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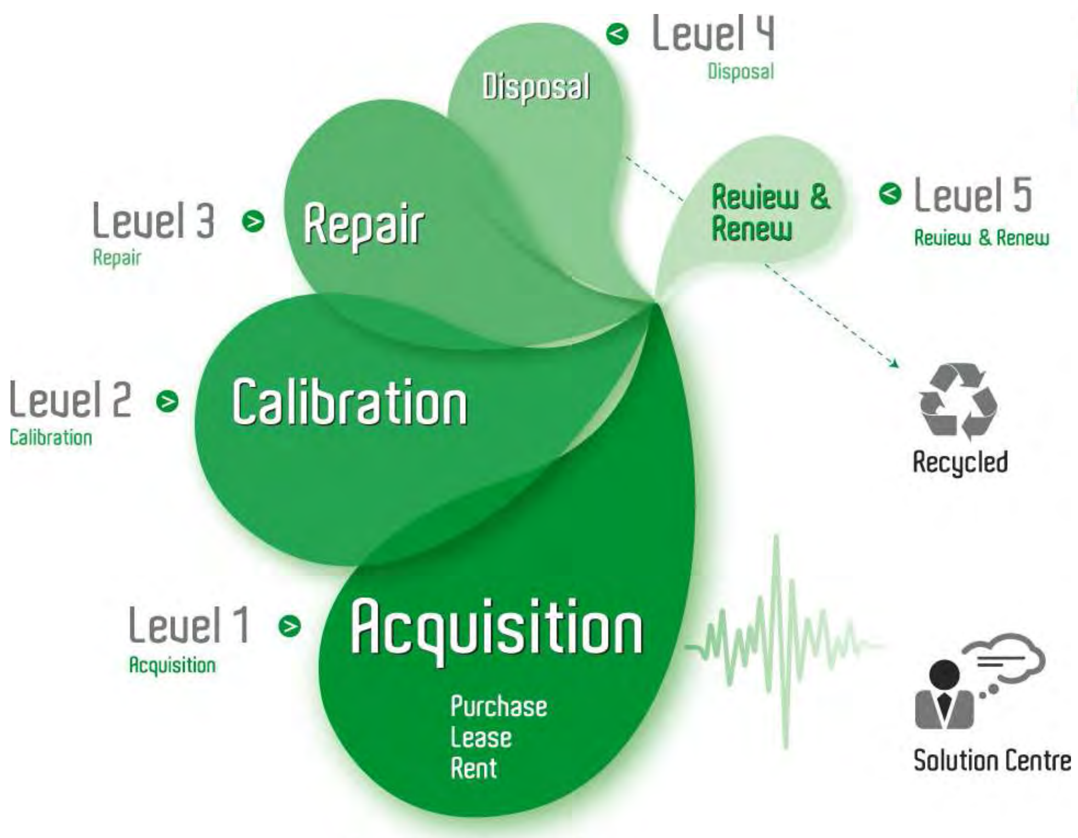

Product Lifecycle Management System

MOHR™

Operator's Manual

CT100 and CT100HF
Automated Metallic Time-Domain Reflectometers

Part No.: CT100-M-OM-003
CAGE Code: 4JEE1
Revised: July 20, 2010

Copyright Notice

Mohr and Associates, 1440 Agnes Street, Richland, WA 99352 USA

Warranty

Purchase and/or use of this product signifies your agreement to the terms of this Warranty. Mohr and Associates (Mohr) warrants that this product will be free from defects in materials and workmanship for a period of one (1) year from the date of shipment. If any such product proves defective during this warranty period, Mohr, at its option, either will repair the defective product without charge for parts and labor, or will provide a replacement in exchange for the defective product.

In order to obtain service under this Warranty, customers must notify Mohr of the defect before the expiration of the warranty period and make suitable arrangements for the performance of service. Customers shall be responsible for packaging and shipping the defective product to Mohr with shipping charges prepaid. Customer shall be responsible for paying all return shipping charges, duties, taxes, and other charges for units returned to any location.

This Warranty is given by Mohr with respect to this product in lieu of any other warranties expressed or implied. Mohr and its vendors disclaim any implied warranties of merchantability or fitness for a particular purpose. Mohr's responsibility to repair or replace defective units is the sole and exclusive remedy provided to the customer for breach of the Warranty. Mohr and its vendors will not be liable for any indirect, special, incidental, or consequential damages irrespective of whether Mohr or the vendor has advance notice of the possibility of such damages.

Specific limitations of this Warranty:

This Warranty only applies to normal and reasonable use of this product. Damage to this product resulting from improper use, the determination of which is solely at the discretion of Mohr, is specifically excluded from this Warranty.

Electrical damage to this product resulting from connection of a cable or device carrying a static electrical charge to the front panel BNC connector or SMA connector without first properly grounding the conducting elements of the cable or device is specifically excluded from this Warranty.

Electrical damage to this product resulting from connection of a cable or device carrying an electrical signal or other non-zero electrical potential relative to earth ground to the front panel BNC connector or SMA connector is specifically excluded from this Warranty.

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Table of Contents

List of Figures

List of Tables

General Information

Product description

The Mohr CT100 / CT100HF Automated Metallic Time-Domain Reflectometers (MTDRs) use a form of closed-circuit radar known as Time-Domain Reflectometry (TDR) to test cables for defects. These instruments apply a very fast risetime step signal to the cable under test and then measure the reflected voltage at very short time intervals. The resultant TDR trace allows the operator to identify changes in impedance within the cable indicating the presence of faults such as opens, shorts, kinks, defects in the shield or conductor, foreign substances such as water, or thermal damage. The CT100 and CT100HF can find extremely subtle cable defects that may be missed by other testing devices.

The CT100 series TDRs have specifications unmatched by any other commercially-available metallic TDR cable tester. Both devices feature timebase resolution of 0.76 ps regardless of cable length, equivalent to approximately 75 µm in coaxial cable with a Vp of 0.66. This allows for extremely precise cable length measurements and localization of cable defects. Fast system risetimes ensure excellent spatial resolution and make these instruments particularly valuable for troubleshooting modern high-frequency analog/RF and digital communications systems.

The CT100 is able to perform continuous sequential sampling at up to 250 kHz, continuously acquiring up to 500 full 500-point TDR traces per second. In concert with the CT100's high-speed internal 32-bit processor, this allows for rapid automated cable scans, sophisticated real-time digital filtering techniques (averaging, subtraction, derivatives, and more), and accurate characterization of transient cable defects.

The CT100 can store hundreds of full-length high-resolution cable scans or several thousand short or lower-resolution cable scans in its standard 2 GB internal non-volatile flash memory. These scans are easy to call up for comparison so that changes in cable integrity over time can be accurately assessed. To enter data, use the built-in software keyboard or plug an external barcode reader or keyboard into the front-panel USB connector. It is easy to connect the CT100 to a host PC using 10/100 Ethernet or USB to view, analyze, and store your data.

In the remaining sections, the specific requirements, capabilities, and operation of the CT100 and CT100HF are described in detail. Unless otherwise specified, any reference to the CT100 is true of the CT100HF as well. Figures in this text were acquired using both CT100 and CT100HF devices.

Battery pack and AC power requirements

The CT100 may be operated using either the supplied external AC adapter, the internal NiMH batteries (for a minimum 6 hours operating time, typical use), or optional hot-swappable external 14.4 VDC battery packs (for unlimited portable use). The internal NiMH battery charges under AC during normal operation.

The external AC power adapter is intended to be used with either a 120 VAC or 240 VAC RMS power source. Use of a standard 3-prong AC socket with intact ground connection is essential for safe operation of the CT100 with the included AC power adapter. Review the *Safety Summary* section before operating the CT100.

Options and accessories

Options and accessories available for the CT100 are described as part of the *Options and Accessories* section of this manual.

Unpacking and initial inspection

Before opening the shipping package containing the CT100, first 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 CT100 and standard accessories, including an *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 CT100 is damaged, defective, or does not meet operational requirements, contact a Mohr-authorized sales representative.

Repacking for shipment

When the CT100 needs to be shipped to a Mohr-authorized service center for repair, calibration, or other service, affix a label to the outside of the shipping container indicating the name, address, phone, and e-mail of the owner, the name of the Mohr service representative who was contacted regarding the shipment, the serial number of the instrument, and a 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 CT100 for shipment. Otherwise, the following steps should be taken:

1) Obtain a heavy-duty corrugated cardboard box at least 6 in. (15 cm) larger in each dimension than the equipment to be shipped, to allow for protective cushioning material. The shipping carton should have at least 200 lb. (90.7 kg) test strength.

2) Make sure the CT100 is turned off by setting the rear panel power switch to the OFF position.

3) Install the front panel cover.
4) Wrap the CT100 in polyethylene sheeting to protect the case.
5) Place the CT100 in its soft case.
6) Cushion the CT100 on all sides with equal amounts of urethane foam or other firm packing material so that the instrument is centrally situated in the shipping container and there is no free space for the CT100 to move about during shipment.
7) Seal the container with packing tape.

Safety Summary

The safety information presented in this brief summary is only intended for operators of the CT100 and CT100HF. 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 CT100 and take note of safety information not included in this summary.

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.

Terms on the product

DANGER

Indicates an injury hazard immediately accessible as you read the marking.

WARNING

Indicates an injury hazard not immediately accessible as you read the marking.

CAUTION

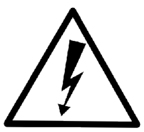
Indicates a hazard to property including the product.

Symbols in the manual

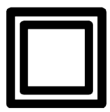
WARNING or CAUTION Information

Symbols on the product

ATTENTION Refer to the Manual



DANGER High Voltage



Double Insulated

Protective Ground (Earth) Terminal

Static charge

Any cable or wire can carry a significant static electric charge that could damage the sensitive electronics of the CT100/CT100HF. For this reason, it is essential to ground any cable or device about to be tested before attaching it to the front panel BNC or SMA adapter.

> *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.*

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. One of the circuit breakers automatically resets after time. When this breaker cools, the CT100 can be restarted. There is also a breaker on the CT207 subassembly A4 charger board. If tripped, this breaker must be reset by taking the rear case off, locating the breaker assembly, and pushing its reset tab. The tab is located at the far end of the board, nearest to the fan.

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

AC power source

The CT100 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 / adapter 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.

Grounding the CT100

When the CT100 is connected to the external AC adapter, the CT100 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 CT100 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 CT100 chassis, screen, and electronic controls. An isolated ground power supply is an optional accessory available upon request.

At all times, the front panel BNC connector is floating and is isolated by at least 500 VDC from the remainder of the CT100. This eliminates measurement errors caused by common-mode noise and slight ground-potential differences in the the cable / device under test. However, care should be taken with respect to electrical safety, as the front panel BNC 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 connector shield represents a floating ground and is never safely grounded even with the use of a properly grounded AC adapter. Never use the CT100 to test any cable or device carrying a non-zero electrical potential relative to earth ground, as this could render an electric shock.

Danger arising from loss of ground

When disconnected from the AC power adapter, the CT100 is no longer grounded unless connected to a grounded USB device. Because the BNC connector shield is floating relative to the remainder of the instrument, the BNC connector may be operating at an elevated voltage even when the AC adapter is connected. Therefore, the BNC 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.*

Explosive atmospheres

Do not operate the CT100 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).

Do not remove covers or panels

To avoid personal injury and risk of electric shock, do not open the CT100 case and do not operate unless the case is fully intact.

Connecting cables to the front panel BNC

To avoid damage to the CT100 and the very sensitive sampling electronics associated with the front panel BNC 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 CT100's front panel BNC connector. Failure to do so can damage the instrument's sensitive sampling electronics and will void the Warranty.*

Battery replacement and disposal

The CT100 contains a 2700 mA·h internal battery pack consisting of 12 AA NiMH batteries, as well as a single Lithium coin cell battery for the internal clock. 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 and Associates for recycling.

Operating Instructions

Overview

Handling

The CT100 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 CT100 front panel is protected from impact by a snap-on front cover, in which an optional small-format version of the *Operator's Manual* can be stored. The carrying handle rotates 360° and can be used to support the instrument for bench-top use.

The CT100 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 CT100 and CT100HF are sensitive to damage introduced by electrostatic discharge. Always properly ground the center conductor of a cable before attaching it, either directly or indirectly, to the front panel BNC or SMA connector. Failure to do so could damage the sampling electronics and void the Warranty.

The CT100 can be stored in temperatures of between -20°C to +60°C with or without a battery installed and can be operated from 0°C to +50°C.

Powering the CT100

The CT100 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 2.5 hours to reach full charge.

There is an option to use external, hot-swappable 14.4 VDC NiMH battery packs to power the CT100. These battery packs plug into the back panel external battery connector and can be charged while the CT100 is run on AC power. When connected, the device automatically powers off of the external battery pack until it is discharged. By default, the CT100 charges the internal battery until full before charging the external battery.

Fusing is internal and based on thermal reset switches and a manual-reset breaker located on CT207 subassembly A4. If one of these fuses trips, it may indicate that a hardware malfunction has occurred. Diagnostic steps should be taken to determine this.

Caring for the battery

The CT100 has an intelligent internal 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. 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.

Charging and power status

The CT100 operates from a 24 volt power adapter, internal battery pack, or an external battery pack. When plugged into an adapter, the CT100 will preferentially charge the internal battery pack over any connected external pack. When operating off of batteries, the CT100 will prefer to use an external battery pack over the internal battery pack.

When an external battery pack is connected and fully charged, the CT100 will return to trickle-charge the internal battery pack. However, as long as the internal pack remains fully charged, the CT100 will immediately switch to charging the external battery each time it is disconnected and a external pack is reconnected. In this fashion, a single CT100 can be used to charge several external battery packs in sequence.

In the *Powe*r menu, a submenu of the *Main* menu, the user can set power save and shut down timers. Different time out values can be set for when the CT100 is using the AC/DC converter or is using 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 CT100 wakes back up. When a shutdown timer expires, the CT100 will turn off.

Also in the *Power* menu, the user can toggle the *Charge External/Internal* option to determine which battery pack has priority when charging. By default, the CT100 will charge the internal battery pack until it is full, then switch to charging the external battery pack.

A voltage readout can be turned off and on with the *Power Display* menu option in the power menu. Power sources that are attached, whether DC (24 volt adapter), battery (internal battery pack), or external, will have their voltages displayed on the screen. The color of the voltage text indicates the state of the power source. If green, then that source is powering the CT100. If red, then that source is being charged.

Batteries and long-term storage

The CT100 has NiMH internal batteries. These batteries will drain if the CT100 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 CT100 is set to the off position.

After several months of storage, the internal batteries may be completely drained. Allow up to 24 hours for the first re-charge of the CT100 after coming out of long-term storage.

Low battery

When a low battery condition is first encountered, the CT100 alerts the user with a red warning. An “Internal Battery Low” message appears when the battery percentage left drops below 20 percent.

Preparing to use the CT100

Before using the CT100, make sure you have read and understand the *Safety Summary* section and power requirements described in the previous sections. Then remove the front cover and turn on the power. You are ready to test cables using the most versatile and sophisticated stand-alone TDR on the market.

Front panel controls and connectors

The following numbered items describe the controls and connectors identified in the front panel diagram below (Figure 1).

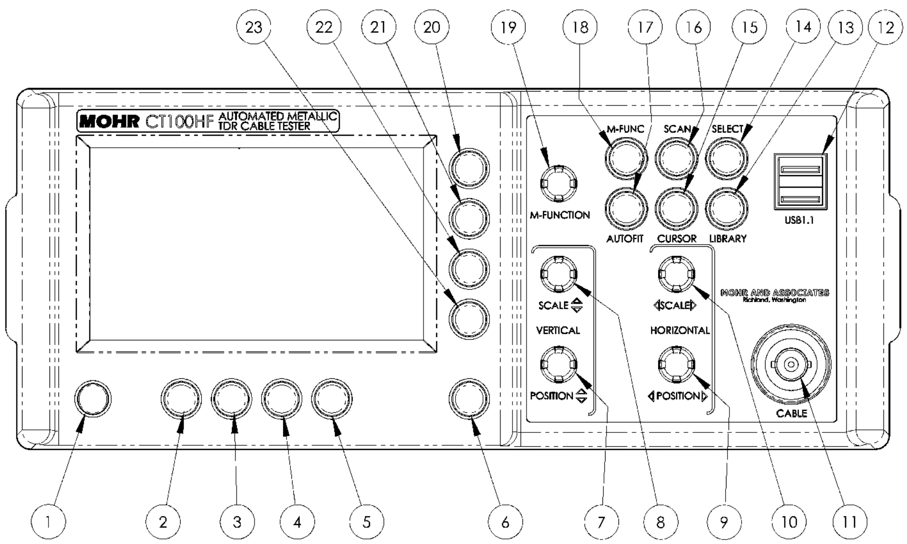


Figure 1: Diagram of the front panel of the CT100 / CT100HF.
Numbered controls and connectors are described in the text below.

1) *POWER* button. Pressing this button turns the instrument on when the main power switch on the rear panel is in the ON position. Press the power button when the unit is on to call up the *Shutdown* menu. It has three options: *Vacuum Database*, which cleans unused records from the device, creating more free space; *Clean Shutdown*, which shuts the unit off in the nicest possible manner (this also results in more available free space); and *Cancel*, which exits the shutdown menu.

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* button. Push to display the top-level menu screen. Allows you to call up and navigate the CT100's internal menus. 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 all traces on the screen. The scale is expanded about the vertical center of the screen.

9) *HORIZONTAL POSITION* knob. Controls the horizontal position of the cursor and displayed trace relative to the start position of the cable scan or relative to the connection to the unit.

10) *HORIZONTAL SCALE* knob. Controls the horizontal scale of the displayed traces; this scale is displayed on the screen in either English or SI units. The scale is expanded about the active cursor.

11) BNC connector. This connects to the cable you wish to test. Be sure to properly ground the cable before connecting it to the BNC connector in order to prevent electrostatic damage to the CT100's sensitive sampling circuitry.

CAUTION: All static charge must be drained from the cable to be tested prior to connection to the BNC connector (11). This is done by shorting the center conductor of the cable to the sheath / ground return. If this procedure is not followed, the sampling electronics can be damaged and you 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 thumbdrive.

13) *LIBRARY* button. Opens the *Library* menu, which contains a database of prior named configurations and saved cable records (scans), and the records of known cable types.

14) *SELECT* button. Used to select between traces on the screen. It has no effect if there are no scanned traces loaded.

15) *CURSOR* button. This button is used to toggle between the two available cursors displayed on the screen. The distance, return loss, and other measurements between the two cursors can be displayed on the screen. If you press and hold the *CURSOR* button for one second, then release, any cursors not on the screen will be moved onto the screen.

16) *SCAN* button. Displays a specialized soft-menu that brings up the *Scan and Trace* menu. It lets you perform automated scans of the entire cable detected by the *AUTOFIT* button (17), a segment of cable defined by the cursors, or the current screen. It also contains the menus for saving, deleting, hiding, and performing mathematical operations on selected traces.

17) *AUTOFIT* button. The *AUTOFIT* function displays the cable connected to the unit from the BNC connection to the end of the cable terminated by either a short or an open or by the location of the last cursor position. This functionality allows the user to immediately display an entire cable, compressed to fit on the screen. The user can then position the active cursor over the location of interest and expand the scale to zoom in.

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.

19) *M-FUNCTION* (multifunction) knob. This knob adopts the function selected through the use of the *M-FUNC* button (18).

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.

Rear panel connectors and switches

The following numbered items describe the connectors and switches identified in the rear panel diagram (Figure 2).

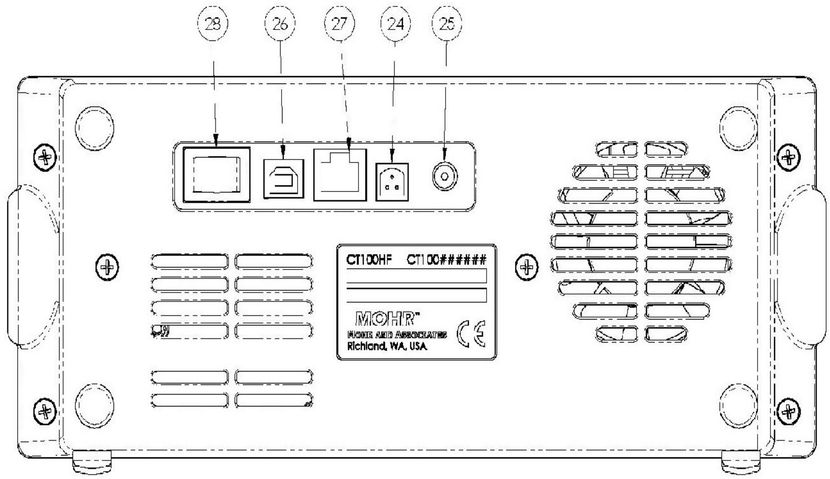


Figure 2: Diagram of the rear panel of the CT100 / CT100HF. Numbered connectors and switches are described in the text below.

24) External 14.4 VDC battery pack connection. The CT100 provides the operator the ability to select whether the external battery or the internal battery is preferentially charged. By default, the internal battery is preferred for charging. In either case, the secondary battery will be charged when the preferred battery is detected to be at full charge.

25) 24 VDC power adapter plug. The provided 24 VDC AC adapter plugs into this port. Only Mohr-approved positive center tip, 24V adapters may be used.

26) Client USB connection. Allows the CT100 to be connected to a host computer for data transfer and PC control.

27) RJ-45 Ethernet port. This is a 10/100 Mb Ethernet port that can be used for data transfer and remote PC control.

28) Power switch. This is a manual ON/OFF power switch that turns the device off and prevents it from powering on.

Setting up the CT100

Setting date and time

The date, time, and timezone must be accurately set for saved data in the CT100 to be correctly time-stamped.

Change the date and time by pressing the blue (*MENU*) button. This calls up the main menu.

Select the *Info* menu option using one of the eight menu hot keys, as labeled on the screen. The *Info* menu appears.

Select the *Time* menu option. The *Time* menu appears.

Select the *Set Time Zone* menu option. A dialog box listing all time zones appears on the screen.

Use the *M-FUNCTION* knob to scroll through the list of time zones. Highlight the correct time zone.

Select the *Select* menu option. The CT100 will prompt you to restart. After doing so, the CT100 will be set to the correct time zone. Note that daylight savings should be turned on, and it will automatically adjust for daylight savings on the correct dates.

After restarting the CT100, the time may already be correct, but if not, return to the *Time* menu by pressing the blue (*MENU*) button, selecting *Info*, then selecting *Time*.

Select the *Time/Date* menu option. A dialog box used to set the date and time appears. See the next section for methods of navigating and entering data into a dialog box.

Press the *OK* menu option when the correct time and date have been entered.

Navigating dialog boxes

Scroll through the different entry boxes with the *M-FUNCTION* knob. With an entry box selected, press the *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* menu option for each one. Get more character options by selecting the *Shift* menu option. Delete the character before the cursor with the *Back* menu option.

With the keyboard open, accept the current entry with the *OK* menu option, or revert to the original entry with the *Cancel* menu option.

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 throwing out all changes.

With a USB keyboard attached, entries can be changed directly. Use the tab key to scroll down through entry boxes, hold down shift and press tab to scroll up through entry boxes. Use the 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*.

Scrolling dialog boxes

Some dialog boxes present a list of items to be selected. Use the *M-FUNCTION* knob to highlight individual items for selection, 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, Mark All,* and *Toggle All*. When an individual item is marked, a symbol will appear in the last column of the scrolling dialog box.

Display features

The CT100 screen holds a lot of useful information. Figure 3 shows some of the typical features you will encounter during testing. Many other features are available, however, and most of them are configurable by the user. These features are described in detail in the following sections.

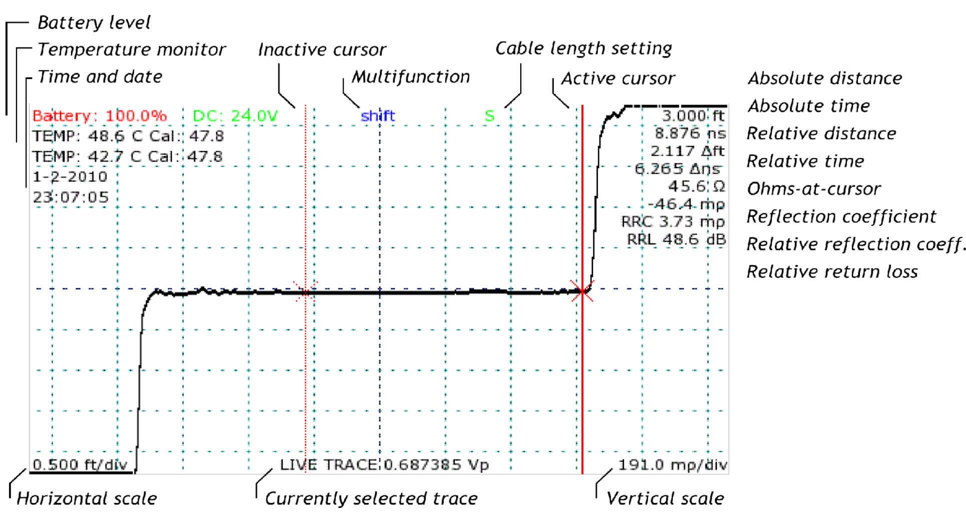


Figure 3: Screenshot showing typical features of the CT100 during testing including dual cursor functionality, scale and Vp settings, and multiple measurements including absolute distance at the active cursor, relative distance between cursors, impedance at the active cursor, relative reflection coefficient between cursors, and return loss between cursors.

License codes

Each CT100 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 and Associates. Installation instructions will be included with the license code.

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 selecting the *License Info* option of the *Info* menu. A dialog showing license date and active features will appear. When the CT100 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 CT100 has a license with pending expiration and you are unsure how to upgrade to a permanent license, please contact Mohr and Associates.

Menu selections and function buttons

M-FUNC button

Used to switch between functions *Shift (Trace)*, *Change Vp (and Fine/Coarse Vp)*, and *Smooth* on the *M-FUNCTION* knob screen function indicator.

The *M-FUNC* button has no effect if another function has captured the *M-FUNCTION* knob (see descriptions of functions below).

SCAN button and menu

Use this button and associated *Scan and Trace* menu to initiate and modify cable scans.

Save

Saves the selected trace to flash memory (scanned traces only).

Delete

Removes selected trace from screen and deletes from flash disk (scanned traces only). This item is not implemented.

Hide

Removes selected trace from screen, but does not delete from flash disk.

Frames/sec

Adjusts frames/sec with *M-FUNCTION* knob (valid for movie mode scans only). This item is not implemented.

Scan

Initiates scan.

Scan Mode (Cursor/Screen)

Switches between scan modes: *Screen* (saves trace as seen on-screen), and *Cursor* (scan between cursors at a set resolution).

Trace Display (Show/Hide)

Shows or hides all scanned traces on the screen.

Math

The *Math* menu contains frequently used mathematical operations. The items in this menu are identical to those found in the *Math* menu available in the *Main* menu.

Set base (1)

Sets the currently selected trace as the base trace, used by other actions in the *Math* menu that operate on more than one trace, such as *Difference*.

Difference

Creates a new trace that is the difference between the base trace (see *Set base* above) and the currently selected trace.

1st derivative

Creates a new trace that is the first derivative of the currently selected trace.

FFT

Creates a new trace that is the Fast Fourier Transform of the currently selected trace, using the data that lies between the cursors. The FFT is transformed using settings from the *FFT settings* submenu.

FFT Settings

FFTWindow

Selects the data window that is applied after padding the data but before the Fast Fourier Transform.

FFTPad

Selects the size of the data window. The data bounded by the cursors is padded with stationary values to fill the window size.

SParam

Creates a new trace that is the negative complex division of the currently selected trace by the base trace. This function only applies to Fast Fourier Transform traces and can be used to calculate the S11 parameter.

Phase

Creates a new trace that shows the phase angle of the currently selected trace. This operation only applies to Fast Fourier Transform traces and SParam traces.

SELECT button

The *SELECT* button switches which trace on-screen is the active trace.

AUTOFIT

Automatically adjusts the TDR resolution to fit an entire cable from beginning to end (identified by open or short termination) on the screen. Pressing the *AUTOFIT* button a second time while autofitting will put both cursors visibly on the screen. If you hold down the *AUTOFIT* button for one second, then release it, the CT100 will perform an automatic vertical measurement correction. More information can be found in the section describing the *Vertical Correction* menu below.

CURSOR

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 move any cursors not on the screen to the screen.

LIBRARY button and menu

Use this menu to access the user library of configurations, cable types, and cable records.

Add Custom Cable Type

Add a custom cable type to be loaded using the option *Load Custom Cable Types* (see below).

Load Custom Cable Types

Opens a scroll dialog filled with user-defined cable types. Using this dialog, the user can load the cable types, including associated settings such as Vp. Cable types are added to this scroll dialog using the *Add Custom Cable Type* option.

Configurations

Call up interface to load a saved configuration.

Cable Types

Call up an interface to browse the library of known cable types, with the ability to load associated settings such as Vp.

Cable Records

Call up an interface to browse the library of known cables, with the ability to load associated settings such as Vp and also associated configurations that have previously been used to scan a given cable.

Save Configurations

Call up interface to save a user configuration.

MENU button and top-level menu selections

If no menu is displayed, *MENU* 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. Top-level menu selections are listed below.

Holding down the *MENU* button while pressing any button (or the *M-FUNCTION* knob) will display a help dialog for that button's current menu selection.

Cable length selection

Use this selection for changing the pulse period to look at different lengths of cable. A green 'S', 'M', or 'L' appears near the upper right of the screen, depending upon which mode is selected. If the letter is green, the settings are saved, if it is red, it has not been saved, and if it is yellow, it is saving.

Short

Use this setting for accurate measurements of short cables of less than 200 feet in length.

Medium

Use this setting for measurements of medium cables of less than 1000 feet in length.

Long

Use this setting for measurements of long cables of less than 4000 feet in length.

Display Settings

Turn on-screen display items on or off using the soft-menu buttons to show or remove a variable. For some items, pressing the button once shows the display item and pressing it again hides the item. Asterisks (on the menu) will appear on the sides of displayed items. Some items may disappear automatically when scanned traces are selected.

Show ohms/rho

This item toggles on or off the impedance display in ohms and the reflectance display in millirho.

Show date/time

This item toggles the date and the time display on or off. The first setting shows both the time and date, the next shows only the time, the next shows only the date, and the last turns the on-screen display of date and time off.

Show distance

This item toggles showing the distance measurements including meters (or feet) and nanoseconds.

Show VSWR

This item toggles the VSWR and RVSWR displays on or off.

Invert screen

This item toggles the screen colors to display a light trace on a dark background or a dark trace on a light background.

Horiz./vert. ruler

This item toggles the horizontal and vertical measurement rulers on and off. The rulers make judging trace values simpler, but also take up a lot of screen area.

Noise value

This items toggles the display of a noise measurement. This is rarely needed except for troubleshooting and calibration checks.

Show scale values

This item toggles the horizontal and vertical scales on and off.

Show cursor/trace intersection

This item toggles an 'x' crosshair where the vertical cursor intersects the on-screen trace.

Show absolute/relative return loss (Decibels)

This item toggles the display of relative return loss at cursor.

Show temperature

This item toggles the temperature displays on and off. These temperatures are accurately measured on the (internal) analog board as a calibration reference. It also serves to display to the user when the device may be running at potentially high temperatures on critically sensitive electronic components.

Power menu

Use this menu to adjust the power save options, the power display and the battery charging preference.

DC power save

This sets the inactivity timeout for power save mode while the device is running on its 24 VDC source.

DC shutdown

This sets the inactivity timeout before the device shuts down while running on its 24 VDC source.

Battery power save

This sets the inactivity timeout for power save mode while the device is running on battery power (either internal or external).

Battery shutdown

This sets the inactivity timeout before the device shuts down while running on battery power (either internal or external).

Power display
This selection shows or hides the on-screen power display.

Battery units
This selection toggles between voltage or battery voltage percent left.

Battery charge preference (Charge Internal/External)
This item overrides the automatic preference for the CT100 to charge the internal battery first. When selected, the CT100 will charge the external battery until full before switching to the internal battery.

Connections
Use this menu to change the way the CT100 connects to external sources. This menu is important for setting up the CT Viewer™ software. Items within this menu need only be used if a CT100 is connected to a network via Ethernet.

Server select
This menu item creates a dialog box used to scroll through a list of CT Viewer™ connections. Select a connection with the "select" option and attempt to connect to it. If the connection succeeds, a message appears on the CT Viewer™ screen, and “File->OpenTester” will now show traces as stored on the connected tester. A connection can be deleted from the list using the "delete" menu option.

Add server
Add a new connection to the "Server Select" list. A dialog appears with three edit boxes. There is a "Server Name" for user reference. This has no bearing on the actual connection. "Server Address" and "Port number" define the TCP connection that will be used to connect to the CT Viewer™ server.

Push test
This item moves a single saved trace from the CT100 to a CT Viewer™ database.

Push all tests
This item moves all saved traces from the CT100 to a CT Viewer™ database.

Network settings
Configure the CT100's Ethernet connection.

Static network settings
This item brings up a dialog window used to modify the network settings. These settings only apply if DHCP is not set. The dialog box allows the user to change the following:

IP Address
The static address of the tester in 4-number-dotted notation

Netmask
The Subnet mask for the tester

Gateway (optional)
The gateway server for the tester.

Nameserver1 and 2 (optional)
DNS server the tester uses to resolve host names. Nameserver2 is used if Nameserver1 fails.

Any changes to the network settings require a reboot to take effect.

DHCP On/Off
This item enables or disables the use of DHCP on the Ethernet connection. When enabled, the tester will attempt to acquire network settings from a DHCP server on the network. When DHCP is off, the tester will use the settings in the *Network Settings* dialog. To directly connect to a computer using a cross-over cable, DHCP must be disabled.

Show IP Config
Displays current Ethernet configurations.

Web export On/Off

This item will enable two Web pages, http://<CT100 IP address>>/www/trace.csv and http://<CT100 IP address>>/www/screenshot.bmp, that show the trace. The first shows it as text data, and the second as a screenshot. Access to the Web pages requires an Ethernet connection and the address of the CT100. This can be found with the *Show IP Config* item under the *Network Settings* menu.

Measurement menu

Use this menu to change units, Vp control, and reflection coefficient calculation method.

Vert. ref. off/on

This menu option will toggle on and off a vertical reference as created using the *Set Vert. Ref.* option (see below).

Set vert. ref.

This option requires both open and short attachments for the CT100. The CT100 will automatically calculate a vertical reference and prompt for a required open or short. When a vertical reference is calculated and applied, vertical values — millirho and ohms — are much more accurate than standard TDR measurements. The vertical reference process, however, can take some time to calculate and is only valid for the temperatures at which it was taken. Vertical references cannot be stored for use across multiple sessions.

Oversample on/off
When oversampling is turned on, the CT100 uses about 1.5 times oversampling when the horizontal scale is large. Oversampling can assist in finding subtle faults while using large scales, but slows down the frame rate. An indicator appears on-screen whenever oversampling is turned on.

Oversampling must be turned off while the CT100 is being calibrated.

Adjust ohms/(unit distance)
This tool can be useful when examining long cables. Select this option to make the *M-FUNCTION* knob change the ohms-per-unit distance loss setting for a cable. When activated, the ohms-per-unit distance tool will correct for resistive loss down the length of the cable. The correction always extends from 0 distance to the position of the *Idle Cursor* — the cursor that is not currently selected. This correction requires accurate Vp measurements and also accurate vertical measurements. It therefore is best used in conjunction with a vertical reference (see above).

This tool may also be used to estimate resistive loss in a cable by adjusting the value until the cable shows no upward or downward trend across its length.

Ohms/(unit distance) correct on/off
Toggle the application of the ohms per meter correction, as described above.

RRC method
This item toggles between how the relative reflection coefficient is calculated. Classic: the measurement is related to the input signal at the fault. 1502C: the measurement is scaled to the input signal at the beginning of the cable (as in the Tektronix® 1502C).

Fine/coarse Vp control
Enable or disable 6 digit (fine) Vp precision.

Units
Switch between meters and feet for horizontal measurements.

Vertical Corrections menu
This menu contains options for adjusting or correcting vertical measurement.

Adjust rho offset
When activated, the adjust rho offset option will change the *M-FUNCTION* knob to adjust the vertical offset. The blue M-FUNC indicator at the top of the screen will also change to show that the units are now in millirho. Turning the *M-FUNCTION* knob will directly change the vertical measurements at the cursor. Advanced operators can use the *M-FUNCTION* knob to manually set vertical measurements to a known value. The adjusted value is never saved; restarting the CT100 will cancel the adjustment. When this correction is in use, automatic temperature adjustment will not correct vertical readings. A message that rho measurements are being manually adjusted will appear near on-screen measurements. Changing the rho

values will change all vertical measurements including impedance, return loss, voltage, standing wave ratio (VSWR), and relative reflection coefficient (RRC).

Cancel rho offset

Use this option to cancel a manual rho correction. Automatic temperature adjustment will resume auto-correction of the vertical measurements.

Auto vertical correction on/off

Use this option to force an automatic vertical correction each time an adjustment for temperature occurs. Typically, the automatic temperature adjustment uses a table of known values to calculate an appropriate adjustment. This option causes the table to be ignored and a re-measurement of the vertical correction value.

Force vertical correction

This option forces the CT100 to perform an automatic correction of vertical measurements immediately. Holding down the *AUTOFIT* button for one second, then releasing it provides a shortcut to this option.

Diagnostics menu

Use this menu to obtain information on the software and hardware versions and to diagnose potential performance issues.

Analog

Run automated diagnostics on the analog trace acquisition circuit board. Results are displayed on-screen in a message box.

Main board

Access this submenu to run a variety of diagnostic memory tests.

Memory

Run automated diagnostics on the main circuit board's memory interface. Results are displayed on-screen in a message box.

GPIO

Run automated diagnostics on General Purpose IO pins connected to the main circuit board. Results are displayed on-screen in a message box.

Peripherals

Run automated diagnostics on main circuit board peripherals. Results are displayed on-screen in a message box.

Service Diagnostics

For a full description of this menu, please see *Appendix C: Operator Performance Check*.

Operator Performance Checks

Horizontal Scale Check

Vertical Position Check

Noise Check

Offset/Gain Check

Sampling Efficiency Check

Aberrations Check

Risetime Check

Jitter Check

RAM/ROM Check

Front Panel Check

This item opens the Front Panel button and knob check screen. Hit each button once and turn every knob in each direction. Press the red power button to exit when finished.

Jitter

Jitter measures signal noise, timebase jitter, and sampling efficiency of the trace. These values are used are part of the calibration checkout for the CT100, and results of interest are explained in the manual section on calibration. A 36 in., 50 Ω test cable must be attached to the CT100 during the measurement.

Calibration menu

For a full description of this menu, please see *Appendix D: Calibration Procedures.*

> *CAUTION: Items within this menu should only be used upon calibration of a CT100 or to verify that a CT100 is calibrated properly. Incorrect or improperly set calibration values will corrupt trace data and may damage the unit.*

Cable length selection

This item is identical to the *Main* menu item of the same name.

Manual Calibration menu

The manual calibration menu is for expert users only, and allows manual changes of calibration values that are meant to be adjusted automatically.

Cable length selection

This item is identical to the *Main* menu item of the same name.

Step pulse reference

Adjusts the fine timing of the firing of the step pulse.

Timebase DAC

Adjusts the maximum range of the fine timing of the sampler.

Hybrid reference
Adjusts the reference voltage as applied to the hybrid unit.

Clear temp lookup
Clears the internal records of temperature calibrations. Clearing these records will cause some interruption to operation as the CT100 self-calibrates for changing temperatures. Temperature lookup data must be cleared immediately after the CT100 has been calibrated.

Hybrid adjust on
Toggle temperature correction for the Hybrid Comp calibration setting

Hybrid adjust info
Show the correction rate and reference temperature for the Hybrid Comp calibration temperature adjustment

Temperature adjustment
When temperature adjustment is on, the CT100 will correct measurements for temperature variations and the CT100 will from time to time pause to adjust to a new temperature. Temperature adjustment should be turned off when calibrating, except when setting horizontal calibration, in which case temperature adjustment should be turned on.

Vertical calibration
Vertical calibration dialog for all three cable lengths.

Driver Start auto calibrate
Step-by-step process with on-screen directions.

Capacitive Load auto calibrate
Step-by-step process with on-screen directions.

Resistive Load auto calibrate
Step-by-step process with on-screen directions.

Horizontal calibration variables
This sets the cursor's position as the zero point for distance measurements. This is normally the first falling edge when nothing is connected to the front cable connector (second rising edge on CT100HF units).

Info menu

This menu provides more information regarding the instrument and its installed software.

License info

This option gives information about the license installed on the CT100, including the license date and enabled options.

License from USB

Use this option to load a license code from a USB flash drive. Detailed instructions will be provided with the license code.

Web update

When a CT100 is connected to the Internet, this item will automatically update the CT100 if newer software is available.

Enter license

As an alternative to loading a license code, it can be manually entered using this option. This is useful for operators who are unable to connect to a computer or use a flash drive.

Software version

Display software and firmware version information. This also serves to verify the communications links between the micro-controllers.

Hardware info

Display hardware information.

Usage

Display usage stats (hours, scans, storage, etc.).

Time

This menu allows a user to change time and date settings.

Set time zone

Change the time zone. Requires a reboot for changes to take effect.

Daylight Savings On/Off

Set whether the CT100 will automatically adjust for daylight savings time on the appropriate dates. Requires a reboot for changes to take effect.

Time/Date

Set the current date and time.

Math

The *Math* menu contains frequently used mathematical operations. The items in this menu are identical to those found in the *Math* submenu of the *Scan* menu

Set base (1)

Sets the currently selected trace as the base trace, used by other actions in the *Math* menu that operate on more than one trace, such as *Difference*.

Difference

Creates a new trace that is the difference between the base trace (see *Set base* above) and the currently selected trace.

1st derivative
Creates a new trace that is the first derivative of the currently selected trace.

FFT
Creates a new trace that is the Fast Fourier Transform of the currently selected trace, using the data that lies between the cursors. The FFT is transformed using settings from the *FFT settings* submenu.

FFT Settings

FFTWindow
Selects the data window that is applied after padding the data but before the Fast Fourier Transform.

FFTPad
Selects the size of the data window. The data bounded by the cursors is padded with stationary values to fill the window size.

SParam
Creates a new trace that is the negative complex division of the currently selected trace by the base trace. This function only applies to Fast Fourier Transform traces and can be used to calculate the S11 parameter.

Phase
Creates a new trace that shows the phase angle of the currently selected trace. This operation only applies to Fast Fourier Transform traces and SParam traces.

Test preparations

Velocity of propagation

Velocity of propagation (Vp), also sometimes abbreviated VoP or VP, is the measure of the velocity of an electrical signal within a cable expressed as a fraction of *c*, the speed of light in a vacuum. With the CT100, Vp can be set in ranges between 0.25 and 1.0. See *Appendix E* for cable types and their estimated Vp.

Change 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”. If *Fine Vp* is enabled from the *Measurement* menu, two “Vp” indicators will be separately available. *Coarse Vp* allows for the modification of the first 3 significant digits and *Fine Vp* allows the the modification of the last 3 significant digits.

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.

An accurate Vp is necessary for accurate cable length and distance-to-fault measurements. For cables of a known type, the Vp can be approximated by using the nominal Vp for that cable type.

The CT100 has a built-in library of cable types and their Vp values. See *Cable library* section below.

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 the "Find an unknown Vp" section.

Find an unknown Vp

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

1) Measure the length of the test cable. Make sure the test cable is of the same type for which you need to find Vp. If there are any adapters used while connecting the cable, include their length in the measurement, or set one of the cursors at the end of the adapter before attaching the cable.

2) Attach the test cable to the CT100.

3) Press the *AUTOFIT* button. The CT100 will now show the beginning and the end of the test cable (Figure 4).

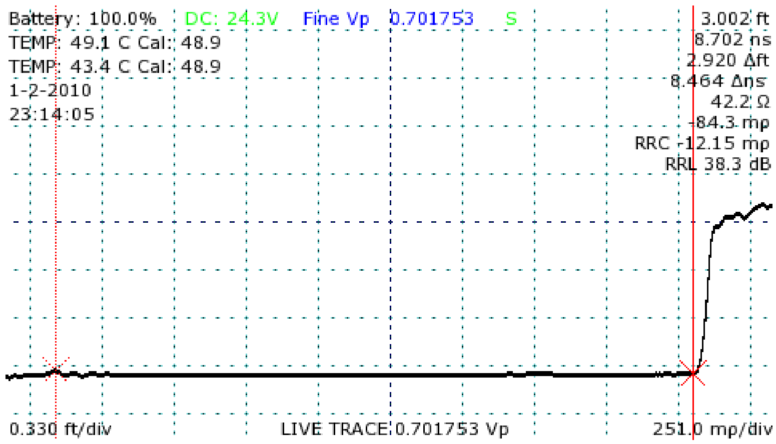


Figure 4: Screenshot showing AUTOFIT result. The cable end, in this case an open termination, has been found at 3.002 feet and the cable has been fit to screen.

4) Position the active cursor at the end of the test cable. Use the *HORIZONTAL SCALE* knob to zoom in on the end of the cable and get an accurate placement (Figure 5).

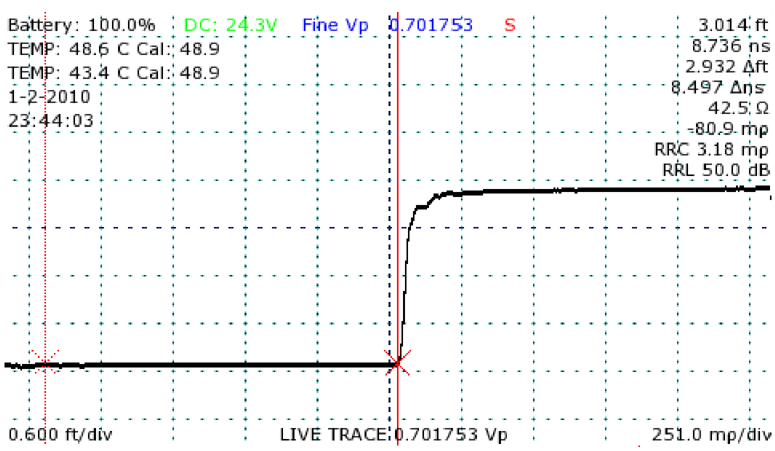


Figure 5: Screenshot after the HORIZONTAL SCALE knob has been used to zoom in on the cable end for greater accuracy in determining Vp.

5) Adjust Vp until the CT100 distance measurement to the active cursor equals the physical measurement. The final Vp value is the true Vp value of the cable.

Temperature correction

The CT100 may take control of the trace from time to time in order to adjust to changes in internal temperatures. A notice will appear on the screen during the adjustment, which may take several seconds.

The device also adjusts for temperature at startup and when changing the cable length settings. At these times, the correction takes somewhat longer than during normal operation. The readout for temperature on the device screen also shows the last temperature at which the device performed a correction. This readout will turn red when the difference between the current temperature and the temperature of last adjustment is too great.

Cable test procedures

Distance to fault

1) Attach the cable to the BNC connector.
2) Set Vp to match the Vp of the attached cable.
3) Press the *AUTOFIT* button. The CT100 trace is now scaled to show the entire cable from beginning to end. See Figure 6.

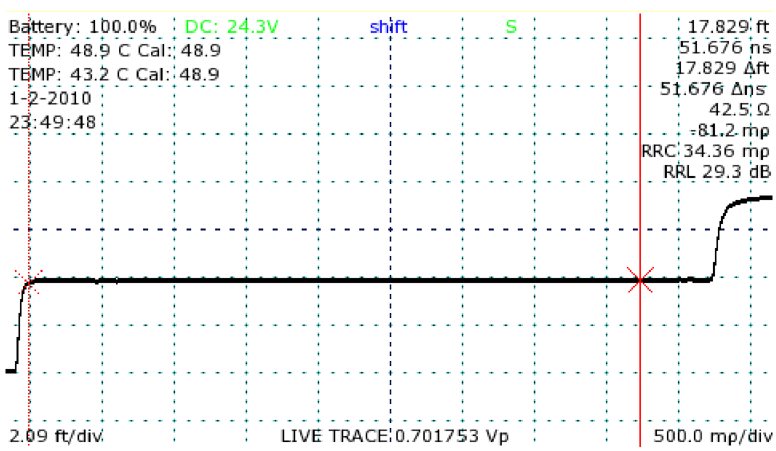


Figure 6: AUTOFIT cable. The cable termination is an open.

4) Position the active cursor on the reflection caused by the fault. Adjusting the vertical scale helps make cable faults more obvious, as in Figure 7.

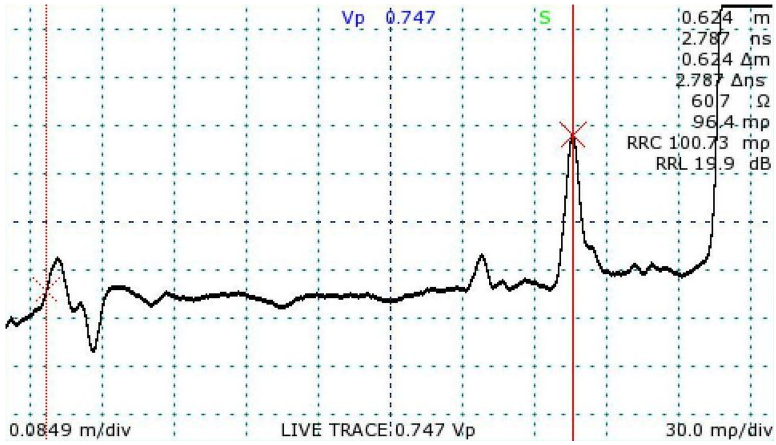


Figure 7: After adjusting the vertical scale, the cable fault marked by the active cursor is more apparent.

5) Use the *HORIZONTAL SCALE* knob to zoom in on the fault to get a more accurate measurement. The distance measurement to the active cursor is the distance to the fault. See Figure 8.

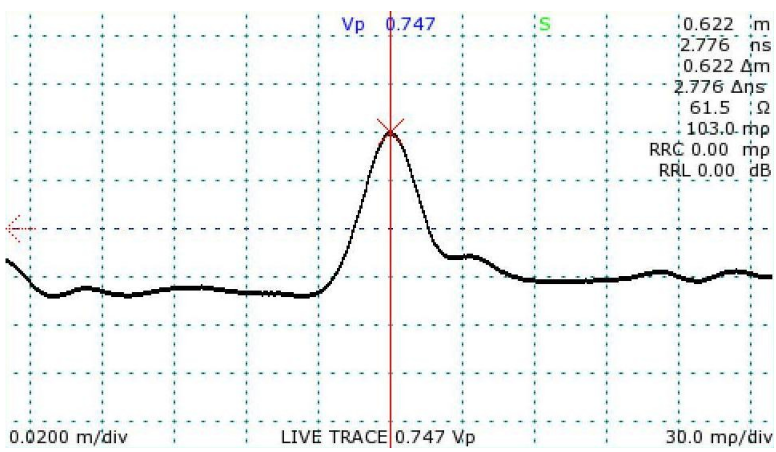


Figure 8: A zoomed-in view of the cable fault in the previous figure, in this case a standard 50 Ω cable with a bad cut in the shielding.

Common types of cable faults

Open faults appear as a pulse upward in the trace (Figure 9):

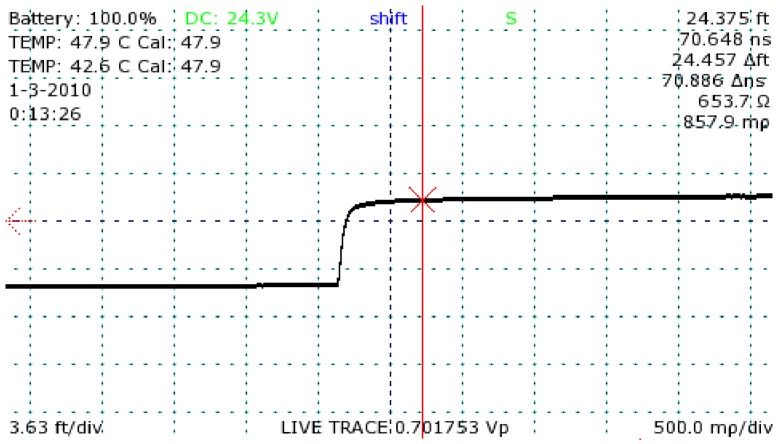


Figure 9: An open cable fault. The step pulse is completely reflected by the open termination of the cable.

Short faults appear as a pulse downward (Figure 10):

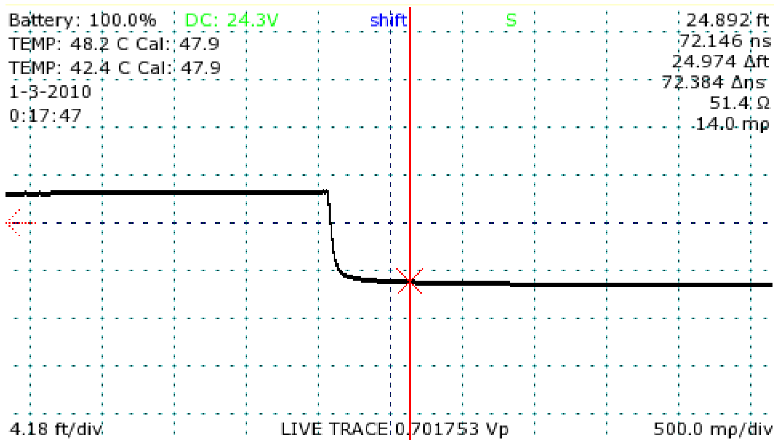


Figure 10: A short cable fault.

Faults that are a long distance from the CT100 will show shallow reflections that are very long because the length of cable attenuates the high frequencies necessary for precise fault localization and characterization (Figure 11). Position the active cursor at the beginning of the reflection where it first deviates from the straight line trace of the cable.

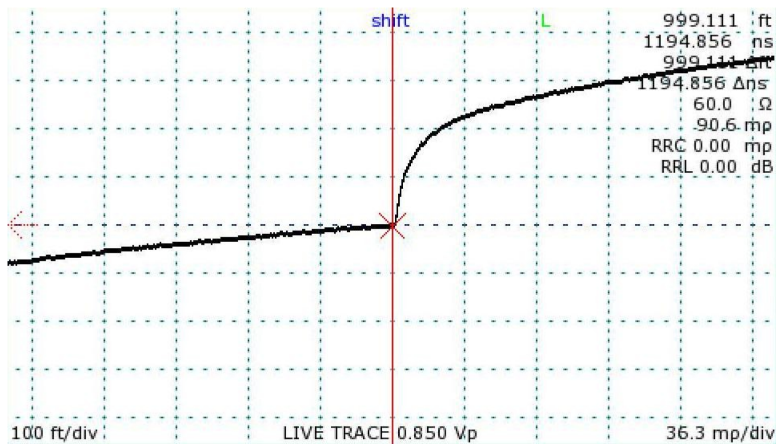


Figure 11: An open cable fault at 1000 ft demonstrates a long, shallow reflected rise caused by cable attenuation of high frequency components of the step pulse.

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

Faults that are not opens and shorts may not appear at the end of the trace after pressing the *AUTOFIT* button, but can appear anywhere along its length.

Any fault is likely to reduce the pulse strength and change the pulse velocity. The accuracy of distance measurement of a fault that appears beyond another fault is reduced.

Reflection coefficient measurements

The reflection coefficient is the ratio of the signal reflected back from a point of interest to the signal going into it. It is also is a measure of the impedance change at that point in a cable.

Reflection coefficient is designated by the Greek letter ρ and is sometimes written as rho.

The CT100 lets you measure ρ three different ways:

The first method is the absolute reflection coefficient**,** which describes the total reflection to the point of the active cursor compared to the input signal from the pulser/sampler at the beginning of the cable.

The vertical scale reading at the bottom of the screen in mρ per division is always based off of the absolute reflection coefficient.

The second and third methods rely on the relative reflection coefficient, which is a measure of the signal reflected between two points in the cable. In the case of the CT100 this is between the passive cursor and the active cursor. The CT100 has two ways to calculate the relative reflection coefficient:

1) In *Classic* mode, the measurement is related to the input signal at the fault. This mode is the standard, most accurate way to measure the relative reflection coefficient and is the default mode.

2) In *Tektronix 1502C* mode, while the measurement is relative to the passive cursor, it is scaled to the input signal at the beginning of the cable. This mode was included so that the CT100 could display reflection measurements that match those measured by the Tektronix® 1502C. However, it is less accurate in longer cables and after multiple faults, as it does not take into account intervening signal losses.

Return loss measurements

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 reflection coefficient ρ by the formula:

$$\textit{Return Loss} = -20 \cdot \log_{10} |\rho|$$

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.

Ohms-at-cursor

The CT100 also displays the impedance in Ohms (Ω) 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.

VSWR

VSWR is Voltage Standing Wave Ratio. 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, VSWR will be 1. If all energy is reflected, VSWR goes to infinity. VSWR is a unitless, scalar value.

The CT100 displays two different VSWR values. The first, labeled VSWR on-screen, will be calculated from the total reflection relative to the output impedance of the CT100 (50 ohms). The second, labeled RVSWR, will be calculated from the reflection between the two cursors. In other words, VSWR is based on the millirho reflection coefficient, while RVSWR is based on the RRC, relative reflection coefficient calculation.

VSWR and RVSWR have a menu option to toggle the display of the values on-screen in the *Display* menu.

Relative distance measurements

The CT100 displays the absolute distance from cable start and also the relative distance from the passive cursor to the active cursor.

Note that Vp must be set accurately for the section of cable between the cursors for the CT100 to measure relative distance accurately. The pulse velocity of any part of the cable that is not between the cursors will not affect the 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 CT100 displays the distance measured between the two cursors as a “Δ” value below the absolute distance measurement. See Figure 12.

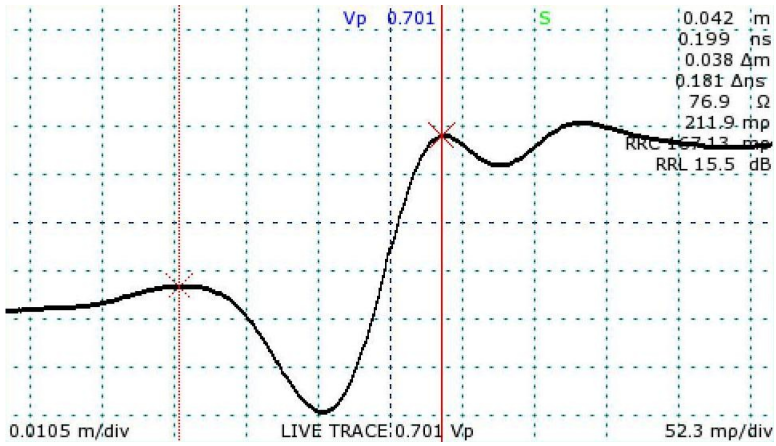


Figure 12: A 50 Ω to 75 Ω BNC to SMA interconnect measuring approximately 3.8 cm and return loss estimated at 15.5 dB.

Scan a trace

The CT100 can scan and save a trace into memory. Saved traces can appear on the screen in addition to the live trace. New traces can be selected by repeatedly pressing the *SELECT* button, and traces can be adjusted vertically independent of other traces.

To scan a cable or cable segment, press the *SCAN* button to bring up the *Scan and Trace* menu, then choose the *Scan* option from the menu to begin the cable scan.

There are two main types of scans: *Screen* scans and *Cursor* scans. *Screen* scans capture the live trace as it appears on the screen. *Cursor* scans capture the entire trace between the two cursors at the current horizontal resolution. In this way, long lengths of cable can be captured at very high resolutions with a single scan. A scanned trace is created with a smoothing factor as set at the time of the scan. Cursor scans that cover a very long distance at a high resolution may take a long time.

During a scan, a menu will appear with a *Cancel* option. Select *Cancel* to immediately abort the scan.

Select a trace

The CT100 always shows one trace on the screen in bold. This is the selected trace. *VERTICAL POSITION* and *VERTICAL SCALE* knobs as well as the *save*, *delete*, *hide, and math* options on the *Scan and Trace* menu are all actions that only operate on the selected trace, leaving other traces on the screen unchanged. 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.

1) Press the *SCAN* button to bring up the *Scan and Trace* menu.

2) Press the *SELECT* button to change which trace is active. Figure 13 demonstrates this principle with three different traces.

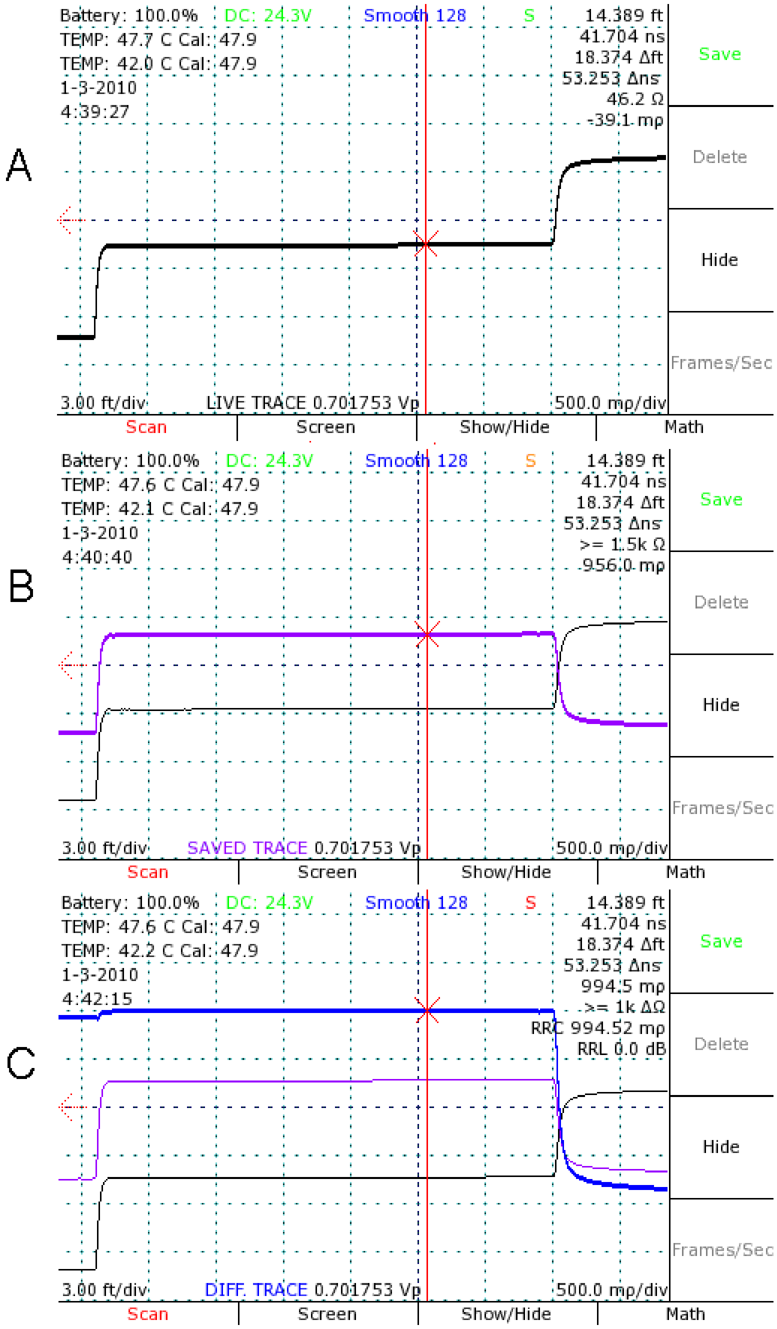


Figure 13: Screenshots showing selection of (A) a live trace, (B) a scanned trace that has been translated vertically using the VERTICAL POSITION knob, and (C) a trace representing the difference between the two.

Store a trace

A scanned trace can be stored for later recall:

1) Press the *SCAN* button. The *Scan and Trace* menu appears.

2) Press the *SELECT* button until the saved trace to be stored is selected.

3) Select the *Save* option from those that appear on the menu.

4) The CT100 requires a name for storage, and will prompt you for one with a dialog box.

5) A dialog menu appears. Choose the menu option to show the on-screen keyboard.

6) Use the *M-FUNCTION* knob and the keyboard menu to select letters and numbers. See Figure 14. Also see "Navigating dialog boxes" on page 15 for more information on using the keyboard menu. Press the Select option to enter the highlighted letter into the name.

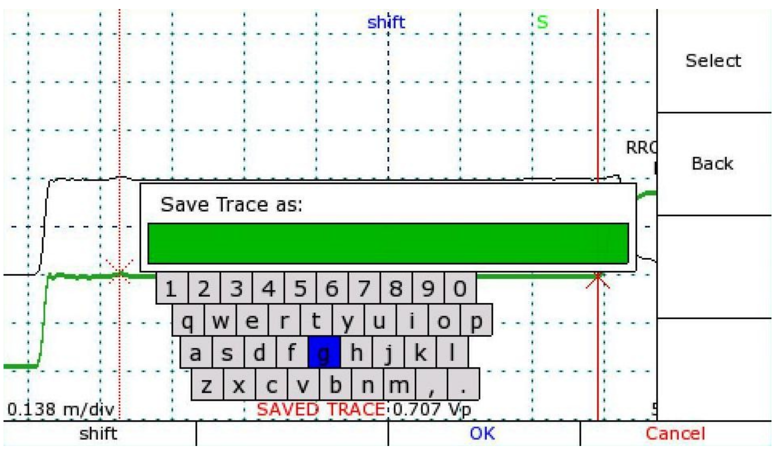


Figure 14: Saving a trace. The software keyboard is being used to enter a name for the scanned trace in red on the screen. Alternatively, an external USB keyboard or barcode reader can be used to enter information.

7) Press the *OK* option from the menu when finished.

The trace is now stored, and can be recalled later by name under C*able Records*.

An FFT Trace can also be stored with the same process. However, be sure to select the base trace scan, not the FFT trace, before storing.

Load a trace (cable records)

Cable records describe configurations used to test individual cables with the CT100. A cable record stores the Vp, tester configuration, and the scanned trace from a test of an individual cable. Use of cable records helps ensure that multiple tests of the same cable use the same tester configuration and Vp value. Cable records do not load calibration values, but use the current set values.

A stored trace can be loaded back to the screen:

1) Press the *LIBRARY* button. The Library menu appears.

2) Select the *Cable Records* option. An interface appears for the selection of a stored trace.

3) Use the *M-FUNCTION* knob and the menu keys to select the trace to load.

4) Press the selected menu option to load the trace. See Figure 15.

The stored trace now appears on the screen. It can be selected and manipulated the same as any scanned trace.

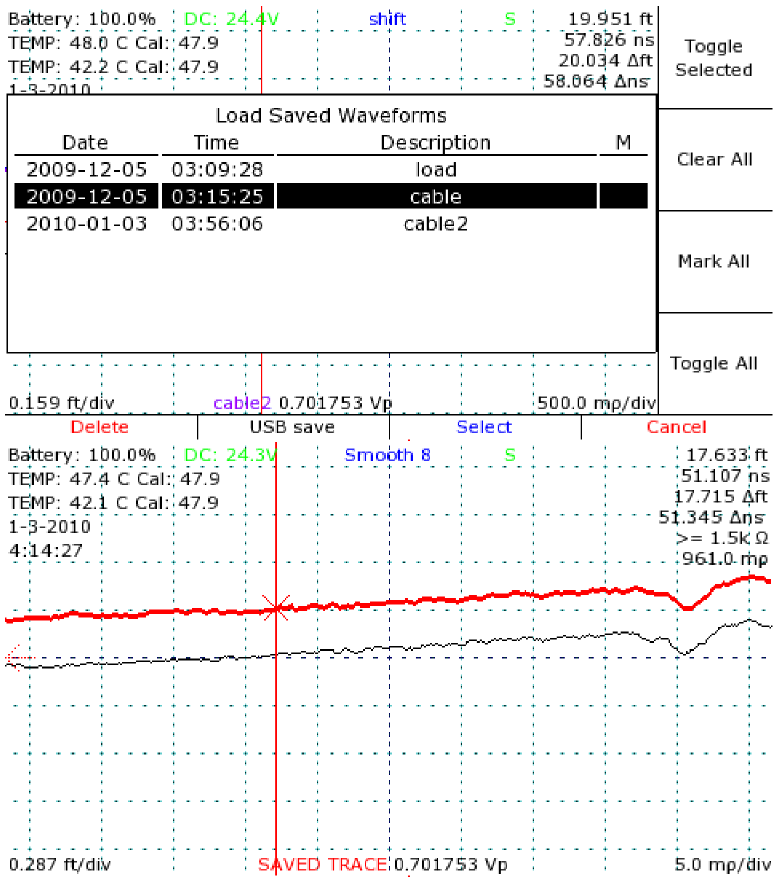


Figure 15: Loading a trace. The loaded trace (bold red) has been translated slightly upward using the VERTICAL POSITION knob in order to improve visualization.

When a previously stored FFT trace is loaded, the FFT trace is automatically re-calculated during loading. This calculation may take several seconds.

Storage space

The CT100 has a large storage space, capable of holding thousands of trace scans. However, with continued use, CT100 storage will eventually fill up. Periodically, an effort should be made to clear stored traces from the device and free up storage space.

Backing up traces

The CT100 ships with a Installation CD for the CT Viewer™ software for Windows. Using either a USB or an Ethernet connection, the CT100 can transfer stored scans to CT Viewer™. These scans are then stored in the Windows computer for later retrieval, review, email, and analysis. See the CT Viewer™ manual for details.

Deleting traces

Once scans are backed up to a computer, they can be deleted from the CT100 either through the CT Viewer™ software or directly as follows.

1) Press the *LIBRARY* button to open the *Library* menu.
2) Select *Cable Records*. A scroll dialog appears, showing all saved trace scans.
3) Highlight 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.

Freeing up space

Deleting traces is the first step to clearing disk space, but the space is not freed until a clean shutdown is ordered from the *Power Button* menu.

1) Press the red *Power* button. The *Power Button* menu appears.
2) Select *Clean Shutdown*. The CT100 will now free up space that was used by deleted traces. Do not turn off the CT100 when using clean shutdown. The CT100 will shut itself down when it is safe to do so.

CAUTION: Switching off power during a clean shutdown could damage the instrument.

View the difference between traces

1) Press the *SCAN* button. The *Scan and Trace* menu appears.

2) Press the *SELECT* button repeatedly until the first trace of interest is selected.

3) Select the *Math* option from the *Scan and Trace* menu and choose *Set Base*. The selected trace 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 trace is created that displays the difference between the base trace and the selected trace. See Figure 16.

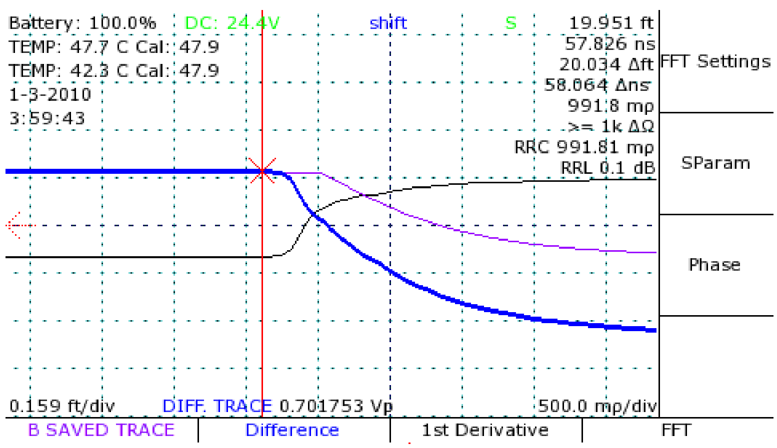


Figure 16: Difference trace. The blue trace is created by subtracting the black (live) trace from the purple trace.

View a first derivative of a trace

The CT100 can perform a wide range of mathematical transforms of on-screen traces, both in static and real-time forms. The following example demonstrates the use of the first derivative plot.

1) Press the *SCAN* button. The *Scan and Trace* menu appears.
2) Press the *SELECT* button until the trace of interest is selected.
3) Select the *Math* option from the *Scan and Trace* 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 17.

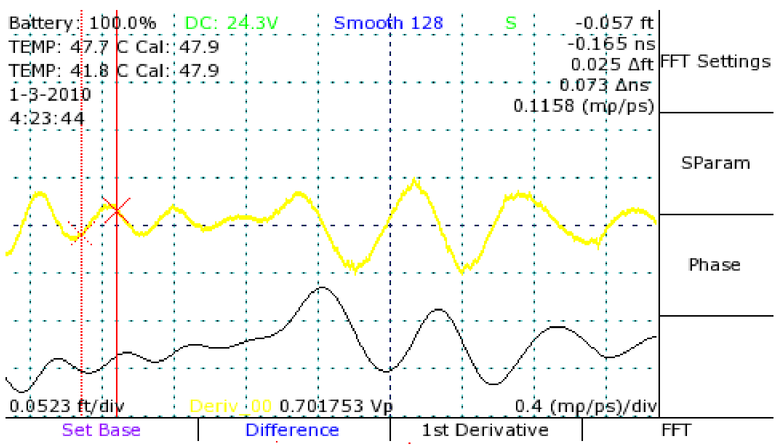


Figure 17: First-derivative plot (yellow) of an on-screen trace (black). A wide range of mathematical transforms can be easily implemented.

View a Fast Fourier Transform of a trace

1) Select the live trace with the *SELECT* button.
2) Use the *CURSOR* button and the *HORIZONTAL POSITION* knob to bound the area for the FFT with a cursor at either end.
3) Press the *SCAN* button to open the *Scan* menu.
4) Select the *Math* menu option to open the *Math* menu.
5) Select the *FFT* menu option. The CT100 will now take a high resolution scan of the live trace between the cursors, then convert the scan into an FFT plot. This may take some time.

FFT traces can be stored and loaded, just as normal scanned traces. When storing an FFT trace, be sure to select the base scan first, not the FFT trace. When the trace is reloaded, the CT100 will take a few seconds to recalculate the FFT trace.

View S-Param trace

The S-Param trace shows the result of complex division of one FFT trace by another. When a reflected short or open waveform at the test plane is chosen as the denominator and the waveform from the device-under-test (DUT) is chosen as the numerator, this feature will produce uncorrected S11 and S22 S-parameters of a two-port device-under-test (e.g., cable or connector), which is equivalent to frequency-specific return loss. When used properly, the S-Param waveform can provide you with a quick, semi-quantitative estimate of frequency-specific return loss between cursors.

1) Press the *SCA*N button. The *Scan* menu will appear.

2) Choose the *Math* menu option. The *Math* menu will appear.

3) Select the first FFT of interest by pressing the *SELECT* button repeatedly.

4) Choose the *Set base* menu item to set the selected trace as the base trace.

5) Select the second FFT of interest by pressing the *SELEC*T button repeatedly.

6) Choose the *S-Param* menu item. A new trace will be created that shows the selected trace divided by the base trace.

Calibrated S-Param trace

The Calibrated S-Param feature is a planned software upgrade that may be included with your instrument. This feature uses precision open, short, and 50 ohm load (OSL) measurements to correct for systemic errors in the pulsing and sampling electronics, producing a more accurate S11 result than the standard S-Param trace. A menu with four options will be available as a submenu of the *Math* menu. These options will allow the selection of individual FFT traces for use as the three calibration measurements. Each of the three measurements must be set before the fourth option can be used on a fourth FFT trace, representing the target trace for the S11 measurement.

Remote control

Using the accompanying CT Viewer™ software, the CT100 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 CT100 is connected by USB only.

The CT100 must first connect to the CT Viewer™ software over Ethernet. Please see the “Connecting the CT100 to the CT Viewer™ software over Ethernet” section of “Using CT Viewer™” (page 43).

Once a connection has been established, CT Viewer™ can be granted remote control over the operation of the CT100. Please consult the CT Viewer™ manual for details about starting remote control and manipulating a remote trace.

Cable type

The CT100 has a library of common cable types. Vp for these cable types can be loaded from the library.

Load a cable type's Vp

1) Press the *Library* button. The *Library* menu appears.

2) Select *Cable Type* from the menu. An interface appears that allows you to scroll through the cable types with the *M-FUNCTION* knob.

3) Select the desired cable type and press *OK*. Vp is now set to the value for that cable type.

User editable cable types

The CT100 is also able to save and load custom cable types.

1) Press the *Library* button to access user editable cable types. There are two new items on the Library menu, *Add Custom Cable Type* and *Load Custom Cable Type*.

2) When *Add Custom Cable Type* is selected, a window appears for entering a cable type name, a Vp for pulse velocity, and an expected impedance. When the window first appears, Vp will be set to the current system Vp, while impedance defaults to 50 ohms.

The other menu option, *Load Custom Cable Type*, opens a window with all of the added user types available for selection. Use the *M-FUNCTION* knob and the *Select* menu option to load a particular cable type. When selected, the operating Vp is changed to match the selected cable type.

The user-added cable types are stored and accessed separately from the standard cable types, which are still available through the *Cable Types* menu item.

Measurement

Change units

Horizontal measurements can be displayed in physical meters, centimeters, feet, inches, or yards; and nanoseconds.

1) If there is a menu on the screen, press the *MENU* button until no menu is on the screen.

2) Press the *MENU* button. The screen will display the *Main* menu.

3) Select *Measurement* from the menu. The *Measurement* settings menu appears.

4) Select *Units meters (feet)* to switch between the different unit options.

All measurements and all traces are immediately updated to reflect the unit change. Nanoseconds are displayed separately.

Fine Vp control

By default, the CT100 displays 3 decimal places for Vp; however, the CT100 can display 6 decimal places for Vp when extremely precise distance measurements are desired.

1) If there is a menu on the screen, press the *MENU* button until the menu disappears.

2) Press the *MENU* button. The screen will display the *Main* menu.

3) Select *Measurement* from the menu. The *Measurement* settings menu appears.

4) Select *Vp 3(6) Sig Figs* from the menu. The CT100 will now display 6 decimal places for the Vp readout on the screen, when *Vp 6 Sig Figs* is shown on the menu.

5) When the CT100 is in *Fine Vp* mode, a new function, *Fine Vp*, is added to the *M-FUNCTION* knob. When the *M-FUNCTION* knob is set to *Fine Vp*, turning the knob will change the Vp value by the millionths. The Vp value can be changed by thousandths as normal by setting the *M-FUNCTION* knob to the *Coarse Vp* function.

Relative reflection coefficient

The CT100 measures the relative reflection coefficient between cursors. When the two cursors of the CT100 are positioned on either side of a change in impedance, this measurement is the reflection coefficient for that change. 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 CT100 can also measure in *1502C* mode, which displays a reflection coefficient relative to the signal at the input of the cable.

1) If there is a menu on the screen, press the *MENU* button until the menu disappears.

2) Press the *MENU* button. The screen will display the *Main* menu.

3) Select *Measurement* from the menu. The *Measurement Settings* menu appears.

4) Select *RRC Method* from the menu. This will toggle the CT100 between the Classic RRC calculation and the 1502C calculation as displayed on the screen.

Vertical reference

Use the vertical reference system to increase the accuracy of vertical measurements, including impedance, reflection coefficient, and return loss.

1) From the *Main* menu, go to the *Measurement* menu. On the right side menu, an option to *Set Vert. Ref* appears.

2) Select the *Set Vert. Ref* option.

3) A set of terminators, both open and short, are included with the CT100 for calibration purposes. Attach these terminators to the CT100 when prompted to do so. (For the CT100, CT100-AC-IBMM is used to open the shorting BNC.) For the short condition, shorting caps are provided for both the CT100 with a shorting BNC and the CT100 with SMA connections.

When the reference measurement is finished, cursor measurements will now appear in blue, and a line saying *using vert. ref.* will appear underneath.

The CT100 is now configured for impedance measurements better than 2% across a wide range of impedances.

The menu option at the top of the right hand side can be used to toggle the vertical reference on and off as needed for a given cable length setting.

Cable resistance correction

The CT100 also has a system for correcting for resistance in 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.

1) From the *Main* menu, go to the *Measurement* menu. On the right side menu, an option to *Adjust Ohms/m* appears.

2) Select *Adjust Ohms/m*.

3) Position the cursor at the end of the cable's trace.

4) Use the *CURSOR* button to switch to the other cursor.

The ohms per unit length correction adjusts values from the zero position out to the position of the nonactive cursor.

The current ohms per unit length setting now appears in the *M-FUNC* indicator at the top of the screen.

5) Rotate the *M-FUNCTION* knob to change the setting. Use the ohms per unit length toggle menu option to turn the correction on or off.

Changing the *Ohms/m* setting will change the slope of the cable's trace, 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.

Use this correction to make more accurate impedance measurements on a length of cable. One technique is to adjust the correction until the cable is as flat as possible. Another 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.

Configurations

The CT100 allows the user to save configurations with a name. A saved configuration stores the values of all CT100 settings. A configuration can be called up by its name, restoring all settings to the values saved in that configuration. By default, the configuration load screen is displayed at start up for easy loading of configurations.

Save configurations

1) Press the *LIBRARY* button. The *Library* menu appears.

2) Select the *Save Config* item. The CT100 will prompt you for a configuration name, then saves the configuration. See “Navigating dialog boxes” on page 15 for information on using the keyboard menu.

Load configurations

1) Press the *LIBRARY* button. The *Library* menu appears.

2) Select the *Configurations* menu item. The *Configurations* dialog box appears.

3) An interface that lets you scroll through the configurations with the *M-FUNCTION* knob is displayed.

4) Press *OK* on the menu when the appropriate configuration is highlighted. All settings saved in that configuration are automatically restored. Measurements and traces are updated to reflect the new settings.

CT Viewer™

The CT Viewer™ host computer software allows users of the Mohr CT100 and CT100HF Metallic Time-Domain Reflectometer (TDR) to transfer, view, and manipulate the 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 MS 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.

For information on installing and using CT Viewer™, please see the CT Viewer™ manual.

Options and Accessories

Options

Model CT100 — standard pulser-sampler (100 ps system risetime, 20-80%)
Model CT100HF — high-frequency pulser-sampler (60 ps system risetime, 20-80%)

Accessories

Standard accessories (CT100)

Precision BNC 36 in. 50 Ω Test Cable	CT100-AC-W536
50 Ω BNC Terminator	CT100-AC-ER50
BNC Capacitive Terminator	CT100-AC-C001
Connector, BNC Female to Female	CT100-AC-IBFF
Connector, BNC male to BNC male	CT100-AC-IBMM
BNC Shorting Cap	CT100-AC-IBS
24 VDC External Power Supply	CT100-AC-PS
Operator's Manual, Printed	CT100-M-OM-xxx*
CT Viewer™ Manual, Printed	CT100-M-CTVM-xxx*
CT Viewer™ Installation CD, w/ Digital Operators and CT Viewer™ Manuals	CT100-S-CTVOM-xxx*
Soft Carrying Case	CT100-AC-CS
NIST-Traceable Calibration with Certificate	CT100-AC-NISTCC

Standard high-frequency accessories (CT100HF)

Precision SMA 36 in. 50 Ω Test Cable	CT100-AC-W536S
50 Ω SMA Terminator	CT100-AC-ER50S
BNC Capacitive Terminator	CT100-AC-C001
Connector, SMA Male to Male	CT100-AC-ISMM
Connector, BNC male to BNC male	CT100-AC-IBMM
Connector, SMA male to BNC Female	CT100-AC-ISMBF
Connector, BNC male to SMA Female	CT100-AC-IBMSF
SMA Shorting Cap	CT100-AC-ISS
24 VDC External Power Supply	CT100-AC-PS
Operator's Manual, Printed	CT100-M-OM-xxx*
CT Viewer™ Manual, Printed	CT100-M-CTVM-xxx*

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

CT Viewer™ Installation CD, w/ Digital Operators and CT Viewer™ Manuals	CT100-S-CTVOM-xxx*
Soft Carrying Case	CT100-AC-CS
NIST-Traceable Calibration with Certificate	CT100-AC-NISTCC

Optional accessories (CT100 / CT100HF)

External Battery Pack (2700 mA·h)	CT100-AC-B2700E
24 VDC Isolated External Power Supply	CT100-AC-PSI
Hard Carrying Case	CT100-AC-CH
Connector, BNC female to Dual Banana Plug	CT100-AC-IBFDBAP
Connector, BNC male to Dual Binding Post	CT100-AC-IBMDBIP
Connector, BNC female to Hook-tip Leads	CT100-AC-IBFL
Connector, BNC male to N female	CT100-AC-IBMNF
Connector, BNC female to N male	CT100-AC-IBFNM
Connector, BNC female to UHF male	CT100-AC-IBFUHFM
Connector, BNC female to UHF female	CT100-AC-IBFUHFF
Connector, BNC female to Type F male	CT100-AC-IBFFM
Connector, BNC male to Type F female	CT100-AC-IBMFF
Adapter 50 Ω to 75 Ω	CT100-AC-I5075
Adapter 50 Ω to 93 Ω	CT100-AC-I5093
Adapter 50 Ω to 125 Ω	CT100-AC-I50125
Small form factor keyboard	CT100-AC-KBD
Clear Screen Protector Pack	CT100-AC-SPC
Anti-Glare Screen Protector Pack	CT100-AC-SPAG
BNC RF Adapter Kit	CT100-AC-BNC
SMA RF Adapter Kit	CT100-AC-SMA
Impedance Matching Kit 75,93,125 Ohm (BNC)	CT100-IK-BNC
Impedance Matching Kit 75,93,125 Ohm (SMA)	CT100-IK-SMA
Impedance Matching Adapter, 75 Ohm (BNC)	CT100-AC-I5075-BNC
Impedance Matching Adapter, 93 Ohm (BNC)	CT100-AC-I5093-BNC
Impedance Matching Adapter, 125 Ohm (BNC)	CT100-AC-I50125-BNC
Impedance Matching Adapter, 75 Ohm (SMA)	CT100-AC-I5075-SMA
Impedance Matching Adapter, 93 Ohm (SMA)	CT100-AC-I5093-SMA
Impedance Matching Adapter, 125 Ohm (SMA)	CT100-AC-I50125-SMA

Service accessories (CT100 / CT100HF)

Technical Service Manual, Printed	CT100-M-TSM-xxx*
Technical Service Manual, Digital w/ CT Viewer™ Installation	CT100-S-CTVTSM-xxx*

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

Appendix A: Specifications

Electrical specifications

Characteristic	Specification	Notes
Reflected risetime, CT100 10-90%	150 ps typ, 200 ps max	10 to 90%, into 50 Ω terminator
Reflected risetime, CT100 20-80%	100 ps typ, 150 ps max	20 to 80%, into 50 Ω terminator
Reflected risetime, CT100HF 10-90%	100 ps typ, 130 ps max	10 to 90%, into 50 Ω terminator
Reflected risetime, CT100HF 20-80%	60 ps typ, 90 ps max	20 to 80%, into 50 Ω terminator
Jitter	15 ps max (peak-to-peak)	< 1 ps rms typ.
Output impedance	50 Ω ± 2%	
Pulse amplitude	295 ± 5 mV	Into 50 Ω load
Pulse width	Adjustable from 1 to 100 μs	
Pulse repetition time	Adjustable from 4 to 125 μs	
Sequential sampling rate	Adjustable from 8 to 250 kHz	
Vertical scale	0.5 mρ/div	
Vertical accuracy	± 3% full scale	
Vertical position	Any trace point is movable to the center of the screen.	
Sampling efficiency, CT100	50% to 90%	into 50 Ω terminator
Sampling efficiency, CT100HF	45% to 90%	into 50 Ω terminator
Noise	± 5 mρ peak-to-peak	
Input susceptibility	± 1 A	Into diode clamps
Distance cursor resolution	1/45th of one major division	
Cursor readout range	≤ -0.3m (-1 ft.) to > 1000 m (3300 ft.)	
Cursor readout resolution	0.0002 m (0.0007 ft.)	
Distance measurement accuracy	< 1 cm (0.3 in.) or ± 0.5% of measurement plus uncertainty in Vp, whichever is greater	
Ohms readout ranges	<1 Ω to >1.5 kΩ	
Resolution	3 significant digits	
Accuracy	±10%, relative measurement ± 2%	< 1% or 1 Ω typ.
Horizontal scale	0.01 m/div (0.03 ft/div) to ≥ 61 m/div (200 ft./div) (variable with pulse width)	

Characteristic	Specification	Notes
Horizontal range	< 0 m to > 1000 m (3300+ ft.)	
Horizontal position	Any distance to full scale can be moved on the screen.	
Vp range	0.250000 to 1.000000	
Vp default resolution	0.001	
Vp fine resolution	0.000001	
Vp default accuracy	± 0.1%	
Vp fine accuracy	± 0.0001%	
USB host port	USB 1.1	The USB host connections on the front of the instrument are powered. The host supplies up to 500 mA per channel to power any device connected. The USB host is isolated from the analog board by 500 V.
USB client port	USB 1.1	The USB client is isolated from the analog board by 500 V.
Ethernet port	The instrument includes a 10/100mbps Ethernet port for network communication.	The Ethernet port is isolated from the analog board by 500 V.
DC power supply	24 VDC, 2.5A, Positive Tip. Use only the Mohr-approved power supply.	The DC power supply is isolated from the analog board by 500 V.
Battery pack	12 NiMH AA cells, fused at 2.5 A	Pack may wear out over time.
External battery pack	12 NiMH AA cells, optional	This pack is identical to the internal pack and may be charged by the internal battery charger.
Battery operation time	> 6 hours. Power save options may extend operating time.	18V full charge down to 12V battery low, 35% duty cycle.
Battery charge time	2.5 hours from fully discharged state	The instrument has smart charging circuitry, and can charge either the internal or an authorized external battery.
Overcharge protection	Charging discontinues once full charge is attained or switches to external battery charge.	
Discharge protection	Instrument turns off prior to battery damage	Software shutdown when battery is low.
Charge capacity	2.7 Amp-Hours (nominal-new)	

Mechanical specifications

Weight

Without cover	2150 g (4.740 lb.)
With cover	2323 g (5.121 lb.)
With cover and ext. battery pack	2778 g (6.124 lb.)

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.)

Environmental specifications

Temperature

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

Certifications and Compliances

EC

The CT100 and CT100HF comply with all applicable EU Directives.

FCC Compliance

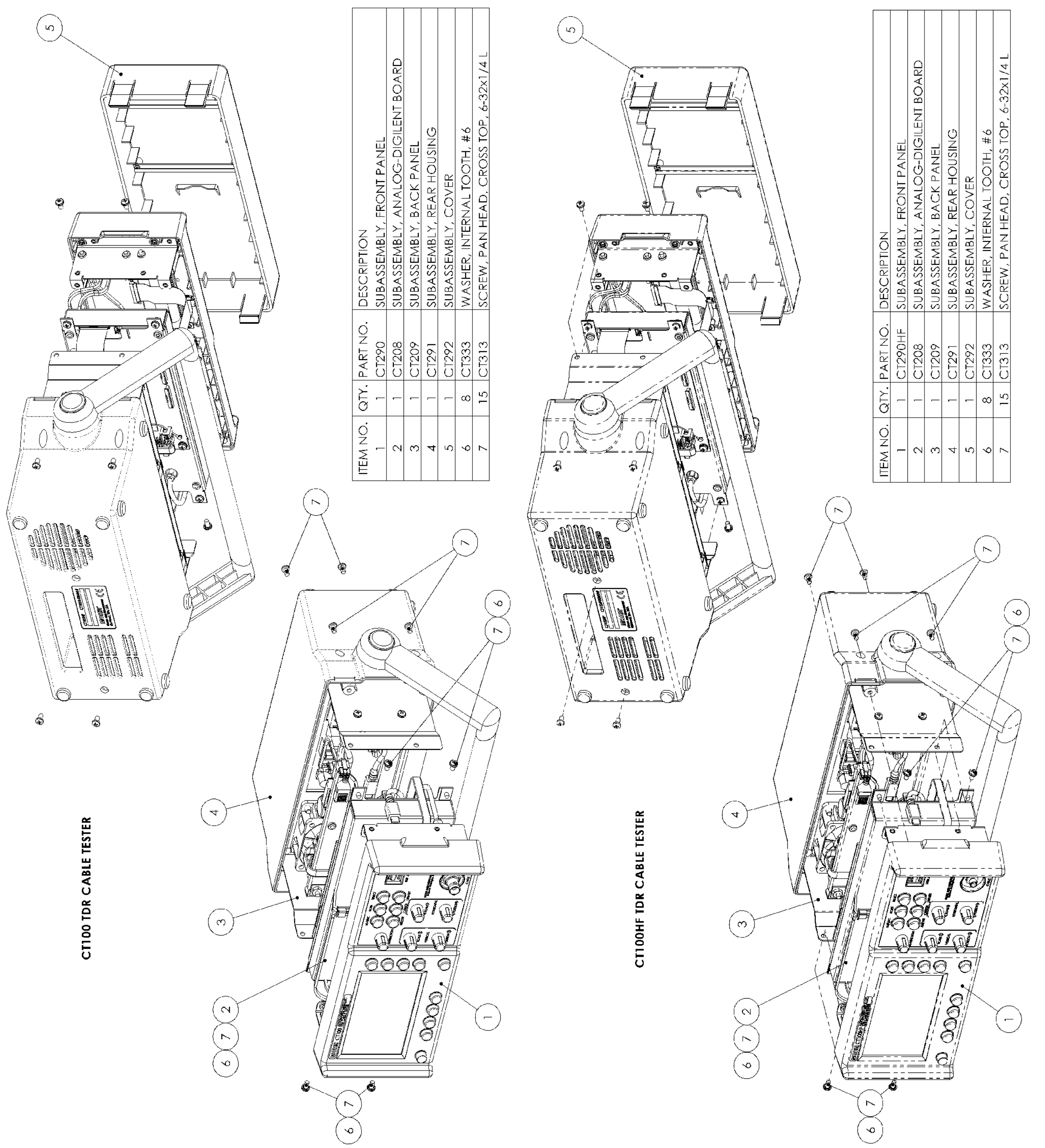
CT100 and CT100HF emissions comply with FCC Code of Federal Regulations 47, Part 15, Subpart B, Class A Limits.

Appendix B: Subassembly Drawings and Parts List

Subassembly drawings

The following drawings of the CT100 and associated mechanical and electrical subassemblies are included on the next six (6) pages:

1) CT100 full assembly, demonstrating the entire CT100 with all included subassemblies — see Figure 18.
2) CT207 power and charger subassembly — see Figure 19.
3) CT208 analog / digicomp subassembly — see Figure 20.
4) CT209 back panel subassembly — see Figure 21.
5) CT290 front panel subassembly — see Figure 22.
6) CT290HF front panel subassembly — see Figure 23.

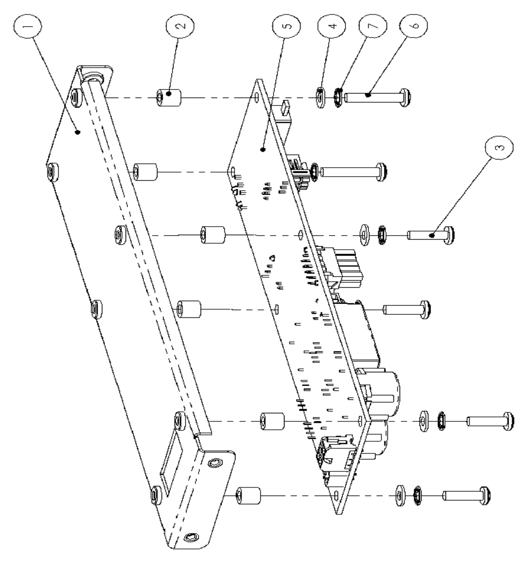


ITEM NO.	QTY.	PART NO.	DESCRIPTION
1	1	CT290	SUBASSEMBLY, FRONT PANEL
2	1	CT208	SUBASSEMBLY, ANALOG-DIGILENT BOARD
3	1	CT209	SUBASSEMBLY, BACK PANEL
4	1	CT291	SUBASSEMBLY, REAR HOUSING
5	1	CT292	SUBASSEMBLY, COVER
6	8	CT333	WASHER, INTERNAL TOOTH, #6
7	15	CT313	SCREW, PAN HEAD, CROSS TOP, 6-32x1/4 L

ITEM NO.	QTY.	PART NO.	DESCRIPTION
1	1	CT290HF	SUBASSEMBLY, FRONT PANEL
2	1	CT208	SUBASSEMBLY, ANALOG-DIGILENT BOARD
3	1	CT209	SUBASSEMBLY, BACK PANEL
4	1	CT291	SUBASSEMBLY, REAR HOUSING
5	1	CT292	SUBASSEMBLY, COVER
6	8	CT333	WASHER, INTERNAL TOOTH, #6
7	15	CT313	SCREW, PAN HEAD, CROSS TOP, 6-32x1/4 L

Figure 18: CT100 complete mechanical and electrical assembly.

CT207 SUBASSEMBLY, POWER SUPPLY-BATTERY CHARGER



ITEM NO.	QTY.	PART NO.	DESCRIPTION
1	1	CT106	PS MOUNTING BRACKET
2	6	CT306	STANDOFF, ROUND, THRU-HOLE, #6x1/4 L
3	4	CT311	SCREW, PAN HEAD, CROSSTOP, 6-32x1/2 L
4	6	CT327	#6 NYLON FLAT WASHER .032 THK
5	1	A4-A5	POWER-CHARGER ASSEMBLY
6	2	CT307	SCREW, PAN HEAD, CROSSTOP, 6-32x3/4 L
7	6	CT333	WASHER, INTERNAL TOOTH, #6

Figure 19: CT207 (power) subassembly.

CT208 SUBASSEMBLY, ANALOG-DIGICOMP - BILL OF MATERIALS

ITEM NO.	QTY.	PART NO.	DESCRIPTION
1	1	A1	ANALOG ASSEMBLY
2	1	A2	DIGICOMP ASSEMBLY
3	1	CT104	SUBASSEMBLY, ANALOG MOUNTING BRACKET
4	1	CT117	SHIELDING ENCLOSURE
5	3	CT306	STANDOFF, ROUND, THRU-HOLE, #6x1/4 L
6	1	CT335	STANDOFF, ROUND, THRU-HOLE, AL, #6x1/4 L
7	5	CT320	STANDOFF, ROUND THRU-HOLE, #6x3/8 L
8	5	CT321	SCREW, PAN HEAD, CROSSTOP, 6-32x5/8 L
9	5	CT326	#6 NYLON FLAT WASHER .062 THK
10	3	CT327	#6 NYLON FLAT WASHER .032 THK
11	4	CT328	SCREW, PAN HEAD, CROSSTOP, 6-32x7/16 L
12	8	CT333	WASHER, INTERNAL TOOTH, #6
13	1	CT338	WAVE DISC SPRING 0.194 ID x .242 OD
14	1	W1W9C1	COAX ASSEMBLY
15	1	W2W1C1	DIGICOMP - ANALOG BOARD FFC
16	1	W2W3C1	SERIAL PORT ASSEMBLY, FRONT
17	1	W2W3C2	USB HOST CABLE
18	1	W2W4C2	UMCC PLUG-PLUG CABLE ASSEMBLY

CT208 SUBASSEMBLY, ANALOG-DIGICOMP

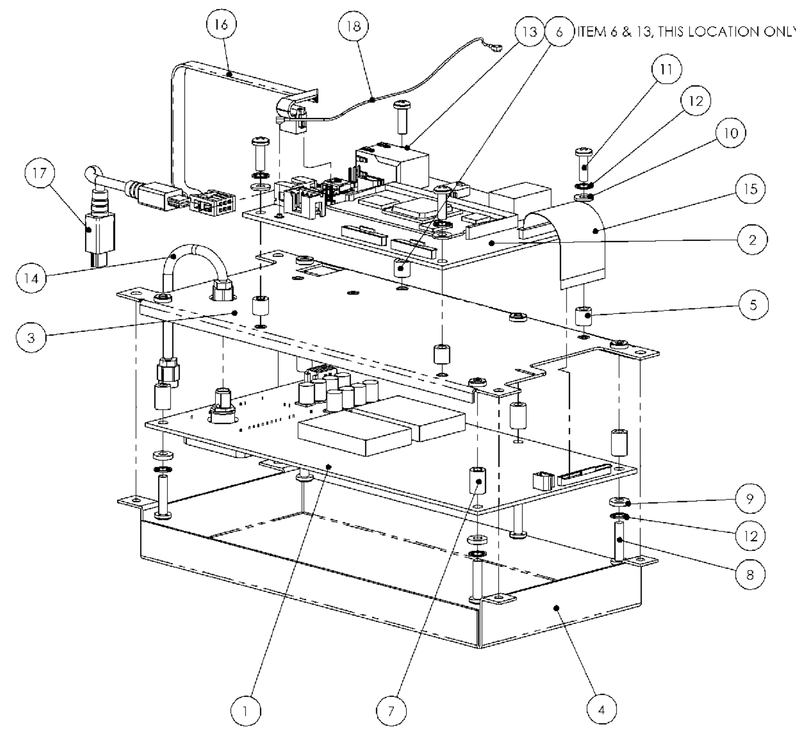


Figure 20: CT208 (analog) subassembly.

CT209 Subassembly, Back Panel

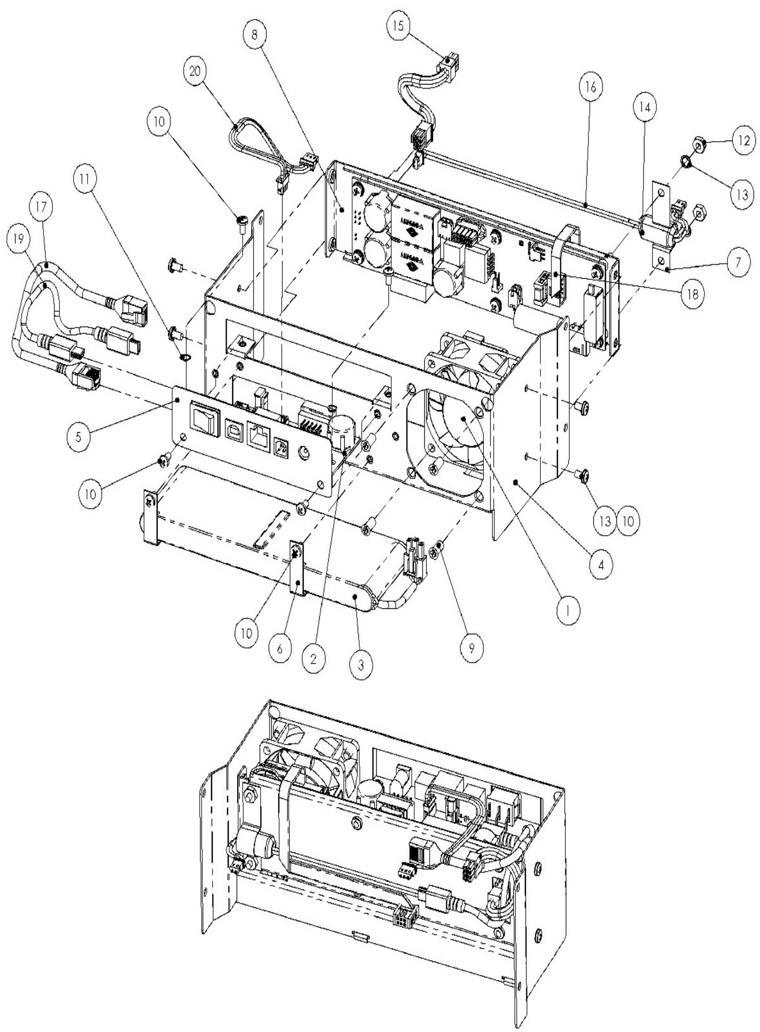


Figure 21: CT209 (back panel) subassembly.

CT209 Subassembly, Back Panel - Bill of Materials

ITEM NO.	QTY.	PART NO.	DESCRIPTION
1	1	A4A2	FAN ASSEMBLY, 60x60x25mm
2	1	A6	BACK PANEL ASSEMBLY
3	1	CT100-AC-B2700	INTERNAL BATTERY
4	1	CT119	FRAME
5	1	CT120	IO BEZEL
6	2	CT121	BATTERY CLIP
7	1	CT134	FERRITE SUPPORT BRACKET
8	1	CT207	SUBASSEMBLY, PS-BATTERY CHARGER
9	4	CT312	SCREW, FAN
10	10	CT313	SCREW, PAN HEAD, CROSS TOP, 6-32x1/4 L
11	2	CT338	WAVE DISC SPRING 0.194 ID x .242 OD
12	2	CT331	NUT, MACHINE, 6-32
13	6	CT333	WASHER, INTERNAL TOOTH, #6
14	1	M2	FERRITE EMI FILTER
15	1	W1W5C1	ANALOG POWER ASSEMBLY
16	1	W1W5C2	DIGITAL POWER ASSEMBLY
17	1	W2W6C1	ETHERNET ASSEMBLY
18	1	W2W4C1	POWER SERIAL PROGRAM CABLE
19	1	W2W6C3	USB CLIENT CABLE
20	1	W2W6C2	ETHERNET LED CABLE

CT290 Subassembly, Front Panel - Bill of Materials

ITEM NO.	QTY.	PART NO.	DESCRIPTION
1	1	A3	FRONT PANEL ASSEMBLY
2	1	A5A2	SUBASSEMBLY, POWER SWITCH
3	1	A7	ASSEMBLY, VIDEO
4	1	A7A2	SHARP LCD SCREEN
5	1	CT123-L	FRONT PANEL BRACKET
6	1	CT123-R	FRONT PANEL BRACKET
7	1	CT124	DISPLAY BACKPLANE
8	1	CT128	FERRITE SUPPORT BRACKET
9	1	CT131	ESD FP BRACKET
10	1	CT132	ESD VM BRACKET
11	1	CT133	ESD VD BRACKET
12	1	CT213	SCREEN
13	5	CT219	CONTROL KNOB
14	1	CT228	DISPLAY GASKET
15	1	CT293	SUBASSEMBLY, FRONT PANEL
16	1	CT295	ESD MODULE
17	4	CT302	SCREW, CROSSTOP, #8-32 x 3/8 L
18	12	CT304	SCREW, PLASTITE, #2-28 x 1/4 L
19	5	CT313	SCREW, PAN HEAD, CROSS TOP, 6-32x1/4 L
20	3	CT319	SCREW, PLASTITE, #2-28 x 1/2 L
21	2	CT322	STANDOFF, ROUND, THRU-HOLE, #2x3/16 L
22	5	CT333	WASHER, INTERNAL TOOTH, #6
23	1	CT336	STANDOFF, ROUND, THRU-HOLE, AL, #2x3/16 L
24	1	CT338	BELLEVILLE DISC SPRING
25	4	CT339	WASHER, INTERNAL TOOTH, #8
26	1	M1	BNC ASSEMBLY
27	1	M2	FERRITE EMI FILTER
28	1	W2W7C1	DIGICOMP - VIDEO PCB FFC
29	1	W3W3C1	FRONT PANEL TO 4 BUTTON PCB
30	1	W3W3C2	FRONT PANEL TO 5 BUTTON PCB
31	1	W3W3C3	FRONT PANEL TO 6 BUTTON PCB
32	1	W5W2W7W3C1	DIGITAL POWER ASSEMBLY

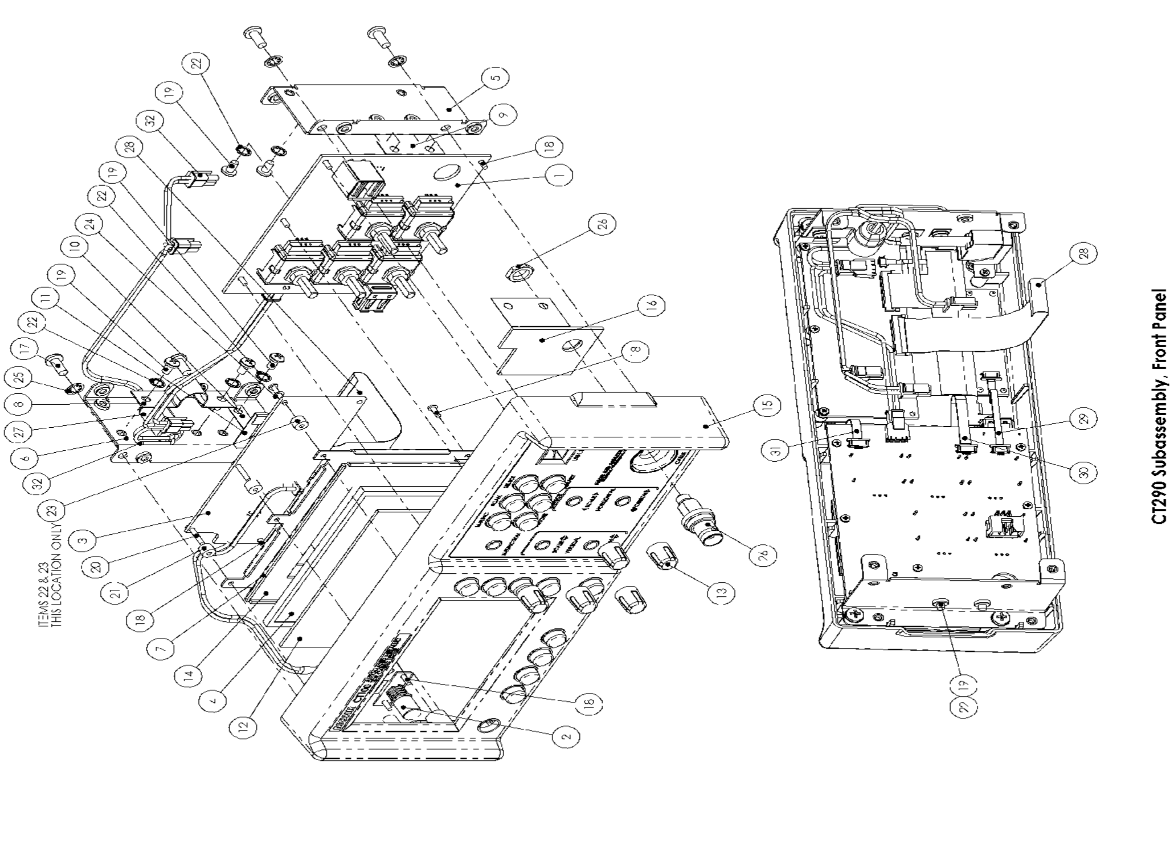
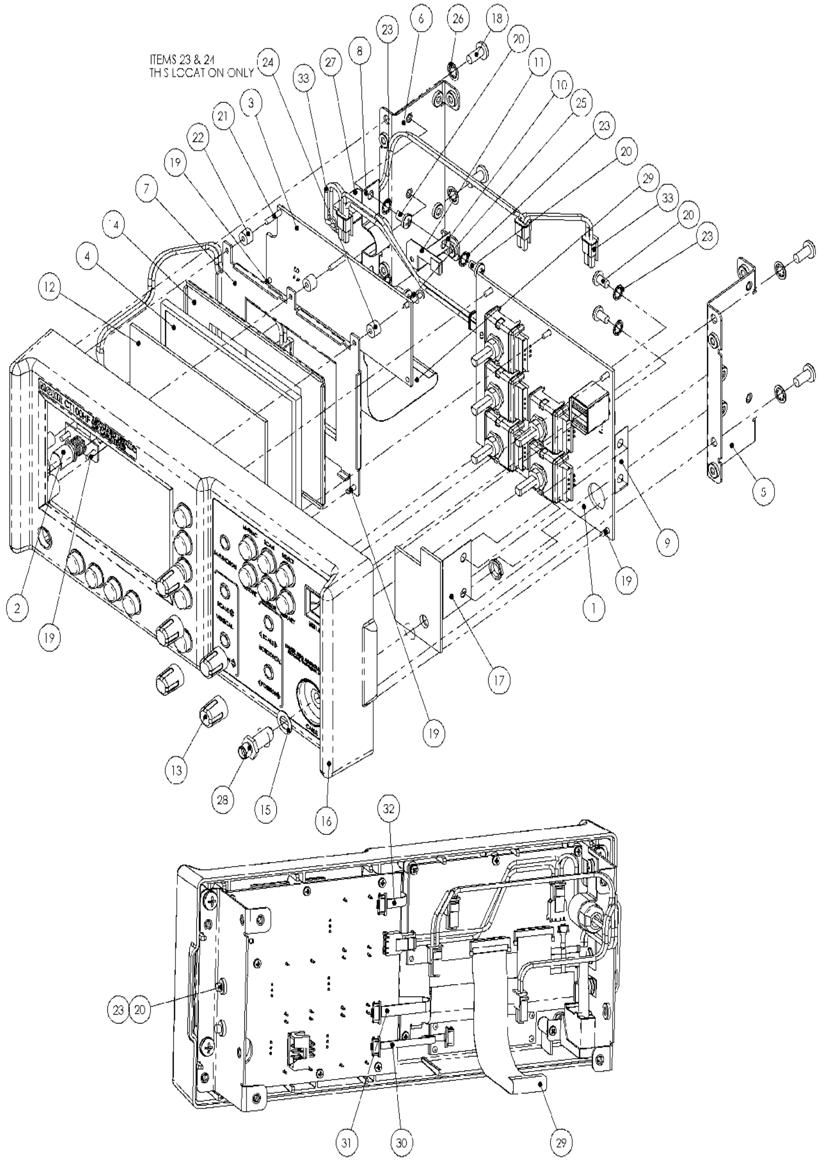


Figure 22: CT290 (front panel) subassembly.

CT290HF Subassembly, Front Panel - Bill of Materials

ITEM NO.	QTY.	PART NO.	DESCRIPTION
1	1	A3	FRONT PANEL ASSEMBLY
2	1	A5A2	SUBASSEMBLY, POWER SWITCH
3	1	A7	ASSEMBLY, VIDEO
4	1	A7A2	SHARP LCD SCREEN
5	1	CT123-L	FRONT PANEL BRACKET
6	1	CT123-R	FRONT PANEL BRACKET
7	1	CT124	DISPLAY BACKPLANE
8	1	CT128	FERRITE SUPPORT BRACKET
9	1	CT131	ESD FP BRACKET
10	1	CT132	ESD VM BRACKET
11	1	CT133	ESD VD BRACKET
12	1	CT213	SCREEN
13	5	CT219	CONTROL KNOB
14	1	CT228	DISPLAY GASKET
15	1	CT233	CASE, FRONT BUSHING
16	1	CT293HF	SUBASSEMBLY, FRONT PANEL
17	1	CT295HF	SMA ESD ASSEMBLY
18	4	CT302	SCREW, CROSSTOP, #8-32 x 3/8 L
19	12	CT304	SCREW, PLASTITE, #2-28 x 1/4 L
20	5	CT313	SCREW, PAN HEAD, CROSS TOP, 6-32x1/4 L
21	3	CT319	SCREW, PLASTITE, #2-28 x 1/2 L
22	2	CT322	STANDOFF, ROUND, THRU-HOLE, #2x3/16 L
23	5	CT333	WASHER, INTERNAL TOOTH, #6
24	1	CT336	STANDOFF, ROUND, THRU-HOLE, AL, #2x3/16 L
25	1	CT338	BELLEVILLE DISC SPRING
26	4	CT339	WASHER, INTERNAL TOOTH, #8
27	1	M2	FERRITE EMI FILTER
28	1	M5	SMA BULKHEAD CONNECTOR
29	1	W2W7C1	DIGICOMP - VIDEO PCB FFC
30	1	W3W3C1	FRONT PANEL TO 4 BUTTON PCB
31	1	W3W3C2	FRONT PANEL TO 5 BUTTON PCB
32	1	W3W3C3	FRONT PANEL TO 6 BUTTON PCB
33	1	W5W2W7W3C1	DIGITAL POWER ASSEMBLY



CT290HF Subassembly, Front Panel

Figure 23: CT290HF (front panel) subassembly.

Parts list

Subassembly	*Item*	*Part No*	*Qty*	*Description*
Front Panel		CT 290		LCD display, front control board, switches, and knobs
	1	A3	1	Front panel switch board, encoders and controller
	2	A5A2	1	Subassembly, Power switch
	3	A7	1	Video assembly board
	4	A7A2	1	Sharp LCD 4.3" diagonal screen
	5	CT123-L	1	Front panel bracket left side
	6	CT123-R	1	Front panel bracket right side
	7	CT124	1	Display backplane bracket
	8	CT128	1	Ferrite support bracket
	9	CT131	1	ESD FP bracket
	10	CT132	1	ESD VM bracket
	11	CT133	1	ESD VD bracket
	12	CT213	1	Lexan LCD screen display cover
	13	CT219	5	Control knobs – 6mm shaft, flat sided
	14	CT228	1	Display impact absorbing gasket – PORON 0.060"
	15	CT293	1	Front panel assembly with switch panels and front decals
	16	CT295	1	ESD Module
	17	CT302	4	Screw #8-32 X 3/8" SS cross top pan head
	18	CT304	12	Screw plastite, # 2-28 X 1/4L
	19	CT313	5	Screw, pan head, cross top, 6-32x1/4l SS
	20	CT319	3	Screw plastite # 2-28 X 1/2L
	21	CT322	2	Standoff, round, thru-hole, #2 X 3/16 L
	22	CT333	5	Washer, internal tooth # 6
	23	CT336	1	Standoff, round, thru-hole, AL, #2 X 3/16L
	24	CT338	1	Belleville disc spring
	25	CT339	4	Washer, internal tooth #8
	26	M1	1	BNC assembly
	27	M2	1	Ferrite EMI filter
	28	W2W7C1	1	Digicomp-video PCB FFC 40 pin flat-flex 0.5mm space
	29	W3W3C1	1	Front panel to 4 button PCB cable
	30	W3W3C2	1	Front Panel to 5 button PCB cable
	31	W3W3C3	1	Front Panel to 6 button PCB cable
	32	W5W2W7W3C1	1	Digital power assembly cable
High-Frequency Front Panel		CT 290HF		LCD display, front control board, switches, and knobs
	1	A3	1	Front panel switch board, encoders and controller
	2	A5A2	1	Subassembly, Power switch
	3	A7	1	Video assembly board
	4	A7A2	1	Sharp LCD 4.3" diagonal screen
	5	CT123-L	1	Front panel bracket left side
	6	CT123-R	1	Front panel bracket right side
	7	CT124	1	Display backplane bracket
	8	CT128	1	Ferrite support bracket
	9	CT131	1	ESD FP bracket
	10	CT132	1	ESD VM bracket
	11	CT133	1	ESD VD bracket
	12	CT213	1	Lexan LCD screen display cover
	13	CT219	5	Control knobs – 6mm shaft, flat sided
	14	CT228	1	Display impact absorbing gasket – PORON 0.060"
	15	CT233	1	Case, front bushing
	16	CT293HF	1	Front panel assembly with switch panels and front decals
	17	CT295HF	1	ESD Module
	18	CT302	4	Screw #8-32 X 3/8" SS cross top pan head
	19	CT304	12	Screw plastite, # 2-28 X 1/4L
	20	CT313	5	Screw, pan head, cross top, 6-32x1/4l SS
	21	CT319	3	Screw plastite # 2-28 X 1/2L
	22	CT322	2	Standoff, round, thru-hole, #2 X 3/16 L
	23	CT333	5	Washer, internal tooth # 6
	24	CT336	1	Standoff, round, thru-hole, AL, #2 X 3/16L
	25	CT338	1	Belleville disc spring
	26	CT339	4	Washer, internal tooth #8
	27	M2	1	Ferrite EMI filter
	28	M5	1	SMA bulkhead connector
	29	W2W7C1	1	Digicomp-video PCB FFC 40 pin flat-flex 0.5mm space

Subassembly	***Item***	***Part No***	***Qty***	***Description***
	30	W3W3C1	1	Front panel to 4 button PCB cable
	31	W3W3C2	1	Front Panel to 5 button PCB cable
	32	W3W3C3	1	Front Panel to 6 button PCB cable
	33	W5W2W7W3C1	1	Digital power assembly cable
Analog-Digicomp		CT208		
	1	A1	1	Analog assembly
	2	A2	1	Digicomp assembly
	3	CT104	1	Subassembly, analog mounting bracket (aluminum)
	4	CT117	1	Shielding enclosure (aluminum)
	5	CT306	3	Standoff, round, thru-hole, #6X1/4L
	6	CT335	1	Standoff, round, thru-hole, AL, #6X1/4L
	7	CT320	5	Standoff, round, thru-hole, #6X3/8L
	8	CT321	5	Screw, pan head, cross top, #6-32X5/8L
	9	CT326	5	#6 Nylon flat washer 0.062 THK
	10	CT327	3	#6 Nylon flat washer 0.032 THK
	11	CT328	4	Screw, pan head; cross top, 6-32X7/16L
	12	CT333	8	Washer, internal tooth #6
	13	CT338	1	Wave disc spring 0.194 ID X .242 OD
	14	W1W9C1	1	Coaxial assembly cable
	15	W2W1C1	1	Digicomp-analog board FFC cable
	16	W2W3C1	1	Serial port cable assembly
	17	W2W3C2	1	USB host cable
	18	W2W4C2	1	UMCC Plug-plug cable assembly
Back Panel		CT209		
	1	A4A2	1	Fan assembly, 60 x 60 x 25mm
	2	A6	1	Back panel assembly
	3	CT100-AC-B2700	1	Battery set NiMH with thermistors (2700 mA·h)
	4	CT119	1	Frame (aluminum)
	5	CT120	1	IO bezel (aluminum)
	6	CT121	2	Battery clip (aluminum)
	7	CT134	1	Ferrite support bracket
	8	CT207	1	Subassembly, Ps-battery charger
	9	CT312	4	Screw, fan
	10	CT313	10	Screw, pan head, cross top, 6-32x1/4l SS
	11	CT338	2	Wave disc spring 0.194 ID X .242 OD
	12	CT331	2	Nut, machine 6-32
	13	CT333	6	Washer, internal tooth #6
	14	M2	1	Ferrite EMI filter
	15	W1W5C1	1	Analog power assembly cable
	16	W1W5C2	1	Digital power cable to digital side of analog board A1
	17	W2W6C1	1	Ethernet assembly cable
	18	W2W4C1	1	Serial controller cable
	19	W2W6C3	1	USB client cable
	20	W2W6C2	1	Ethernet LED cable
Power		CT207		
	1	CT106	1	PS mounting bracket
	2	CT306	6	Standoff, round, thru-hole, #6X1/4L
	3	CT311	4	Screw, pan head, cross top, 6-32X1/2L
	4	CT327	6	#6 Nylon Flat Washer 0.032 THK
	5	A4/A5	1	Power Charger assembly
	6	CT307	2	Screw, pan head, cross top, 6-32x3/4L
	7	CT333	6	Washer, internal tooth #6

Appendix C: Operator Performance Check

General information

The CT100 and CT100HF Operator Performance Check is a series of procedures used to verify the calibration of a CT100 or CT100HF unit. 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 it requires recalibration.

The following series of steps are designed to allow a CT100 operator to completely verify the properties of an individual CT100 unit to each published specification.

> *NOTE: If a CT100 fails any Operator Performance Check, it should be serviced.*

Required equipment

Item	**Mohr part number**
50 Ω precision terminator	CT100-AC-ER50 (for CT100)
	CT100-AC-ER50S (for CT100HF)
Capacitive calibrator	CT100-AC-C001
Connector, SMA male to BNC female	CT100-AC-ISMBF (for CT100HF)
Shorting cap	CT100-AC-IBS (for CT100)
	CT100-AC-ISS (for CT100HF)
36-inch calibration cable	CT100-AC-W536 (for CT100)
	CT100-AC-W536S (for CT100HF)
Male-male BNC connector	CT100-AC-IBMM (for CT100)

Additionally, a device capable of taking accurate pulse measurements with documented calibration will be required.

Getting ready

Disconnect any cables from the front BNC connector. Connect the instrument to a suitable power source, either a fully charged battery (internal or external) or the external 24V power supply connected to a standard 3-prong AC source.

Reflected Rise Time Check (10-90%)

To measure reflected rise time of an individual CT100 it is important that nanoseconds and millirho are visible on the unit screen. The two units may be enabled within the *Display* submenu.

To determine the CT100 rise time:

1) Apply the shorting cap to the CT100 front panel cable connector.

2) Ensure that the RRC method is set to the 1502C method.

3) Adjust the on-screen trace so that the internal cable is shown completely. Figure 24 displays the internal cable on a CT100HF unit.

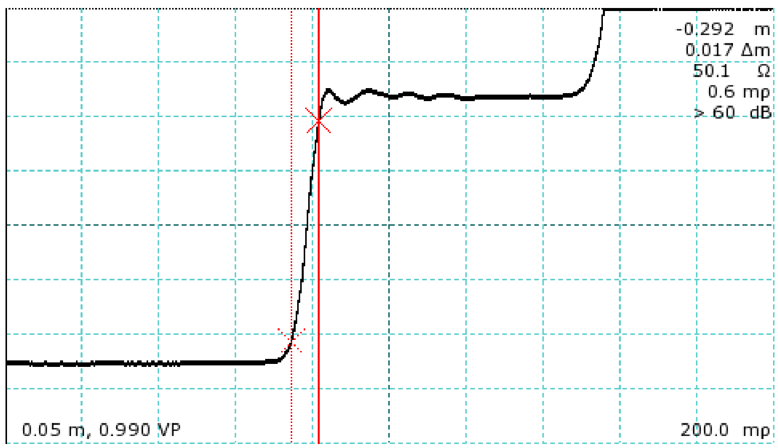


Figure 24: Trace preparation for rise time measurement. The internal cable trace is fully displayed on-screen, and the rising edge is centered.

4) Position the trace so that the leading edge of the internal cable (the left side of the trace) is centered on the screen.

5) Adjust the horizontal scale so that the trace is positioned diagonally across the screen, and adjust the vertical scale so that the left side of the trace runs along the base of the screen and the right side of the trace runs along the top of the screen. The difference between the two sides is considered 100% of the rise time and should be close to 1000mρ.

6) To find the 10-90% rise time, position one cursor at -900mρ and the second cursor at -100mρ. Figure 25 shows a trace correctly positioned for Rise Time Measurement on a CT100HF screen, with the cursors placed at the 10% and 90% points.

The difference in time between the two cursors is the 10-90% reflected rise time.

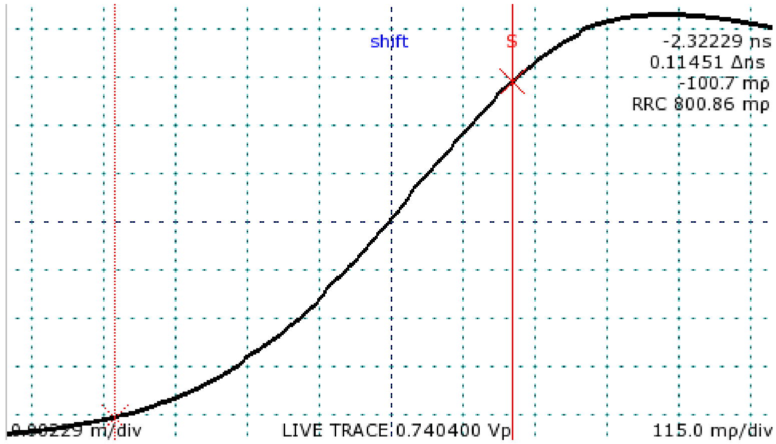


Figure 25: Cursor placement for determination of 10-90% rise time. The active cursor is at -100.7mρ while the inactive cursor is at -900.3mρ. The difference in time between cursors is the 10-90% rise time, in this case 0.11451 nanoseconds.

Reflected Rise Time Check (20-80%)

This procedure is identical to the Reflected Rise Time Check (10-90%) except that the two cursors should be positioned at -800mρ and -200mρ.

The difference in time between the two cursors is the 20-80% reflected rise time.

Jitter, Noise, and Sampling Efficiency Check

1) Connect a 50 Ω terminator to the CT100 front panel cable connector.

2) From the main menu, select the *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 CT100 is Jitter P2P, the second value in the second to last line of the results.

The value for Noise is the second number on the first line of the result, Noise P2P.

Output Impedance Check

1) Disconnect any cables from the CT100 front panel cable connector.

2) Position a cursor before the falling edge of the trace.

3) Position the second cursor well beyond the falling edge.

4) Attach a precision 50 Ω terminator to the CT100.

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

Pulse Amplitude Check

Pulse amplitude measurement should be taken with a device that can accurately measure frequency, pulse width, period, and amplitude.

Connect one end of the 36-inch calibration cable to a capable pulse measurement device and the other end of the 36-inch calibration cable to the CT100 front panel cable connector. A waveform should appear on the device display. Switch the CT100 into the short pulse setting from the main menu. Measure the pulse amplitude coming off the front panel cable connector. The pulse amplitude into 50 Ωs should be between 290mv and 300mv.

Repeat pulse amplitude comparison for medium and long pulse settings.

Pulse Width Check

Pulse width measurement should be taken with a device that can accurately measure frequency, pulse width, period, and amplitude.

Connect one end of the 36-inch calibration cable to a capable pulse measurement device and the other end of the 36-inch calibration cable to the CT100 front panel cable connector. A waveform should appear on the device display. Switch the CT100 into the short pulse setting from the main menu. Measure the pulse width coming off the front panel cable connector. The pulse width should be between 1 and 100 µsec.

Repeat pulse width comparison for medium and long pulse settings.

Pulse Repetition Rate Check

Pulse repetition rate measurement should be taken with a device that can accurately measure frequency, pulse width, period, and amplitude.

Connect one end of the 36-inch calibration cable to a capable pulse measurement device and the other end of the 36-inch calibration cable to the CT100 front panel cable connector. A waveform should appear on the device display. Switch the CT100 into the short pulse setting from the main menu. Measure the pulse repetition rate coming off the front panel cable connector. The pulse repetition rate should be between 4 and 125 µsec.

Repeat pulse repetition rate comparison for medium and long pulse settings.

Sequential Sampling Rate Check

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

Vertical Scale Check

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

Vertical Accuracy Check

1) Attach a 50 Ω precision terminator to the CT100.
2) Position a cursor on the trace so that it is well after the connection between the CT100 and the terminator.
3) The absolute value of the vertical measurement in mρ divided by 2000mρ full scale is the percent error for vertical measurement.

Vertical Position Check

1) Increase vertical scale to 500mρ/div by turning the *VERTICAL SCALE* knob to the left.
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 CT100 must succeed at both operations to pass the Vertical Position Check.

Input Susceptibility Check

Input susceptibility is a design value determined by the hybrid manufacturer and cannot be measured by the user.

Distance Cursor Resolution Check

Distance cursor resolution is a value determined by a software constant, and should not be measured. It can be measured by counting distinct locations that a cursor may occupy between two division lines, including one of the division lines.

Cursor Readout Range Check

In the main menu, set cable length to “long” maximum cable length.

Turn the *HORIZONTAL SCALE* knob to the left until horizontal scale is maximized.

Using the *M-FUNC* button and *M-FUNCTION* knob, set Vp to 1.

With the *HORIZONTAL SCALE* knob, position a cursor to the right most possible position.

The absolute distance measurement for the cursor is the upper limit for cursor readout range. This number should be larger than 1000 meters or 3300 feet.

Position a cursor at the most far left position.

The absolute distance measurement for the cursor is the lower limit for cursor readout range. This number should be less than 1 foot (0.3 meters).

Cursor Readout Resolution Check

Use the *HORIZONTAL SCALE* knob to set the horizontal scale to 0.00330 feet/div or 0.001 meters/div.

Position a cursor on the screen and note the absolute distance measurement for the cursor.

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.

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 pulse settings.

Ohm Readout Range Check

Connect the 36-inch calibration cable to the CT100.

Position a cursor on the trace well beyond the end of the cable. The vertical impedance measurement should read >=1k ohm.

Position a cursor on the trace well before the leading edge of the pulse. The vertical impedance measurement should read <= 1 ohm.

Resolution Check

Position a cursor at a point of the trace where the vertical impedance measurement is greater than 1 ohm and less than 1000 ohms. The CT100 should display 3 digits for this measurement.

Vertical Accuracy Check

Vertical accuracy is checked by comparing CT100 resistance (ohmage) measurements against a known value. The supplied 50 Ω terminator is required.

To view vertical accuracy, the ohmage at cursor must be displayed. Enable ohmage at cursor readings from within the *Display* submenu.

To determine vertical accuracy, connect a 50 Ω terminator onto the front panel cable connector. Move a cursor out to a length greater than 1m. Ohmage may change a small amount from point to point. An average ohmage amongst a number of points along the trace determines vertical accuracy.

Ohmage at cursor should be between 45 and 55 ohms.

Vertical accuracy should be checked for short, medium, and long maximum cable lengths.

Horizontal Scale Check

From the main menu, choose the cable length so that it is set to long maximum cable length.

Using the *M-FUNC* button and *M-FUNCTION* knob, set Vp to 1.00.

Turn the *HORIZONTAL SCALE* knob to the left. Horizontal scale should increase beyond 61 meters/div or 200 feet/div.

Turn the *HORIZONTAL SCALE* knob to the right. Horizontal scale should decrease below 0.01 meters/div or 0.03 feet/div.

Horizontal Range Check

See the cursor readout range instructions above. Horizontal range and cursor readout range are always equal.

Horizontal Position Check

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

Pulse Frequency Check

Pulse frequency measurement should be taken with a device that can accurately measure frequency, pulse width, period, and amplitude.

Connect one end of the 36-inch calibration cable to a capable pulse measurement device and the other end of the 36-inch calibration cable to the CT100 front panel cable connector. A waveform should appear on the device display. Switch the CT100 into the short pulse setting from the main menu. Measure the pulse frequency coming off the front panel cable connector. Repeat pulse frequency measurements for short, medium, and long pulse settings. The pulse frequency should be 250 kHz for short, 50 kHz for medium, and 12.5 kHz for long.

Appendix D: Calibration Procedures

General information

The purpose of this procedure is to calibrate the CT100 to published specifications. Following this procedure will ensure that a CT100 or CT100HF unit will provide accurate measurements within published specifications. This procedure should only be performed if a CT100 is found to need recalibration, or is operating outside of published specifications after following the *CT100 and CT100HF Operator Performance Check*.

This procedure is not intended to familiarize a user with the instrument. Only extremely experienced users should perform the *CT100 and CT100HF Calibration Procedure*. Those inexperienced with CT100 operation should read the section titled *Operating Instructions*.

Calibration Procedures must be performed at stable internal and external temperatures. Ensure that the testing environment will have no temperature variation and that the CT100 internal temperature does not fluctuate.

Calibration interval

The CT100 should be calibrated annually as described in this appendix.

Required equipment

Item	Mohr part number
50 Ω precision terminator	CT100-AC-ER50 (for CT100)
	CT100-AC-ER50S (for CT100HF)
Capacitive calibrator	CT100-AC-C001
Connector, SMA male to BNC female	CT100-AC-ISMBF (for CT100HF)
Shorting cap	CT100-AC-IBS (for CT100)
	CT100-AC-ISS (for CT100HF)
36-inch calibration cable	CT100-AC-W536 (for CT100)
	CT100-AC-W536S (for CT100HF)
Male-male BNC connector	CT100-AC-IBMM (for CT100)

Optional: At the beginning of calibration, optionally verify pulse properties using an external device capable of taking accurate pulse measurements.

Getting ready

CT100 calibration requires specific device settings before continuing.

1) Disconnect any cables from the front panel cable connector.

2) Ensure that smoothing is set to 1 by pressing the *M-FUNC* button (Button 18) until the device displays the smoothing value. Rotate the *M-FUNCTION* knob counter-clockwise until the smoothing value is set to 1.

3) Set Vp to a value greater than 0.700 by pressing the *M-FUNC* button (Button 18) until the device displays the Coarse Vp value. Rotate the *M-FUNCTION* knob until the current Vp is greater than 0.700. Ideally the Vp used should be that of the supplied 36-inch calibration cable. Refer to the label attached to the 36-inch cable for a precise Vp.

4) Set the CT100 to use meters as the length unit. From the main screen press the blue *MENU* button. Select the *Measurement* submenu (Button 2). The menu item above Button 4 displays the current units. Press Button 4 until the menu displays “Units meters.”

5) Also on the *Measurement* menu, set Oversample to “off.”

The following checks and steps must be performed in the order described. The first procedure may be skipped if pulse verification is unnecessary.

Pulse measurement checks (optional)

Pulse measurements should be taken with a device that can accurately measure frequency, pulse width, period, and amplitude.

Connect the CT100 to a capable device using the 36-inch calibration cable. Switch the CT100 into the short pulse setting from the main menu. Measure each pulse value and compare it against the values given in the supplied CT100 Calibration Certificate. If a certificate is unavailable, the published specifications listed in *Appendix A* may be used as a basis for comparison. If values fall outside of specifications, discontinue calibration and refer to the Troubleshooting section of the Technical manual. Repeat value comparison for medium and long maximum cable lengths.

Turn off temperature adjustment

Temperature adjustment must be disabled to complete the manual calibrations. To disable automatic temperature adjustment:

1) Press the blue *MENU* button repeatedly until the main menu appears.

2) Enter the *Diagnostics* submenu.

3) Enter the *Calibration* submenu.

4) Read the displayed warning message and select *OK* to continue.

5) Disable temperature adjustment. Temperature adjustment is disabled when there are no asterisks bracketing the menu item.

Set manual calibration values

Rough calibration values should be set manually before performing each specific calibration.

To enter manual calibrations from the test screen:

1) Enter the *Manual Calibration* menu by pressing Button 21 from the *Calibration* submenu.

   Before setting manual calibration values, clear the existing temperature lookup table. To clear the table select *Clear Temp Lookup*. A warning message will appear. Press Button 4 for *OK* to continue.

To set the Step Pulse Reference:

1) Press *Step Pulse Ref* (Button 20) to display the Driver Comp Value on the CT100 screen.
2) Twist the *M-FUNCTION* (Knob 18) knob until the displayed Driver Comp Value reads 10000. This will ensure the driver activation signal is timed correctly.

To set the Timebase DAC value:

1) Display the Sampler Comp value by pressing *Timebase DAC* (button 21).
2) Twist the *M-FUNCTION* knob until the displayed Sampler Comp value reads 35000. This will ensure that the timebase DAC sampler voltage is set correctly during calibration.

To set the Hybrid Reference Value:

1) Display the Hybrid Comp value on the CT100 screen by pressing *Hybrid Reference* (button 22).
2) Twist the *M-FUNCTION* knob until the displayed Hybrid Comp value reads 45000. This will ensure the Hybrid reference voltage is accurately set during calibration.

Choose the *CABLE LEN* menu option to set the maximum cable length to a new setting.

Set the Step Pulse Reference to 10000, Timebase DAC value to 35000, and Hybrid Reference Value to 45000.

Choose the *CABLE LEN* menu option again to set the maximum cable length to the third setting.

Set the Step Pulse Reference to 10000, Timebase DAC value to 35000, and Hybrid Reference Value to 45000.

Capacitive load calibration

Capacitive load calibration is the first part of CT100 calibration and requires a capacitive calibrator (Part CT100-AC-C001).

1) From the *Calibration* submenu select the *Capacitive Load* item (Button 3).

Capacitive load calibration will commence.

Driver start calibration

1) Start automatic driver calibration by selecting *Driver Start* from the *Calibration* menu. Completion of the step may take some time.

Resistive load calibration

Resistive load calibration should be performed after capacitive load calibration has completed.

1) Remove any attachments from the CT100 front cable connector.

2) Start resistive load calibration by selecting the *Resistive Load* menu item (Button 4) from the *Calibration* submenu.

Resistive load calibration will commence. In the resistive load calibration routine the CT100 may display a message instructing the operator to attach a shorting cap or an open to the front of the cable connector. The precise devices required will depend on what sort of cable connector your CT100 has.

Vertical calibration

Vertical calibration should be performed immediately after resistive load calibration has completed. A 50 Ω Precision Terminator is required.

1) Attach the 50 Ω precision terminator to the front panel cable connector.

2) Start vertical calibration by selecting *Vertical Calibration* (Button 23) from the *Calibration* submenu.

Vertical calibration will continue and complete.

Manually verify calibration values

After the automated calibrations have completed, it is a good idea to verify the adjusted values and modify them if necessary.

Manually verify capacitive calibration

1) Attach the capacitive calibrator to the front panel cable connector.

2) Rotate the *HORIZONTAL POSITION* knob until one cursor is at the farthest left point on the screen. Keep moving the cursor left until the cursor sits at the earliest possible position on the trace.

3) Press the *CURSOR* button to switch to the second cursor.

4) Move the second cursor across the screen until the change in time between the two cursors reads close to 50ns. At 50ns from the start of the trace, there is a clock pulse, or "rollover". When the capacitive calibration is correct, the timing of the trace is synchronized across the pulse so that the trace before 50ns lines up with the trace after 50ns.

5) Magnify the 50 nanosecond rollover by adjusting vertical and horizontal scale while keeping the live trace on-screen using the *VERTICAL* and *HORIZONTAL SCALE* and *POSITION* knobs. Scale values of 0.1 ft/div (0.03m/div) and 5mp/div are acceptable, but a break at a larger scale may be visible.

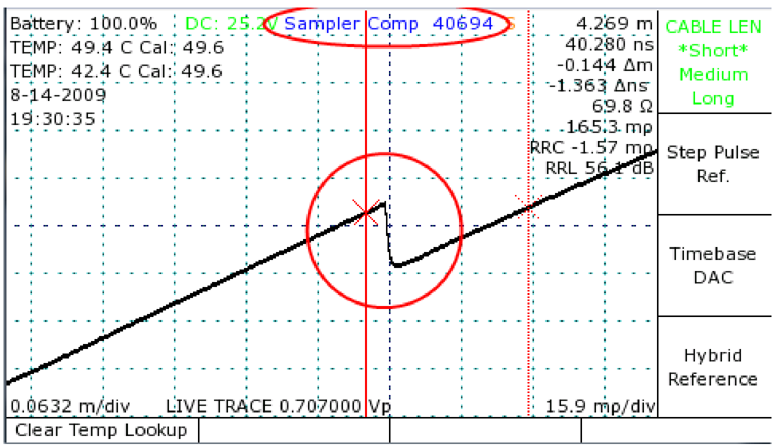


Figure 26: Example of an incomplete capacitive calibration. The circled area is the 50ns point. The separation between traces is indicative of a CT100 that needs Sampler Comp adjustment.

At this point, the CT100 should display the live trace diagonally across the screen.

If calibration needs additional manual adjustment the live trace will appear to show a break at the 50ns point. Figure 26 displays the appropriate scale. The 50ns rollover is surrounded by a red circle. However, in Figure 26, the capacitive calibration needs to be adjusted. Figure 27 displays a trace that does not need manual capacitive calibration.

If adjustment is necessary, adjust the Sampler Comp value until the live trace shows no breaks as per Figure 27. If the trace appears linear across the 50ns rollover, steps 6 through 9 may be skipped.

6) Enter the *Calibration* submenu

7) Enter the *Manual Calibration* submenu

8) Select *Timebase DAC* by pressing Button 21.

9) Rotate the *M-FUNCTION* knob until the live trace appears linear as in Figure 27.

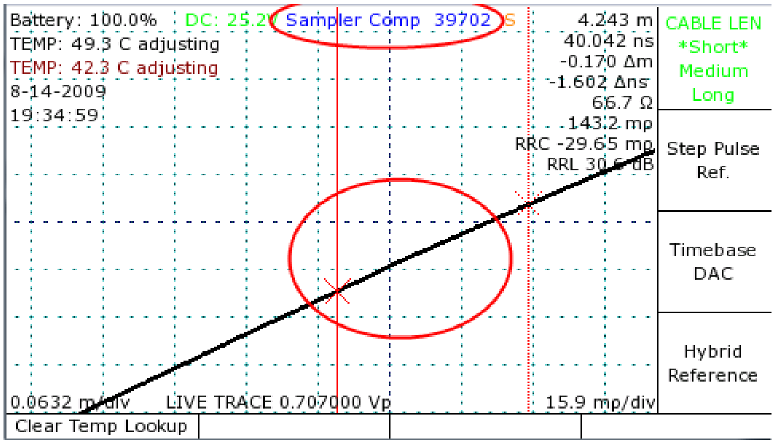


Figure 27: Example of a correctly set capacitive calibration. The circled area is the 50 rollover. Compare against Figure 26 where manual adjustment is necessary.

10)Repeat steps 1 through 9 for short, medium, and long maximum cable lengths.

Manually verify resistive load calibration

The following text discusses the manual resistive load calibration procedure, which you can use at any time to check and/or manually adjust the vertical calibration of the instrument for maximum precision of vertical measurements. From the *Main* menu, select *Calibration*, press *OK* when the warning appears, and then select *Manual Calibration*.

1) Remove all cables from the front panel cable connector.

2) Adjust the CT100 scale to 0.5 ft/div (0.15 m/div) and 500 mρ/div.

3) Place the cursor as is shown in Figure 28 on the rising edge of the internal cable segment.

4) Center the cursor in the middle of the screen using the position knobs.

5) Expand the scale to 0.070 ft/div and 40 mρ/div.

6) Push the *Hybrid Comp* button to start the manual resistive load calibration. The automatic calibration option is discussed elsewhere in this manual. At this point the words “Hybrid Comp” appear at the top of the screen with a 5 digit number as shown in Figure 28. This trace is typical of a CT100 with the self-grounding BNC test port and/or with a shorting terminator applied. The CT100HF does not have the shorting BNC and will show an open condition at the end of the trace if a shorting terminator is not applied.

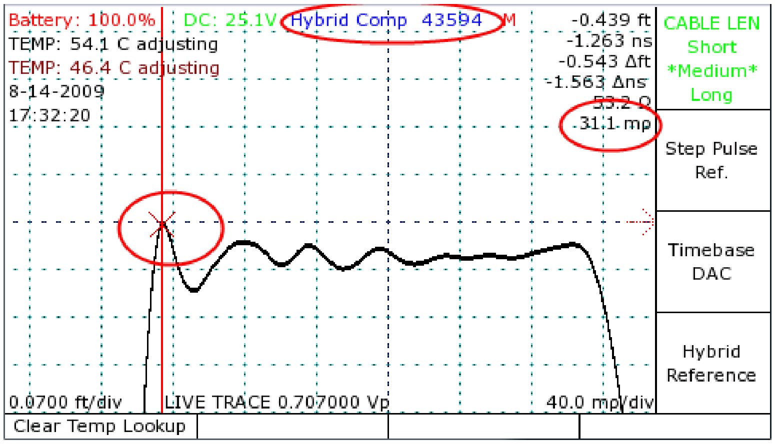


Figure 28: Typical trace from a CT100 with a shorting terminator applied to the test port. The active cursor is set at the reflected rise. The right hand side of the trace shows the effect of the shorting terminator.

7) The next step is to adjust *Hybrid Comp* to minimize the vertical shift that occurs when changing between open and short conditions. The value of *Hybrid Comp* can be adjusted by turning the *M-FUNCTION* knob on the front panel. For CT100 units with the self-grounding BNC test port, a male–male BNC adapter is used to provide an open condition. For CT100HF units with an SMA test port, leave the test port empty.

   Figure 29 shows an open condition at the test port. The apparent reflection coefficient of the trace has changed from 31 mρ to -53.6 mρ, indicating that an adjustment of Hybrid Comp is required.

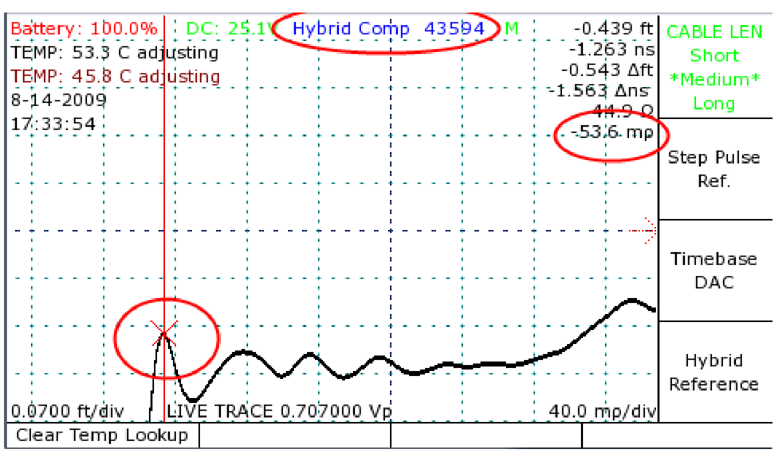


Figure 29: Hybrid Comp adjustment with open BNC and cursor at the reflected rise. Note for most applications the horizontal gain should be at 0.004 ft/div and the vertical scale should be set at 2 mρ/div. The male–male BNC adapter can be used to provide an "open" condition.

Figure 30 shows the open trace after adjustment of *Hybrid Comp* with the vertical and horizontal gain set to the recommended ranges.

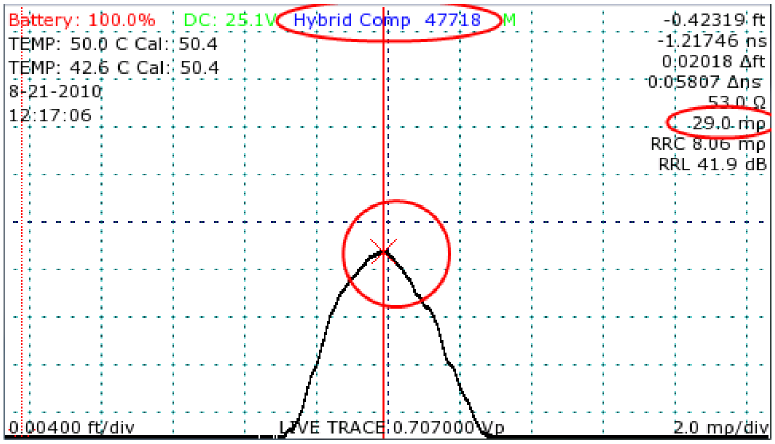


Figure 30: Hybrid Comp adjustment with open terminator and cursor at the reflected rise. The horizontal scale is set at 0.004 ft/div and the vertical scale is set at 2 mp/div. The male–male BNC adapter can be used to provide an "open" condition.

Figures 31 and 32 show the deviation in vertical position of the trace after adjustment of *Hybrid Comp* and application of a shorting terminator. For better accuracy, high horizontal and vertical gain should be used, as in Figures 30 and 32.

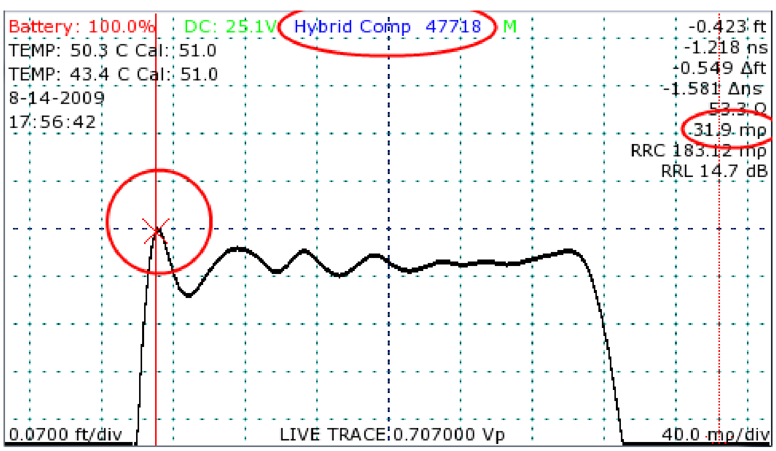


Figure 31: Hybrid Comp adjustment with the shorting terminator and the cursor at the reflected rise. Hybrid Comp has been adjusted so that the reflection coefficient of the trace is unchanged between short and open. The horizontal scale should be 0.004 ft/div and the vertical scale should be set to 2 mp/div to obtain maximum accuracy.

Notice that the reflection coefficient indicated on the screen changes from 30.1 to 29.0 between open and short (Figures 30 and 32) for a difference of 1.1mρ, an acceptable variation.

Steps 1 through 7 must be carried out separately for short, medium, and long cable length settings.

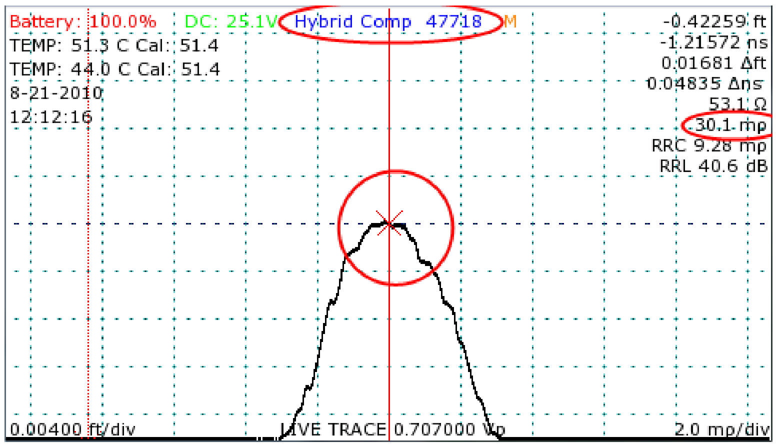


Figure 32: Hybrid Comp adjustment with the shorting terminator and the cursor at the rising edge. The Hybrid Comp value has been changed so that the reflection coefficient of the trace is unchanged whether or not the port condition is short or open.

Enable temperature adjustment

Before finalizing calibration, automatic temperature adjustment should be re-enabled. To re-enable temperature adjustment from the *Main* menu:

1) Enter the *Calibration* submenu by selecting the *Calibration* menu option.

2) Select the *Temperature Adjustment* menu item to enable temperature adjustment. When temperature adjustment is enabled, the menu item will be bracketed by asterisks, '*'.

Horizontal calibration

Horizontal calibration sets the start position for distance measurements. For precise measurements it is extremely important to perform horizontal calibration as accurately as possible.

To horizontally calibrate the CT100:

1) Connect the shorting cap to the front panel cable connector.

2) Set smoothing to 64 frames.

3) Position one cursor immediately before the falling edge of the live internal cable trace.

4) Center the cursor in the middle of the screen using the position knobs.

5) Expand the scale to 0.0100 ft/div and 1.0 mρ/div.

6) Locate the small break in slope on the falling edge shortly after the final peak on the live internal cable trace.

   It may be necessary to adjust the scale further to find the obvious break point signifying the cable end. Refer to Figure 33 for an example.

7) Position one cursor at the end of the break point.

8) Enter the *Calibration* submenu.

9) Press *Horizontal* (Button 5) to set horizontal calibration.

10) Press Button 4 for *OK* to continue.

Figure 33: Identification of cable start position. The circled portion of the trace is the point signifying the front panel cable connector. The active cursor should be moved to the flat section of the trace pointed to by the arrow.

Horizontal calibration must be set for each pulse setting. Change to the next pulse setting and repeat steps 1 through 9. Repeat again for the final pulse setting.

After horizontal calibration, measure a known length of cable to verify accurate start point positioning.

Clear temperature lookup table

After calibration is completed, it is necessary to clear the temperature lookup table used to expedite temperature calibration while the CT100 is in use. Clearing this table will force the temperature lookup table to be rebuilt using the newly calibrated values.

To clear the temperature lookup table:

1) From the main screen, push the blue *MENU* button.
2) Enter the *Calibration* submenu (Button 4).
3) Select *OK* to continue (Button 4).
4) Select *Manual Calibration* (Button 21).
5) Select *Clear Temp Lookup* by pressing Button 23. A warning message will be displayed asking to verify the clearing of temperature adjustment.
6) Select *OK* to complete clearing the temperature lookup table.

Appendix E: Operator Troubleshooting

General information

Use this troubleshooting guide when there is a problem with a CT100 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 CT100 if it exhibits signs of thermal overload, such as emitting heat or smoke, or if it smells of burning plastic.*

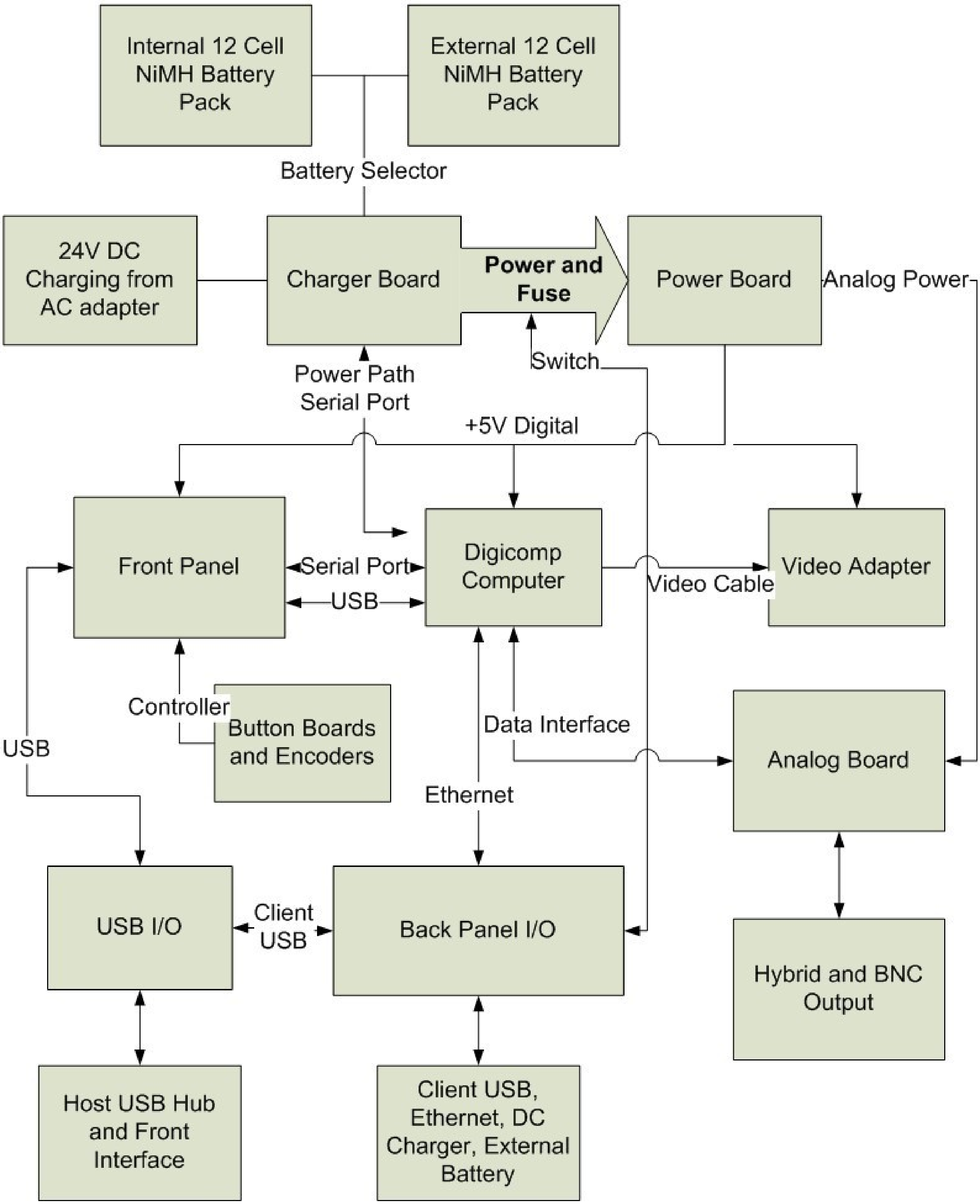
Power on test

Verify that the back switch is in the ON position. Press the red front 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.

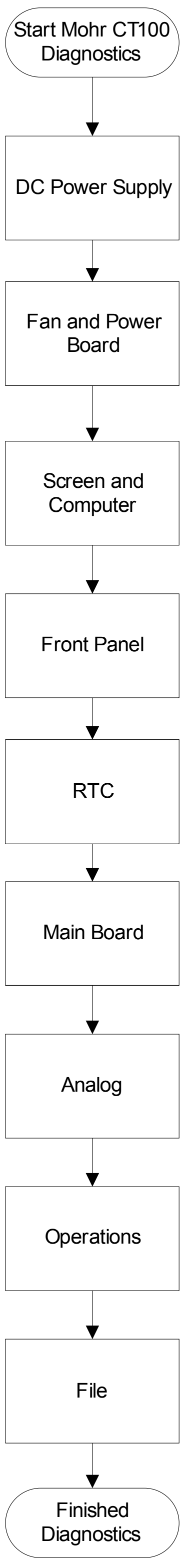
Functional block diagram and troubleshooting flowchart

Use the following functional block diagram and troubleshooting flowcharts for various parts of the CT100 to determine if your CT100 requires service.

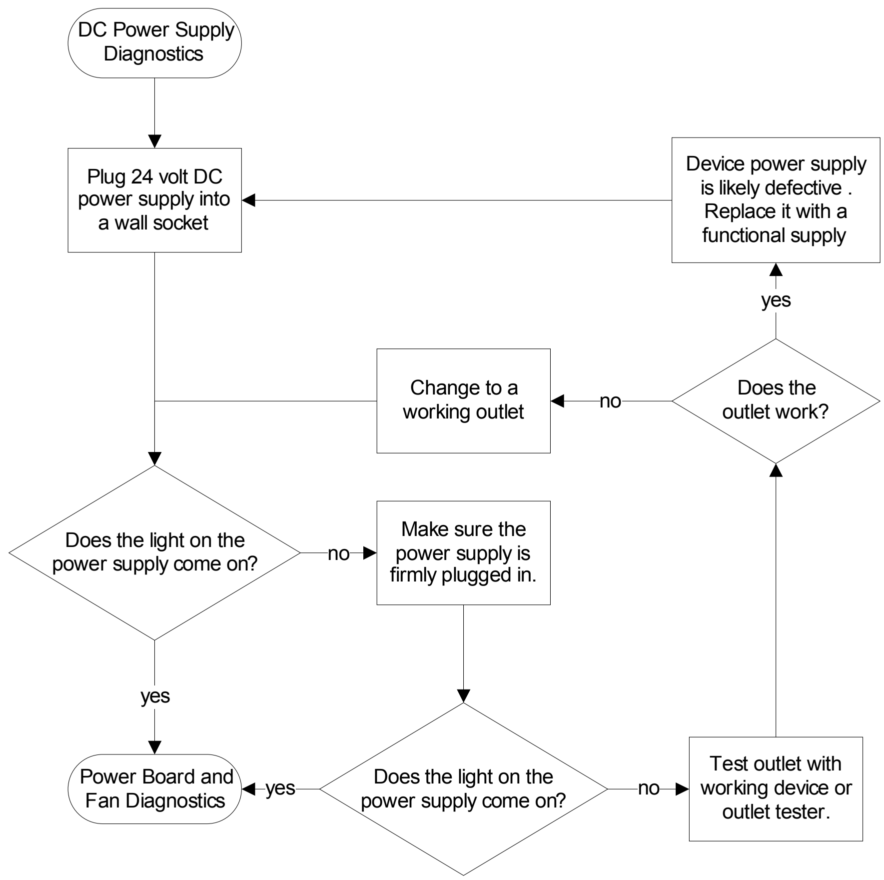
CT100 Functional Block Diagram



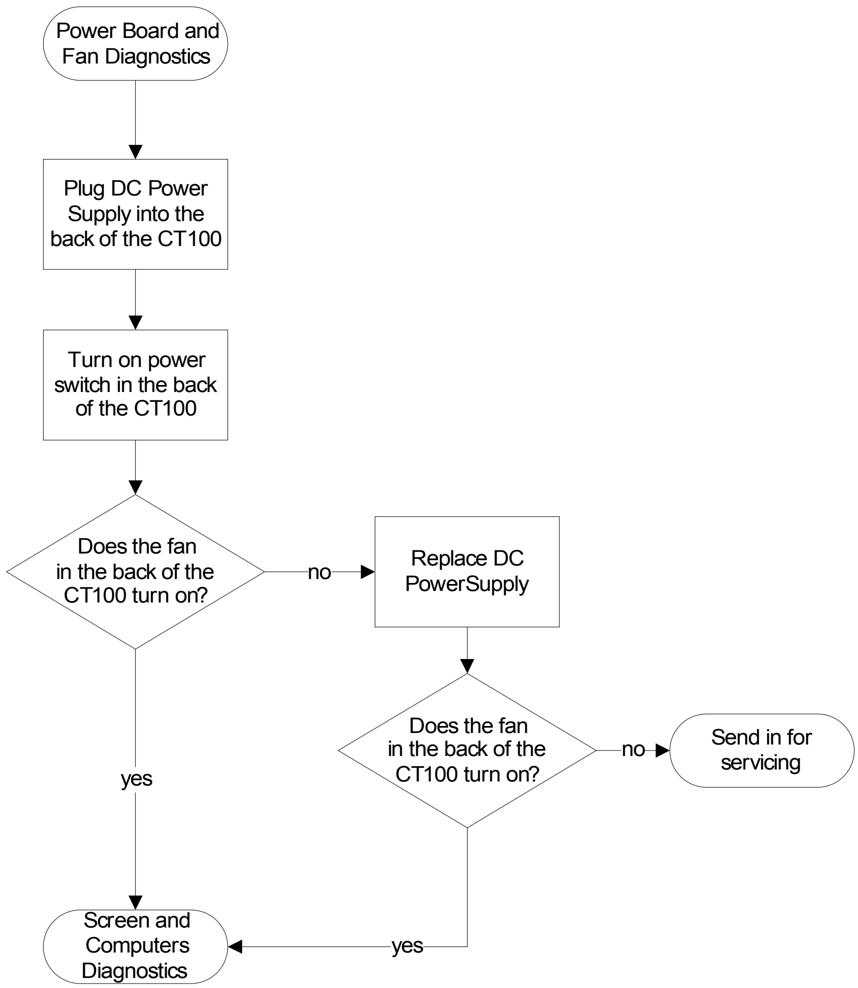
Main Diagnostic Sequence



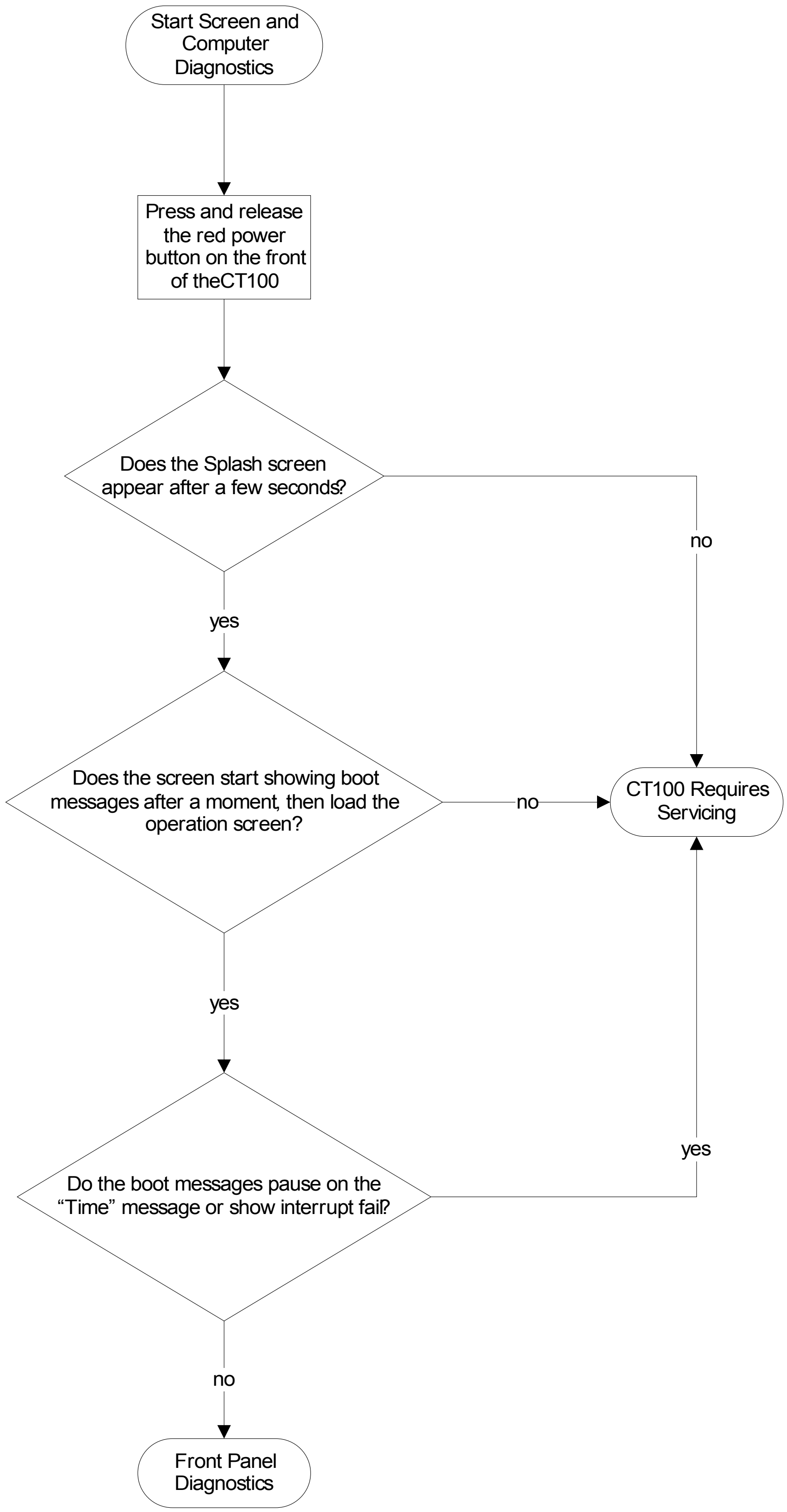
DC Power Supply

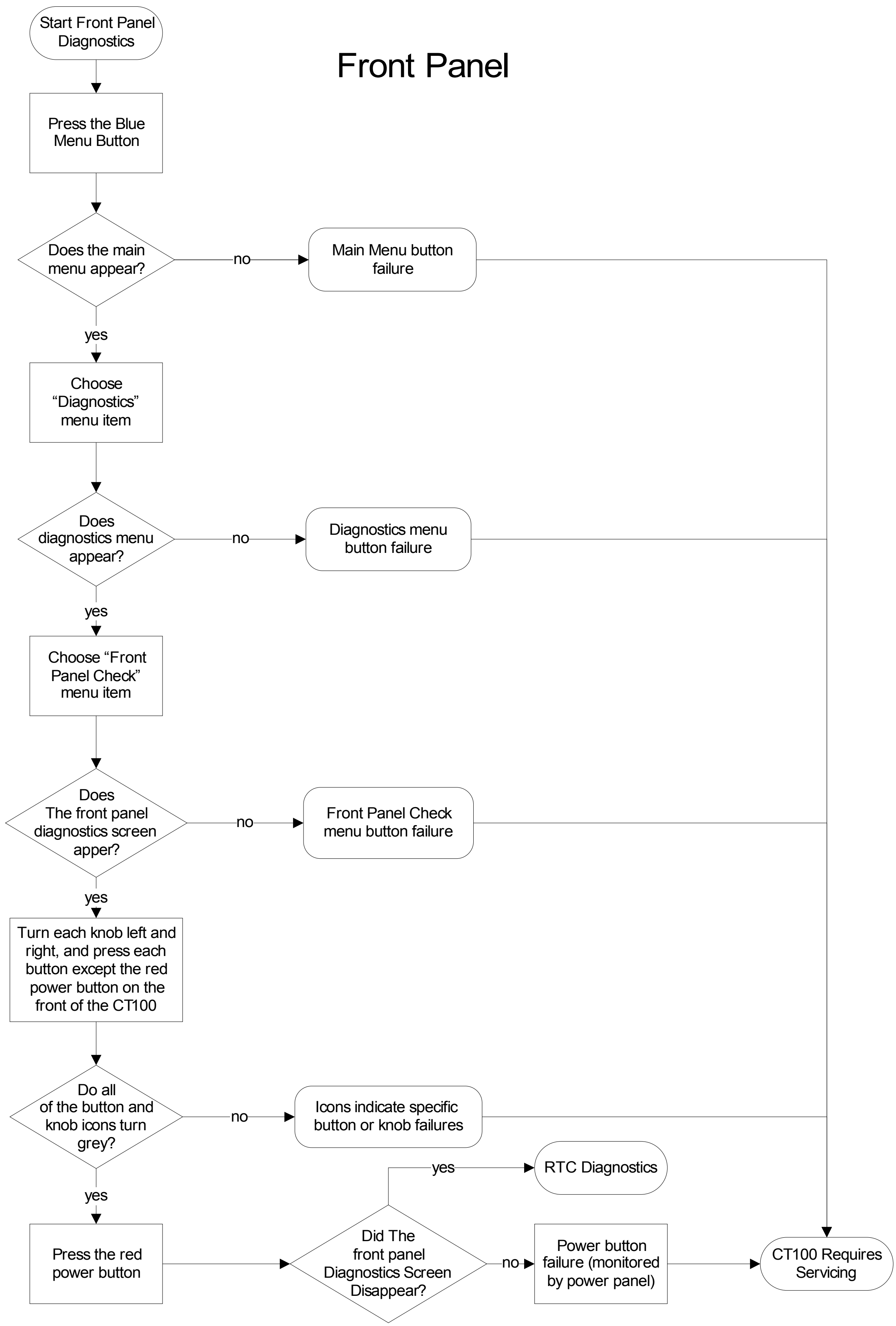


Power Board and Fan

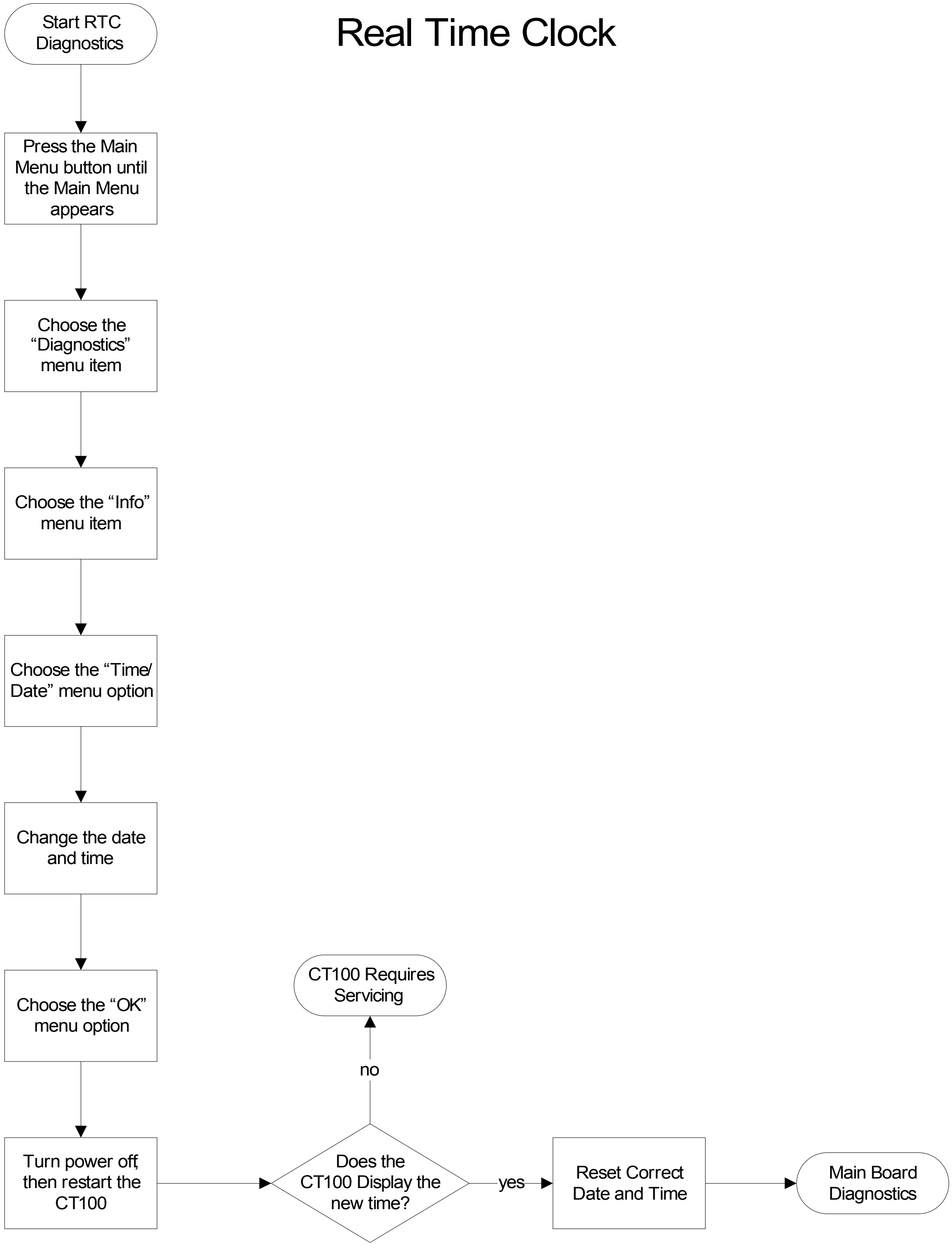


Screen and Computer

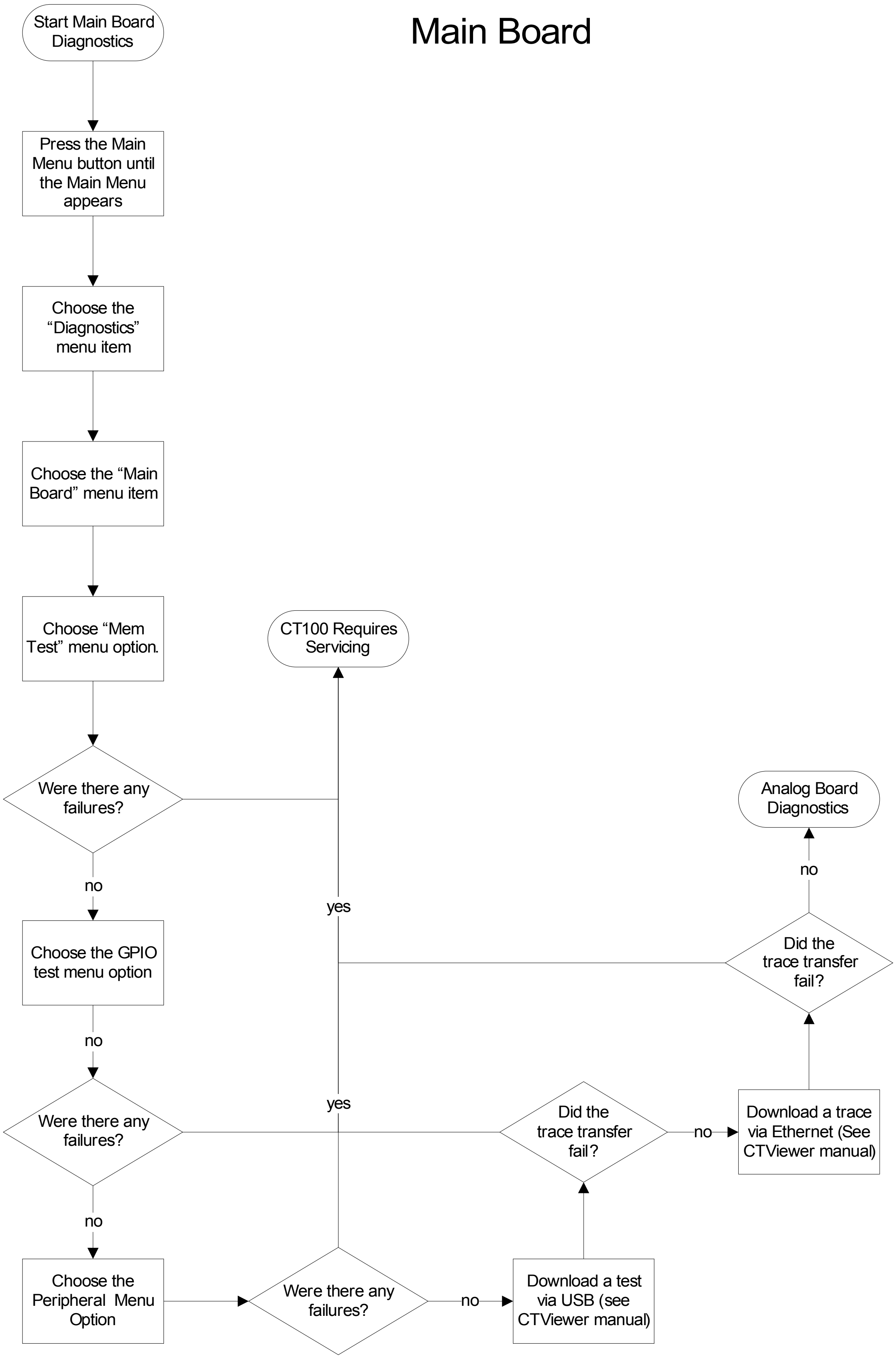



Front Panel
Start Front Panel Diagnostics
Press the Blue Menu Button
Does the main menu appear?
no
Main Menu button failure
yes
Choose “Diagnostics” menu item
Does diagnostics menu appear?
no
Diagnostics menu button failure
yes
Choose “Front Panel Check” menu item
Does The front panel diagnostics screen apper?
no
Front Panel Check menu button failure
yes
Turn each knob left and right, and press each button except the red power button on the front of the CT100
Do all of the button and knob icons turn grey?
no
Icons indicate specific button or knob failures
yes
Press the red power button
Did The front panel Diagnostics Screen Disappear?
yes
RTC Diagnostics
no
Power button failure (monitored by power panel)
CT100 Requires Servicing

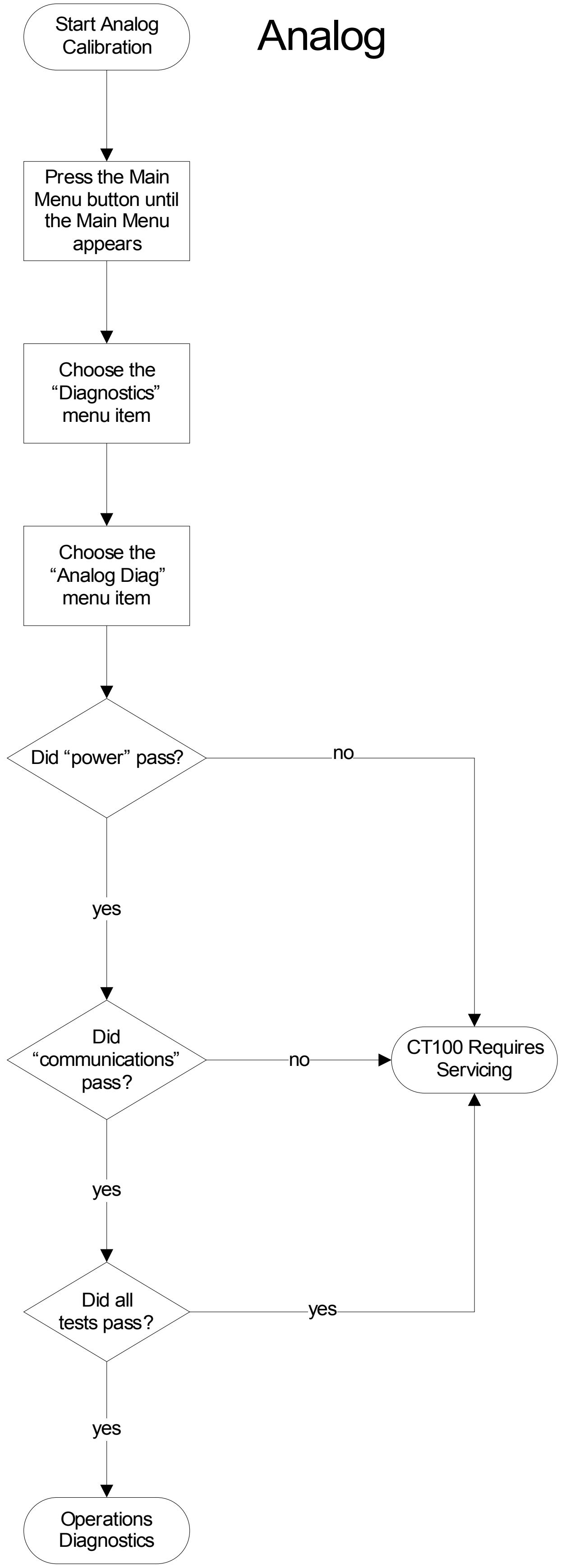
Real Time Clock



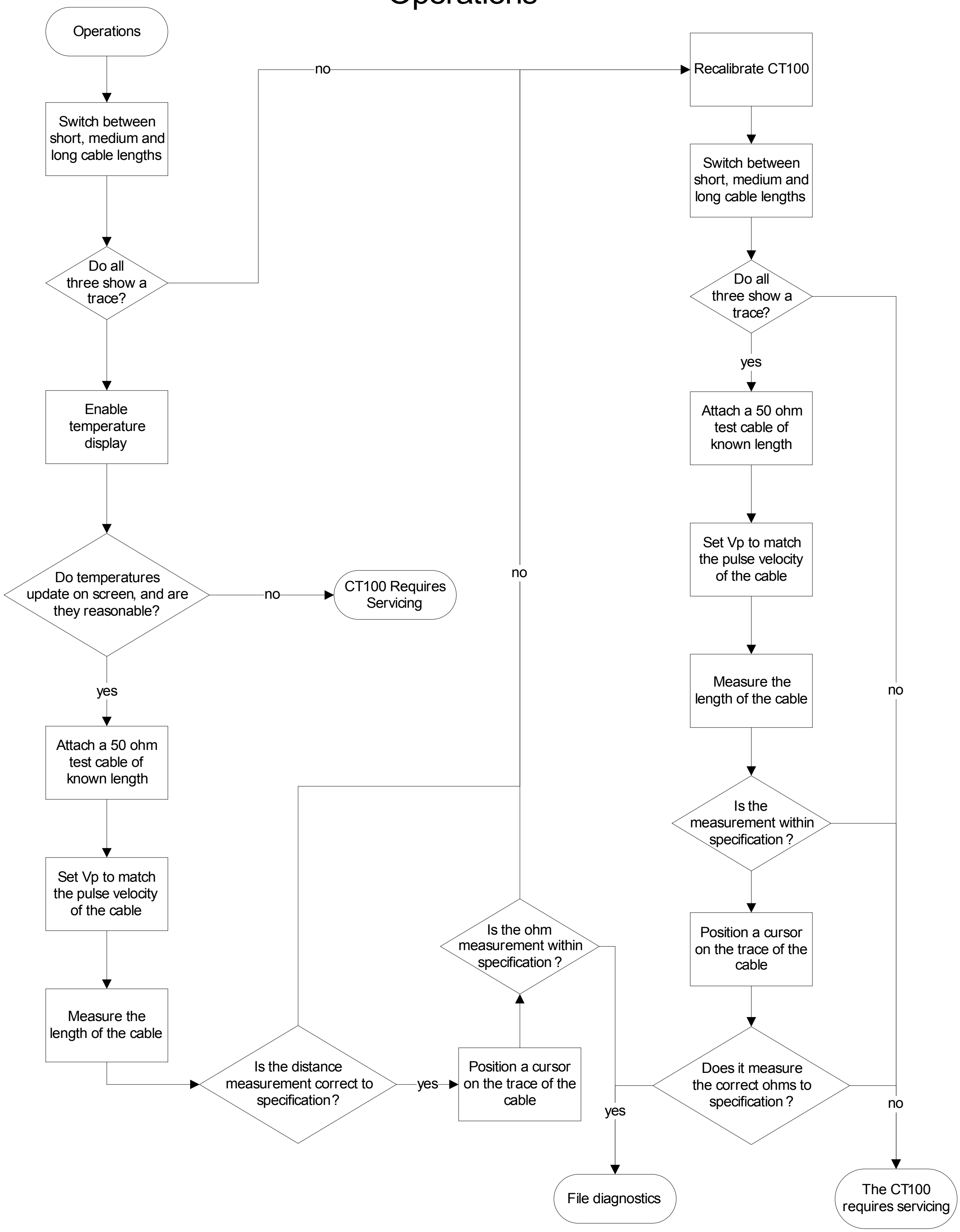
Main Board


Start Main Board Diagnostics
Press the Main Menu button until the Main Menu appears
Choose the "Diagnostics" menu item
Choose the "Main Board" menu item
Choose "Mem Test" menu option.
CT100 Requires Servicing
Were there any failures?
yes
no
Choose the GPIO test menu option
no
Were there any failures?
yes
no
Choose the Peripheral Menu Option
Were there any failures?
no
Download a test via USB (see CTViewer manual)
Did the trace transfer fail?
no
Download a trace via Ethernet (See CTViewer manual)
Did the trace transfer fail?
no
Analog Board Diagnostics

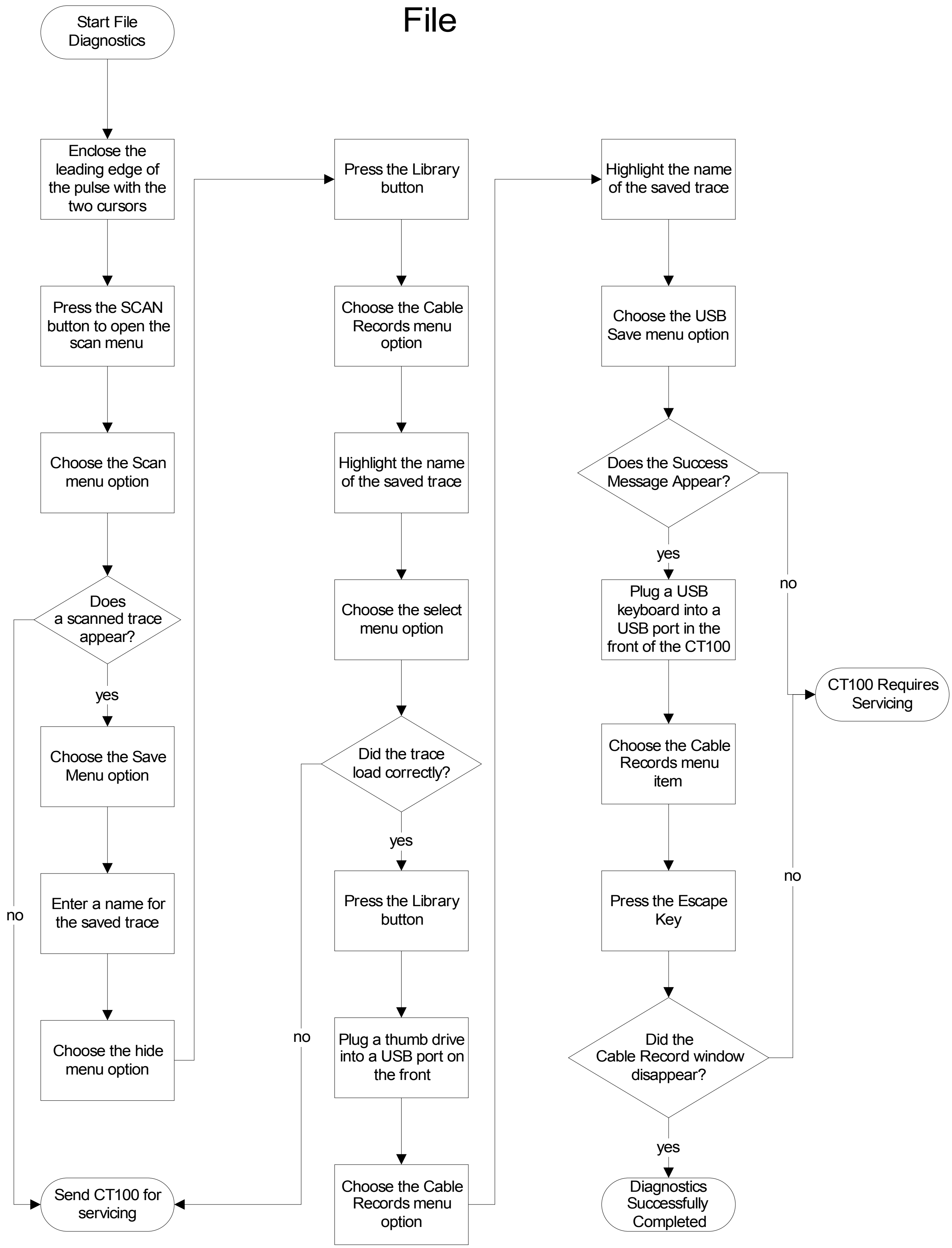
Analog


Start Analog Calibration
Press the Main Menu button until the Main Menu appears
Choose the "Diagnostics" menu item
Choose the "Analog Diag" menu item
Did "power" pass?
no
yes
Did "communications" pass?
no
CT100 Requires Servicing
yes
Did all tests pass?
yes
yes
Operations Diagnostics

Operations


Operations
Switch between short, medium and long cable lengths
Do all three show a trace?
no
Enable temperature display
Do temperatures update on screen, and are they reasonable?
no
CT100 Requires Servicing
yes
Attach a 50 ohm test cable of known length
Set Vp to match the pulse velocity of the cable
Measure the length of the cable
Is the distance measurement correct to specification?
yes
Position a cursor on the trace of the cable
Is the ohm measurement within specification?
no
Recalibrate CT100
Switch between short, medium and long cable lengths
Do all three show a trace?
yes
Attach a 50 ohm test cable of known length
Set Vp to match the pulse velocity of the cable
Measure the length of the cable
Is the measurement within specification?
Position a cursor on the trace of the cable
Does it measure the correct ohms to specification?
yes
File diagnostics
no
no
The CT100 requires servicing

File


Start File Diagnostics
Enclose the leading edge of the pulse with the two cursors
Press the SCAN button to open the scan menu
Choose the Scan menu option
Does a scanned trace appear?
yes
no
Choose the Save Menu option
Enter a name for the saved trace
Choose the hide menu option
Send CT100 for servicing
Press the Library button
Choose the Cable Records menu option
Highlight the name of the saved trace
Choose the select menu option
Did the trace load correctly?
yes
no
Press the Library button
Plug a thumb drive into a USB port on the front
Choose the Cable Records menu option
Highlight the name of the saved trace
Choose the USB Save menu option
Does the Success Message Appear?
yes
no
Plug a USB keyboard into a USB port in the front of the CT100
Choose the Cable Records menu item
Press the Escape Key
Did the Cable Record window disappear?
yes
no
CT100 Requires Servicing
Diagnostics Successfully Completed

Appendix F: Vp of Common Cables

Cable types

Commonly encountered cable designations, along with their associated characteristic impedances and typical Vp values, are listed below. A more complete listing is stored in the CT100's internal memory.

Note that the actual Vp 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 Vp of the cable using the CT100 and a known length of the cable you wish to test. See *Operating Instructions* > *Test preparations* > *Find an unknown Vp* for more information on determining the Vp of a cable.

Dielectric material

Type	**Z_0 (Ω)**	**Probable Vp**
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

RG standards

Designation	**Z_0 (Ω)**	**Vp**
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

Designation	Z_0 (Ω)	Vp
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

MIL-C-17 standards

Designation	Z_0 (Ω)	Vp
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

Commercial designations

Designation	Z_0	Vp
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

Twisted pair

Designation	Z_0 (Ω)	Vp
CAT5	100	0.71
CAT6	100	0.71

Appendix G: Maintenance and Service Instructions

Cleaning and lubrication

Clean the CT100 with a damp cloth. Clean the LCD screen with Windex. Do not use any powerful solvents when cleaning the CT100. The CT100 does not require lubrication.

Cleaning and lubrication interval

Clean once per week, or as necessary.

Battery removal

See figures 18 and 21 in *Appendix B* for related diagrams.

1) Ensure that the CT100 power is 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 (CT290), 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, undo the above steps in reverse order.

Inspection

Inspection should proceed as follows.

1) From the *Diagnostics* menu, perform the *Front Panel Check* to verify the front panel controls. Each of the front panel controls is represented on-screen. See the section on the *Diagnostics* menu for more information.

2) Remove any connectors from the CT100.

3) From the *Diagnostics* menu, *Main Board* submenu, perform the *Memory, GPIO,* and *Peripherals* check. See the section on the *Diagnostics* menu for more information.

4) From the *Diagnostics* menu, perform the *Analog* check. See the section on the *Diagnostics* menu for more information.

5) Use the instructions in *Appendix C* of this manual to perform a calibrations check.

Inspection interval

The CT100 should be inspected every 6 months.

Calibration and calibration interval

See *Appendix D* for the appropriate calibration interval and detailed instructions on how to calibrate a CT100.

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 $db = 20 \cdot \log_{10}(V_i / V_l)$ where V_i is the voltage of the incident pulse and V_l is the voltage reflected back by the load. The dB vertical scale on the CT100 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 $vertical\ scale = 20 \cdot \log_{10}(100) = 40\ dB.$

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 example of a DC voltage source.

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. Also see 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 contradistinction 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.

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. Also see 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 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 CT100 is a step rise signal with a finite risetime. See Risetime.

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.

Jitter

The uncertainty in measurement of time in a TDR, causing a particular voltage sample to be misregistered slightly with respect to time. The main effect of timebase jitter is to cause apparent vertical noise in areas of changing impedance. Areas of constant impedance, such as a flat segment of 50 Ω cable, will show no abnormality.

LCD

Liquid Crystal Display. The display used by this instrument is an active-matrix thin-film transistor LCD, abbreviated TFT-LCD.

Millirho

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.

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 Rho (ρ) is defined by the relation $\rho=(Z_t-Z_0)/(Z_t+Z_0)$ 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 millirho. The coefficient ρ ranges from -1 (short circuit) to +1 (open circuit). A reflection coefficient of zero indicates 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 CT100 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 demonstrate 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 risetime 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, ρ: $RL(dB) = -20\log_{10}|\rho|$ 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 (ρ)

See Reflection Coefficient.

Risetime

With respect to the incident pulse, the time required for the signal to change from 10% to 90% (or 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 risetime of a pulser-sampler system is proportional to the root sum of squares of the pulse and sampler risetimes.

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: $x_{rms} = \sqrt{((x_1^2 + x_2^2 + x_3^2 + ... + x_n^2)/n)}$ where x represents discrete samples and n is the total number of samples.

Sampling Efficiency

The CT100 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.

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.

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 (Vp) 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 CT100 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 Averaging

See Noise.

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.

Index