler, stainless-steel SMA-type test port

### C.2. Accessories

#### C.2.1. Standard BNC Accessories – CT100B (BNC)

BNC 50 ohm 36 in. Reference Cable	CT100-AC-W536
SMA 50 ohm Terminator	CT100-AC-ER50-S
Connector, SMA Female to BNC Male	CT100-AC-ISFBM
BNC Female to Female Adapter	CT100-AC-IBFF
BNC Male to Male Adapter	CT100-AC-IBMM
BNC Shorting Cap	CT100-AC-IBS
24 VDC External Charger/Power Supply	CT100-AC-PS
Operator's Manual, Printed	CT100B-M-OM-xxx*
CT Viewer™ 2 Quick User Guide, Printed	CT100B-M-CTVM-xxx*
CT Viewer™ 2 Installation DVD, w/ Digital Operator's and CT Viewer™ 2 Manuals	CT100-S-CTV2-xxx*
Soft Carrying Case	CT100-AC-CS
NIST-Traceable Calibration with Certificate	CT100-AC-NISTCC

\* xxx applies to revision number. Accessory part number is incremented per revision.

**C.2.2. Standard SMA Accessories – CT100B (SMA), CT100HF**

SMA 50 ohm 36 in. Reference Cable	CT100-AC-W536-S
SMA 50 ohm Terminator	CT100-AC-ER50-S
SMA Male to Male Adapter	CT100-AC-ISMM
Connector, SMA Female to BNC Male	CT100-AC-ISFBM
Connector, SMA Male to BNC Female	CT100-AC-ISMBF
Connector, SMA Female Short	CT100-AC-ISSF
SMA Shorting Cap	CT100-AC-ISS
24 VDC External Power Supply	CT100-AC-PS
Operator's Manual, Printed	CT100B-M-OM-xxx*
CT Viewer™ 2 Quick User Guide, Printed	CT100B-M-CTVM-xxx*
CT Viewer™ 2 Installation DVD, w/ Digital Operator's and CT Viewer™ 2 Manuals	CT100-S-CTV2-xxx*
Soft Carrying Case	CT100-AC-CS
NIST-Traceable Calibration with Certificate	CT100-AC-NISTCC

**C.2.3. Optional Accessories**

Hard Carrying Case (Pelican)	CT100-AC-CH
MIL-STD-1553B/TRB Adapter Kit	1553-TRBKIT
Phase Stable Cable 3 ft. SMA (M-F)	CT100-AC- PSCSMSF36
25 ft. (300") 50 Ohm Test Cable	CT100-AC-W5300
Small Form-Factor Keyboard	CT100-AC-KBD
BNC Adapter Kit	CT100-AK-BNC
SMA Adapter Kit	CT100-AK-SMA
Ethernet Adapter Kit	CT100-AK-ETH
Pin and Socket Probe Kit	CT100-AK-PSP
Impedance Matching Kit 75, 93, 125 ohm (BNC)	CT100-IK-BNC
Internal Battery (2700 mAh NiMH, 12 AA cells, 14.40 V, 38.88 Wh)	CT100-AC-B2700



## D. $V_p$ of Common Cables

### D.1. Cable Types

Commonly encountered cable designations, along with their associated characteristic impedances and typical  $V_p$  values, are listed below. A more complete listing is stored in the CT100B's internal memory. Note that the actual  $V_p$  of a given cable can vary by manufacturer, manufactured lot, cable age and condition, whether it is flat or coiled on a roll, and other variables. The most accurate way to test a cable is to determine the  $V_p$  of the cable using the CT100B and a known length of the cable you wish to test. See Section 4.4 for more information on determining the  $V_p$  of a cable.

### D.2. Dielectric Material

**Table D.1.**  $V_p$  of Common Dielectric Materials

Type	Probable $V_p$
Jelly-filled	0.64
Polyethylene	0.66
PTFE / TFE	0.70
Pulp	0.72
Foam / cellular PE	0.78
Semisolid PE	0.84
Air	0.98

### D.3. RG Standards

**Table D.2.**  $V_p$  of RG Standards

Designation	$Z_0$ (ohms)	$V_p$
RG-6/U	75	0.66
RG-6/UQ	75	0.66
RG-8/U	50	0.66
RG-9/U	51	0.66
RG-11/U	75	0.66
RG-58/U	50	0.66
RG-59/U	75	0.66
RG-62/U	92	0.84
RG-62A	93	0.84
RG-174/U	50	0.84
RG-178/U	50	0.69
RG-179/U	75	0.67
RG-213/U	50	0.66
RG-214	50	0.66
RG-218	50	0.66
RG-223	50	0.66
RG-316/U	50	0.66
RG-393	50	0.66

### D.4. MIL-C-17 Standards

**Table D.3.**  $V_p$  of MIL-C-17 Standards

Designation	$Z_0$ (ohms)	$V_p$
M17/2-RG6 (RG-6/U)	75	0.66
M17/163-00001 (RG-8/U)	50	0.66
M17/6-RG11 (RG-11/U)	75	0.66
M17/155-00001 (RG-58/U)	50	0.66
M17/29-59 (RG-59/U)	75	0.66
M17/173-00001 (RG-174/U)	50	0.84
M17/169-00001 (RG-178/U)	50	0.69
M17/094-RG179 (RG-179/U)	75	0.67
M17/172-00001 (RG-316/U)	50	0.66
M17/127-RG393 (RG-393/U)	50	0.66

## D.5. Commercial Designations

**Table D.4.**  $V_p$  of Commercial Designations

Designation	$Z_0$ (ohms)	$V_p$
H155	50	0.79
H500	50	0.82
LMR-200	50	0.83
HDF-200	50	0.83
CFD-200	50	0.83
LMR-400	50	0.85
HDF-400	50	0.85
CFD-400	50	0.85
LMR-600	50	0.87
LMR-900	50	0.87
LMR-1200	50	0.88
LMR-1700	50	0.89

## D.6. Twisted Pair

**Table D.5.**  $V_p$  of Twisted Pairs

Designation	$Z_0$ (ohms)	$V_p$
CAT5	100	0.71
CAT6	100	0.71



## E. Maintenance and Service Instructions

### E.1. Cleaning and Lubrication

Ensure that the CT100B power is off before cleaning. Clean the CT100B with a damp cloth. Clean the LCD screen with LCD screen cleaner or optical lens cleaner. Do not use any powerful solvents when cleaning the CT100B.

The CT100B does not require lubrication.

### E.2. Cleaning and Lubrication Interval

Clean as necessary. The CT100B does not require lubrication.

### E.3. Battery Removal/Replacement

1. Ensure that the CT100B is powered off.
2. Remove all external devices and power connections from the instrument.
3. Apply the front cover (part CT292) and lay the instrument face down on a smooth surface.
4. Remove the two cross-top screws from the rear of the instrument.
5. Swing the handle to the back of the instrument.
6. Using a long handled cross-top screwdriver, remove the two pairs of screws from both ends of the instrument nearest the handle mounts.
7. Carefully remove the rear housing (CT291) from the front panel (CT290B), using the handle for gripping. The housing may be tight and the rubber feet may momentarily catch while they slide past the metal frame.
8. The battery pack should now be exposed at the lower rear of the instrument.
9. Unclip the 3-pin battery connector by pressing on the release tab and pulling on the connector housing.
10. Remove the two cross-top screws mounting the battery clips (part CT112) to the chassis.
11. Lift the battery pack out.

To re-install or replace the battery, repeat the above steps in reverse order.

### E.4. Calibration and Calibration Interval

The recommended calibration interval is 1 year, and operator performance checks should be completed every 6 months. See Appendix B for instructions on how to determine if your instrument should be calibrated between scheduled calibrations. Contact MOHR to schedule calibration.

## E.5. Install CT100B License

The CT100B license can be installed on the device using either CT Viewer 2 or a USB flash drive.

### E.5.1 Install License Using CT Viewer 2

1. On a computer with CT Viewer 2 installed, start up CT Viewer 2 by double-clicking on the icon.
2. Power on the CT100B and let it boot completely.
3. Connect the CT100B to the computer using either USB or Ethernet from the back of the device. See Section 6 for instructions on connecting to a CT100B over Ethernet.
4. In CT Viewer 2, click on *Help* → *Install License*.
5. Select the license file sent by MOHR.
6. Click *OK*.
7. After receiving a message of a successful install, restart the device.

### E.5.2 Install a License Using a USB Flash Drive

**Note:** If multiple license files are on a USB flash drive, the CT100B will reject the file. Make sure the intended license file is the only MOHR license file on the drive.

1. Copy the file to an empty USB flash drive. (Do not change the file name.)
2. Power on the CT100B device and let it boot completely.
3. Attach the USB flash drive to a front USB port on the CT100B.
4. Push the blue button (*MENU* button) to bring up the *Main* menu.
5. Using the soft-menu buttons, navigate to *Settings* → *Info* → *License* → *License from USB*.
6. After receiving a message of a successful install, restart the device.

## E.6. Clean Storage

The CT100B has a large storage capacity, but if more space is needed, perform the following steps to clean the internal storage of the CT100B.

1. Delete saved traces following the instructions in Section 4.9.5.2. If desired, first archive the traces by transferring them to CT Viewer 2.
2. After removing the scans, clean the database with *Settings* → *Diagnostics* → *Database* → *Clean Database*.

## F. Operator Troubleshooting

### F.1. General Information

Use this troubleshooting guide when there is a problem with a CT100B or to assist with problem identification. This will help you to determine if the instrument should be repaired or is acceptable to continue using. Any time one of the internal thermal fuses actuates with an audible click, indicating thermal overload, turn off the rear panel battery-disconnect switch immediately and have the instrument serviced as soon as possible.



*CAUTION: DO NOT continue using the CT100B if it exhibits signs of thermal overload, such as emitting heat or smoke, or if it smells of burning plastic.*

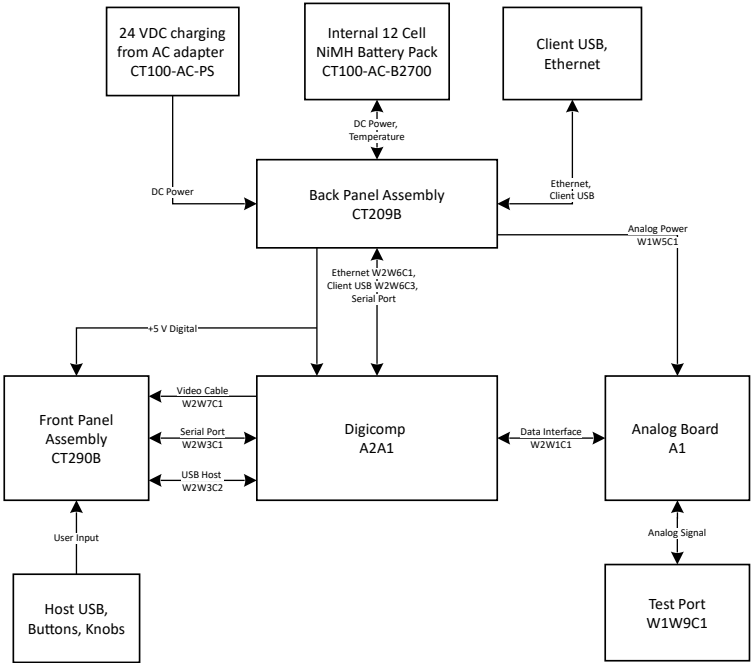
### F.2. Power On Test

Verify that the back switch is in the ON position. Press the front red button to turn the instrument on. If the instrument does not show anything on the screen within 20 seconds, turn the back switch to the OFF position, unplug all USB and Ethernet devices, and attempt to turn it on again.

### F.3. Functional Block Diagram and Troubleshooting Flowcharts

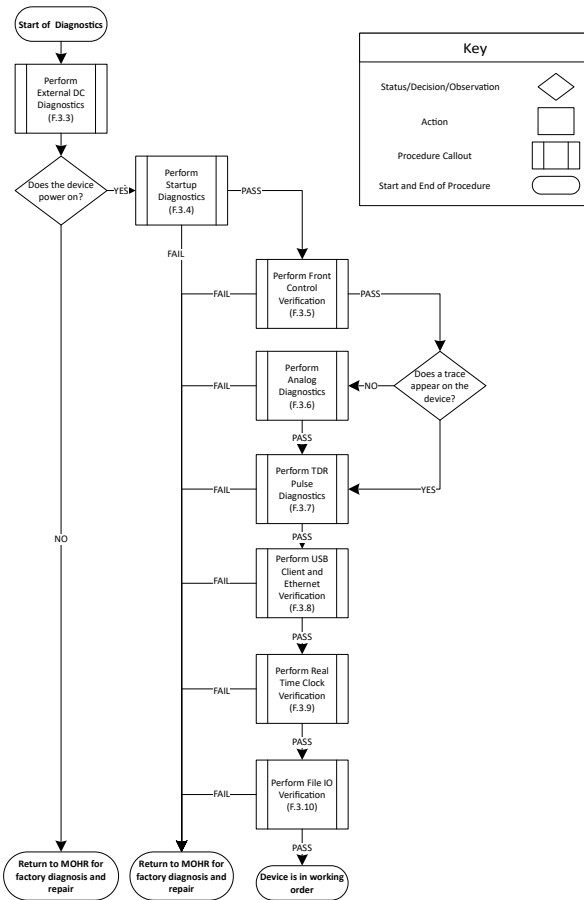
Use the following functional block diagram and troubleshooting flowcharts for various parts of the CT100B to determine if your CT100B requires service. See Parts List for a replaceable parts list.

F.3.1 Functional Block Diagram

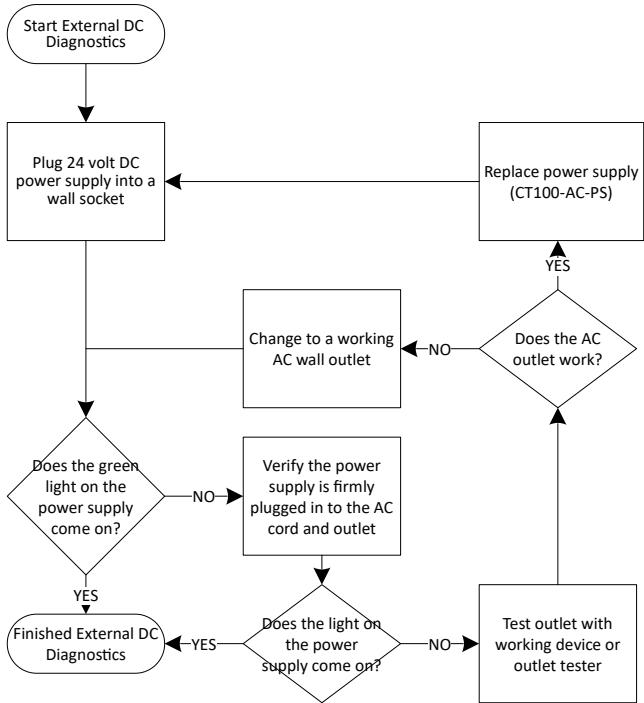




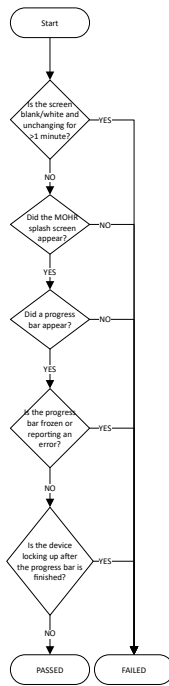
## F.3.2 Main Diagnostic Sequence



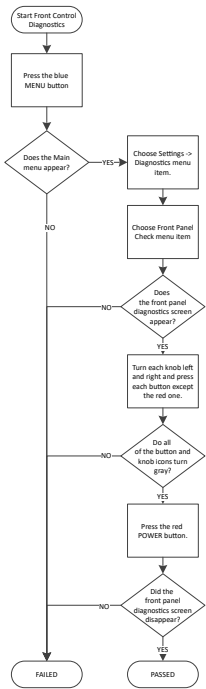
F.3.3 External DC Diagnostics



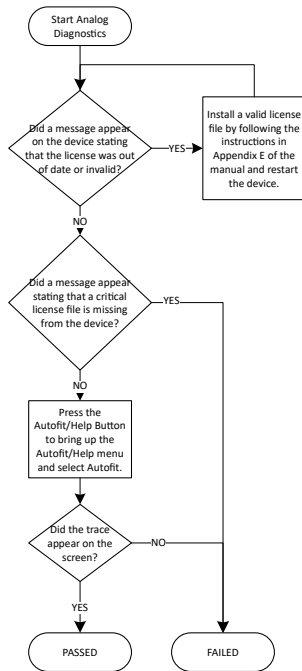
### F.3.4 Startup Diagnostics



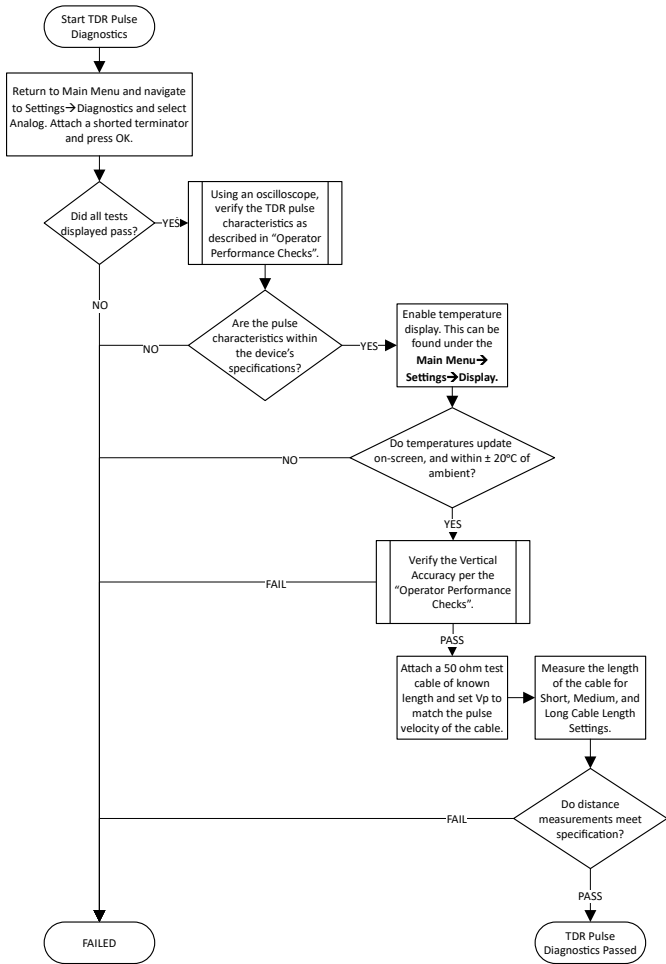
F.3.5 Front Control Verification



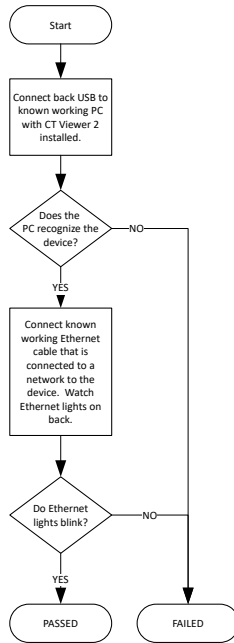
### F.3.6 Analog Diagnostics



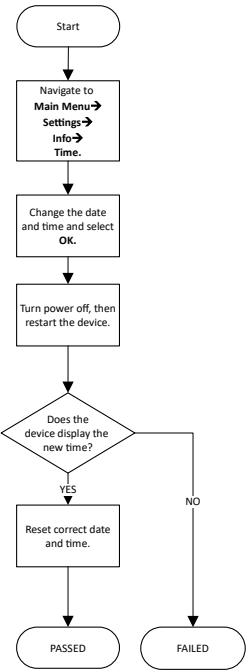
F.3.7 TDR Pulse Diagnostics



### F.3.8 USB Client and Ethernet Verification

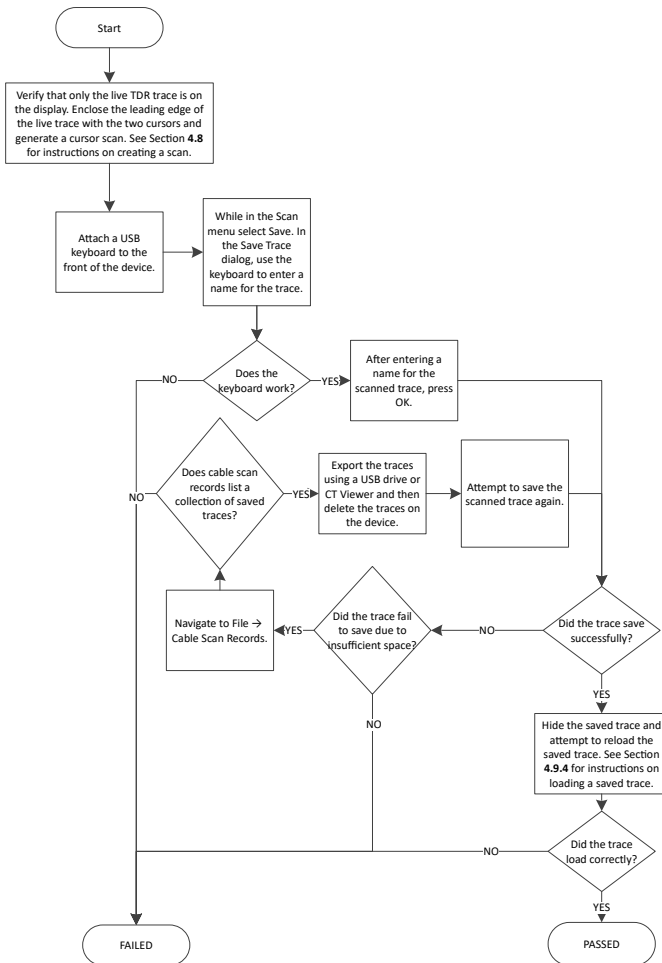


F.3.9 Real Time Clock Verification





### F.3.10 File IO Verification



## F.4. Parts List

Subassembly	Item	Part No.	Qty.	Description
CT100B	—	CT100B	—	CT100B TDR Cable Tester
	1	CT291	1	Rear Housing
	2	CT292	1	Front Cover
Front Panel Assembly	—	CT290B	—	LCD display, front control board, switches, cables, and knobs
	1	W2W7C1	1	Digicomp-video PCB FFC 40 pin flat-flex 0.5 mm space
	2	W1W9C1	1	Coaxial Cable Assembly
Analog-Digicomp Assembly	—	CT208B	—	Analog-Digicomp Assembly
	1	A1	1	Analog Board Assembly
	2	A2A1	1	Digicomp Board
	3	A2A3	1	microSD Card
	4	A2A4	1	Clock Battery
	5	W2W1C1	1	Digicomp to Analog Board FFC
	6	W2W3C1	1	Serial Port Cable Assembly, Front
	7	W2W3C2	1	USB Host Cable
Back Panel Assembly	—	CT209B	—	Power board, back bezel, battery, cables, and fan
	1	CT100-AC-B2700	1	Battery set NiMH with thermistors (2700 mAh)
	2	W1W5C1	1	Analog Power Cable
	3	W2W6C1	1	Ethernet cable
	4	W2W6C2	1	Ethernet LED Cable
	5	W2W6C3	1	USB client cable

# Glossary

- Aberrations** Imperfections or undesired variations in a signal. For example, aberrations in a TDR's excitation signal are the result of the finite switching speed of the instrument's electronics and cause it to deviate from a perfect step signal.
- AC** Alternating current, a method of delivering electrical energy by periodically changing the direction of the electric field in a conductor.
- Accuracy** The difference between a measured or estimated value of a quantity and its true value. Accuracy and precision are both important factors to consider when assessing the reliability of a measurement.
- Analog** Refers to a signal that is continuous with respect to both time and value. Analog circuitry produces and/or measures analog signals. This is in contradistinction to digital signals, which are discontinuous in both time and value. The sampling circuitry of a TDR converts the analog voltage signal detected on a cable to a digital value for representation on the display and in the instrument's memory.
- Cable** Conductors of electricity that are usually shielded and insulated. Cables typically contain at least two conductors, one to deliver the electrical signal and one to act as the return path. The conductor acting as the return path may be referred to as the "shield", "ground", or "ground wire". A cable with such a ground return path is known as an unbalanced cable, an example of which is typical coaxial cable. Another general type of cable is called balanced cable, an example of which is twisted-pair Ethernet cable. In balanced cable, two signal wires carrying differential signals of opposite polarity are both separated from ground by an equal impedance.
- Cable Attenuation** A quantity describing the energy in a signal that is absorbed, reflected, or otherwise lost during propagation through a cable. Higher frequencies are typically the most susceptible to attenuation. Cable attenuation can distort some TDR measurements. Attenuation is often expressed in decibels (dB) at one or more frequencies. See also dB and Return Loss.
- Cable Fault** A defect in a cable or other condition that makes a cable less able to deliver electrical energy than was designed. Damage to the shield, conductor, or insulation, bad splices, and poorly mated connectors are frequently encountered cable faults.
- Capacitance** See Reactance
- Characteristic Impedance** The ratio of the amplitude of voltage and current in an electrical signal propagating in a cable. In a coaxial cable, this value (usually written  $Z_0$ ) is, in large part, related to the geometrical relationship of conductor to return path conductor. Cables are usually designed to match the impedance of the source and load to which they are attached in order to maximize power transfer.
- Conductor** A substance that allows electricity to flow through it with minimal resistance. Most conductors are metals. However, there are many

non-metallic conductors, including salt solutions, graphite, and any element in its plasma state.

- dB** dB is the abbreviation for decibel. Decibels are a method of expressing power or voltage ratios as logarithms. When used for voltage ratios, as in TDR, the formula for decibels is  $dB = 20 \cdot \log_{10}(V_i/V_r)$  where  $V_i$  is the voltage of the incident pulse and  $V_r$  is the voltage reflected back by the load. The dB vertical scale on the CT100B refers to the amount of voltage gain the instrument applies to the signal before displaying it. For example, when the instrument is amplifying the voltage by a factor of 100, this indicator would read:  $verticalscale = 20 \cdot \log_{10}(100) = 40 \text{ dB}$ .
- DC** Direct current is unidirectional flow of electrical current. The term DC is also synonymous with constant; for example, a perfect DC voltage source does not vary from a set value. Batteries are an example of a DC voltage source.
- DHCP** Dynamic Host Configuration Protocol. Used in computer networks to automatically assign network settings to computers.
- Dielectric** A nonconducting substance or insulator. May also refer to the dielectric strength or relative permittivity of a medium, which is a measure of the electrical energy stored by a medium when an electrical potential of a given frequency is applied across it. See also Insulation.
- Digital** Refers to signals in which information is represented by variables that are discrete or discontinuous both in time and in value. This is in contradiction to an analog signal, which is continuous both in time and value.
- Domain** A mathematical term that refers to the set of values for which a function is defined. A time-domain instrument such as a TDR performs its function by recording measurements as a function of time.
- DUT** Device Under Test. The DUT is the electrical cable, device, or network that is attached to the port of the CT100B. It is the object to be measured.
- FFT** The Fast Fourier Transform algorithm is a fast method of performing a discrete Fourier transform on a time history. A Fourier transform converts time-domain data into the frequency domain. Since the CT100B always uses the FFT algorithm, the term is used in this manual to describe both the algorithm and its outputs. An “FFT Trace” is a frequency-domain trace created by running the FFT algorithm on a TDR trace.
- Impedance** The ratio of voltage to electrical current in a cable or circuit. Impedance is a frequency-dependent value that is influenced both by resistive and reactive components. Impedance is expressed in terms of ohms but should not be confused with resistance, which is a frequency-independent quantity. Most cables have impedances that vary little over the range of frequencies with which they are used. Impedance is described by  $Z = R + j \cdot X$  where  $R$  is resistance,  $j$  is the imaginary unit, and  $X$  is the reactance at a given frequency. See also Reactance and Resistance.
- Impedance Mismatch** A point in a cable or device under test in which the characteristic impedance changes, causing a partial reflection of the energy in a test signal. See also Reflection Coefficient.
- Incident Pulse** The excitation pulse produced by a TDR and injected into the cable under test. The trace produced by the TDR is the temporally resolved reflections produced by the cable in response to the incident

- pulse. The incident pulse in the CT100B is a step-rise signal with a finite rise time. See also Rise Time.
- Inductance** See Reactance.
- Insulation** A coating on an electrical conductor that inhibits the flow of electricity. Insulation serves as both a means of providing electrical safety and ensuring signal integrity.
- IP** Internet Protocol. The universal protocol used to send data through the internet. Also used in many other computer networks. Each computer on a network must have a unique IP address.
- Jitter** The uncertainty in measurement of time in a TDR. The main effect of jitter is to cause apparent vertical noise in areas of changing impedance. Areas of constant impedance, such as a flat segment of 50  $\Omega$  cable, will show no abnormality.
- Layer Peeling** A mathematical technique for reducing multiple reflections in a TDR trace. TDRs measure reflections from changes in impedance, but if there are multiple impedance changes, then the reflections from one will partially reflect back off of another. Reducing the effect of these extra reflections improves the measurement of the impedance changes.
- LCD** Liquid crystal display. The display used by this instrument is an active-matrix thin-film transistor LCD, abbreviated TFT-LCD.
- Millirho** ( $m\rho$ ) See Reflection Coefficient.
- Noise** Any undesirable electrical energy that impairs the ability of an electronic system to transmit or receive a signal or make an accurate measurement. In TDR, noise is typically related to thermal and/or electrical noise that interferes with the timebase or sampling circuitry and is usually random, although a nearby strong electromagnetic radiator can cause non-random synchronous noise to be measured on unshielded cable. In the case of random noise, averaging is an effective means of noise suppression.
- Open Circuit** Describes a non-terminated cable or cable with a broken conductor that reflects all energy within the incident pulse.
- OSL (Open Short Load)** A method of calibrating one-port analyzers using precision open, short, and load terminations, where the load matches the output impedance of the analyzer. Each termination contributes to reducing error in an  $S_{11}$  measurement.
- Phase** A horizontal shift in a sinusoid. Phase is given as an angle. A sinusoid with phase of  $\pi$  radians (180 degrees) is precisely inverted compared to the same sinusoid with 0 phase. A sinusoid with phase of  $2\pi$  radians (360 degrees) is precisely equal to the same sinusoid with 0 phase, i.e., it has no phase shift.
- Precision** The variation in the value of a variable measured multiple times. Precision and accuracy are both important factors in determining the reliability of a given measurement. Precision may also be used to describe the number of digits or the unit of the least significant digit with which a particular quantity is expressed.
- Reactance** The imaginary component of electrical impedance. Reactance describes the opposition of a conductor to the flow of alternating current.

Impedance is described by  $Z = R + j \cdot X$  where  $R$  is resistance,  $j$  is the imaginary unit, and  $X$  is the reactance at a given frequency. If  $X > 0$ , the impedance is inductive, if  $X = 0$  then the impedance is purely resistive, and if  $X < 0$  the impedance is capacitive.

**Reflection Coefficient** In TDR, a coefficient describing the amplitude of a reflected signal produced by an impedance mismatch in relation to the incident pulse. The reflection coefficient Gamma ( $\Gamma$ ) is defined by the relation  $\Gamma = (Z_t - Z_0)/(Z_t + Z_0)$  where  $Z_t$  is the impedance at time  $t$  and  $Z_0$  is the characteristic impedance of the cable, and is usually described in parts per thousand with units of rho ( $\rho$ ) or millirho ( $m\rho$ ). The coefficient  $\rho$  ranges from -1 (short circuit) to +1 (open circuit). A reflection coefficient of zero indicates that there is no impedance mismatch and no reflection of electrical energy.

**Reflectometer** An instrument that measures reflections to determine the state of a system. The CT100B measures the reflections of electrical energy.

**Resistance** A conductor's opposition to electrical current. The reciprocal of resistance is conductance. Electrical resistance can often be considered a constant that does not vary with respect to the voltage or current applied to an object. When considering the impedance of a circuit element, resistance is also frequency invariant. Most materials, including conductors, have some degree of electrical resistance. A special class of materials called superconductors demonstrates zero electrical resistance.

**Resolution** For a given parameter, the smallest increment that can be measured or displayed. In the setting of TDR, resolution may refer to timebase resolution, which describes the smallest increment of time used by the pulser-sampler system to produce signals and measure reflections, or spatial resolution, which is dependent on the system rise time and determines the ability of the TDR to separate two closely spaced cable faults.

**Return Loss** A measure of the power reflected by impedance changes in a cable. Return loss is typically expressed as a logarithm of the reflection coefficient,  $\rho$ :  $RL(dB) = -20 \cdot \log_{10} |\rho|$  where RL is return loss. Cable faults such as shorts and opens, which return all of the incident energy in the TDR signal, have return losses of 0 dB.

**Rho ( $\rho$ )** See Reflection Coefficient

**Rise Time** With respect to the incident pulse, the time required for the signal to change from 10% to 90%, or alternatively 20% to 80%, of its final value. With respect to the sampling electronics, the time required for the sampled value to change from 10% to 90% of the final value when a perfect step signal is applied. The rise time of a pulser-sampler system is approximately equal to the root sum of squares of the pulse and sampler rise times.

**RMS** An acronym for Root Mean Square, also abbreviated rms and known as the quadratic mean. This is a useful statistical technique when considering time-varying electrical quantities for which simple DC definitions are not accurate, such as when determining the power dissipated by an AC source. The formula for calculating an rms value of a given time-varying signal is:

$$x_{rms} = \sqrt{\frac{x_1^2 + x_2^2 + x_3^2 + \cdots + x_n^2}{n}}$$

where  $x_i$  represent discrete samples and  $n$  is the total number of samples.

- S<sub>11</sub>** A scattering parameter that measures complex return loss on port 1 of a linear electronic device. See Scattering Parameters.
- S<sub>21</sub>** A scattering parameter that measures complex transmission loss from port 1 to port 2 on a linear electronic device. See Scattering Parameters.
- Sampling Efficiency** The CT100B makes measurements through a process known as sequential sampling. In sequential sampling, a succession of incident pulses followed by discrete samples progressively builds up a given TDR trace. Sampling efficiency describes the ability of the sampling circuitry to adjust to rapid changes in impedance within a TDR trace. Low sampling efficiency leads to a trace that appears too smooth.
- Scattering Parameters** Scattering parameters are the complex ratios of output signal to input signal for a linear electronic device. For a device with two ports, four scattering parameters may be generated:  $S_{11}$ ,  $S_{21}$ ,  $S_{12}$ , and  $S_{22}$ . A one-port device has only one parameter,  $S_{11}$ , while a four-port device has 16.  $S_{11}$  is the complex ratio of output at port 1 to an input at port 1.  $S_{21}$  is the complex ratio of an output on port 2 to an input on port 1, and so on. The assignment of port 1 and port 2 is arbitrary. A full set of scattering parameters are considered a complete characterization of a linear device for the frequency range of the scattering parameters.
- Short Circuit** The condition in which the conductor in a cable or circuit comes into direct contact with the return path conductor or earth ground. The electrical length of the cable measured by TDR is shortened to the point of the short circuit.
- Smith Chart** A method for displaying complex valued electrical measurements, such as an  $S_{11}$ , on a polar plot, graphically showing both magnitude and phase angle.
- Smoothing** Any technique for reducing noise in a signal. The CT100B uses time averaging to smooth traces.
- SP232** A serial protocol used by the Tektronix 1502B and 1502C. This protocol allowed transmission of TDR trace data across a serial port. Using a USB to serial port adapter, a CT100B can emulate this protocol.
- Stability** The change in the accuracy of a measurement or piece of test equipment over a period of time such as the calibration interval. Stability may also refer to changes in accuracy related to a specific environmental influence such as vibration, temperature, or humidity.
- TDR** Acronym for Time-Domain Reflectometer or Reflectometry. TDR instruments use a form of closed-circuit radar to detect cable faults. A series of pulses are sent into a cable and reflected voltage is measured as a function of time. If the velocity of propagation ( $V_p$ ) is known, the length of a cable and the distance to cable faults can be determined. TDR traces produced by step-rise TDRs like the CT100B describe the impedance of a cable along its length and can accurately detect a wide range of cable faults that can impair high-frequency analog/RF and digital communications systems.
- Trace** A displayed or stored signal. When displayed, a trace appears as a line across the screen. A trace may be a direct TDR measurement, as with the live trace, or derived trace, such as a difference trace or an  $S_{11}$  trace. A trace is sometimes referred to as a “waveform”. A scanned or saved trace may be called a “scan”. A trace is a visual representation of the waveform generated by a TDR. Traces on the CT100B may be in either time or frequency domain depending upon their purpose.
- Trace Averaging** See Noise.

**USB** Universal Serial Bus. A common system for connecting a peripheral, such as a printer, phone, or CT100B, to a computer.

**Velocity of Propagation (Vp)** Velocity of propagation of an electrical signal within a cable as a fraction of  $c$ , the speed of light in a vacuum. Coaxial cable usually has a Vp of between 0.6 and 0.9.

**Vertical Reference (Vert Ref)** A feature of the CT100B that improves vertical measurements by referencing them to scans from short and open calibration terminations.



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