

TDR9100™ and T-Doble 3.3 Circuit Breaker Test System

User Guide



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Preface

The *TDR9100 Circuit Breaker Test System User Guide* introduces the TDR9100, describes how to perform tests, and explains how to interpret test results. It also provides troubleshooting and maintenance procedures, conceptual information, and other supporting documentation.

Who Should Read This Guide

This guide is intended for anyone who works with the TDR9100™ Circuit Breaker Test System. It is assumed that the reader is familiar with professional standards and safety practices.

Document Conventions

Typefaces

This document uses two special typefaces to indicate particular kinds of information:

- **Bold**—Used for software controls and user-entered text, such as buttons, checkboxes, or other items that you click or select.
Example:

Click **Close**.

Also, any text you must type in is shown in this typeface:

Example: Type in **1500 ms**.

- **Monospace**—Used for text that T-Doble displays in the user interface, such as an error message or prompt. Example:

Uploading test results.

Notes and Warnings

This document uses icons to draw your attention to information of special importance, as follows.



NOTE! Notes provide supplemental information that may apply to only some circumstances.



CAUTION! Cautions provide information that prevents damage to hardware or data.



WARNING! Warnings tell you how to prevent injury or death to anyone near the test set or high-voltage equipment.

1. What's New: Ganging of Instruments

This section explains the new ganging option for the TDR9100. It contains the following sections:

- [“Introduction” on page 15](#)
- [“When to Use Ganging” on page 16](#)
- [“Two Styles of Hardware Setup” on page 16](#)
- [“Ganging Setup in Software” on page 19](#)
- [“Channel Mapping for Ganged Instruments” on page 20](#)

Introduction



NOTE: Ganging is available for the TDR9100 only.

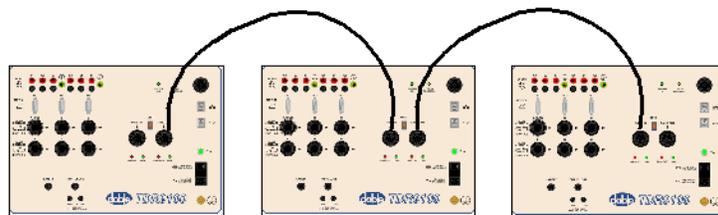


Figure 1 Three Ganged TDR9100 Instruments

Two or three TDR9100 instruments can now be ganged together to double or triple the usable Main Contact channels from 12 to 24 (8 breaks per phase) or 36 (12 breaks per phase). Ganging is especially useful when you are testing a complicated breaker over multiple contacts and inputs.

[Table 1](#) lists the increased numbers of channels available when two or three TDR9100 instruments are ganged.

Table 1 Channels Available in Single or Ganged Units

Channel or Contact	1 Unit	2 Ganged Units	3 Ganged Units
Motion	3	6	9
Event	6	11*	16*
Main Contact	12	24	36

* Event-12 (E6 in ganged unit 2) and Event-18 (E6 in ganged unit 3) are unavailable because of system constraints in the ganged configuration.

When to Use Ganging

Ganging is most useful for testing these types of configuration:

- EHV breakers with more than 4 breaks per phase
- Configurations requiring more than 6 event channels
- Configurations requiring more than 3 motion channels

Ganging can also be used to extend the physical reach of the test system by the length of the ganging cable.

Test Modes and Ganging

Ganged TDR9100 configurations can be used with test plans that include EHV-style main contact testing, as well as test plans that do not include any main contact channels. Ganged operation with OCB or GCB-style main contact test plans is not supported in T-Doble v 3.3.

Two Styles of Hardware Setup

Ganged TDR9100 instruments can be set up in two styles:

- One phase per unit
- All phases per unit

One Phase Per Unit

This option is available for three ganged units only. It may be more convenient to assign one TDR9100 to Phase A (pole 1), one to Phase B (pole 2), and one to Phase C (pole 3), of an EHV breaker with many breaks per phase.

Figure 2 shows an EHV breaker with 6 breaks per phase. Three ganged TDR9100 instruments are set up in One Phase Per Unit style.

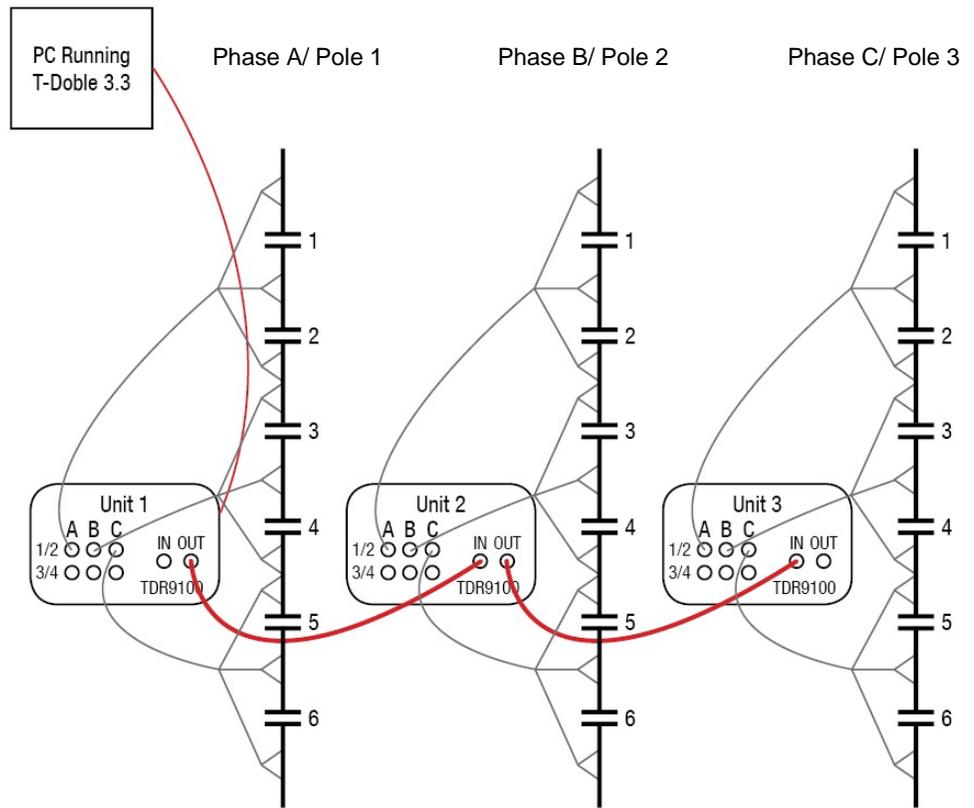


Figure 2 Example: Three TDR9100s Ganged in One Phase Per Unit

All Phases Per Unit

“All Phases Per Unit” is the default setting for all configurations, including single unit. Each instrument connects to Phase A (Pole 1), Phase B (Pole 2), and Phase C (Pole 3).

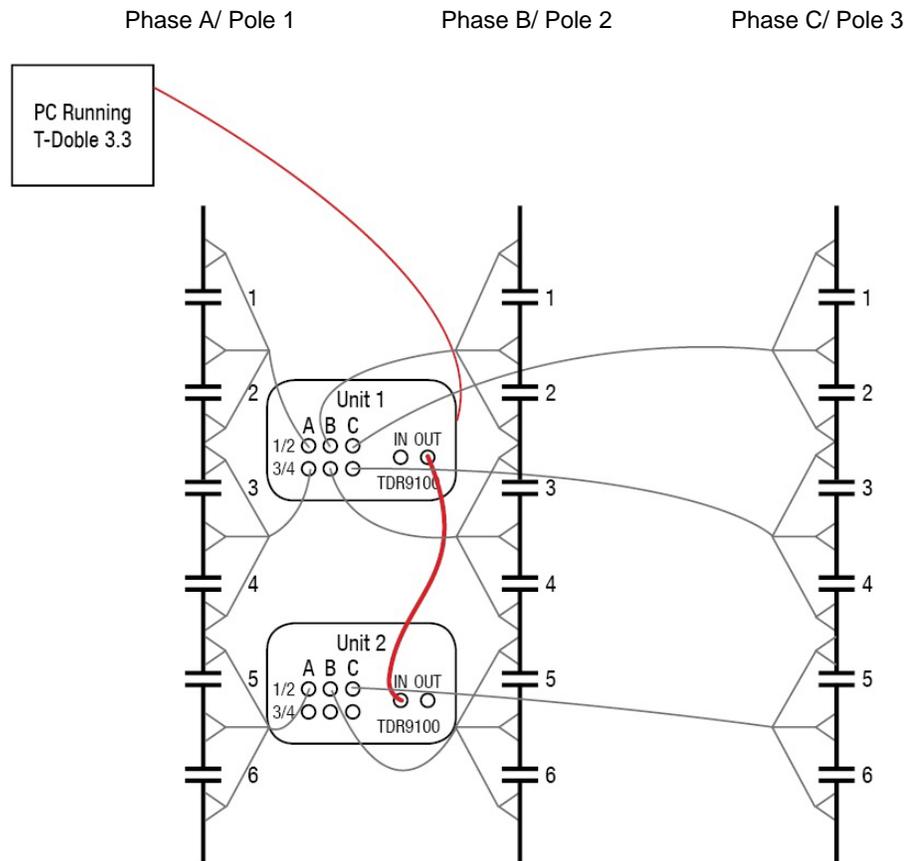


Figure 3 Sample All Phases Per Unit Setup with Two Ganged Units

Ganging Setup in Software

To set up ganging in T-Doble 3.3, make the settings in this order:

1. Open the **Breaker** tab and the **Start Here** subtab (Figure 5).

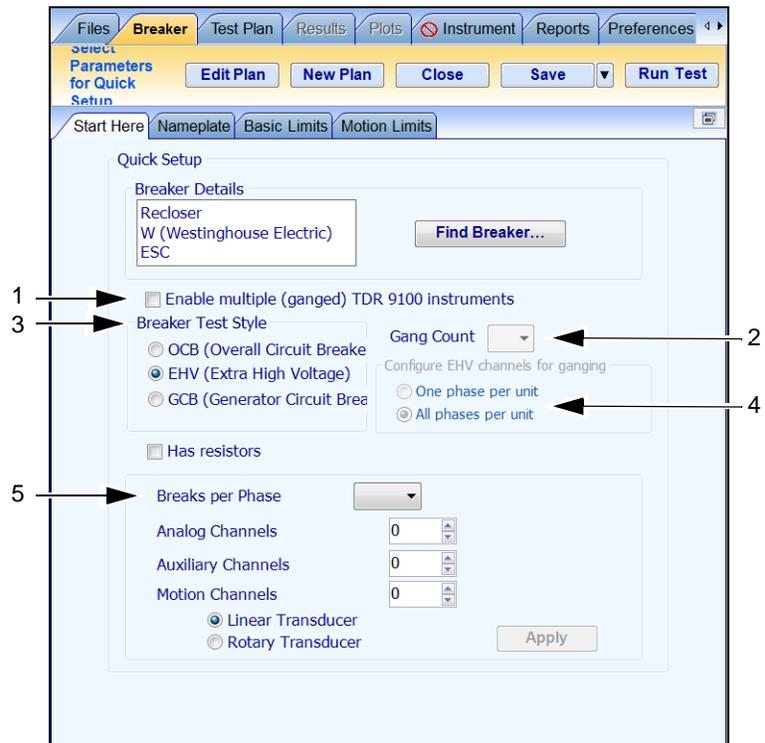


Figure 4 Start Here Subtab of Breaker Tab

2. Select **Enable multiple ganged TDR9100 instruments** (Item 1 in Figure 4).



NOTE: Ganging is available for the TDR9100 only. Never use the ganging options in T-Doble 3.3 for a TDR900 or TDR9000.

3. Select a Gang Count of **3** or leave the default of **2** (Item 2 in Figure 4).
4. Select a Breaker Test Style of **EHV** if applicable (Item 3 in Figure 4). (OCB and GCB styles are not supported in ganged mode.)

5. EHV only: configure the EHV channels for ganging (Item 4 in [Figure 4](#)). To gang:
 - 2 instruments—**All phases per unit** is selected by default. You cannot change it.
 - 3 instruments—Select one:
 - **One phase per unit**—For more information, see [“One Phase Per Unit” on page 17](#).
 - **All phases per unit**—For more information, see [“All Phases Per Unit” on page 18](#).
 - Select a number of Breaks Per Phase (Item 5 in [Figure 4](#)).
6. Make all remaining selections on the tab.
7. Press **Apply**.

Channel Mapping for Ganged Instruments

After ganging is established on the Start Here subtab of the Breaker tab, T-Doble 3.3 displays channel assignments on the Main Contact Channels tab, Motion Channels tab, and Aux, Analog tabs.

Main Contact Channel Mapping and Hardware Setup

[Figure 5](#) and [Figure 6](#) show you the T-Doble user interface channel mapping and the corresponding hardware setup.

[Figure 5](#) shows channel mapping for this test configuration:

- Two ganged units
- Six breaks per phase
- All Phases Per Unit mode

Main Contact Channel Setup					
	Channel (at breaker)	Connector (at TDR)	Enable	Label	Phase
	EHV-A1	Unit 1 - A1/2	<input checked="" type="checkbox"/>		Phase A
	EHV-A2		<input checked="" type="checkbox"/>		
	EHV-A3	Unit 1 - A3/4	<input checked="" type="checkbox"/>		Phase A
	EHV-A4		<input checked="" type="checkbox"/>		
	EHV-A5	Unit 2 - A1/2	<input checked="" type="checkbox"/>		Phase A
	EHV-A6		<input checked="" type="checkbox"/>		
	EHV-B1	Unit 1 - B1/2	<input checked="" type="checkbox"/>		Phase B
	EHV-B2		<input checked="" type="checkbox"/>		
	EHV-B3	Unit 1 - B3/4	<input checked="" type="checkbox"/>		Phase B
	EHV-B4		<input checked="" type="checkbox"/>		
	EHV-B5	Unit 2 - B1/2	<input checked="" type="checkbox"/>		Phase B
	EHV-B6		<input checked="" type="checkbox"/>		
	EHV-C1	Unit 1 - C1/2	<input checked="" type="checkbox"/>		Phase C
	EHV-C2		<input checked="" type="checkbox"/>		
	EHV-C3	Unit 1 - C3/4	<input checked="" type="checkbox"/>		Phase C
	EHV-C4		<input checked="" type="checkbox"/>		
	EHV-C5	Unit 2 - C1/2	<input checked="" type="checkbox"/>		Phase C
	EHV-C6		<input checked="" type="checkbox"/>		

Figure 5 T-Doble Mapping for Ganged Main Contact Channels

Please note that the column titles circled in [Figure 5](#) have the following meaning:

- Channel (at breaker)—Physical location on breaker
- Connector (at TDR)—Connector on front panel of TDR9100

Figure 6 shows the associated hardware setup.

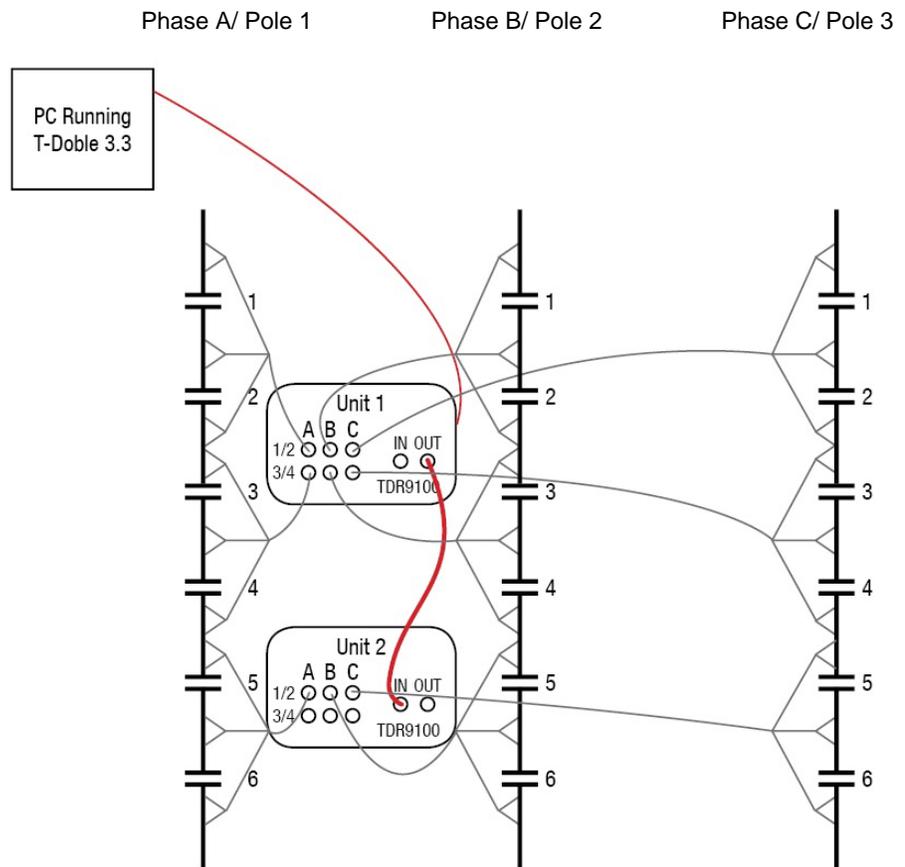


Figure 6 Ganged Hardware Setup Six Breaks Per Phase

Motion Channel Mapping

Figure 7 shows an example of Motion channel mapping for two ganged TDR9100 instruments.

Motion Channel Setup				
Channel	Connector (at TDR)	Enable	Motion Label	V
Motion-1	Unit 1:M-1	<input checked="" type="checkbox"/>		
Motion-2	Unit 1:M-2	<input checked="" type="checkbox"/>		
Motion-3	Unit 1:M-3	<input checked="" type="checkbox"/>		
Motion-4	Unit 2:M-1	<input checked="" type="checkbox"/>		
Motion-5	Unit 2:M-2	<input checked="" type="checkbox"/>		
Motion-6	Unit 2:M-3	<input checked="" type="checkbox"/>		

Figure 7 Sample Motion Channel Mapping for Two Ganged TDR9100 Units

Aux, Analog Channel Mapping

Figure 8 shows an example of Auxiliary and Analog mapping for two ganged TDR9100 instruments.

Auxiliary Contact Channels				
Channel	Connector (at TDR)	Enable	Label	
Event-1	Unit 1:E-1	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>
Event-2	Unit 1:E-2	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>
Event-3	Unit 1:E-3	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>
Event-4	Unit 1:E-4	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>
Event-7	Unit 2:E-1	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>
Event-8	Unit 2:E-2	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>

Analog Channels				
Channel	Connector (at TDR)	Enable	Label	Phase
Event-5	Unit 1:E-5	<input checked="" type="checkbox"/>		Unassigned
Event-6	Unit 1:E-6	<input checked="" type="checkbox"/>		Unassigned
Event-9	Unit 2:E-3	<input checked="" type="checkbox"/>		Unassigned
Event-10	Unit 2:E-4	<input checked="" type="checkbox"/>		Unassigned
Event-11	Unit 2:E-5	<input checked="" type="checkbox"/>		Unassigned

Figure 8 Sample Auxiliary and Analog Channel Mapping for Two Ganged TDR9100 Units

2. Introduction to the TDR9100

This chapter describes the TDR9100 hardware and optional accessories. It contains the following sections:

- [“Introduction” on page 25](#)
- [“Standard Components and Accessories” on page 26](#)
- [“Front Panel Characteristics” on page 27](#)
- [“Measurement Channels” on page 28](#)
- [“Command Functions” on page 35](#)
- [“Communications Options” on page 38](#)
- [“Supported Tests” on page 38](#)
- [“T-Doble Software” on page 39](#)

Introduction

The TDR9100 Circuit Breaker Test System is a state-of-the-art instrument designed to test all types of circuit breakers. It performs timing functions for up to four breaks per phase with motion measurements using a single, field-portable instrument. By providing configurable test parameters, the T-Doble software program makes it easy to perform multiple tests under varying test conditions in the field.



Figure 9 TDR9100 Circuit Breaker Test System

Standard Components and Accessories

For a complete list of standard components, accessories, and part numbers, refer to [Appendix D, "Parts."](#)

Front Panel Characteristics

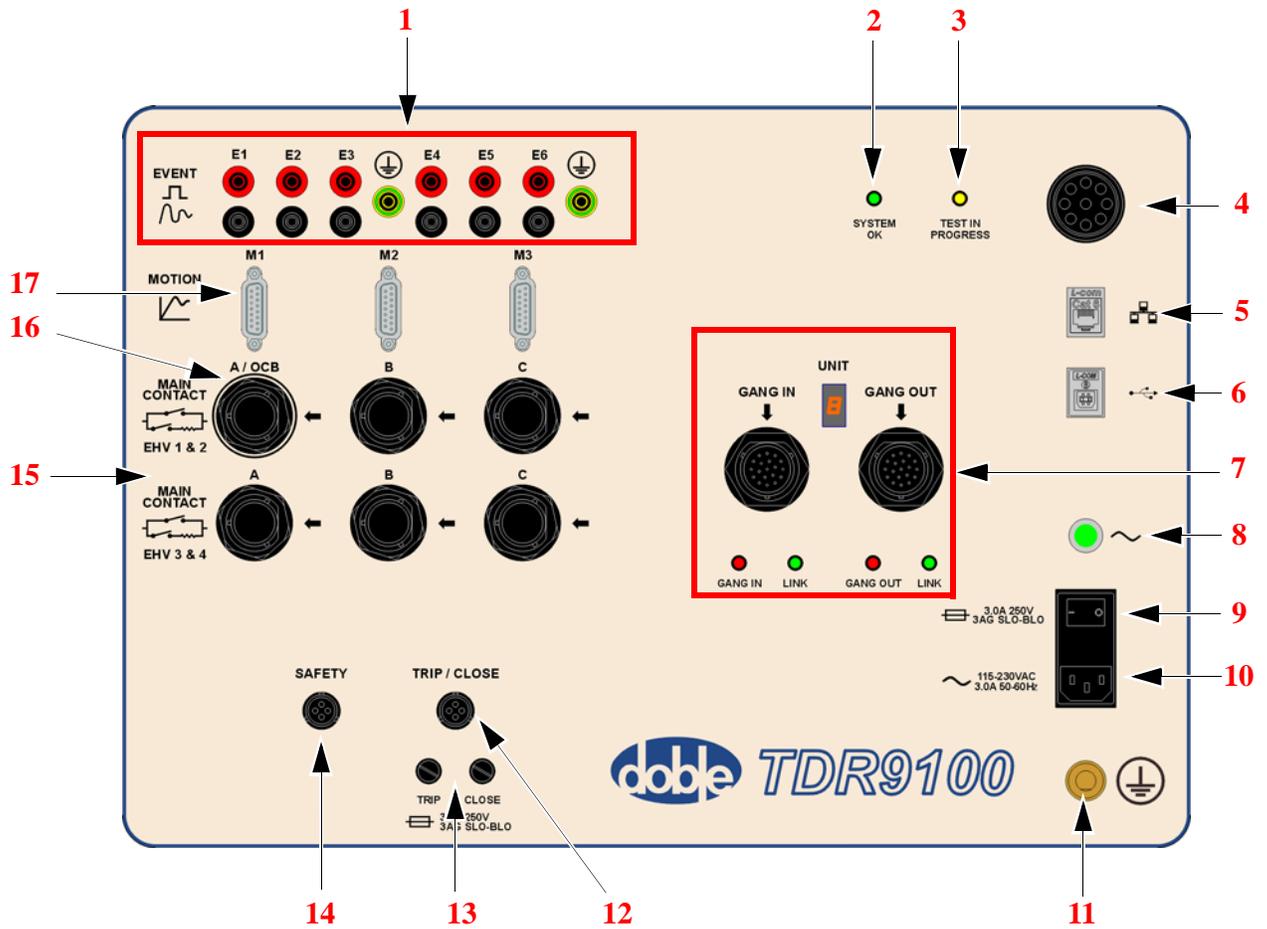


Figure 1.1 TDR9100 Front Panel

Table 2 describes the connections and controls present on the TDR9100 Front Panel. For technical detail, see Appendix E, “TDR9100 Circuit Breaker Test System Specifications.”

Table 2 TDR9100 Front Panel Connections and Switches

Item	Description
1	Shrouded 4 mm banana jack connectors. Programmable for: <ul style="list-style-type: none"> • Auxiliary contact timing measurement • General-purpose analog voltage measurement

Table 2 TDR9100 Front Panel Connections and Switches

Item	Description
2	DC power sources valid operation LED
3	LED indicating that a test is in progress
4	Speaker
5	Ethernet port
6	USB port
7	Ganging connectors and indicators (not supported T-Doble versions earlier than 3.3)
8	Main power indicator light
9	<ul style="list-style-type: none"> • IEC standard power cord connector, 3-pronged male • AC fuses
10	Power ON/OFF switch
11	System safety ground twist-lock connector for the ground cable
12	Trip/Close control connector, 4-pin male
13	Trip and Close fuses
14	Safety switch cable or Safety Bypass Flag connector, 4-pin female
15	EHV main contact test cable connectors, circular 12-pin male
16	OCB cable connector (upper left main contact connector only)
17	Motion transducer cable connectors, 15-pin female

Measurement Channels

The TDR9100 provides three types of measurement channels:

- OCB (EHV and OCB test styles)
- EHV (digital)
- Motion (dual-function)

Event Channels (Analog and Auxiliary)

There are two types of event channel functions:

- Analog
- Auxiliary contact

Each of the six event channels on the TDR9100 has dual functions and can be programmed to act as either an analog channel or an auxiliary contact channel.

A combination of these channels is used to monitor the characteristics of the circuit breaker mechanism and control circuit. It is sometimes beneficial to monitor aux contacts, coil currents, phase currents, or battery voltage. Analog and Auxiliary channels may also be used for triggering or timing reference. (For more information, see [Chapter 7, “Triggering and Timing Setup.”](#))

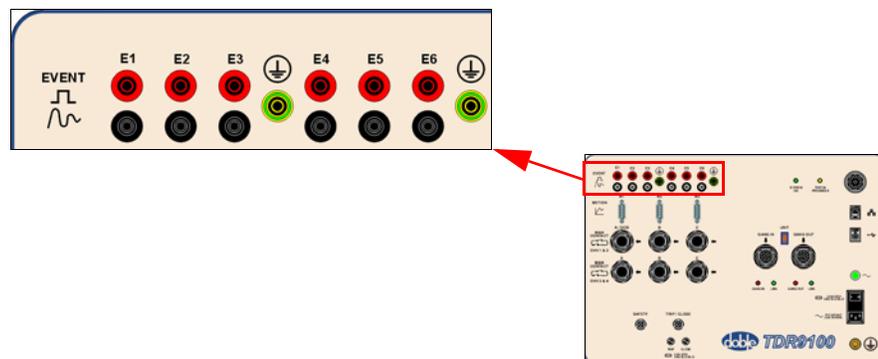


Figure 10 Programmable Connectors

Analog Channels

The general-purpose analog inputs can be configured individually in T-Doble to read inputs from current shunts and probes, as well as voltages. Analog inputs are converted by a high speed 12-bit analog-to-digital converter and then recorded at the TDR9100 sample rate. These channels are rated at ± 300 V peak.

NOTE



For applications using a current probe, you must zero the probe. See [“Doble Probe” on page 164.](#)

Auxiliary Contact Channels

The auxiliary contact channels monitor the state of auxiliary contacts, ascertaining whether a contact is:

- Closed
- Open Dry: No voltage detected on the open contact
- Open Wet: Voltage detected on the open contact, based on a minimum station battery of 48 V

The TDR9100 has an automatic *wetting circuit* that wets (applies a test voltage to) a dry open contact, which allows the open/closed state of the circuit to be determined.

Setting the Event Parameters

The analog and auxiliary channels are set on the Aux, Analog tab of the Test Plan page (see [page 108](#) for configuration).

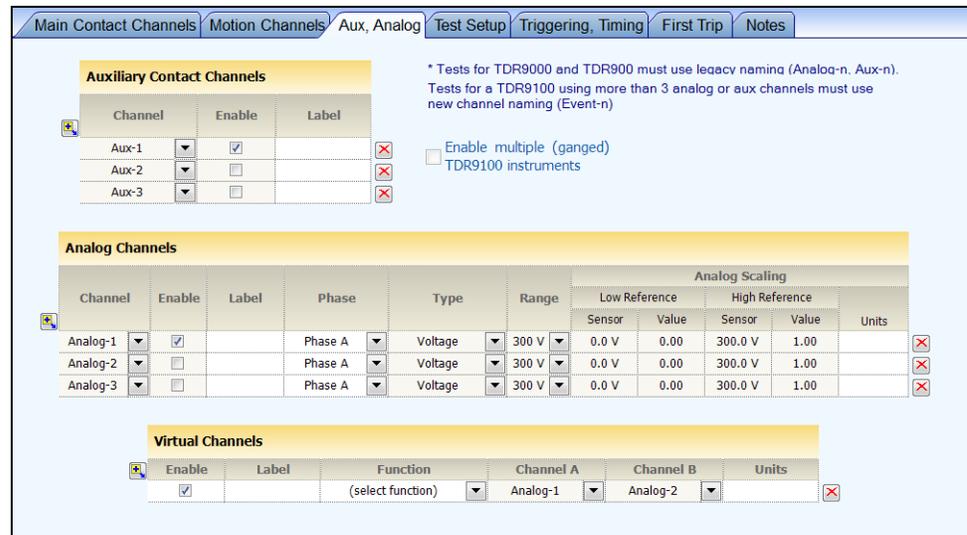


Figure 11 Analog and Auxiliary Settings on the Aux, Analog Tab

Motion Channels

The motion channels record the travel and velocity of the circuit breaker contacts through a digital rotary or linear transducer attached to the circuit breaker mechanism.

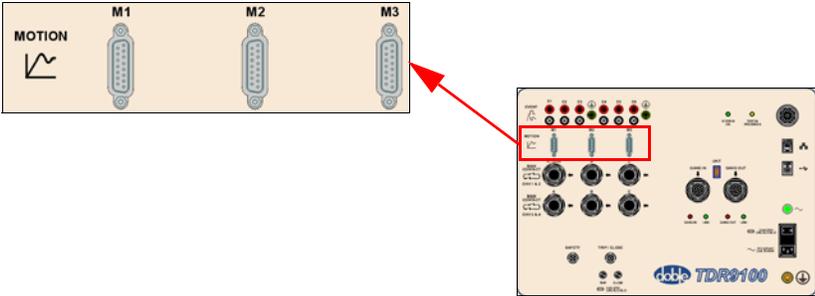


Figure 12 Motion Connectors

Setting the Motion Parameters

Motion parameters are set in two locations:

- Motion Channels tab of the Test Plan page (see Figure 13). See page 102 for configuration.
- Motion Limits tab of the Breaker page (see Figure 14). See page 77 for configuration.

Motion Channel Setup											
Channel	Enable	Motion Label	Velocity Label	Phase	Transducer Type	Motion Limits	Motion Units	Transducer Scaling			
								Value at Transducer	Value at Contacts		
Motion-1	<input checked="" type="checkbox"/>	LINKAGE		Phase A	Linear	Limits #1	Linear	1.0 mm	1.0 mm	✗	
Motion-2	<input checked="" type="checkbox"/>	MECHANISM		Phase B	Linear	Limits #2	Linear	80.0 mm	120.0 mm	✗	
Motion-3	<input type="checkbox"/>	Motion-3		Phase C	Linear	*	Linear	1000.0 mm	1000.0 mm	✗	

Figure 13 Motion Settings on the Motion Channels Tab

Travel Limits										
	Travel Type	Label		Total Travel	Overtravel		Rebound		Contact Wipe	
					Open	Close	Open	Close		
Limits Set #1 (Linear)	Linear		Expected	120.0 mm	*	*	*	*	*	
			Tolerance	+	2.0 mm	*	*	*	*	*
				-	2.0 mm	*	*	*	*	*
Limits Set #2 (Linear)	Linear		Expected	120.0 mm	*	*	*	*	*	
			Tolerance	+	2.0 mm	*	*	*	*	*
				-	2.0 mm	*	*	*	*	*

Average Velocity Limits								
	Action	Zone	Zone Details				Velocity	
			Zone Type	From	To	Minimum	Maximum	
Limits Set #1 (Linear)	Open	1	Open; Time	Open	10.0 ms	4.300 m/s	5.300 m/s	
		2	Distance; Distance	*	*	*	*	
	Close	1	Time; Close	10.0 ms	Close	3.500 m/s	5.000 m/s	
		2	Distance; Distance	*	*	*	*	
Limits Set #2 (Linear)	Open	1	Open; Time	Open	10.0 ms	4.300 m/s	5.300 m/s	
		2	Distance; Distance	*	*	*	*	
	Close	1	Time; Close	10.0 ms	Close	3.500 m/s	5.000 m/s	
		2	Distance; Distance	*	*	*	*	

Figure 14 Motion Settings on the Motion Limits Tab

OCB Channels

The OCB channels measure main contact and resistor contact timing for circuit breakers that allow access to only a single measurable break per phase. Trip and Close resistor value ranges are configurable and this configuration applies to all three contacts of the OCB connector. Contact status information is recorded and plotted. The OCB connector has three OCB channels.

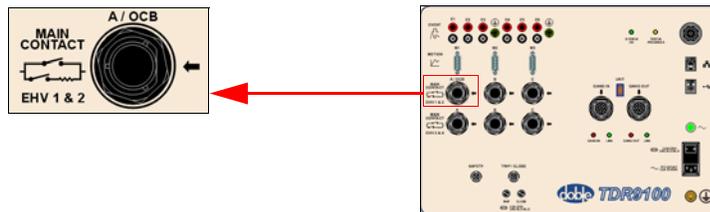


Figure 15 OCB Connector

OCB-style testing is usually performed on three types of breakers:

- Dead tank breakers
- Live tank breakers, one break per phase
- Live tank breakers, overall

Setting the OCB Parameters

OCB parameters are set in two locations:

- Main Contact Channels tab of the Test Plan page (Figure 16). See page 56 for configuration.
- Basic Limits tab of the Breaker page (Figure 17). See page 101 for configuration.

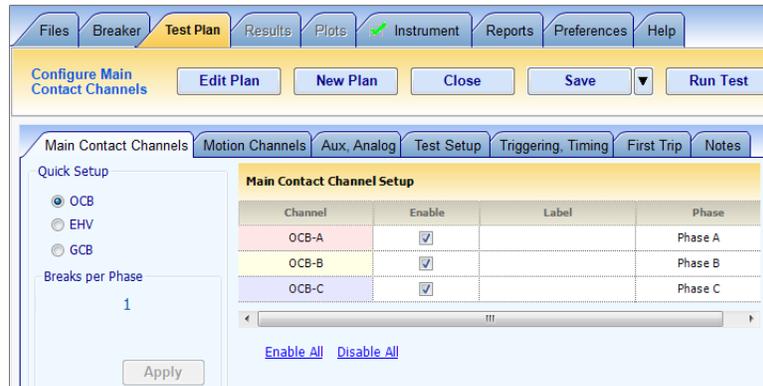


Figure 16 OCB Parameters on the Main Contact Channels Tab

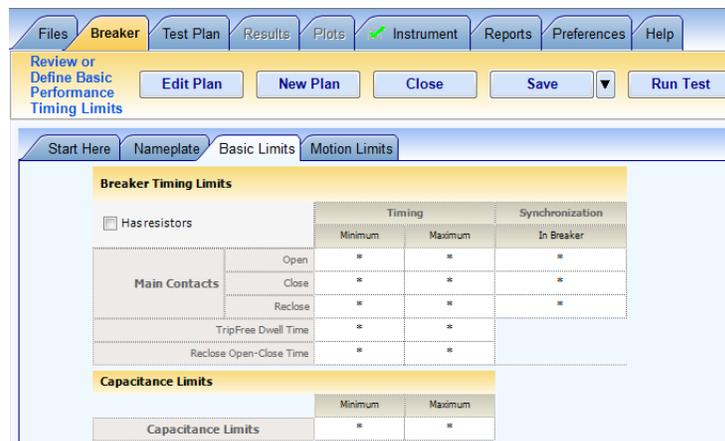


Figure 17 OCB Parameters on the Basic Limits Tab

EHV Channels

The EHV option measures the main contact and resistor contact timing for circuit breakers with one to four measurable breaks per phase. T-Doble records and plots each EHV channel that is enabled.

Each EHV connector has two EHV channels.

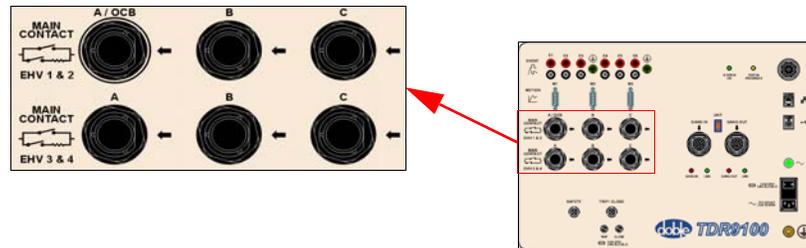


Figure 18 EHV Connectors

EHV-style testing is usually performed on two types of breakers:

- Dead tank breakers, ganged or independent-pole type
- Live tank breakers with up to four breaks per phase

Setting the EHV Parameters

EHV parameters are set in two locations:

- Main Contact Channels tab of the Test Plan page (Figure 19). See page 56 for configuration.
- Basic Limits tab of the Breaker page (Figure 20). See page 101 for configuration.

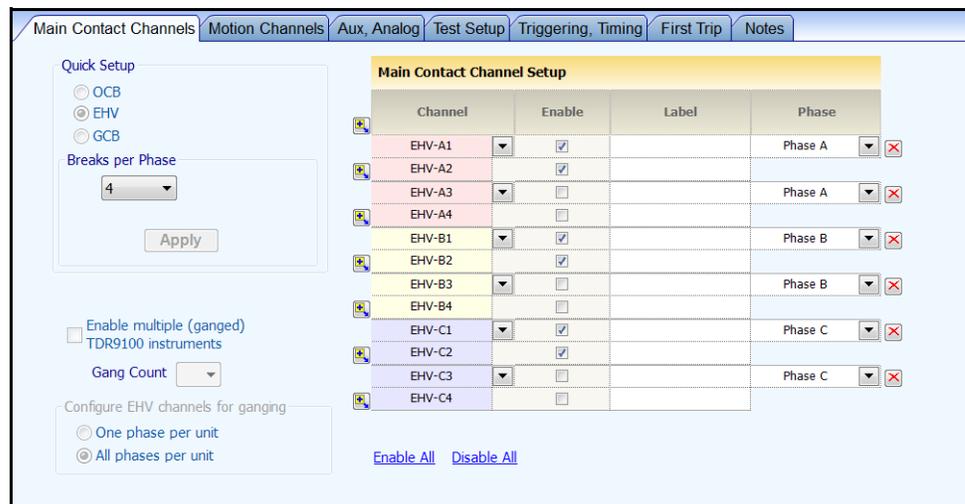


Figure 19 EHV Settings on the Main Contact Channels Tab

Breaker Timing Limits

Has resistors

		Timing		Synchronization		
		Minimum	Maximum	In Breaker	In Phase	In Module
Main Contacts	Open	10.0 ms	22.0 ms	2.8 ms	2.8 ms	2.8 ms
	Close	45.0 ms	55.0 ms	4.2 ms	4.2 ms	4.2 ms
	Reclose	*	*	*	*	*
TripFree Dwell Time		*	*			
Reclose Open-Close Time		*	*			

Resistor Timing Limits

		Timing		Synchronization		
		Minimum	Maximum	In Breaker	In Phase	In Module
Relative to Test Initiation	Open	*	*	*	*	*
	Close	*	*	*	*	*
Relative to Main	Open	0.0 ms	12.0 ms	2.8 ms	2.8 ms	2.8 ms
	Close	0.0 ms	12.0 ms	4.2 ms	4.2 ms	4.2 ms

Resistor Debounce: 200 μ s

Resistance Limits

	Minimum	Maximum
Open Resistance	190.0 Ω	210.0 Ω
Close Resistance	190.0 Ω	210.0 Ω

Capacitance Limits

	Minimum	Maximum
Capacitance Limits	2700.0 pF	3300.0 pF

Figure 20 EHV Settings (“Has Resistors”) on Basic Limits Tab

Command Functions

The TDR9100 provides the following command functions:

- Test instrument initiation—Safety Switch or Safety Bypass Flag.
- Circuit breaker Trip and Close control—The TDR9100 includes internal trip and close control switches (solid state relays) that may be used to complete the circuit breakers trip and close circuits, thereby initiating the applicable circuit breaker operation. Each of these internal control switch circuits includes a function to measure the current flowing through the circuit breaker controls (that is, through the internal trip/close leads) during the test.

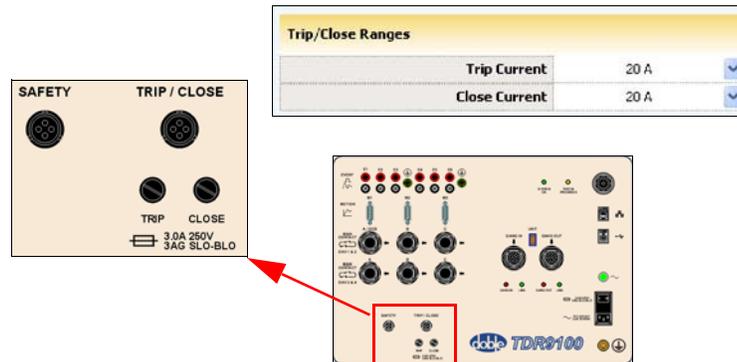


Figure 21 Command Functions and Trip/Close Parameters

Safety Switch Cable Connector

This connector enables you to:

- Attach a 25 ft (7.6 m) cable containing a switch so you can run the tests from a safe distance.
- or
- Plug the Safety Bypass Flag into this connector and initiate the tests from the controller PC, without using the Safety Switch.

Trip/Close Command Function

The Trip/Close command function operates the circuit breaker under test through the action of solid-state relays that trip or close the circuit breaker. Because the function is polarity-insensitive, the user need not know lead polarity.

Trip/Close command functions enable the TDR9100 to control these tests:

- Trip (O)
- Close (C)
- TripFree (CO)
- C-O
- Reclosing (O-C and O-0.3 s-C)
- O-0.3 s-CO
- O-CO and O-C-O

The Trip/Close command function normally connects across the circuit breaker manual Trip or Close switch, as shown in [Figure 22](#).

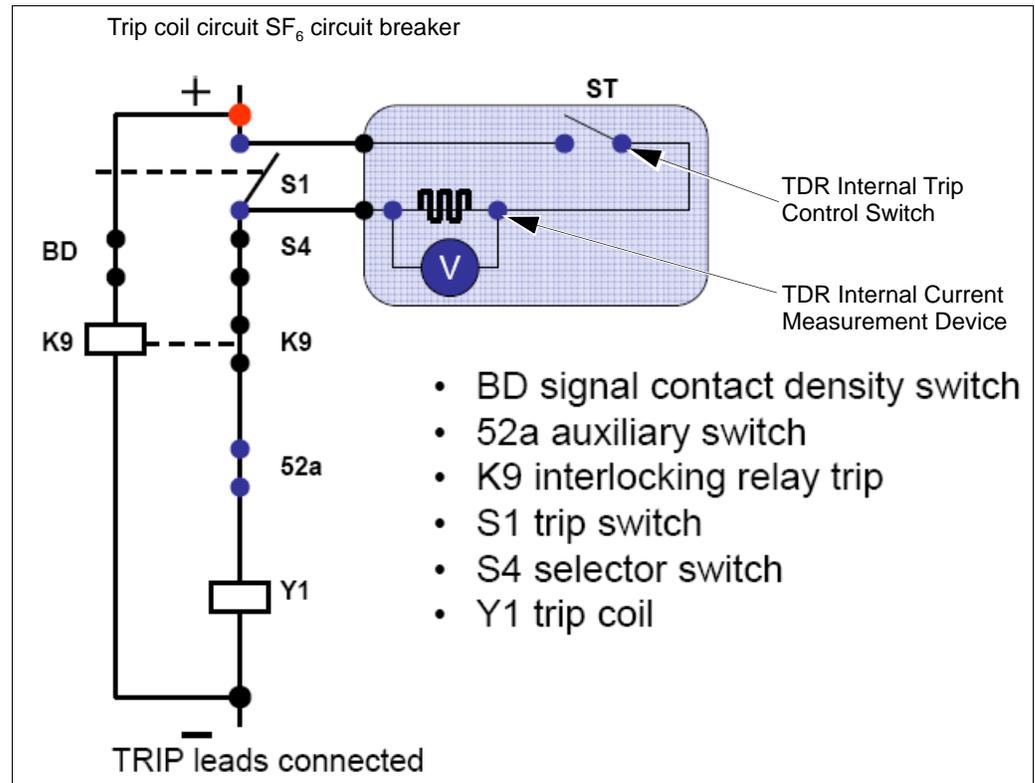


Figure 22 Trip/Close Command Application

Trip/Close Current

The Trip/Close command function includes an internal current measurement for the Trip and Close circuits. To measure the Trip and Close circuit current, the Trip/Close test:

- Passes the Trip and Close currents through current meters
- Displays the result as a current waveform and as a peak current value

Triggers

The TDR9100 can use internal or external triggers to initiate tests.

Setting the Trigger Parameters

The Trigger parameters are set in the Triggering, Timing tab of the Test Plan page. (For more information, see [Chapter 7, "Triggering and Timing Setup."](#))

Communications Options

The TDR9100 provides the following communications options:

- Ethernet port
- USB port

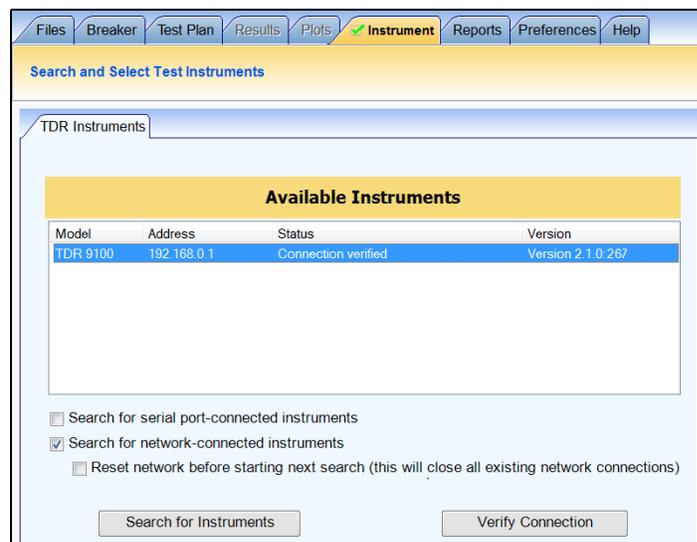


Figure 23 Ethernet and USB Ports and the Instrument Page

Supported Tests

Table 3 lists the nine circuit breaker tests that the TDR9100 performs and gives a state description of the sequencing that comprises the test. When a test is run, the TDR9100 stores and plots the data. The data can be printed to the optional printer in the field or to an office printer.

All tests can be initiated by either an internal or external trigger.

Table 3 Circuit Breaker Test Types

Test	Initial State	Intermediate		Final State
		State 1	State 2	
Trip	Closed	—	—	Open
Close	Open	—	—	Closed
TripFree (CO)	Open	Closed	—	Open
Reclosing (O-C)	Closed	Open	—	Closed
C-O	Open	Closed	—	Open
O-CO	Closed	Open	Closed	Open
O-C-O	Closed	Open	Closed	Open
First Trip	Closed	—	—	Open
Record Only	—	—	—	—

For detailed information about setting up and running tests, including First Trip tests, and interpreting results, please see:

- [Chapter 6, “Setting Up Tests”](#)
- [Chapter 7, “Triggering and Timing Setup”](#)
- [Chapter 8, “Running a Test”](#)
- [Chapter 9, “Displaying and Interpreting Test Results”](#)

T-Doble Software

T-Doble enables you to create or modify library test plans, analyze test data, and store circuit breaker test data. The test plan is the key to simplifying circuit breaker testing. By creating a library test plan, you eliminate the time-consuming work of entering repetitive circuit breaker ID information and test parameters. Once this data has been entered, it is saved for reuse later.

Instructions for using T-Doble appear throughout this manual.

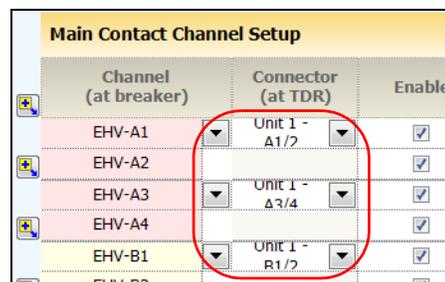
Functions

When installed on any controller PC, T-Doble can perform the following functions:

- Create individual library test plans. Each library test plan adds to the database of test results available for analysis. Completed individual tests contain not only the test results gathered, but also a record of the library test plan used.
- Display the results of an individual test graphically and tailor the presentation of results to highlight behaviors of interest.
- Automatically update test results when editable fields, such as limit values, are changed. T-Doble compares test results against circuit breaker specifications and presents a *Pass* or *Warning* determination for each measurement for which a comparative value is set in the test plan.
- Overlay the results from different tests for comparison.

Column Width and Readability

Sometimes the default width of a column is not large enough to accommodate the text it displays (Figure 24)

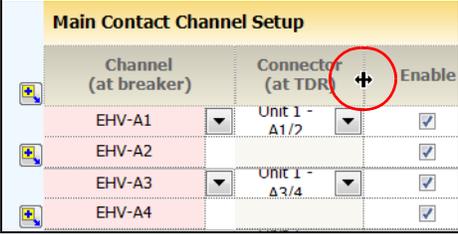


Channel (at breaker)	Connector (at TDR)	Enable
EHV-A1	Unit 1 - A1/2	<input checked="" type="checkbox"/>
EHV-A2		<input checked="" type="checkbox"/>
EHV-A3	Unit 1 - A3/4	<input checked="" type="checkbox"/>
EHV-A4		<input checked="" type="checkbox"/>
EHV-B1	Unit 1 - B1/2	<input checked="" type="checkbox"/>
EHV-B2		<input checked="" type="checkbox"/>

Figure 24 Column Too Narrow, Text Obscured

To make the text visible:

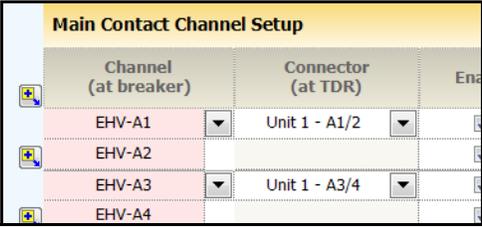
1. Grab the column title boundary with the mouse (Figure 25).



Main Contact Channel Setup			
Channel (at breaker)	Connector (at TDR)	+	Enable
EHV-A1	Unit 1 - A1/2		<input checked="" type="checkbox"/>
EHV-A2			<input checked="" type="checkbox"/>
EHV-A3	Unit 1 - A3/4		<input checked="" type="checkbox"/>
EHV-A4			<input checked="" type="checkbox"/>

Figure 25 Grab Column Title Boundary

2. Adjust the column width to display all text (Figure 26).



Main Contact Channel Setup			
Channel (at breaker)	Connector (at TDR)		Ena
EHV-A1	Unit 1 - A1/2		<input checked="" type="checkbox"/>
EHV-A2			<input checked="" type="checkbox"/>
EHV-A3	Unit 1 - A3/4		<input checked="" type="checkbox"/>
EHV-A4			<input checked="" type="checkbox"/>

Figure 26 Adjusted Column Width

3. Safety Considerations

This chapter reviews safety practices for the TDR9100. It contains the following sections:

- [“Grounding the TDR9100” on page 43](#)
- [“Instrument Precautions” on page 44](#)
- [“Testing in the Field” on page 44](#)
- [“Safely Testing with the TDR9100” on page 45](#)

Grounding the TDR9100

General requirements:

- *Always* first be certain that the apparatus under test is solidly grounded along with the TDR9100 and any other external equipment in use.
- *Always* connect the supplied Safety Ground cable to the TDR9100 when using the system in the field.
- *Never* cut or remove the grounding prong from the power cord.
- When the TDR9100 is permanently housed in a vehicle, ground the vehicle chassis and bind the TDR9100 ground to it.

When dealing with capacitors:

1. Close all the grounding switches on the device housing in order to ground the bottom terminals of the capacitor.
2. Make sure capacitor stacks are discharged before personnel come into contact with them.

Do not rely on internal resistors for discharging individual capacitor cells; consider suspect the resistors in failed capacitor cells. For additional protection, Doble recommends applying a shorting wand to the terminals of individual cells before personnel come in contact with them.

Instrument Precautions

- Do not drop or throw the TDR9100 or transducers.
- Do not use the TDR9100 or transducers as a step or platform.
- Do not store the TDR9100 or transducers in temperatures lower than $-13\text{ }^{\circ}\text{F}$ ($-25\text{ }^{\circ}\text{C}$) or greater than $158\text{ }^{\circ}\text{F}$ ($70\text{ }^{\circ}\text{C}$).
- Do not operate the TDR9100 or transducers in temperatures lower than $32\text{ }^{\circ}\text{F}$ ($0\text{ }^{\circ}\text{C}$) or greater than $122\text{ }^{\circ}\text{F}$ ($50\text{ }^{\circ}\text{C}$).
- Do not store the TDR9100 or transducers in excessively humid environments.
- Do not expose the TDR9100 or transducers to rain, snow, sand, or dust.
- Always transport the TDR9100 or transducers with their protective covers in place.

Testing in the Field

When performing field tests:

- Perform all tests, except First Trip and Record Only, with the apparatus under test removed from service and made safe for testing. Record Only can be performed with a breaker in or out of service.

First Trip testing is done with an energized breaker. For specialized First Trip safety procedures, see [“Safety Considerations for First Trip Tests” on page 137](#).

- Strictly observe all company rules for safe practice in testing, including tagging during testing and maintenance work.

Always adhere to manufacturer’s circuit breaker specifications. State, local, and federal regulations, such as OSHA regulations, may also apply. ***Company rules and government regulations take precedence over Doble recommendations.***



WARNING! Once a test is loaded, never attempt to disconnect the cables from either the test specimen or from the TDR9100 until the test is completed or cancelled.

Do not handle main contact test cable test connections while a test is running. Up to 60 V DC can be present. During capacitance tests, up to 100 V AC can be present.

Safely Testing with the TDR9100

To ensure a safe testing environment:

- Use the correct voltage to power the TDR9100 in order to avoid an electrical short circuit, overheating, and shocks. If in doubt, check the electrical rating label attached to each unit.
- Turn power OFF and disconnect from line power before reaching into the TDR9100.
- Never insert metal objects, such as screwdrivers or paper clips, inside the TDR9100 while power is ON.
- Unplug the TDR9100 if it is not to be used for an extended period of time, or before cleaning.
- If the TDR9100 is dropped, have it checked by a qualified service technician before placing it back in service. Dropping the TDR9100 can disturb the insulation system.

4. Test Plan Setup

This chapter explains how to perform preliminary setup for a new or edited test plan, and add breaker data into the plan. It contains the following sections:

- [“Preliminary Setup” on page 47](#)
- [“Start Here Tab” on page 54](#)
- [“Nameplate Tab” on page 55](#)
- [“Basic Limits Tab” on page 56](#)
- [“Motion Limits Tab” on page 77](#)

Preliminary Setup

Preliminary setup involves these steps:

- [“Selecting a Test Plan Option” on page 47](#)
- [“Selecting the TDR9100” on page 49](#)
- [“Setting System Preferences” on page 50](#)
- [“Opening Files” on page 53](#)

Selecting a Test Plan Option

You can create a test plan from an existing plan or create an entirely new plan:

1. Double-click the **T-Doble** icon, or run **T-Doble** from your Start menu. The T-Doble window language selection window appears.

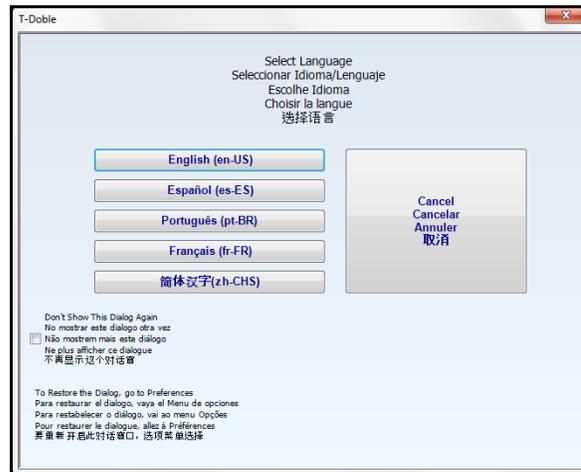


Figure 27 Language Window

2. Select a language.

The Doble splash screen appears.

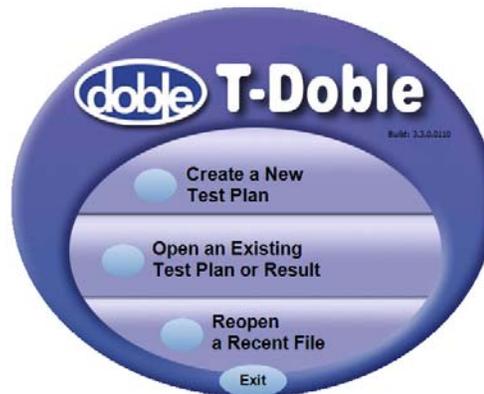


Figure 28 Doble Splash Screen

3. Make one of the following selections:

- **Create a New Test Plan**
- **Open an Existing Test Plan or Result**
- **Reopen a Recent File**

The T-Doble window displays tabs that provide access to the following pages:

- **Files**—Provides access to saved test plans and results

- Breaker—Provides identifying data for most commercially available breakers, and enables you to enter test limits
- Test Plan—Enables you to configure a test plan
- Results—Displays result data
- Plots—Displays result graphs
- Instrument—Lists all connected instruments and enables you to select the TDR9100 of interest
- Reports—Enables you to choose the appearance and contents of the reports you wish to generate
- Preferences—Provides options for display, plotting, file saving, and window behavior
- Help—Provides T-Doble product identification



Figure 29 Tabs Providing Access to T-Doble Main Pages

Selecting the TDR9100

The Instrument page enables you identify and to select a TDR9100 that is currently connected to the computer.

To select the correct instrument:

1. Click the **Instrument** tab.

All available instruments are displayed. If no instruments are shown, click **Search for Instruments** to update the list of available instruments.

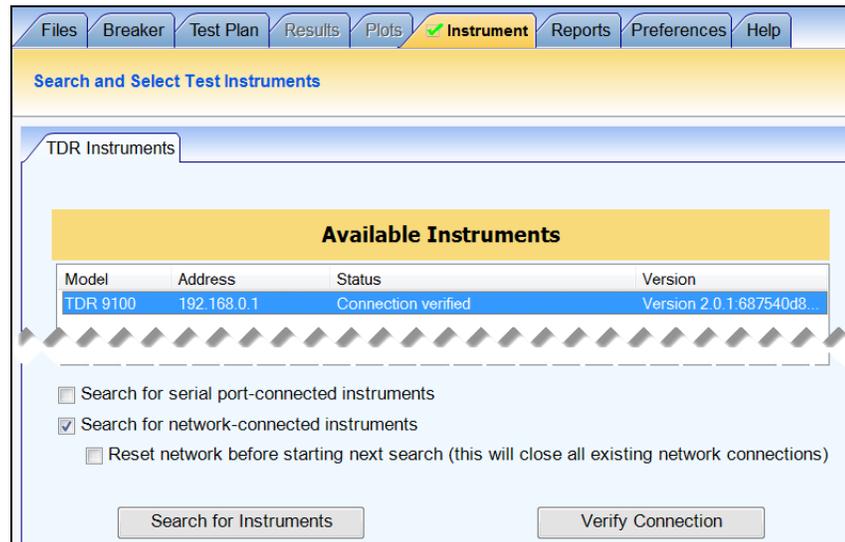


Figure 30 Instrument Tab Listing Connected Instruments

2. Select an instrument from the list and click **Verify Connection**.
When the connection is verified, a confirmation message appears.

Setting System Preferences

The Preferences page enables you to select the T-Doble behavior you prefer.

Display Units Tab

The Display Units tab sets units of measurement and power system defaults:

- Time
- Length
- Velocity
- Angular Velocity
- Rotation
- System Reference Frequency
- Phase Naming

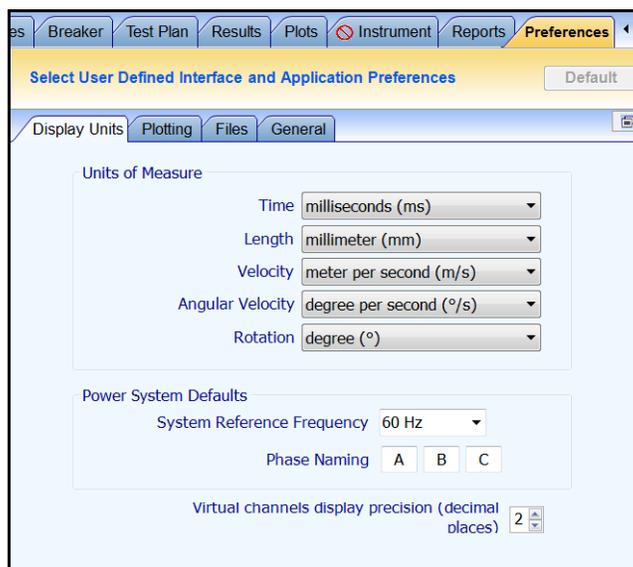


Figure 31 Display Units Subtab of Preferences Tab

Plotting Tab

The Plotting tab provides such settings as line thicknesses, axis characteristics, colors, and so on. [“Setting Plotting Preferences” on page 190](#) for more information.

Files Tab

The Files tab provides settings related to saving and importing files. See [“Saving Test Results” on page 202](#) for a discussion of how to save data.

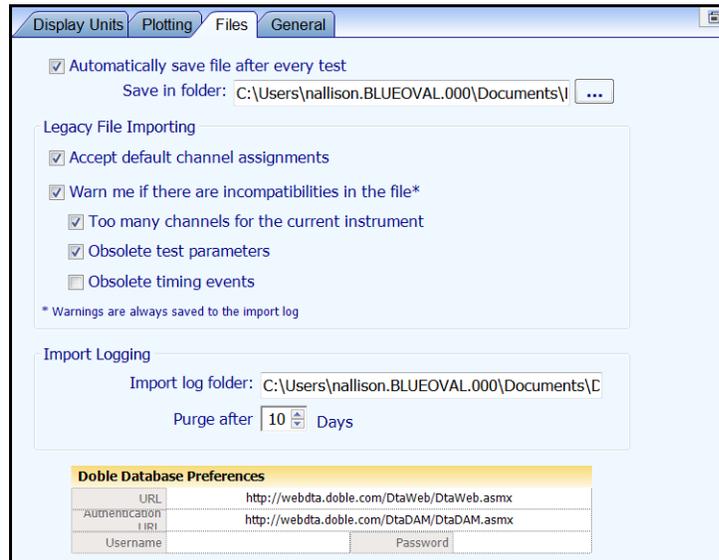


Figure 32 Files Subtab of Preferences Tab

General Tab

The General tab provides options governing the opening and closing of T-Doble windows and of T-Doble itself. It also provides precision preferences for the virtual channels, and the option to restore the column defaults on the Files subtabs (Browse Files, Recently Opened Files, and Doble Database).

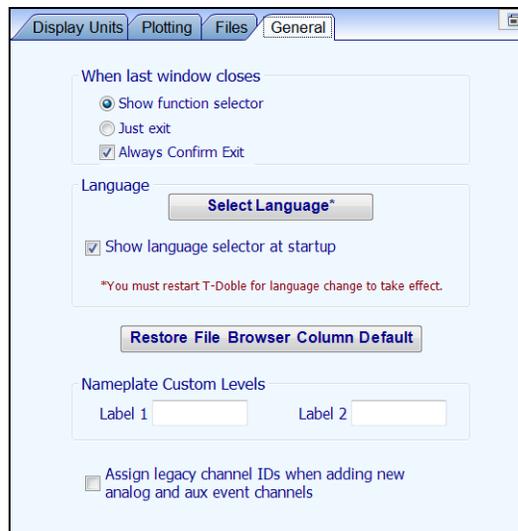


Figure 33 General Subtab of Preferences Tab

Opening Files

Go to the Files page if you wish to work from an existing test plan. The Files page enables you to find test plans and data files:

- **Browse Files**—Opens by default in the Data folder. The Look in Folder field enables you to browse to other locations. Use the check boxes at the bottom of the window to filter the displayed files by Library plan, breaker plan, or test result.
- **Recently Opened Files**—Displays those files that have most recently been opened in T-Doble.
- **Doble DTAWeb**—Provides access to the web-based Doble database.

File ▲	Location	Breaker Type	Manufacturer	Model	Special ID	File Type	Test Date
CB-01__Breaker Plan.tbrx	Watertown	SF6	A-BB	145-PM-40-20	CB-01	Breaker Plan	
CB-01_10-14-2008_154232_ROJ.dbrx	Watertown	SF6	A-BB	145-PM-40-20	CB-01	Record Only	2008-10-14 19:
CB-01_10-14-2008_154920_SlowClo...	Watertown	SF6	A-BB	145-PM-40-20	CB-01	Slow Close	2008-10-14 19:
VWE__LibraryPlan.tbrx		Vacuum	AMCNI	VWE		Library Plan	

Figure 34 Files Page and Browse Files Tab

Start Here Tab

The Start Here tab enables you to make basic hardware selections for your test. All other T-Doble configuration windows are populated with the data you provide here, eliminating the need to set up these parameters repeatedly.

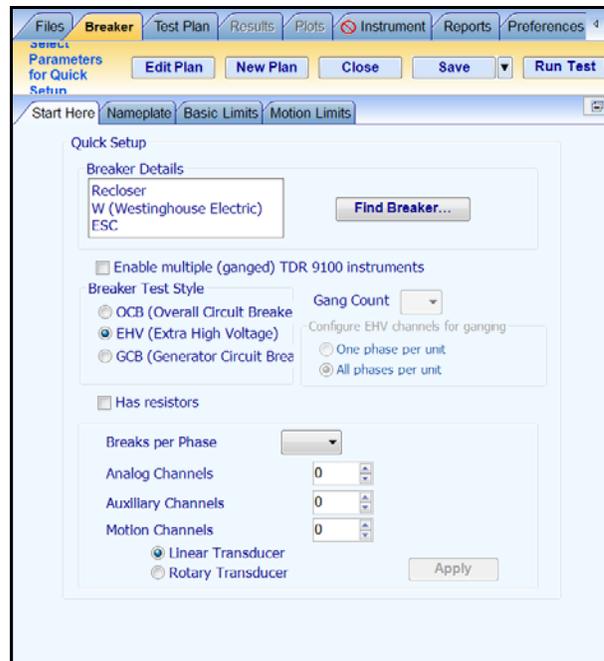


Figure 35 Start Here Subtab of Breaker Tab

To enter data:

1. Click the **Find Breaker** button and select the type of breaker, manufacturer, and model number from the popup menus.
2. Select the style of breaker (**OCB**, **EHV**, or **GCB**).
3. Select breaks-per-phase and channel information and click **Apply**.

Nameplate Tab

The Nameplate tab enables you to enter more information about the breaker you wish to test. [Figure 36](#) shows the Nameplate tab.

The screenshot shows the 'Nameplate' subtab of the 'Breaker' tab. The 'Breaker Test Details' section includes radio buttons for OCB, EHV (selected), and GCB, along with a 'Find Breaker...' button and a 'Has resistors' checkbox. The 'Nameplate' section is a table with the following fields:

Required	Type of Breaker	Recloser	Description
	Manufacturer	W	Circuit Number
	Model Number	ESC	Mechanism Type
	Company*		Mechanism Book Number
	Location*		Instruction Book Number
	Division		Operation Counter
	Serial Number*	xxxxx	Line Frequency
	Special ID*	xxxxx	60 Hz
	*Required for Breaker Plan		Operator
			<custom label 1>
			<custom label 2>
	Plan Type	Library Test Plan	Test Run
			*

Figure 36 Nameplate Subtab of the Breaker Tab

Required Information

Library and Breaker plans require different sets of information, as follows.

Library Plans:

- Type of Breaker
- Manufacturer
- Model Number

Breaker Plans:

- Type of Breaker
- Manufacturer
- Model Number
- Company
- Location—Select a location from the drop-down list, or select **Add a Location** and type in a new location.
- Serial Number
- Special ID

Basic Limits Tab

The Basic Limits tab enables you to enter breaker timing, motion, resistance, and capacitance limits. [Figure 37](#) shows timing limits for an OCB overall test, or for breakers with one break per phase.

The screenshot displays the 'Basic Limits' subtab within the 'Breaker' test plan configuration. It is divided into several sections:

- Breaker Timing Limits:** Includes a checked 'Has resistors' option. It features a table for 'Timing' (Minimum, Maximum) and 'Synchronization' (In Breaker, In Phase, In Module) for 'Main Contacts' (Open, Close, Reclose), 'TripFree Dwell Time', and 'Reclose Open-Close Time'.
- Resistor Timing Limits:** Similar table for 'Relative to Test Initiation' and 'Relative to Main' (Open, Close), plus a 'Resistor Debounce' dropdown set to 'Bounce'.
- Resistance Limits:** A table for 'Open Resistance' and 'Close Resistance' with 'Minimum' and 'Maximum' columns.
- Capacitance Limits:** A table for 'Capacitance Limits' with 'Minimum' and 'Maximum' columns.

Figure 37 Basic Limits Subtab of Breaker Tab

Breaker Timing Limits

This section provides the following plots:

- “Main Contacts: Open” on page 57
- “Main Contacts: Close” on page 61
- “Main Contacts: Reclosing” on page 63
- “Main Contacts: TripFree Dwell Time (Close-Open Time)” on page 64
- “Main Contacts: Reclosing Open-Close Time” on page 65

Figure 38 shows the timing limits for EHV breakers with multiple breaks per phase.

		Timing		Synchronization		
		Minimum	Maximum	In Breaker	In Phase	In Module
Main Contacts	Open	*	*	*	*	*
	Close	*	*	*	*	*
	Reclose	*	*	*	*	*
TripFree Dwell Time		*	*			
Reclose Open-Close Time		*	*			

Figure 38 Breaker Timing Limits Table

Main Contacts: Open

IEEE designation: O

Opening time is the interval of time between the time when the actuating quantity of the release circuit reaches the operating value, and the instant when the primary arcing contacts have parted.

Parameters include:

- Minimum—Minimum time for the main contacts to part
- Maximum—Maximum time for the main contacts to part

Figure 39 shows contact opening time (the time between test initiation and the last contact to part).

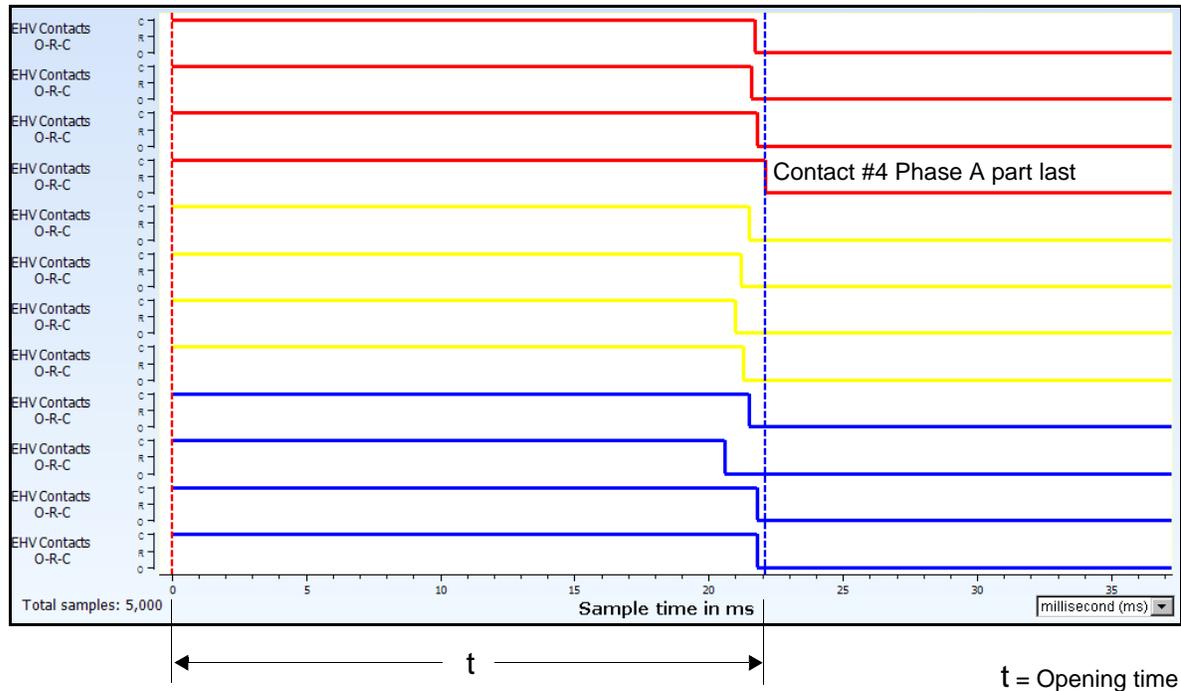
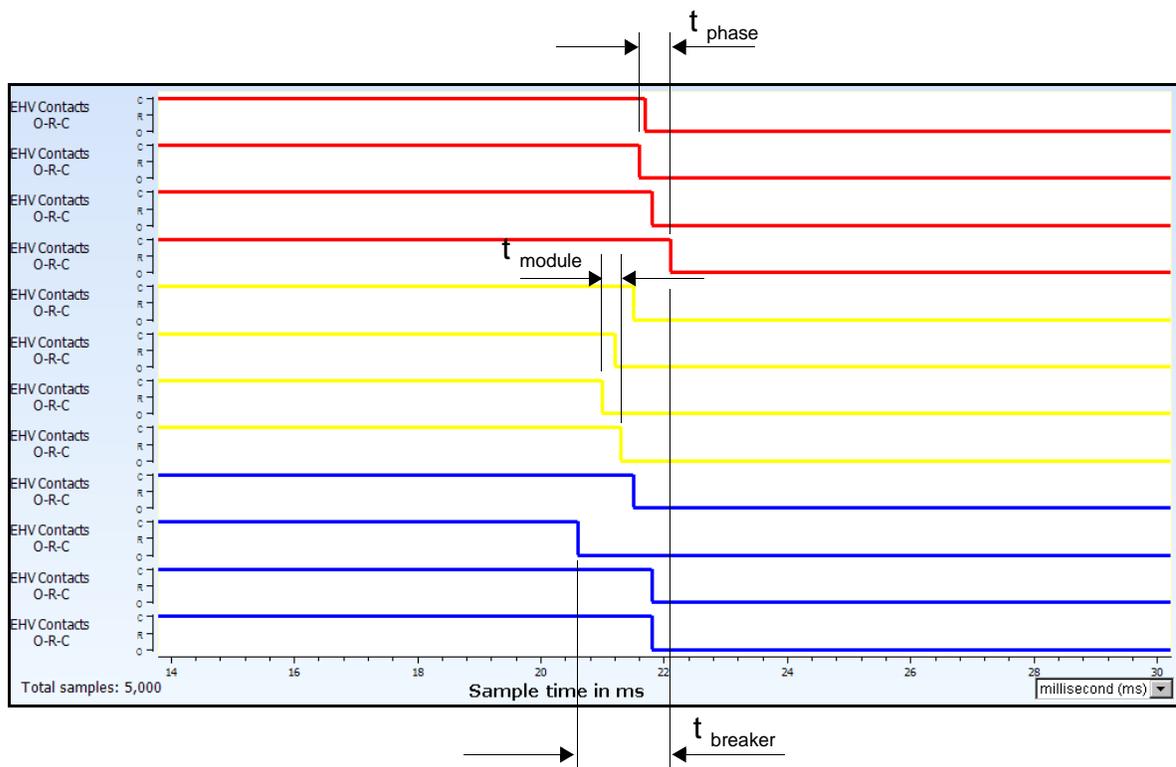


Figure 39 Main Contacts Opening Time

Figure 40 shows open synchronization in module, phase, and breaker.

- Module** Maximum allowable difference in time between the first and last main contacts to open in any module
- Phase** Maximum allowable difference in time between the first and last main contacts to open in a phase
- Breaker** Maximum allowable difference in time between the first and last main contacts to open in a circuit breaker



- t_{module} = Synchronization time for Phase B, Module 2
 t_{phase} = Synchronization time for Phase A
 t_{breaker} = Synchronization time for breaker

Figure 40 Open Synchronization in Module, Phase, and Breaker

Figure 41 provides test results of a sample synchronization.

Main Contact Timing Measurements										
Timing Reference: From Test Initiation			Main Contact Timing							
Channel ID	Label	Phase	Opening Time	Synchronization						
				In Module		In Phase		In Breaker		
EHV-A1	A-EHV 1	Phase A	21.7 ms	✓						
EHV-A2	A-EHV 2	Phase A	21.6 ms	✓	0.1 ms	✓				
EHV-A3	A-EHV 3	Phase A	21.8 ms	✓			0.5 ms	✓		
EHV-A4	A-EHV 4	Phase A	22.1 ms	⚠	0.3 ms	✓				
EHV-B1	B-EHV 1	Phase B	21.5 ms	✓						
EHV-B2	B-EHV 2	Phase B	21.2 ms	✓	0.3 ms	✓				
EHV-B3	B-EHV 3	Phase B	21.0 ms	✓			0.5 ms	✓	1.5 ms	
EHV-B4	B-EHV 4	Phase B	21.3 ms	✓	0.3 ms	✓				
EHV-C1	C-EHV 1	Phase C	21.5 ms	✓						
EHV-C2	C-EHV 2	Phase C	20.6 ms	✓	0.9 ms	✓				
EHV-C3	C-EHV 3	Phase C	21.8 ms	✓			1.2 ms	✓		
EHV-C4	C-EHV 4	Phase C	21.8 ms	✓	0.0 ms	✓				
			Trip Limits							
			Maximum	22.0 ms	2.8 ms	2.8 ms	2.8 ms			
			Minimum	19.0 ms						

Figure 41 Sample Synchronization Test Results

Main Contacts: Close

IEEE designation: C

Closing time is the interval of time between the initiation of the closing operation and the instant when metallic continuity is established in all poles.

Parameters include:

- Minimum—Minimum time for the main contacts to make
- Maximum—Maximum time for the main contacts to make

Figure 42 shows contact closing time (the time between test initiation and last contact to close).

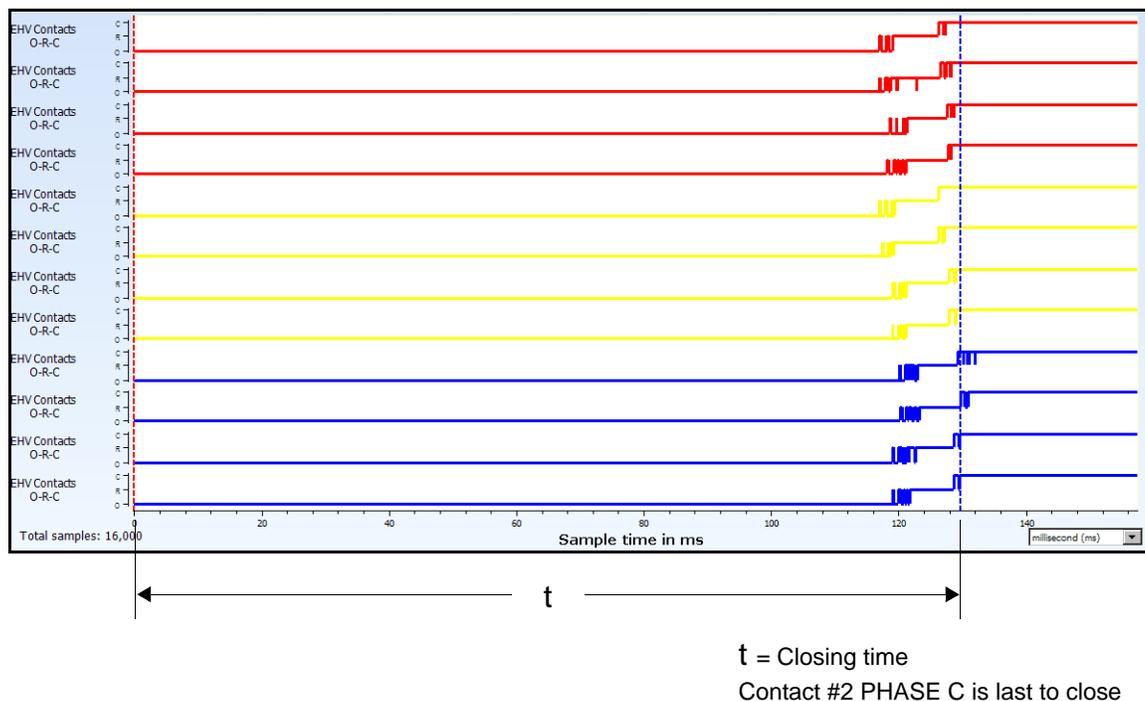
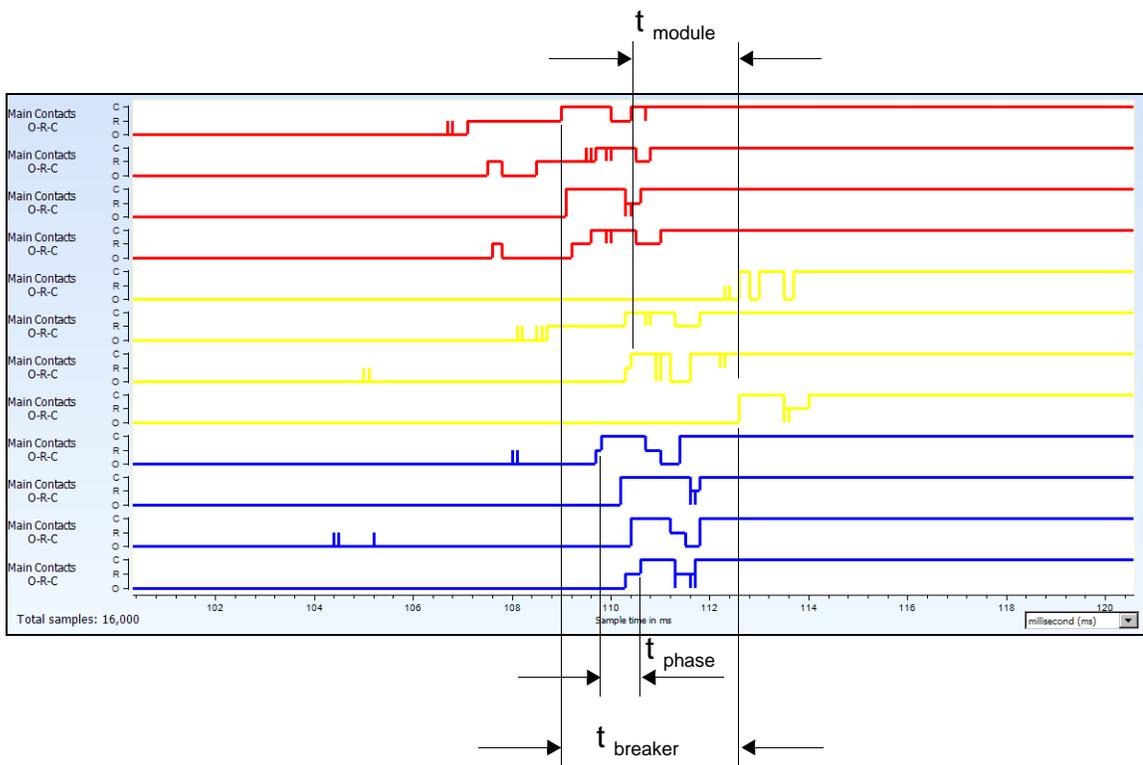


Figure 42 Module-Level Contact Close Synchronization

Figure 43 shows close synchronization in module, phase, and breaker.

- Module** Maximum allowable difference in time between the first and last main contacts to close in any module
- Phase** Maximum allowable difference in time between the first and last main contacts to close in a phase
- Breaker** Maximum allowable difference in time between the first and last main contacts to close in a circuit breaker



- t_{module} = Synchronization time for Phase B, Module 2
- t_{phase} = Synchronization time for Phase C
- t_{breaker} = Synchronization time for breaker

Figure 43 Close Synchronization in Module, Phase, and Breaker

Main Contacts: Reclosing

IEEE designation: O - 0.3 s - C

Reclosing time is the interval between the beginning of the opening time and the instant when the contacts touch in all poles during a reclosing cycle.

Parameters include:

- Minimum—Minimum time from trip initiation to main contact close
- Maximum—Maximum time from trip initiation to main contact close

[Figure 44](#) shows overall reclose timing (time from test initiation to last contact close).

Module	Maximum allowable difference in time between trip initiation and the last closing of the two main contacts in any module
Phase	Maximum allowable difference in time between trip initiation and the last closing of the main contacts in any phase
Breaker	Maximum allowable difference in time between trip initiation and the last closing of the main contacts in a circuit breaker

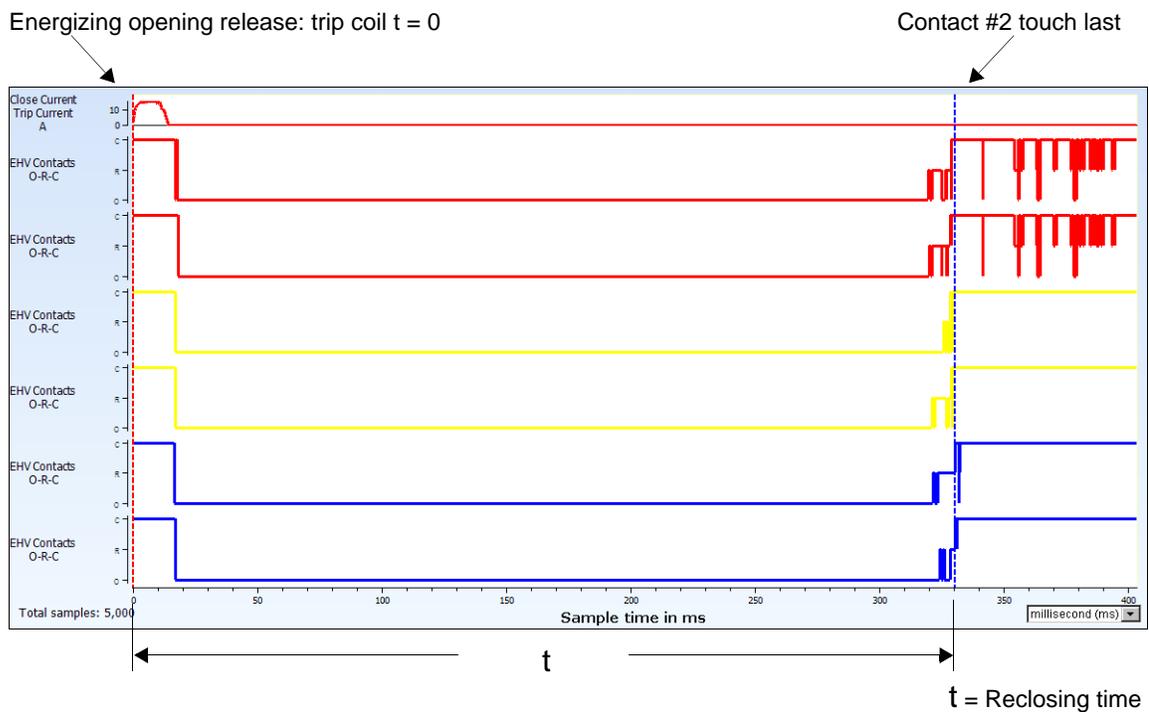


Figure 44 Main Contact Timing – Reclosing

Main Contacts: TripFree Dwell Time (Close-Open Time)

Dwell time (close-open time) is the interval between:

- The instant of time when the first contact closes during the closing operation
- and
- The instant of time when the last contact opens during the subsequent opening operation

TripFree Dwell Time parameters include:

- Minimum—Minimum time the main contacts are CLOSED during a TripFree test
- Maximum—Maximum time the main contacts are CLOSED during a TripFree test

Figure 45 shows the TripFree dwell time.

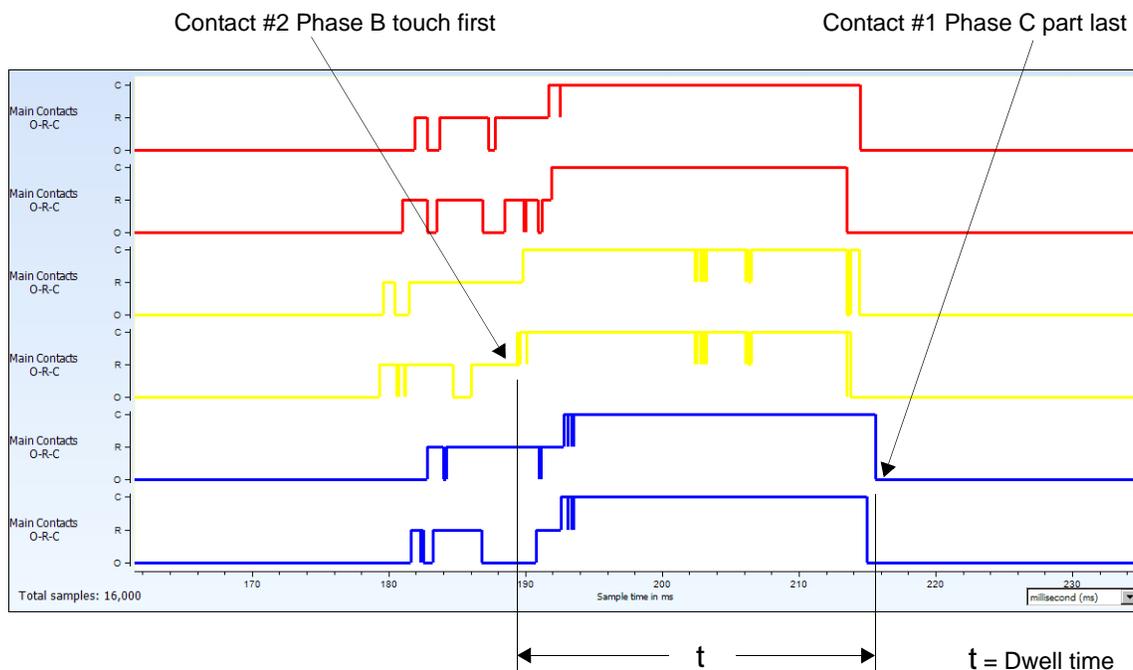


Figure 45 TripFree Dwell Time

Main Contacts: Reclosing Open-Close Time

Dead time (during reclosing) is the interval of time between the instant when the arcing contacts have separated in all poles and the instant when the contacts touch in the first pole during a reclosing cycle.

Reclosing open-close time parameters include:

- Minimum—Minimum time the main contacts are OPEN during a Reclosing test
- Maximum—Maximum time the main contacts are OPEN during a Reclosing test

Figure 46 shows the Reclosing open-close time.

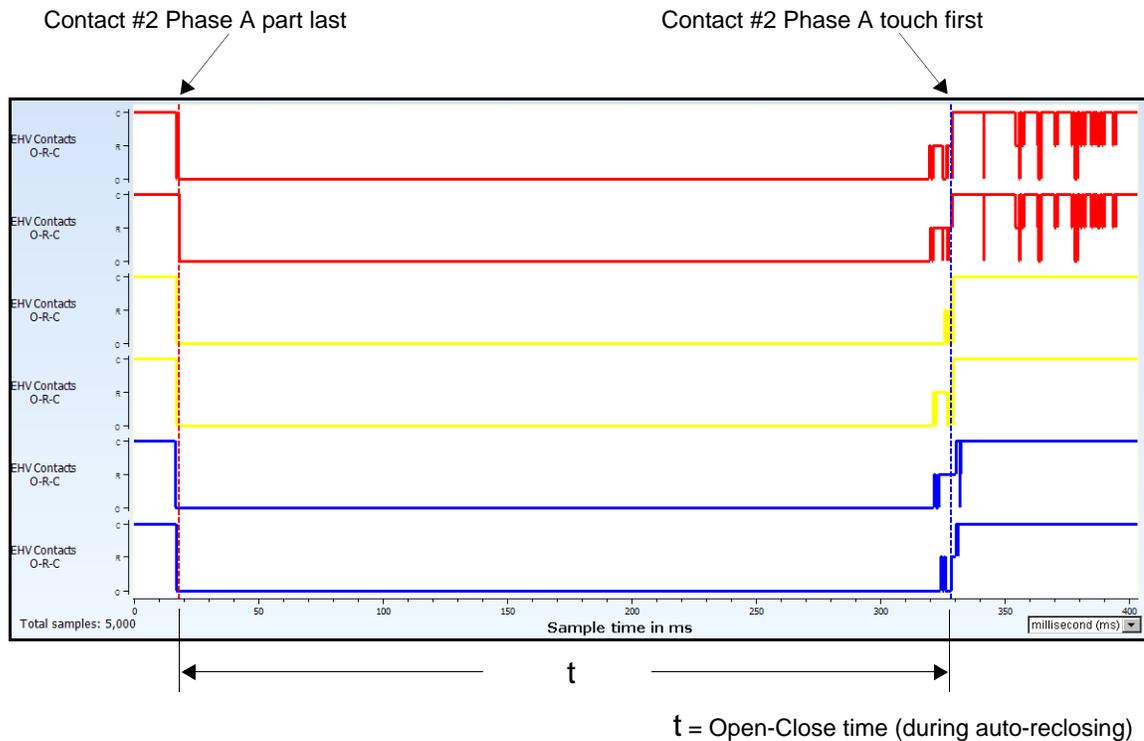


Figure 46 Reclosing Open-Close Time

Resistor Timing Limits

This section discusses three types of resistor timing limits:

- “Resistor Timing – Open” on page 67
- “Resistor Timing – Close” on page 69
- “Resistor Debounce Values for First Touch Tabulation” on page 72

Figure 47 shows the resistor timing limits available for the circuit breaker resistor contacts.

		Timing		Synchronization		
		Minimum	Maximum	In Breaker	In Phase	In Module
Relative to Test Initiation	Open	*	*	*	*	*
	Close	*	*	*	*	*
Relative to Main	Open	*	*	*	*	*
	Close	*	*	*	*	*
Resistor Debounce		Bounce <input type="button" value="v"/>				

Figure 47 Resistor Timing Limits

Resistor Timing – Open

You can time resistor contacts in two ways using these options:

- Relative to test initiation
- Relative to main (the opening of the main contacts)

Parameters include:

- Minimum—Minimum time for the resistor contacts to part
- Maximum—Maximum time for the resistor contacts to part

Figure 48 shows Opening time relative to main and test initiation.

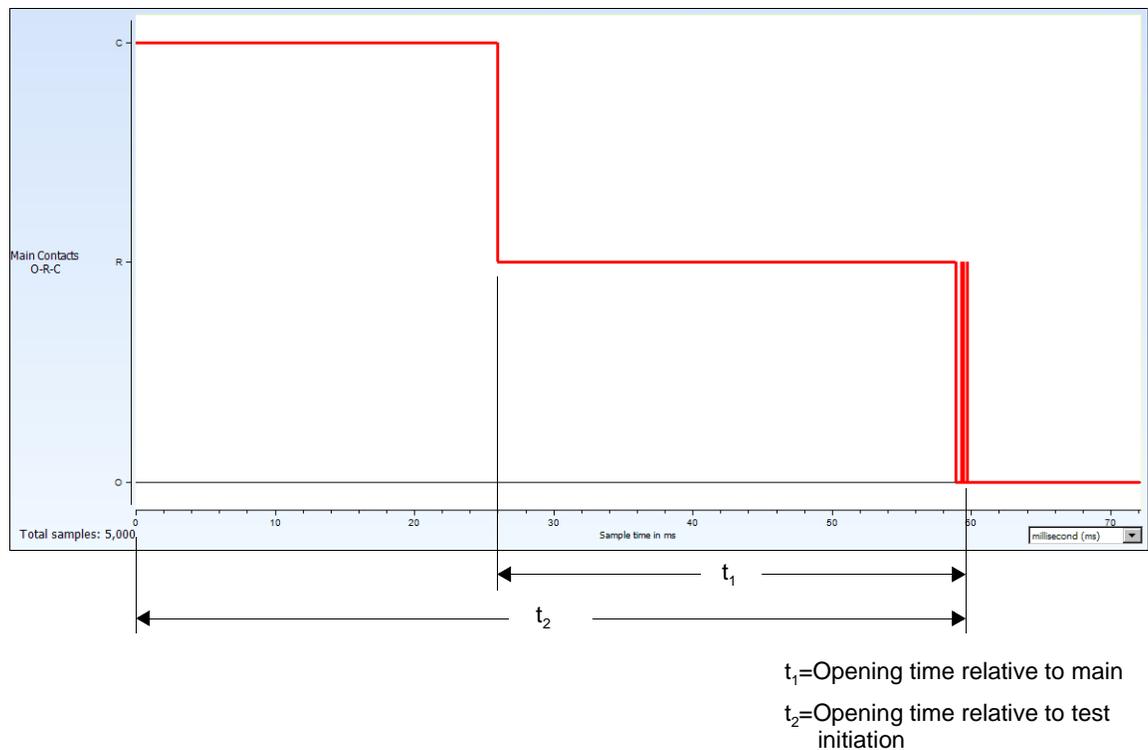


Figure 48 Opening Time – Resistor Contact

Figure 49 shows how contact and resistor contact timing open synchronization occurs on a module-by-module level.

- Module** Maximum allowable difference in time between the opening of the two resistor contacts in any module
- Phase** Maximum allowable difference in time between the opening of the two resistor contacts in a phase
- Breaker** Maximum allowable difference in time between the opening of the two resistor contacts in a circuit breaker

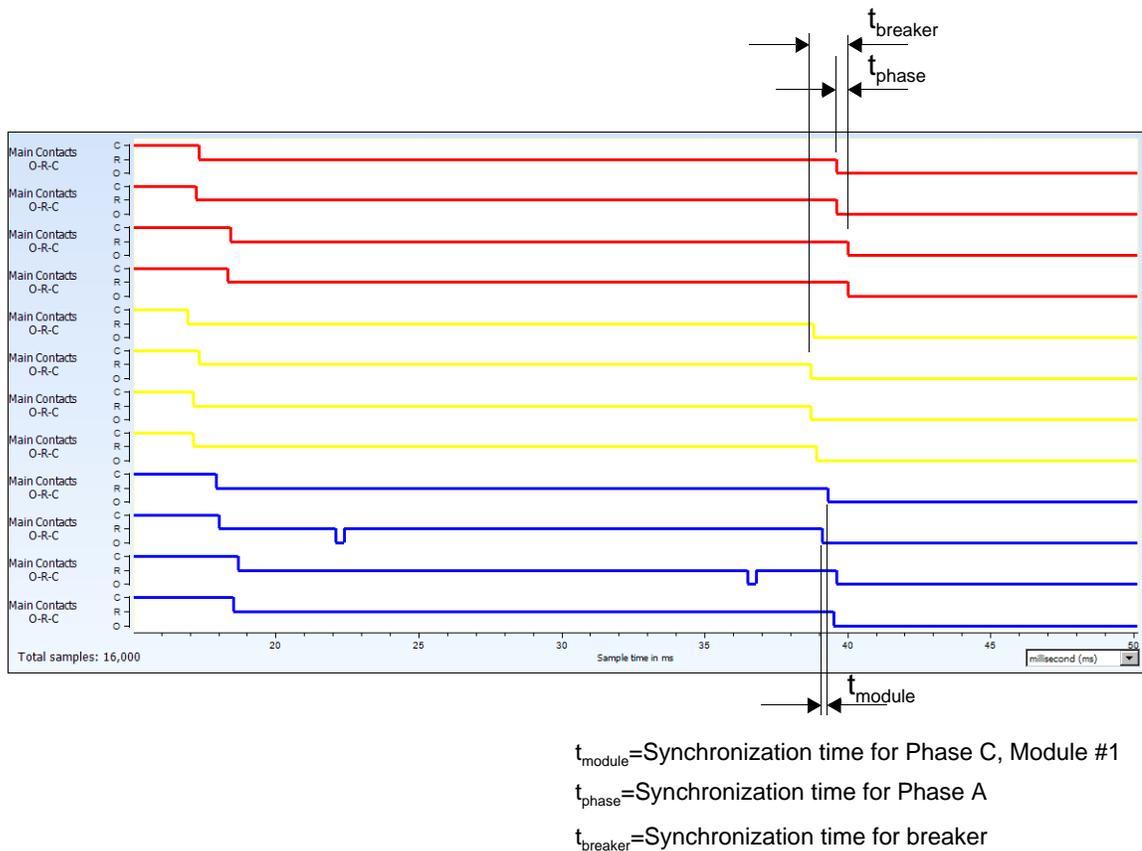


Figure 49 Resistor Contact Open Synchronization

Resistor Timing – Close

Some circuit breakers use insertion resistors during closing to control the transient overvoltages that occur during closing. The timing of the closure of the resistor contacts may be measured during the circuit breaker timing test.

You can time resistor contacts in two ways using these options:

- Relative to Test Initiation
- Relative to Main (the closing of the main contacts)

Parameters include:

- **Minimum**—Minimum time for the resistor contacts to close if measured relative to test initiation, or minimum time that resistors are in the circuit (the time interval between resistor contact closure and main contact closure) when measured relative to main contacts.
- **Maximum**—Maximum time for the resistor contacts to close if measured relative to test initiation, or maximum time that resistors are in the circuit (the time interval between resistor contact closure and main contact closure) when measured relative to main contacts.

Figure 50 shows closing time from test initiation until resistor contact touch.

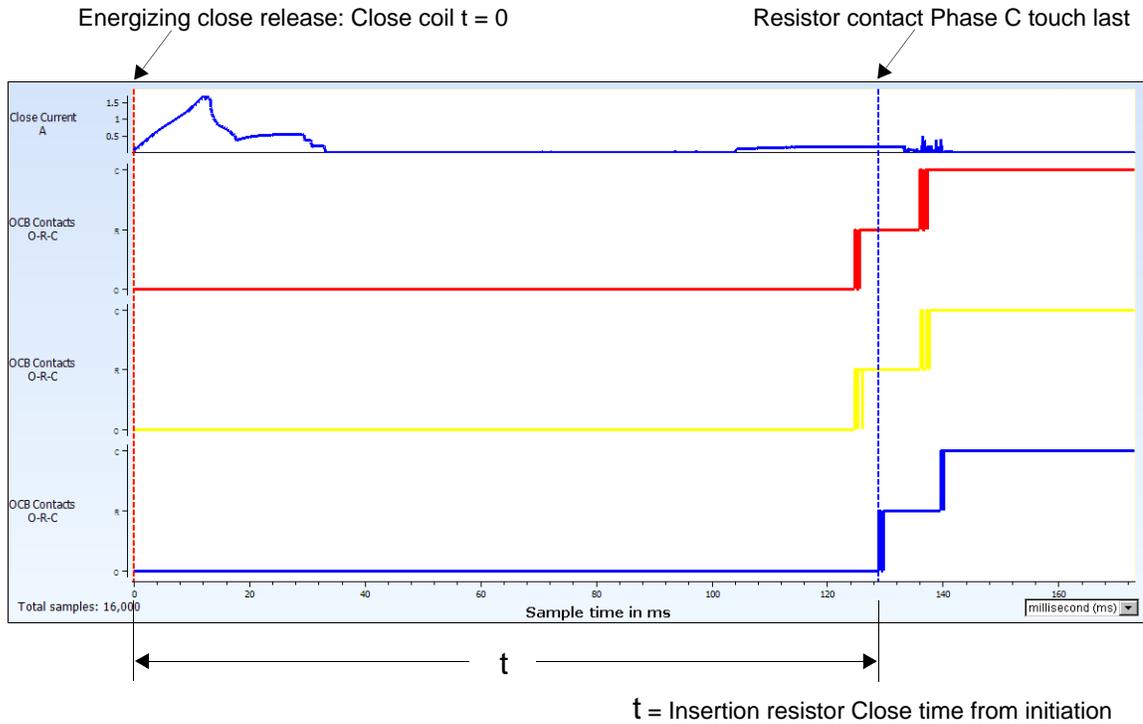
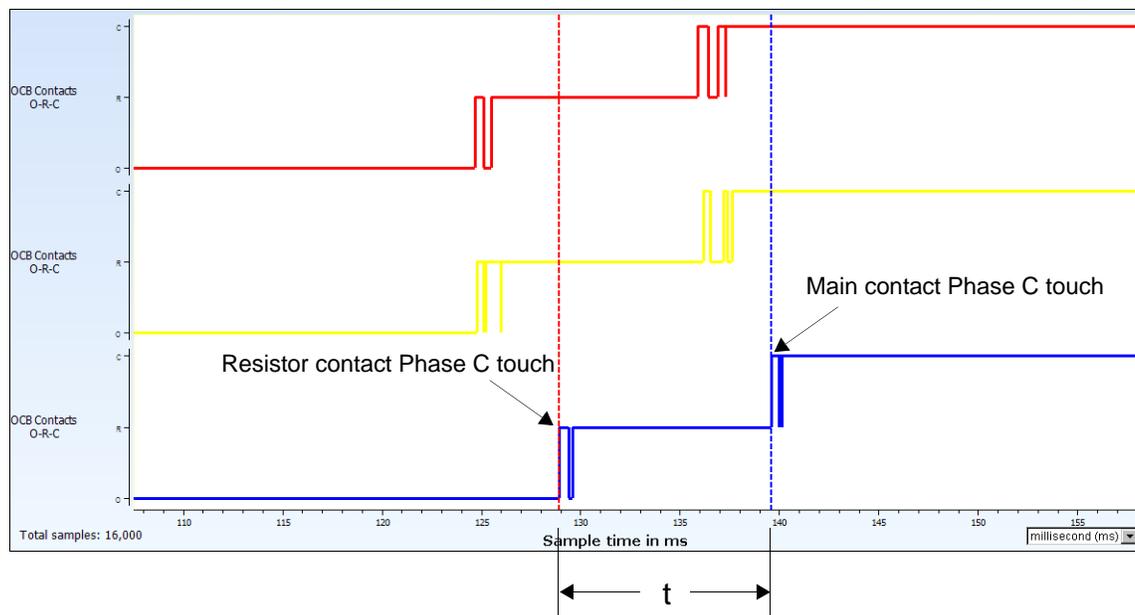


Figure 50 Resistor Contact Timing Measure Relative to Test Initiation

Figure 51 shows timing from resistor contact touch until main contact close.



t = Length of time resistor is in closed position before main contact close

Figure 51 Resistor Contact Timing Relative to Main Contact Closure, Phase C

Figure 52 shows how contact and resistor contact timing close synchronization occurs on a module-by-module level.

- Module** Maximum allowable difference in time between the closing of the two resistor contacts in any module
- Phase** Maximum allowable difference in time between the closing of the two resistor contacts in a phase
- Breaker** Maximum allowable difference in time between the closing of the two resistor contacts in a circuit breaker

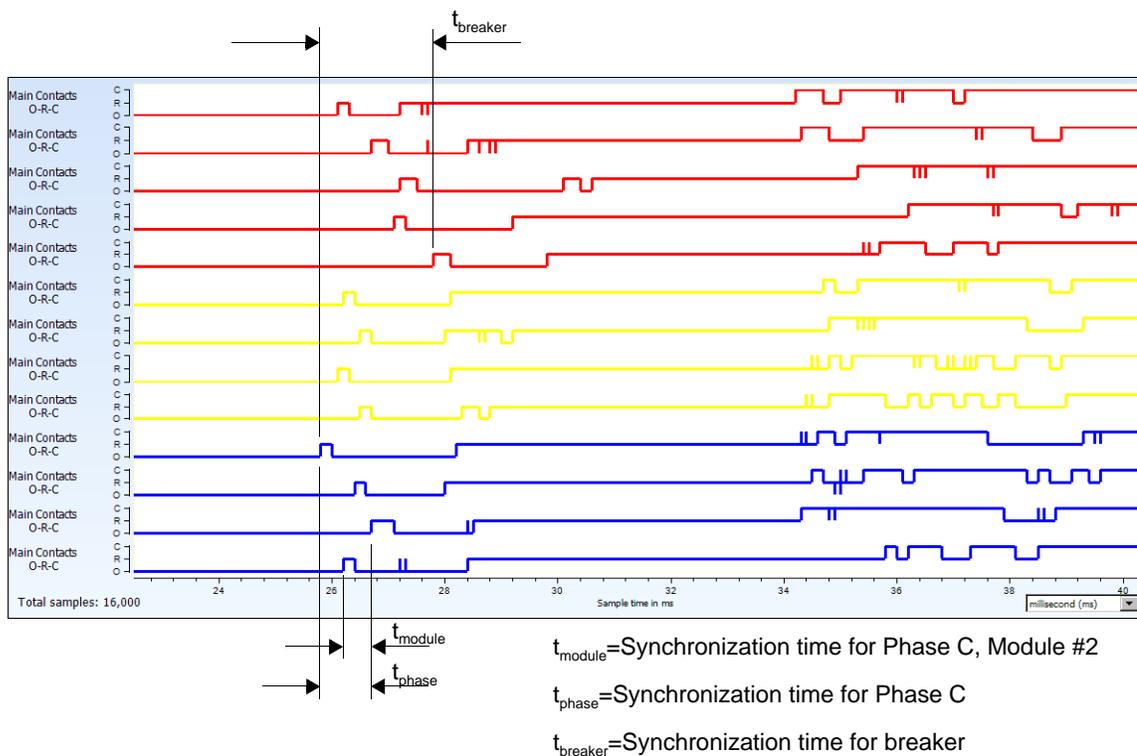


Figure 52 Resistor Contact – Close Synchronization

Resistor Debounce Values for First Touch Tabulation

The Resistor Debounce field sets the minimum amount of time the TDR9100 discriminator must recognize the resistor state before the transition to resistor is used for purposes of timing calculations. When the circuit breaker makes a transition into the resistor state and stays there, without bouncing open, for a period of time long enough to satisfy the Resistor Debounce criteria, the software uses the initial moment of transition to mark the beginning of the resistor level for purposes of resistor timing calculations.

Figure 53 shows the location of the Resistor Debounce field.

The screenshot shows the 'Review or Define Basic Performance Timing Limits' dialog box. The 'Resistor Timing Limits' section is expanded, showing a table with columns for Timing (Minimum, Maximum) and Synchronization (In Breaker, In Phase, In Module). The 'Resistor Debounce' dropdown menu is highlighted with a red circle, showing options: Bounce, 100 µs, and 200 µs.

		Timing		Synchronization		
		Minimum	Maximum	In Breaker	In Phase	In Module
Main Contacts	Open	*	*	*	*	*
	Close	*	*	*	*	*
	Reclose	*	*	*	*	*
	TripFree Dwell Time	*	*			
Reclose Open-Close Time		*	*			

		Timing		Synchronization		
		Minimum	Maximum	In Breaker	In Phase	In Module
Relative to Test Initiation	Open	*	*	*	*	*
	Close	*	*	*	*	*
Relative to Main	Open	*	*	*	*	*
	Close	*	*	*	*	*

Resistor Debounce: **Bounce** (selected), 100 µs, 200 µs, Maximum

Figure 53 Location of Resistor Debounce Field

The Resistor Debounce field provides these options: 100 µs, 200 µs, and Bounce. If 100 µs or 200 µs is selected, the resistor level must be present during the entire period specified (100 µs or 200 µs) without any transitions or bounces for the transition to be acceptable.



NOTE! The transition to the resistor level is identified by the first resistor contact closure during a Close operation, and by the last resistor contact open during an Opening operation.

Different resistor debounce values are needed to accommodate the characteristics of different circuit breakers:

- If the resistor contact of a circuit breaker tends to bounce extensively during operation, and the bouncing results in no resistor contact touching long enough to match the qualifier setting, then the resistor contact is not seen by the test set, and the operating time of the resistor contact is not tabulated.

In such a case, the Resistor Debounce time can be reduced from the default value of 200 μ s to 100 μ s to observe the resistor contact (despite its bouncing) and obtain a tabulated value. This is acceptable if the bouncing is a normal part of operation for this particular circuit breaker. If it is an abnormal event, however, reducing the Resistor Debounce time to make the switch visible is self-defeating because the tabulated value has no real meaning.

- To determine a trend in a circuit breaker, and to compare similar circuit breakers, use the largest time setting that consistently yields a tabulated value for the resistor contact timing.
- If Bounce is selected, the first identifiable transition to the resistor level is used for the resistor contact tabulation and it is not necessary to have a resistor level for any minimum amount of time.

Figure 54 and Figure 55 illustrate the effects of resistor debounce values.

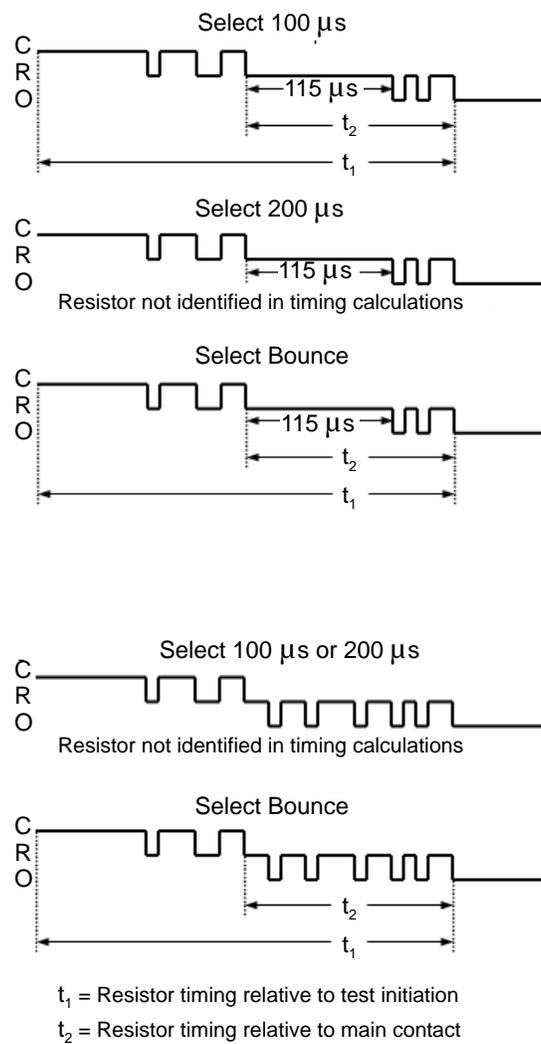


Figure 54 Resistor Debounce Effects – Open Test

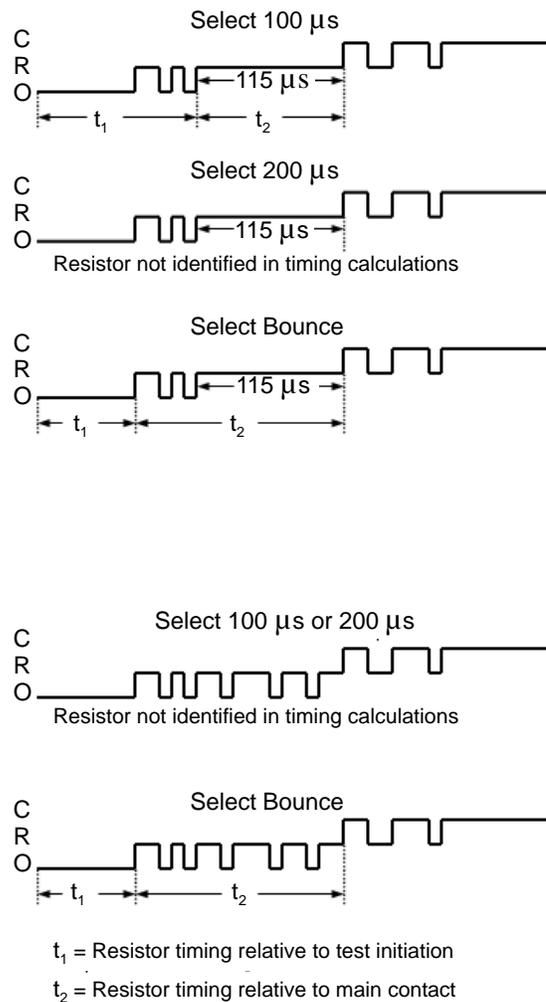


Figure 55 Resistor Debounce Effects – Close Test



NOTE! The Relative to Test Initiation option tabulates resistor contact timing from the beginning of the test ($t = 0$).

The Relative to Main option tabulates resistor contact timing relative to the closing (first contact closed) or opening (last contact open) of the main contact. For further information, refer to [“Resistor Timing – Open” on page 67](#) and [“Resistor Timing – Close” on page 69](#).

Motion Limits Tab

The Motion Limits tab sets travel and average velocity limits. T-Doble can set two user-defined zones for the measurement of average velocities and a range of expected speeds in those zones. In addition, to accommodate the need for indirect measurements on some transducers, T-Doble can apply a transfer function via transducer scaling. Transducer scaling performs a linear scaling calculation using two user-entered values that transform a measurement taken at a transducer to one equal to a contact's travel. You can establish transducer scaling on the Motion Channels subtab of the Test Plan tab. (See [“Transducer Scaling”](#) on page 104 for an explanation of transfer functions).

If you intend to measure two different types of motion at different locations in the same test, you may wish to create multiple motion limit sets. When you create a new travel limit set, T-Doble automatically adds a new average velocity limit set ([Figure 56](#)).

Travel Limits											
	Travel Type	Label		Total Travel	Overtravel		Rebound		Contact Wipe		
					Open	Close	Open	Close			
Limits Set #1 (Angular)	Angular	Mechanism	Expected	*	*	*	*	*	*	✖	
			Tolerance	+	*	*	*	*	*	*	
				-	*	*	*	*	*	*	
Limits Set #2 (Angular)	Angular	Contacts	Expected	*	*	*	*	*	*	✖	
			Tolerance	+	*	*	*	*	*	*	
				-	*	*	*	*	*	*	

Average Velocity Limits							
	Action	Zone	Zone Details			Velocity	
			Zone Type	From	To	Minimum	Maximum
Limits Set #1 (Angular)	Open	1	Distance; Distance	*	*	*	*
		2	Distance; Distance	*	*	*	*
	Close	1	Distance; Distance	*	*	*	*
		2	Distance; Distance	*	*	*	*
Limits Set #2 (Angular)	Open	1	Distance; Distance	*	*	*	*
		2	Distance; Distance	*	*	*	*
	Close	1	Distance; Distance	*	*	*	*
		2	Distance; Distance	*	*	*	*

Figure 56 Motion Limits Subtab of Breaker Tab

Travel Limits

Figure 57 shows the Travel limits available for a circuit breaker.

Travel Limits									
	Travel Type	Label		Total Travel	Overtravel		Rebound		Contact Wipe
					Open	Close	Open	Close	
Limit Set #1 (Linear)	Linear		Expected	*	*	*	*	*	*
			Tolerance	+	*	*	*	*	*
				-	*	*	*	*	*

Figure 57 Travel Limits

Travel Type

You can select a travel type of Linear or Angular.

Total Travel and Contact Wipe

Total Travel has the following two values:

- Expected—The total circuit breaker main contact travel during close or open operations.
- Tolerance—You can specify negative and positive tolerances. The negative tolerance for total travel must never be greater than the specified total travel.

Contact Wipe has the following two values:

- Expected—The distance the transducer connecting rod or rotary adapter moves from the first main contact closure to the fully closed position of the circuit breaker.

The main contact used to calculate wipe is determined by the phase selected in the Motion Channel Parameters. For more information, refer to [“Motion Channels Tab” on page 102](#).

- Tolerance—You can specify positive and negative tolerances. Negative tolerance for contact wipe must never be greater than the specified contact wipe.

The TDR9100 determines wipe for each Motion Channel that is activated and has a transducer connected to it. By default, Phase A always corresponds to Motion Channel 1, Phase B to Motion Channel 2, and Phase C to Motion Channel 3.

Example: To measure Contact Wipe on the phase A contact ([Figure 58](#)):

- Mount the transducer on phase A.
- Connect the motion transducer cable to the M1 connector.

- Activate Motion Channel 1 on the Motion Channels subtab of the Test Plan tab, and label it A.
- Connect Main Contact Test Cable 1 to Phase A.

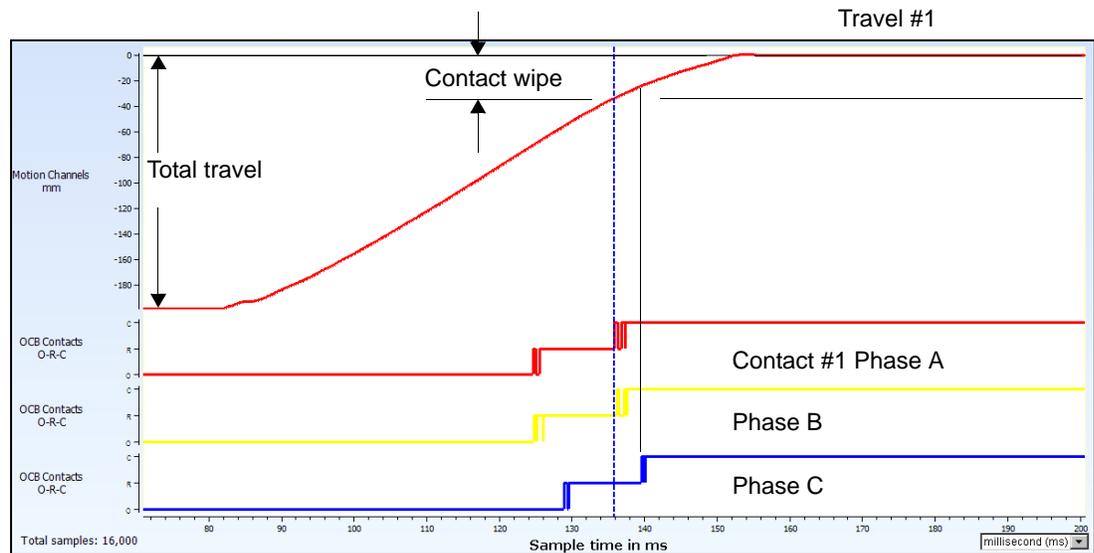


Figure 58 Contact Wipe Measurement

For an EHV circuit breaker (module type), the TDR9100 determines wipe for activated Contact 1 of the phase that has a corresponding activated Motion Channel and a transducer connected to it.

Figure 59 shows timing for contact wipe during total travel operation.

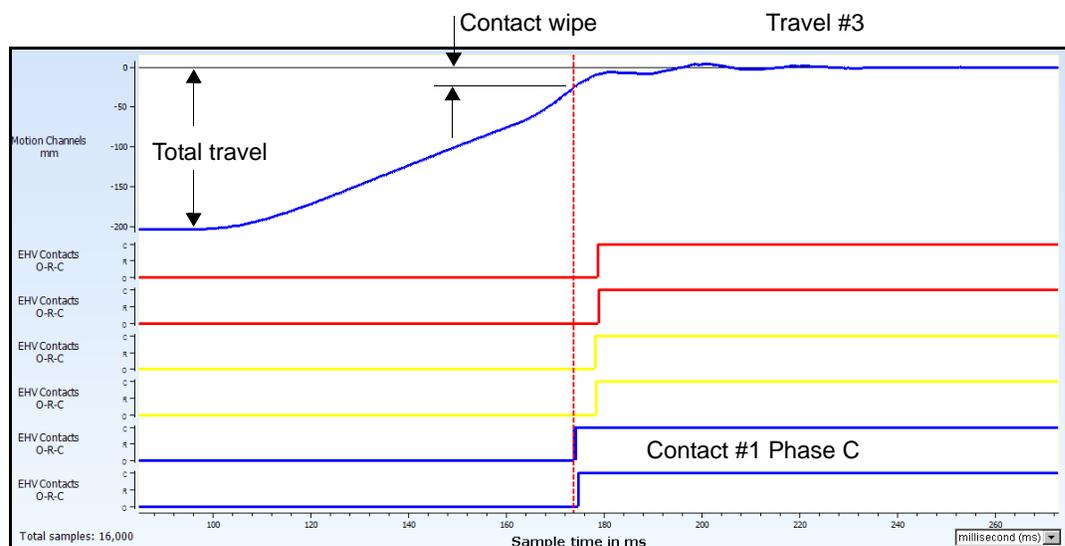


Figure 59 Contact Wipe and Total Travel for Multiple Breaks

Figure 60 shows timing for contact wipe during trip operation.

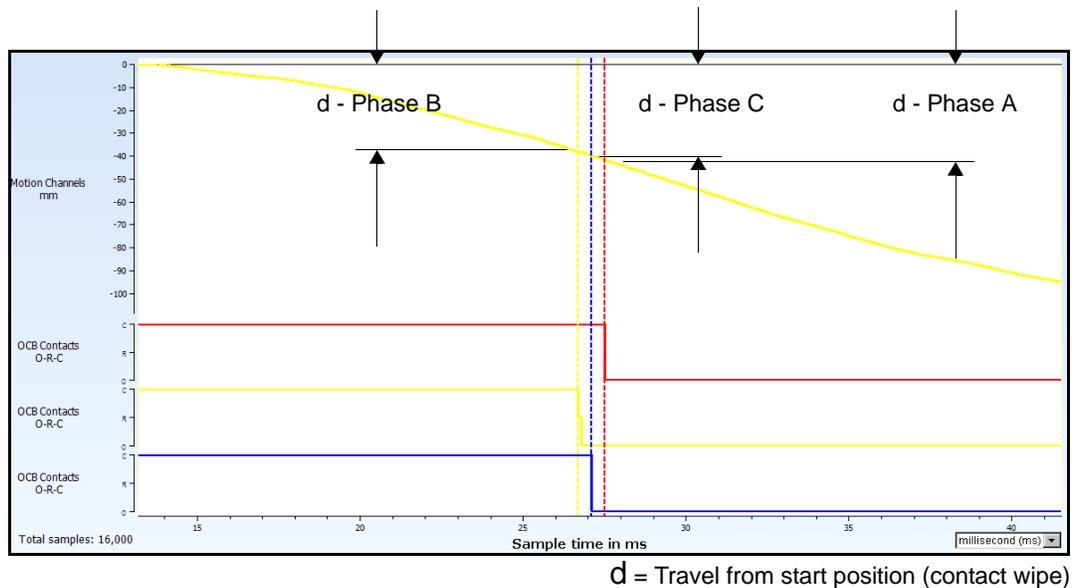


Figure 60 Contact Wipe During Trip Operation

Overtravel, Rebound – Open

Overtravel has the following two values:

- Expected—The distance between the maximum temporary displacement of the circuit breaker main contacts beyond the final open position.
- Tolerance—You can specify negative and positive tolerances. Negative tolerance for overtravel must never be greater than the specified overtravel.

Rebound has the following two values:

- Expected—The distance between the maximum temporary displacement of the circuit breaker main contacts short of the final open position.
- Tolerance—You can specify negative and positive tolerances. Negative tolerance for rebound must never be greater than the specified rebound.

Figure 61 shows how overtravel and rebound are calculated during a circuit breaker opening operation.

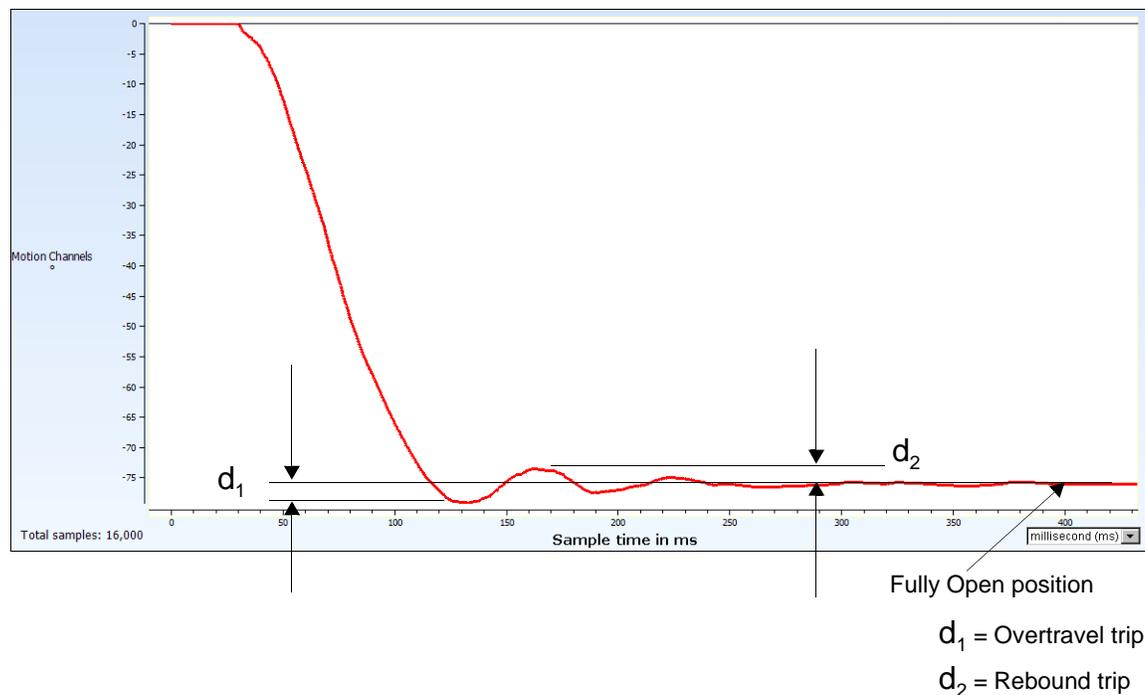


Figure 61 Overtravel/Rebound Open

Overtravel, Rebound – Close

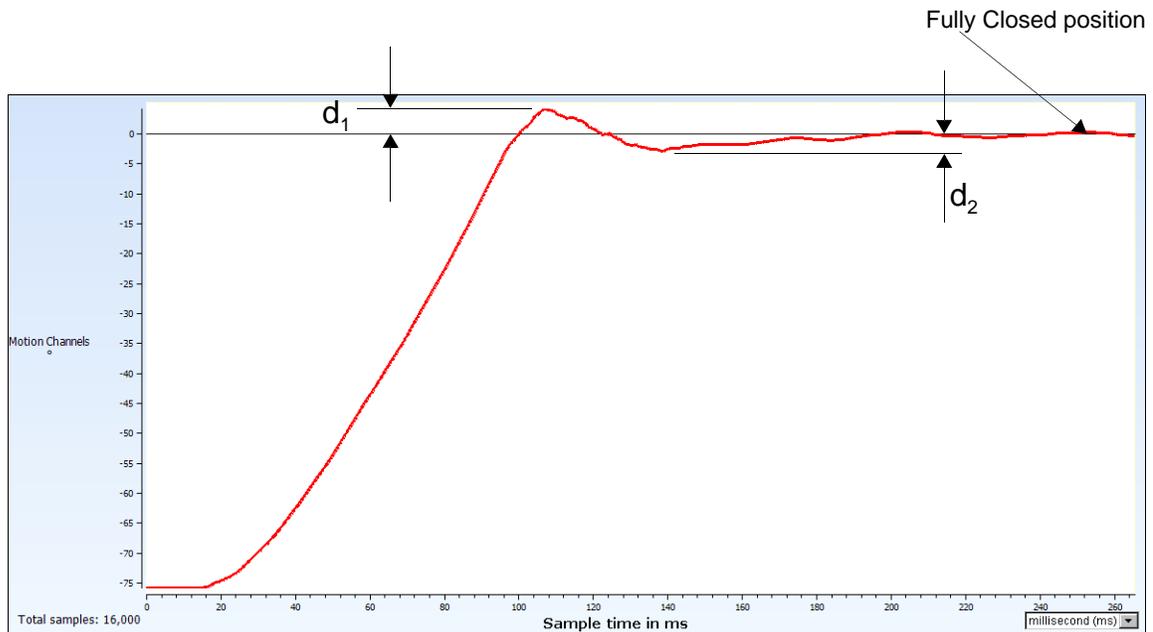
Overtravel has the following two values:

- Expected—The distance between the maximum temporary displacement of the circuit breaker main contact beyond the final closed position.
- Tolerance—You can specify negative and positive tolerances. Negative tolerance for overtravel must never be greater than the specified overtravel.

Rebound has the following two values:

- Expected—The distance between the maximum temporary displacement of the circuit breaker main contacts short of the final closed position.
- Tolerance—You can specify negative and positive tolerances. Negative tolerance for rebound must never be greater than the specified rebound.

Figure 62 shows how overtravel and rebound are calculated or measured for a circuit breaker closing operation.



d_1 = Overtravel Close
 d_2 = Rebound Close

Figure 62 Overtravel/Rebound Closed

Average Velocity Limits

Figure 63 shows the average velocity limits table.

Average Velocity Limits								
	Action	Zone	Zone Details			Velocity		
			Zone Type	From	To	Minimum	Maximum	
Limits Set #1 (Linear)	Open	1	Distance; Distance	▼	*	*	*	*
		2	Distance; Distance	▼	*	*	*	*
	Close	1	Distance; Distance	▼	*	*	*	*
		2	Distance; Distance	▼	*	*	*	*

Figure 63 Average Velocity Limits

Average Velocity – Open

You must enter a zone before the TDR9100 can make a calculation. There are six zone types for average velocity measurements during open test. They serve as the Open and Close conditions that define each zone. These same parameters apply to Velocity Open Zone 2.

- Distance to Distance
- Distance to Time
- Time to Time
- Open to Time
- Open to Distance
- Open to Travel

Velocity Open Zone 1

Velocity Open Zone 1 is calculated using the zone parameters listed above. If used, Zone 2 is identified by zone parameters representing a different part of the opening motion curve. (See [Figure 70 on page 90.](#))

- Distance to Distance—The circuit breaker average velocity is calculated between the two distances specified. Distances are relative to the starting closed position (0.000 in/mm). The end distance (*TO*) must be greater in magnitude than the start distance (*FROM*). (See [Figure 64.](#))

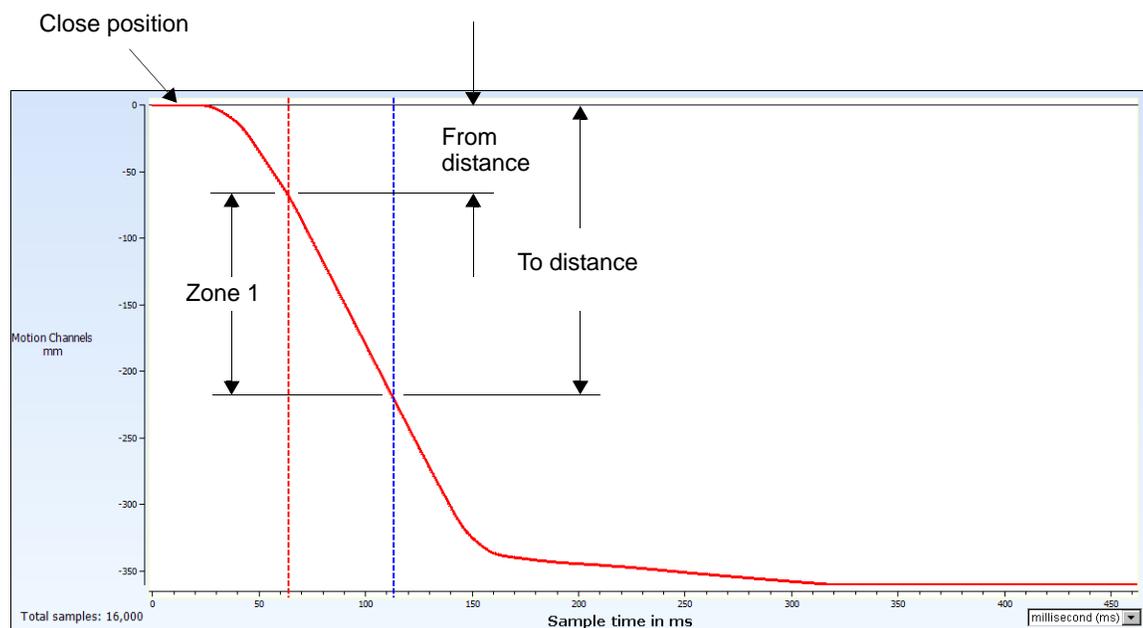


Figure 64 Average Velocity Distance to Distance



NOTE! When selecting values for calculating average velocity, avoid choosing beginning or ending distances of 0.000 in/mm. Because the circuit breaker remains in those positions for a relatively long period of time, incorrect average velocities are calculated.

- Distance to Time—The circuit breaker average velocity is calculated between the distance specified and a time after the circuit breaker mechanism passes the specified point. Distance is relative to the starting closed position (0.000 in/mm). (See [Figure 65.](#))

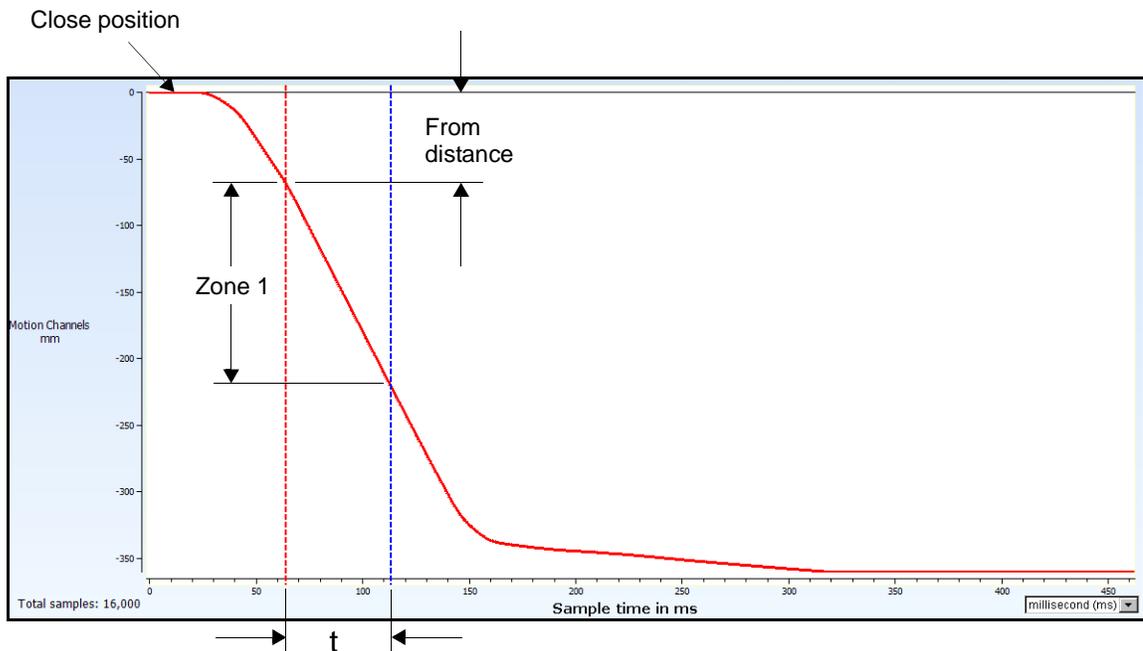


Figure 65 Average Velocity Distance to Time Trip Operation

- Time to Time—The circuit breaker average velocity is calculated between the two times specified. In [Figure 66](#), the end time (*TO*) must be greater than the start time (*FROM*).

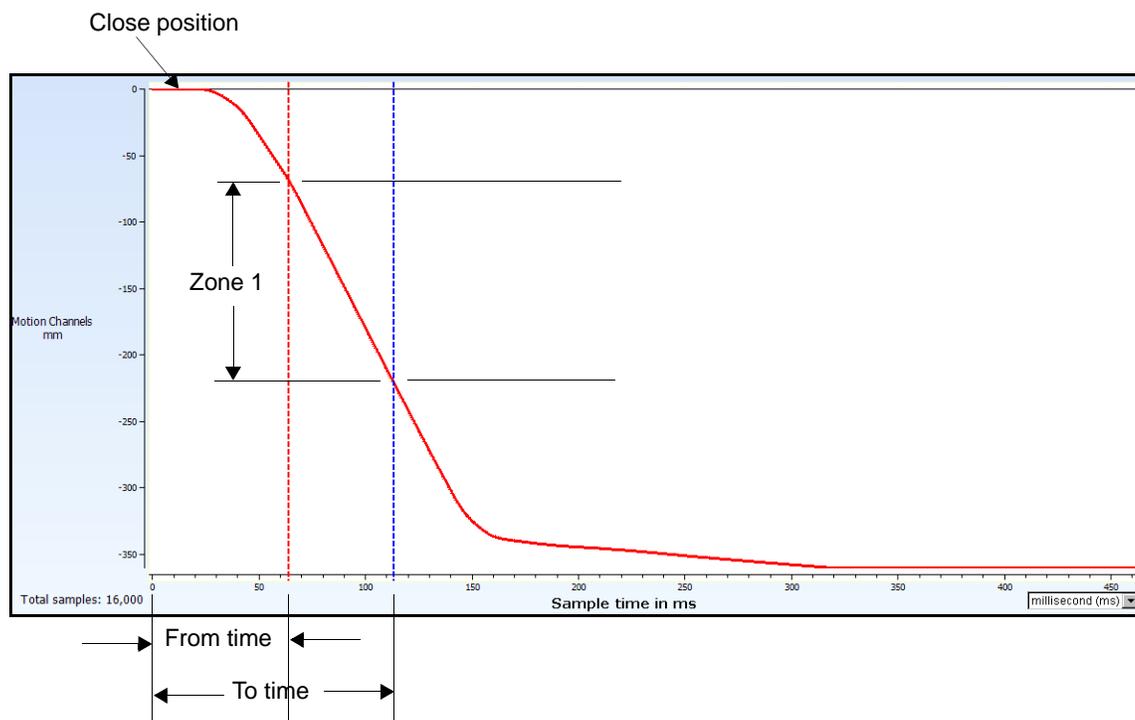


Figure 66 Average Velocity Time to Time

- Open to Time—The circuit breaker average velocity is calculated for the period between when the main contacts part and the specified time after that moment.
If only one transducer is used, the TDR9100 uses the main contact data for the phase in which the motion channel is activated. (See [Figure 3.1.](#))

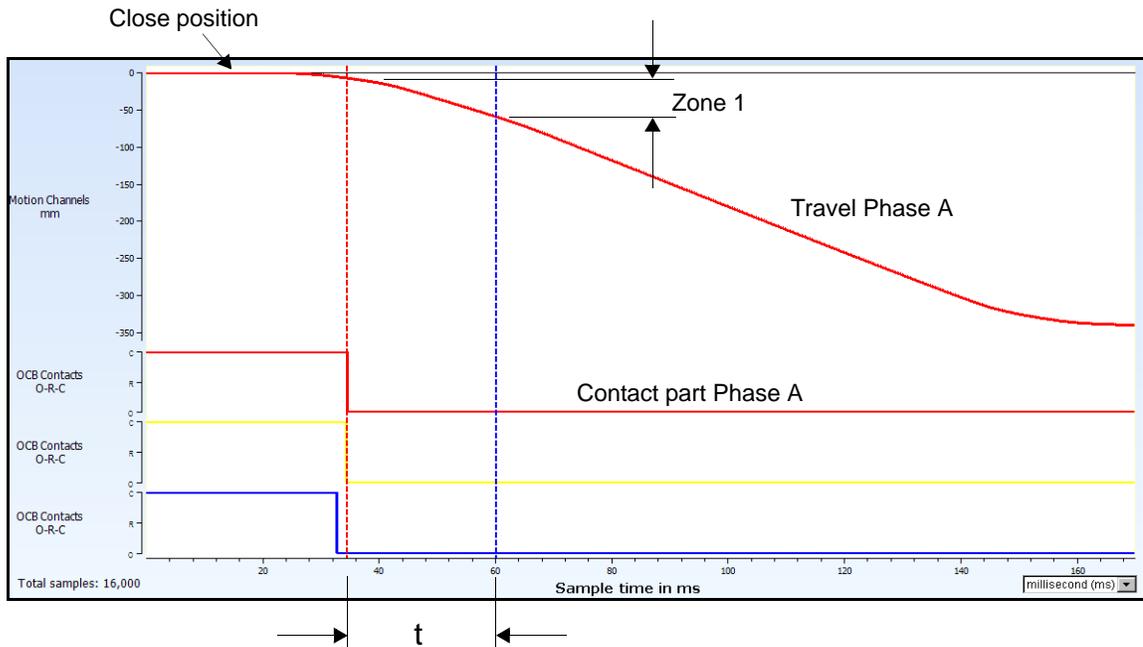


Figure 3.1 Average Velocity Contact Open to Time OCB Overall One Break per Phase



NOTE! For the EHV circuit breaker (Figure 67), the TDR9100 uses the data for Main Contact 1 from the phase for which the motion channel is activated to calculate the average velocity. In Figure 67, Motion Channel 3 (corresponding to Phase C) is active. Therefore, Phase C Contact #1 is used for the average velocity calculation.

Figure 3.2 and Figure 68 show the operation of this zone type.

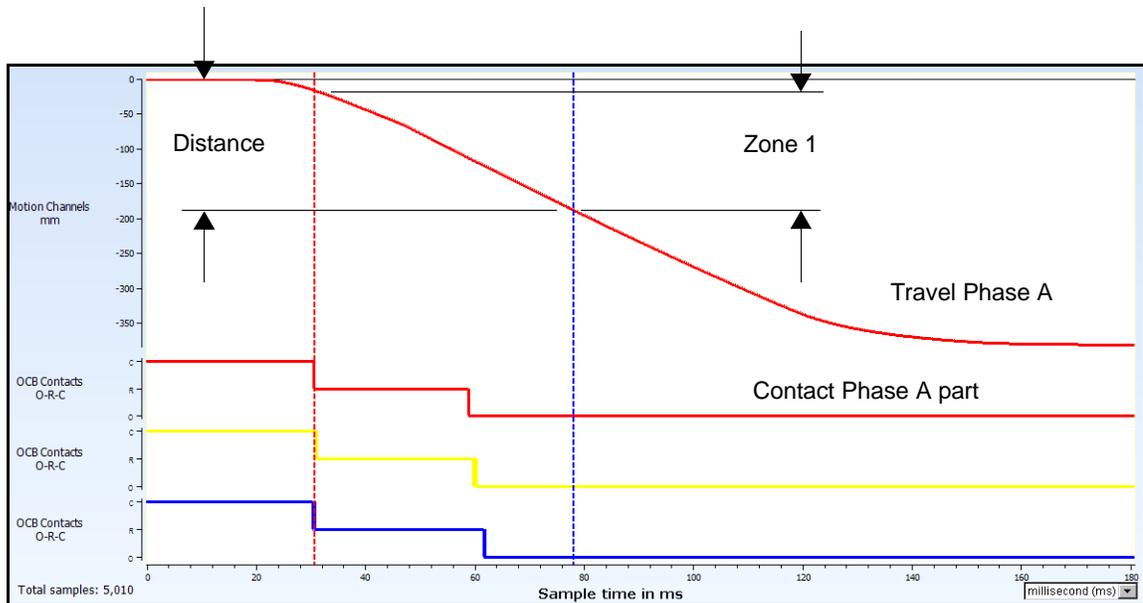


Figure 3.2 Average Velocity Contact Open to Distance for Single Break per Phase, Motion Channel #1 (Phase A) Active

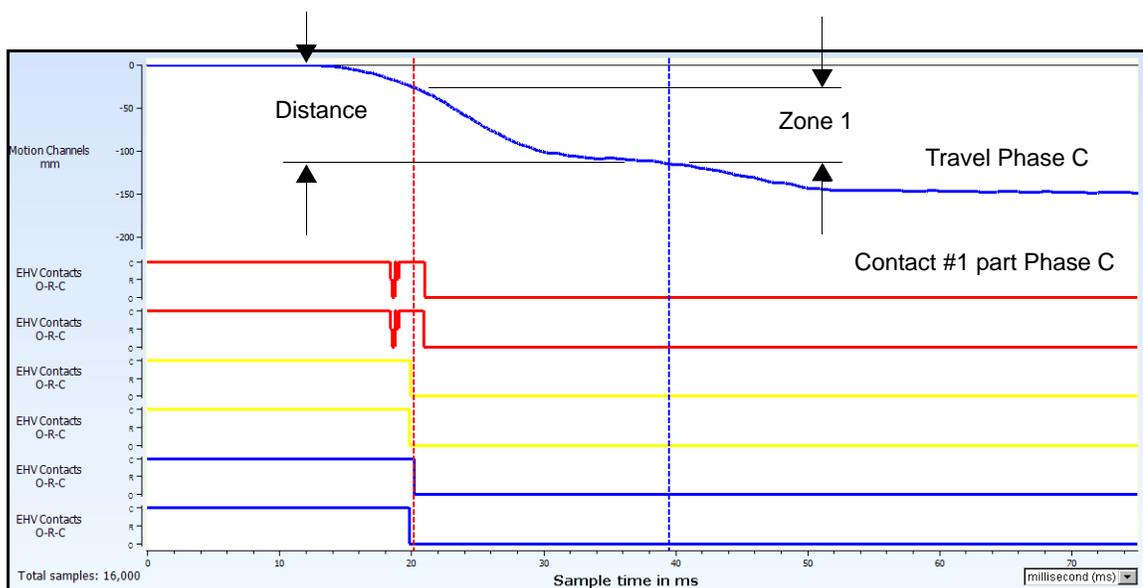


Figure 68 Average Velocity Contact Open to Distance for Multiple Breaks Per Phase, Motion Channel #3 (Phase C) Active

- Open to Travel—The circuit breaker's average velocity is calculated for the interval between the contact part and a specific displacement that occurs after the point of contact part. Unlike distance, travel references the point of contact part and not the fully closed position.

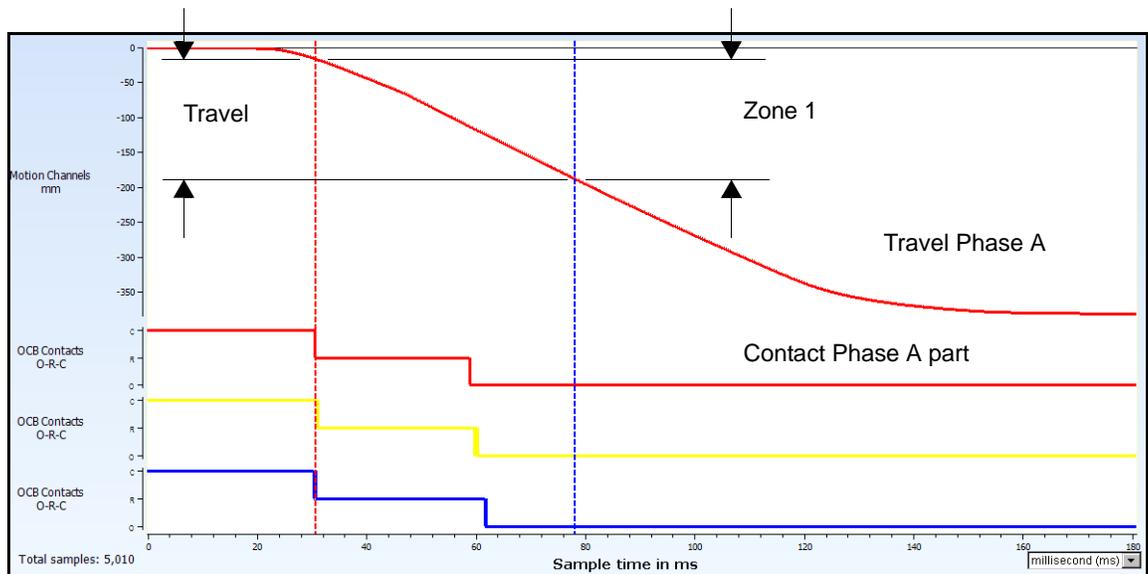


Figure 3.3 Average Velocity Contact Open to Travel for Single Break per Phase, Motion Channel #1 (Phase A) Active

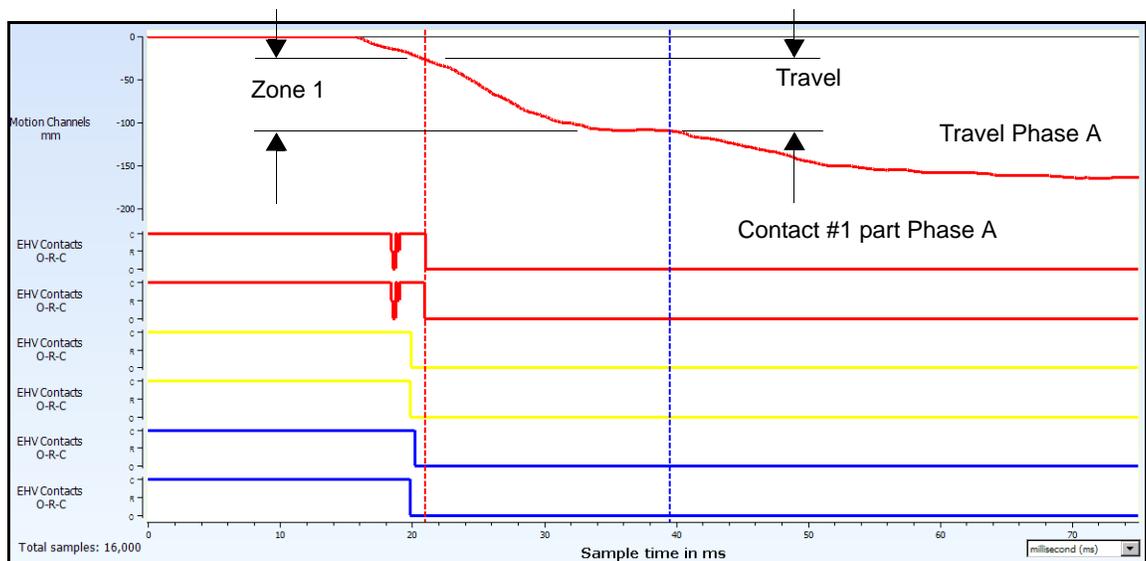


Figure 69 Average Velocity Contact Open to Travel for Multiple Breaks Per Phase, Motion Channel #1 (Phase A) Active

Velocity Open Zone 2

Zone 2 is independent of Zone 1 (Figure 70).

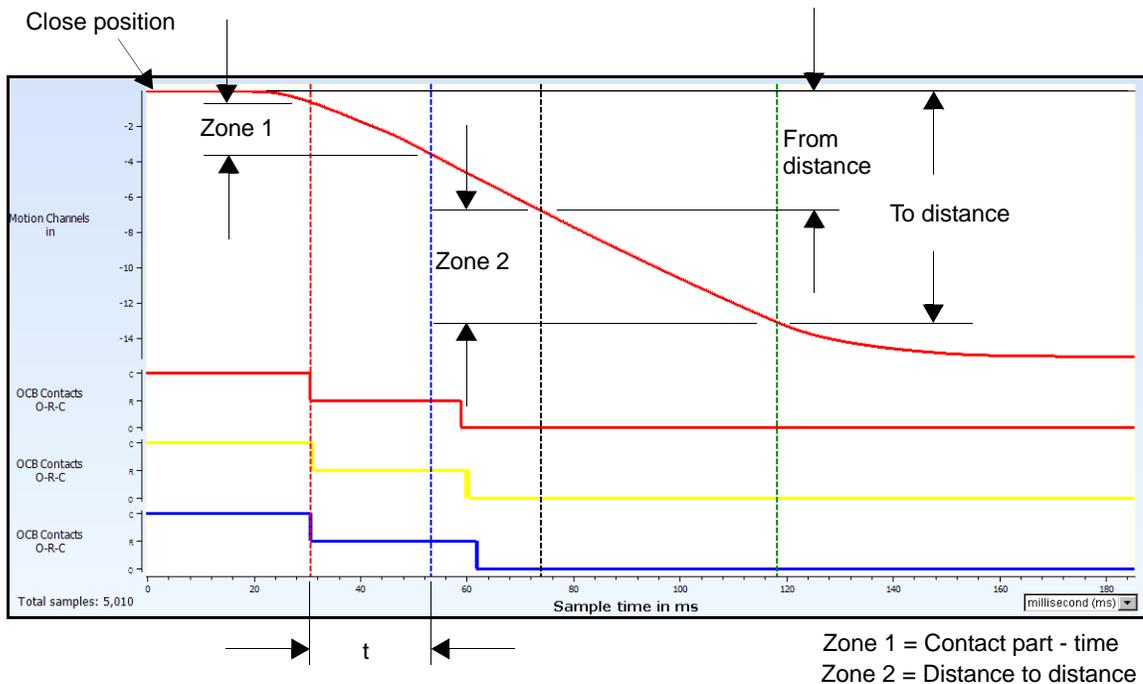


Figure 70 Average Velocity for Zone 1 and Zone 2, Motion Channel #1 (Phase A) Active

Average Velocity – Close

You must enter a zone before the TDR9100 can make a calculation.

There are six zone types for average velocity measurements during close test:

- Distance to Distance
- Distance to Time
- Time to Time
- Time to Close
- Distance to Close
- Travel to Close

These serve as the Start and Stop conditions that define each zone. The same parameters apply to Velocity Open Zone 2.

Velocity Close Zone 1 and 2

Velocity Close Zone 1 is comprised of the Start and Stop parameters listed above. If used, Zone 2 is identified by zone parameters representing a different part of the opening motion curve (Figure 78).

- Distance to Distance—The circuit breaker average velocity is calculated between the two distances specified. Distances are relative to the final closed position (0.000 in/mm) of the circuit breaker as shown in Figure 71. The end distance (*TO*) must be smaller in magnitude than the start distance (*FROM*).

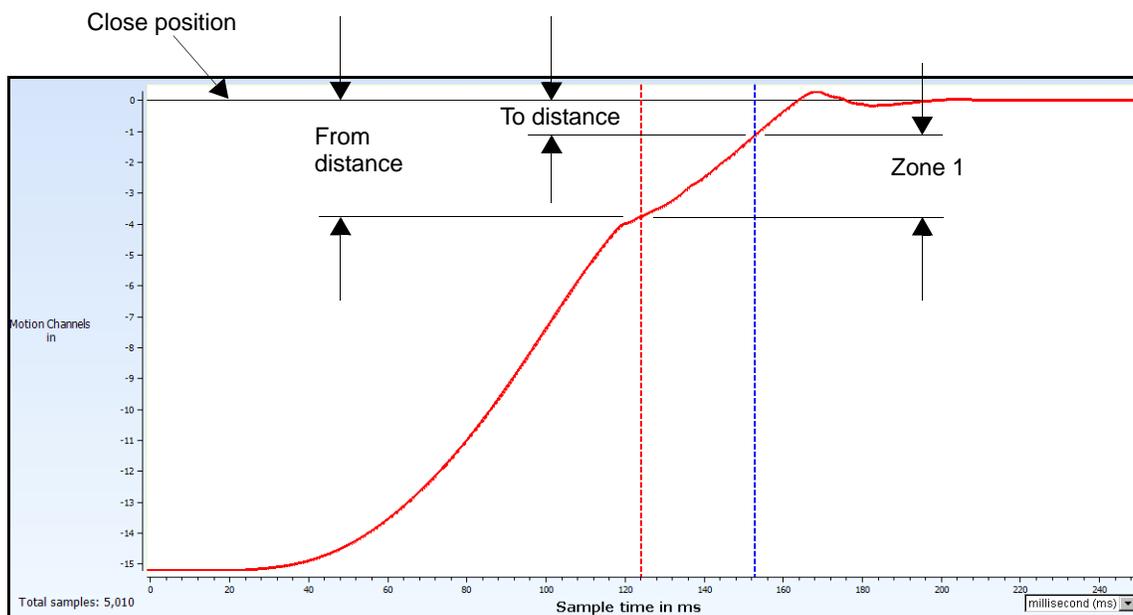


Figure 71 Average Velocity Distance to Distance Close Operation

- Distance to Time—The circuit breaker average velocity is calculated between the distance specified and a time after the circuit breaker mechanism passes the first specified point. Distance is relative to the circuit breaker's final closed position (0.000 in/mm). See Figure 72.

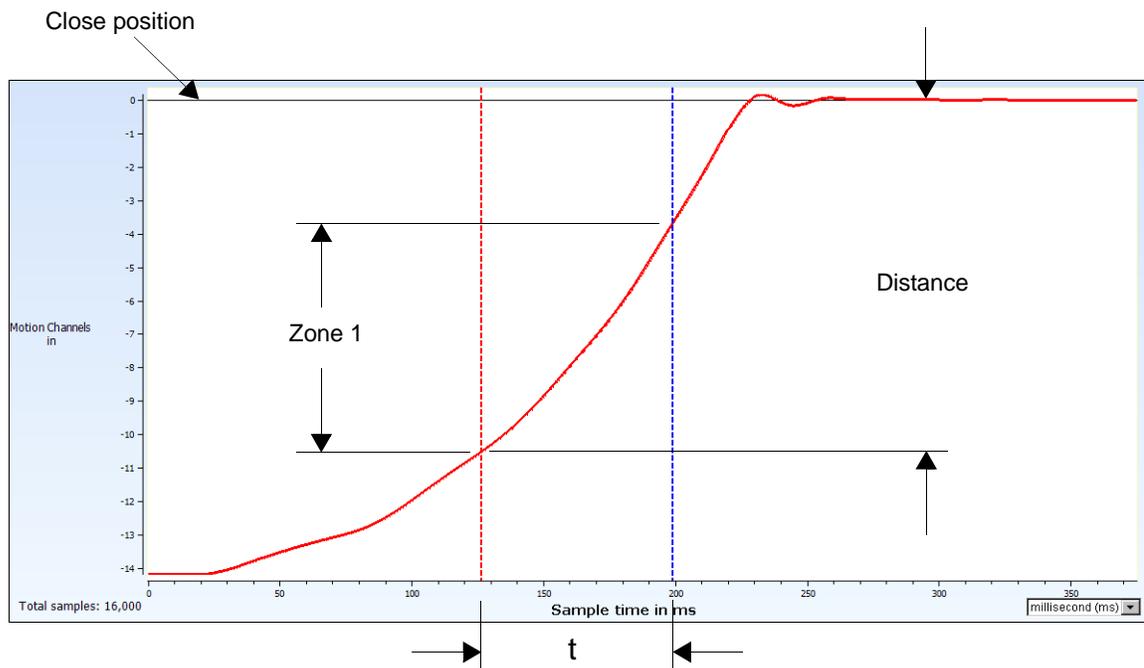


Figure 72 Average Velocity Distance to Time Close Operation

- Time to Time—The circuit breaker average velocity is calculated between the two times specified. In [Figure 73](#), the end time (*TO*) must be greater than the start time (*FROM*).

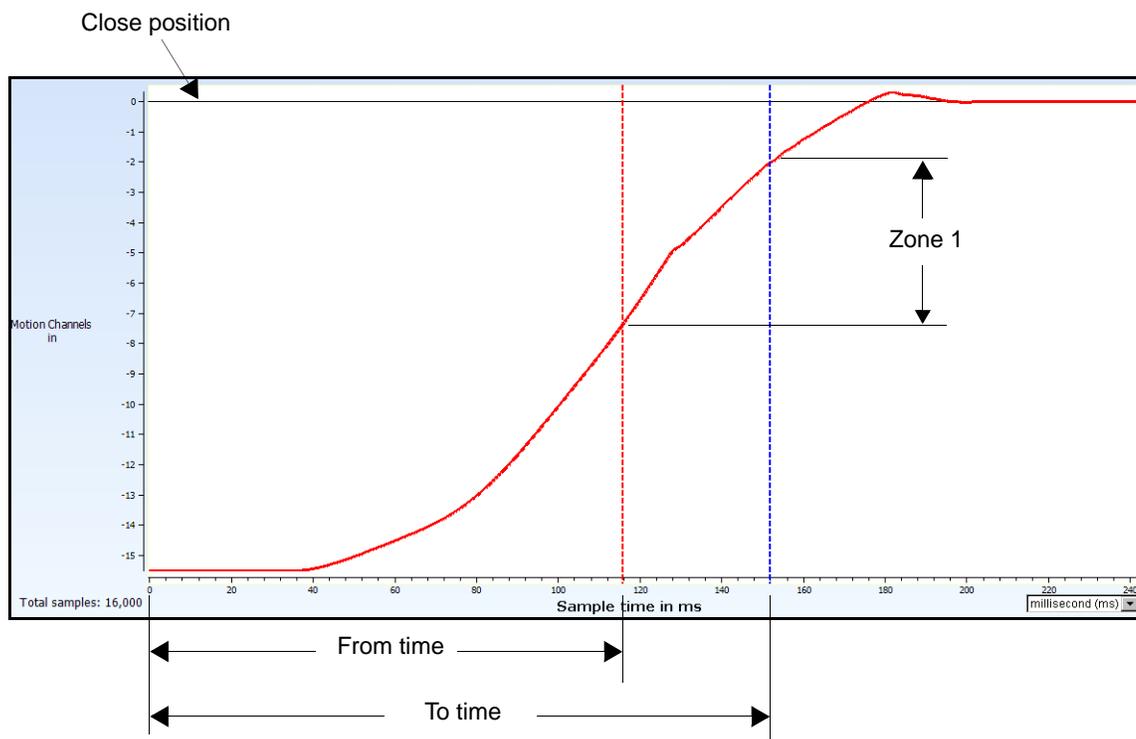


Figure 73 Average Velocity Time to Time Close Operation

- Time to Close—The circuit breaker average velocity is calculated for the period between the moment when the main contacts close and the time specified before the closure (Figure 74).

If only one transducer is used, the TDR9100 uses the main contact data for the phase of the active motion channel.

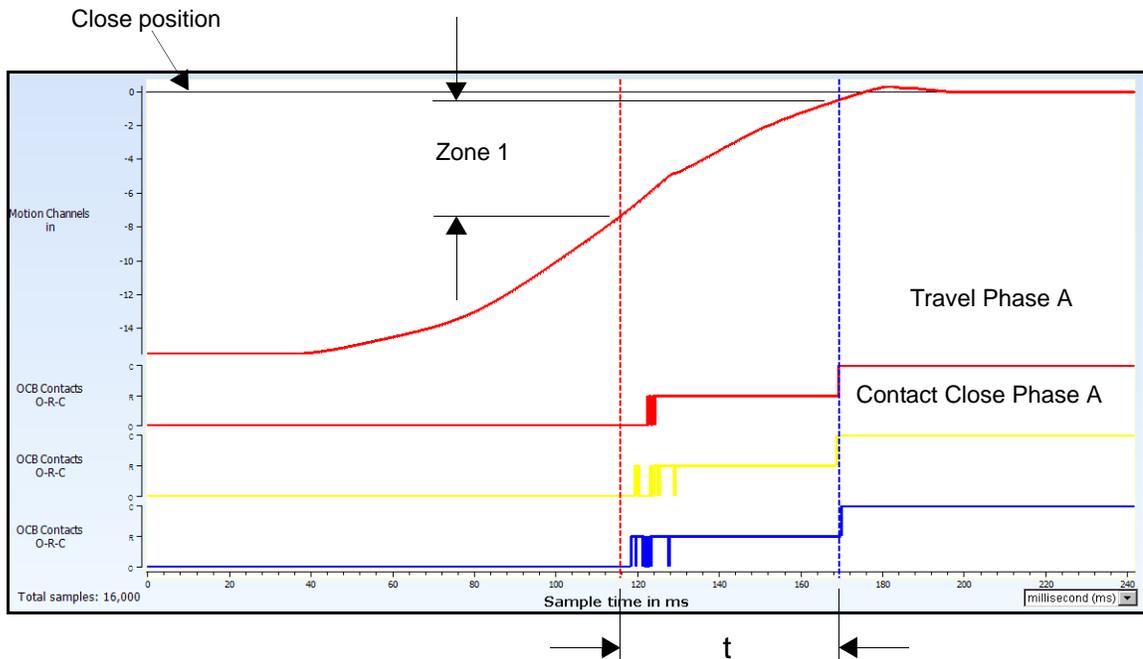


Figure 74 Average Velocity Time to Contact Close, Motion Channel #1 (Phase A) Active

For the EHV circuit breaker, the TDR9100 uses the data for Main Contact 1 from the phase of the active motion channel. [Figure 75](#) shows the average velocity for a Close operation referencing time to contact closure.

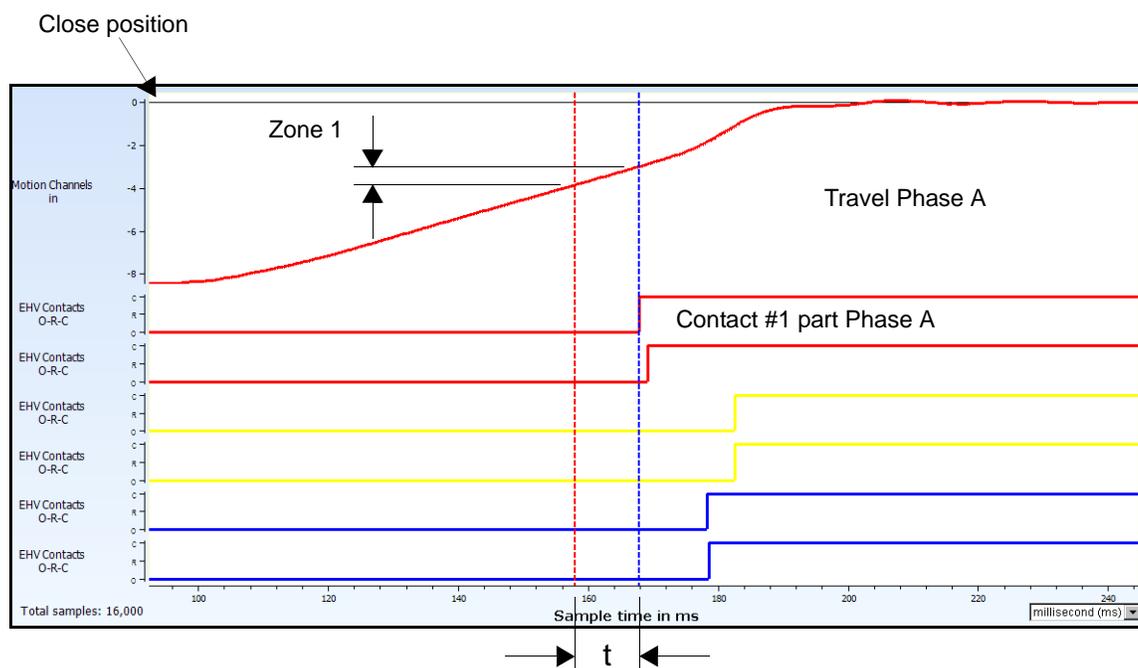


Figure 75 Average Velocity Time to Contact Close, Motion Channel #1 (Phase A) Active (EHV)

- Distance to Close—The circuit breaker average velocity is calculated for the period between the moment when the main contacts make and the distance specified before the final closed position. Figure 76 shows the average velocity for a close operation referencing distance to contact close.

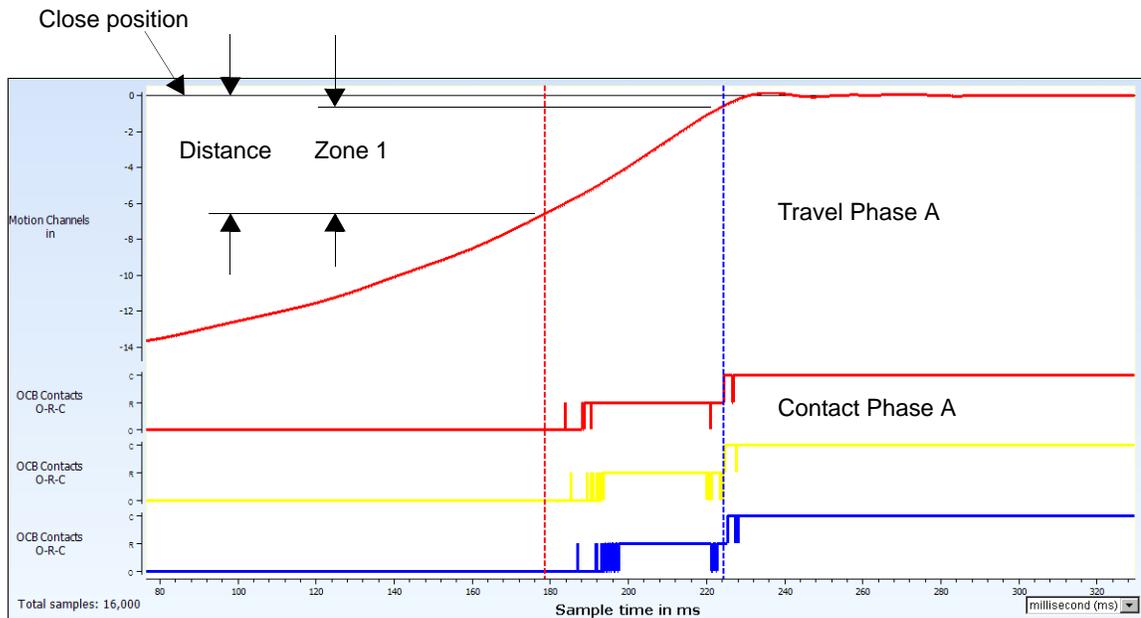


Figure 76 Average Velocity Distance to Contact Close, Motion Channel #1 (Phase A) Active

For the EHV circuit breaker, the TDR9100 uses the data for Main Contact 1 from the phase of the active motion channel (Figure 77).

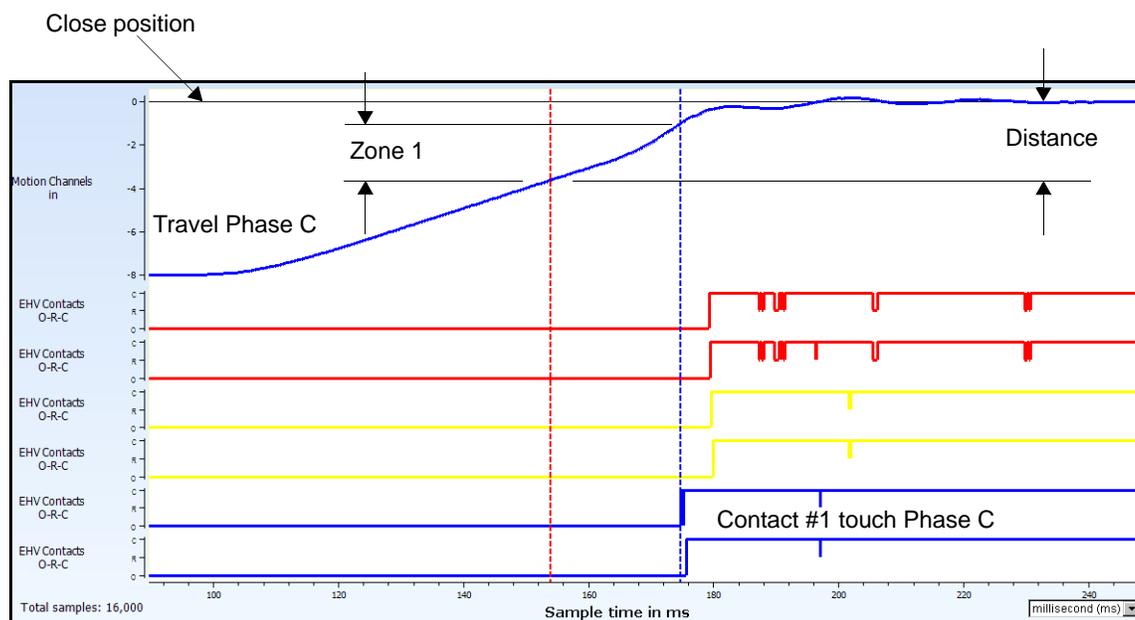


Figure 77 Average Velocity Distance to Contact Touch Closing Operation, Motion Channel #3 (Phase C) Active

Zone 2 is similar to Zone 1 and is independent from Zone 1 (Figure 78).

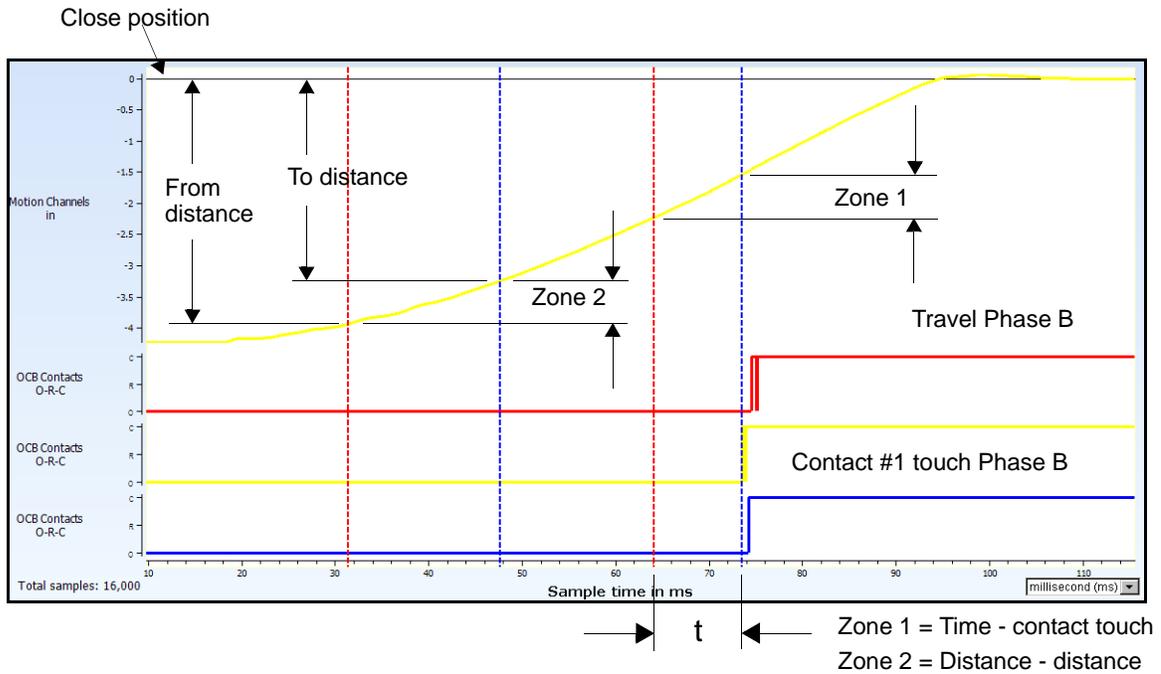


Figure 78 Average Velocity Zone 2 Close Operation, Motion Channel #2 (Phase B) Active

- Travel to Close—The circuit breaker's average velocity is calculated for the interval between the contact make and the travel that occurs before the point of contact make (Figure 79). Unlike distance, travel references the point of contact make and not the fully closed position.

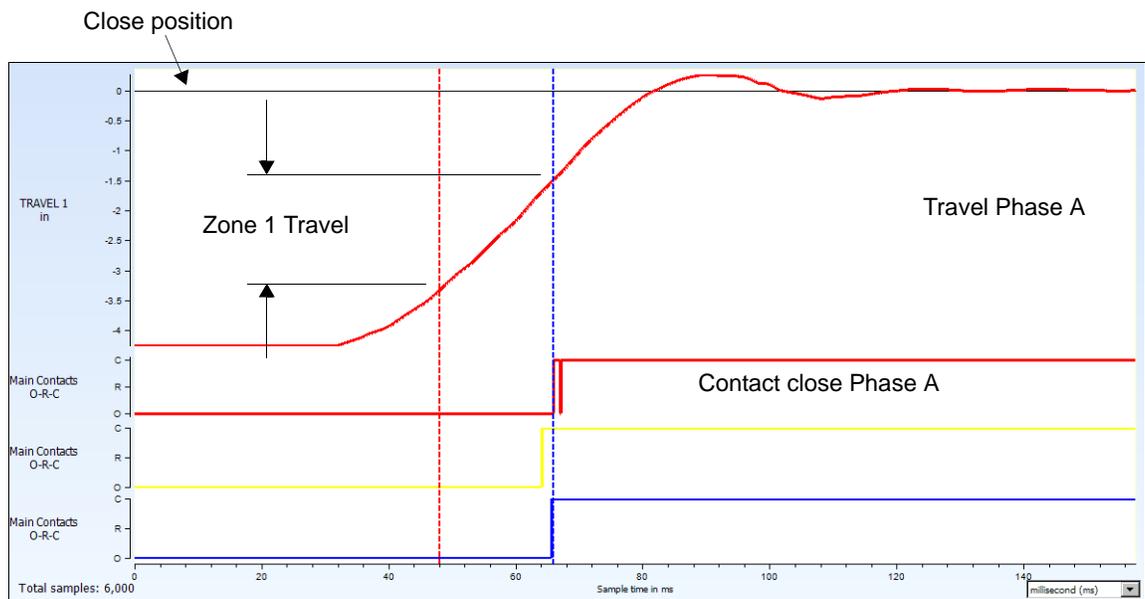


Figure 79 Average Velocity Travel to Close Phase A

5. Channel Setup

This chapter explains how to set up the main contact, analog, auxiliary, virtual, and motion channels. It contains the following sections:

- [“Main Contact Channels Tab” on page 101](#)
- [“Motion Channels Tab” on page 102](#)
- [“Aux, Analog Tab” on page 108](#)

Main Contact Channels Tab

OCB Channel Setup

This section discusses main contact parameters for an overall circuit breaker test, which consists of 1 measurable break per phase (Figure 80). These parameters activate the OCB main contact channels and change the label and/or phase designation for the circuit breaker contacts being monitored.

These channels typically are used to measure the contact timing of any dead tank circuit breaker or live tank circuit breaker with one break per phase. Some dead tank circuit breakers include more than one contact in series in each phase, but there is only one measurable break between the incoming and outgoing bushing terminals in each phase. For dead tank circuit breakers having more than one contact in each phase, the first contact to open (that is, any contact open) results in a measured opening of the phase, and the last contact to close (that is, all contacts closed) results in a measured closure of the phase.

Main Contact Channel Setup			
Channel	Enable	Label	Phase
OCB-A	<input checked="" type="checkbox"/>	Main Contact 1	Phase A 
OCB-B	<input checked="" type="checkbox"/>	Main Contact 2	Phase B 
OCB-C	<input checked="" type="checkbox"/>	Main Contact 3	Phase C 

Figure 80 Dead Tank/OCB – Parameters

EHV Channel Setup

The EHV table activates the EHV contact channels, by pairs, for circuit breaker contact monitoring. These channels typically are used to test live tank circuit breakers or circuit switchers.

Figure 81 shows the configuration for a live tank/EHV circuit breaker with multiple breaks.

Main Contact Channel Setup				
Channel	Enable	Label	Phase	
EHV-A1	<input checked="" type="checkbox"/>		Phase A	<input type="checkbox"/>
EHV-A2	<input checked="" type="checkbox"/>			
EHV-A3	<input checked="" type="checkbox"/>		Phase A	<input type="checkbox"/>
EHV-A4	<input type="checkbox"/>			
EHV-B1	<input checked="" type="checkbox"/>		Phase B	<input type="checkbox"/>
EHV-B2	<input checked="" type="checkbox"/>			
EHV-B3	<input checked="" type="checkbox"/>		Phase B	<input type="checkbox"/>
EHV-B4	<input type="checkbox"/>			
EHV-C1	<input checked="" type="checkbox"/>		Phase C	<input type="checkbox"/>
EHV-C2	<input checked="" type="checkbox"/>			
EHV-C3	<input checked="" type="checkbox"/>		Phase C	<input type="checkbox"/>
EHV-C4	<input type="checkbox"/>			

Figure 81 Live Tank/EHV Configuration

Motion Channels Tab

Enable only the motion channels that have linear/rotary transducers connected. You can edit the channel labels in this table (Figure 82).

Motion Channel Setup										
Channel	Enable	Motion Label	Velocity Label	Phase	Transducer Type	Motion Limits	Motion Units	Transducer Scaling		
								Value at Transducer	Value at Contacts	
Motion-1	<input checked="" type="checkbox"/>			Ganged	Linear	"	Linear	1.0 mm	1.0 mm	
Motion-2	<input checked="" type="checkbox"/>			Ganged	Linear	"	Linear	1.0 mm	1.0 mm	
Motion-3	<input checked="" type="checkbox"/>			Ganged	Linear	"	Linear	1.0 mm	1.0 mm	

Figure 82 Motion Channel Limits

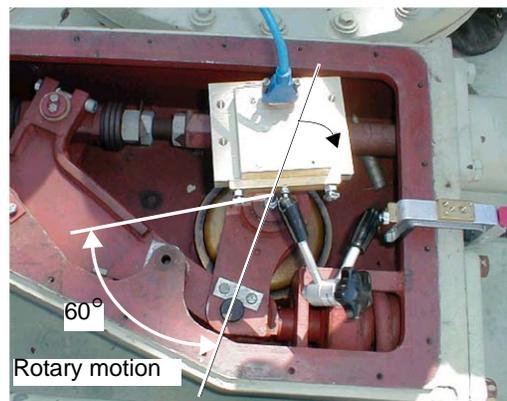
For a transducer type, you can select either linear or rotary (Figure 83).

Motion Channel Setup										
Channel	Enable	Motion Label	Velocity Label	Phase	Transducer Type	Motion Limits	Motion Units	Transducer Scaling		
								Value at Transducer	Value at Contacts	
Motion-1	<input checked="" type="checkbox"/>	Travel 1	Vel 1	Phase A	Linear	*	...	Linear	1.000 in	1.000 in
Motion-2	<input checked="" type="checkbox"/>	Travel 2	Vel 2	Phase B	Linear	*	...	Linear	1.000 in	1.000 in
Motion-3	<input checked="" type="checkbox"/>	Travel 3	Vel 3	Phase C	Rotary	*	...	Linear	1.000 in	1.000 in

Figure 83 Linear Motion Measured in English or Metric Units

There is a microswitch in the TR3190 transducer that alerts the TDR9100 when the transducer is physically configured for rotary operation (the rotary chuck and storage bracket are mounted to the transducer in the rotary configuration). If the transducer is physically configured for rotary operation, but “Rotary” is not selected in the test plan, the TDR9100 does not execute the test and an error message appears.

Figure 84 shows the relationships between the test plan and the transducer rotary motion characteristics



Motion Channel Setup										
Channel	Enable	Motion Label	Velocity Label	Phase	Transducer Type	Motion Limits	Motion Units	Transducer Scaling		
								Value at Transducer	Value at Contacts	
Motion-1	<input checked="" type="checkbox"/>	Travel 1	Vel 1	Phase A	Rotary	*	...	Linear	1.0°	1000.0 mm
Motion-2	<input checked="" type="checkbox"/>	Travel 2	Vel 2	Phase B	Linear	*	...	Linear	1.0°	1000.0 mm
Motion-3	<input checked="" type="checkbox"/>	Travel 3	Vel 3	Phase C	Rotary	*	...	Linear	1.0°	1000.0 mm

Figure 84 Rotary Motion Measured in Degrees

If the measurement units are changed after specifications have been entered, the TDR9100 automatically recalculates the specifications and enters information using the new measurement unit.

Selecting a Motion Limit Set for Each Channel



Caution! The motion limits you assigned in the Motion Limits tab are not automatically applied to the motion channels.

Because multiple motion limit sets can be created in a single plan, if you want T-Doble to apply motion limits to the test results to a specific motion channel, you must select a motion limit set for that channel. (For more information about creating motion limit sets, see [“Motion Limits Tab” on page 77.](#))

To assign a motion limit set to a channel:

1. Select the Test Plan tab and the Motion Channels subtab.
2. For each motion channel, select a Motion Limits set ([Figure 85](#)).

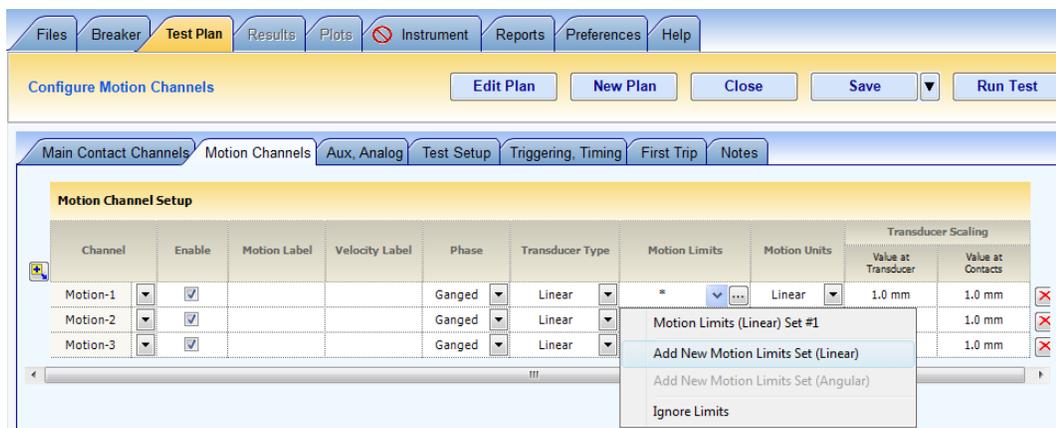


Figure 85 Selecting a Motion Limits Set for a Motion Channel

Transducer Scaling

In most bulk oil circuit breakers, the transducer connecting rod is connected to the moving contact assembly through the operating rod. Thus, the movement of the contact and the transducer connecting rod are essentially identical.

In many circuit breakers, it is not possible to attach a transducer connecting rod to a part of the circuit breaker mechanism that moves directly with the main contacts. However, it should be possible to connect the transducer connecting rod to another location in the mechanism that moves in a secondary relationship to the main contacts.

Under these circumstances, the displacement measured at the transducer may be different than the actual displacement at the contacts. Therefore, transducer scaling may be applied to the measured displacement in order to properly relate it to the actual displacement. For example, 3 inches of displacement measured at the transducer may correspond to 6 inches of movement at the contacts.

Transducer scaling correlates rod travel to main contact travel, and acts on the following quantities: Total Travel, Overtravel, Rebound, Contact Wipe, and Velocity to produce measurements for the main contacts that can be compared to circuit breaker specifications.

Linear-to-Linear Transducer Scaling

Figure 86 shows an example of linear-to-linear transducer scaling.

Motion Channel Setup									
Channel	Enable	Motion Label	Velocity Label	Phase	Transducer Type	Motion Limits	Motion Units	Transducer Scaling	
								Value at Transducer	Value at Contacts
Motion-1	<input checked="" type="checkbox"/>	Travel 1	Vel 1	Phase A	Linear	*	Linear	3,000 in	6,000 in
Motion-2	<input checked="" type="checkbox"/>	Travel 2	Vel 2	Phase B	Linear	*	Linear	3,000 in	6,000 in
Motion-3	<input checked="" type="checkbox"/>	Travel 3	Vel 3	Phase C	Linear	*	Linear	3,000 in	6,000 in

Figure 86 Linear-to-Linear Transducer Scaling

In this example, the TDR9100 has to multiply all travel data by 2 to come up with measurements related to the main contacts. Keep in mind that the value of the transducer scaling affects the resolution of the measurement. Resolution is the smallest change in the characteristic being measured that can unambiguously be detected in a measurement process.

The following example underlines the importance of the transducer resolution when linear-to-linear transfer scaling is used:

If the transducer connecting rod moves 10", these 10" are measured with the resolution 0.00125" (according to the transducer specification).

Figure 87 shows transducer scaling.

Motion Channel Setup									
Channel	Enable	Motion Label	Velocity Label	Phase	Transducer Type	Motion Limits	Motion Units	Transducer Scaling	
								Value at Transducer	Value at Contacts
Motion-1	<input checked="" type="checkbox"/>	Travel 1	Vel 1	Phase A	Linear	*	Linear	1.000 in	3.000 in
Motion-2	<input checked="" type="checkbox"/>	Travel 2	Vel 2	Phase B	Linear	*	Linear	1.000 in	3.000 in
Motion-3	<input checked="" type="checkbox"/>	Travel 3	Vel 3	Phase C	Linear	*	Linear	1.000 in	3.000 in

Figure 87 Transducer Scaling Resolution

If the main contacts have moved 30", that means that for every 0.00125" movement of the transducer connecting rod, the main contacts would move 0.00375". Consequently, when transducer scaling 3:1 is used, the resolution becomes $0.00125 \times 3 = 0.00375$ ".

Practical considerations associated with resolution limit the value of transducer scaling values. The TDR9100 checks to ensure that linear-to-linear transducer scaling is less than or equal to 50:1.

Rotary-to-Linear Transducer Scaling

Figure 88 shows an example of rotary-to-linear transducer scaling.

Motion Channel Setup									
Channel	Enable	Motion Label	Velocity Label	Phase	Transducer Type	Motion Limits	Motion Units	Transducer Scaling	
								Value at Transducer	Value at Contacts
Motion-1	<input checked="" type="checkbox"/>	Travel 1	Vel 1	Phase A	Rotary	*	Linear	50.0°	1.000 in
Motion-2	<input checked="" type="checkbox"/>	Travel 2	Vel 2	Phase B	Rotary	*	Linear	50.0°	1.000 in
Motion-3	<input checked="" type="checkbox"/>	Travel 3	Vel 3	Phase C	Rotary	*	Linear	50.0°	1.000 in

Figure 88 Rotary-To-Linear Transducer Scaling

Rotary-to-linear transducer scaling is used when the manufacturer provides specification for the linear motion of the contacts, but the only physical access to the mechanism is to a rotary motion access point. However, the only access to the mechanism consists of a rotary motion access point (Figure 89).

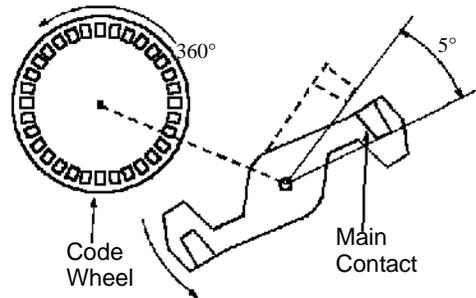


Figure 89 Transducer Wheel

Rotary-to-linear transducer scaling is also checked for the entry of a ratio that is too large to be practical considering the resolution of the transducer.

The correlation between rotary and linear measurement is correct at only three points:

- Beginning (travel zero)
- End (total travel)
- Middle

Because the code wheel has a circumference of 5 inches, the default value for rotary-to-linear transducer scaling using English transducer units is 0.0139 in/1.00 ° (or, 5 in/360 degree).

The following example underlines the importance of the transducer resolution when rotary-to-linear transducer scaling is used.

Example: In the SFA circuit breaker, when the main contacts travel 8.05", the rotation at the rotary input of the transducer is 35.5 deg (Figure 90).

Motion Channel Setup									
Channel	Enable	Motion Label	Velocity Label	Phase	Transducer Type	Motion Limits	Motion Units	Transducer Scaling	
								Value at Transducer	Value at Contacts
Motion-1	<input checked="" type="checkbox"/>	Travel 1	Vel 1	Phase A	Rotary	*	Linear	35.5°	8.050 in
Motion-2	<input checked="" type="checkbox"/>	Travel 2	Vel 2	Phase B	Rotary	*	Linear	35.5°	8.050 in
Motion-3	<input checked="" type="checkbox"/>	Travel 3	Vel 3	Phase C	Rotary	*	Linear	35.5°	8.050 in

Figure 90 Rotary-To-Linear Transducer Scaling

This corresponds to a linear travel at the transducer end of:

$$35.5 \text{ } ^\circ / 360 \text{ } ^\circ \times 5 \text{ } \text{in} = 0.493 \text{ } \text{in}.$$

This results in a primary motion (circuit breaker main contacts) to secondary motion (transducer) ratio of:

$$8.05"/0.493" = 16.32$$

In primary terms, the resolution of the measurement becomes:

$$0.00125" \times 16.32 = 0.0204"$$

This resolution is sufficient for SFA published tolerances (for example, wipe 1.06 ± 0.06). However, give special consideration to transducers with resolutions that exceed 0.00125".

Aux, Analog Tab

- [“Event Channels and the Aux, Analog Tab” on page 108](#)
- [“Analog Channels” on page 111](#)
- [“Analog Scaling” on page 111](#)
- [“Voltage Range Selection” on page 112](#)
- [“Current Selection for Probes” on page 112](#)
- [“Auxiliary Contact Channels” on page 113](#)
- [“Virtual Channels” on page 114](#)

Event Channels and the Aux, Analog Tab

Programmable dual-function Event channels are a new feature of the TDR9100 instrument. An array of six identical channels, the Event channels can be set (in the test plan) to perform either the auxiliary contact or analog measurement function. This array of six dual-function channels is sometimes referred to as a 6A/X configuration (six analog or auxiliary).

Previous TR and TDR instruments provided single-function Event channels in a fixed array of three auxiliary-contact and three analog channels (a 3A/3X [3 analog and 3 auxiliary] configuration).

The TDR9100 programmable Event channels are physically identical. To distinguish them, they are labeled E1 through E6 (for Event-1 through Event-6) as shown in [Figure 91](#).

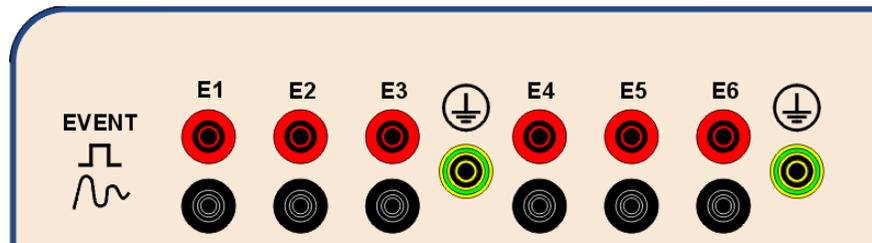


Figure 91 Event Channels on Front Panel of TDR9100

Activating and Assigning Event Channels

TDR9100 Event Channels are activated in the test plan from the Aux, Analog tab.

As you activate each channel, T-Doble automatically assigns an Event-n channel ID in the sequence in which the channel is added to the test plan. You can use the Label field to add more identifying information to each channel (Figure 92).

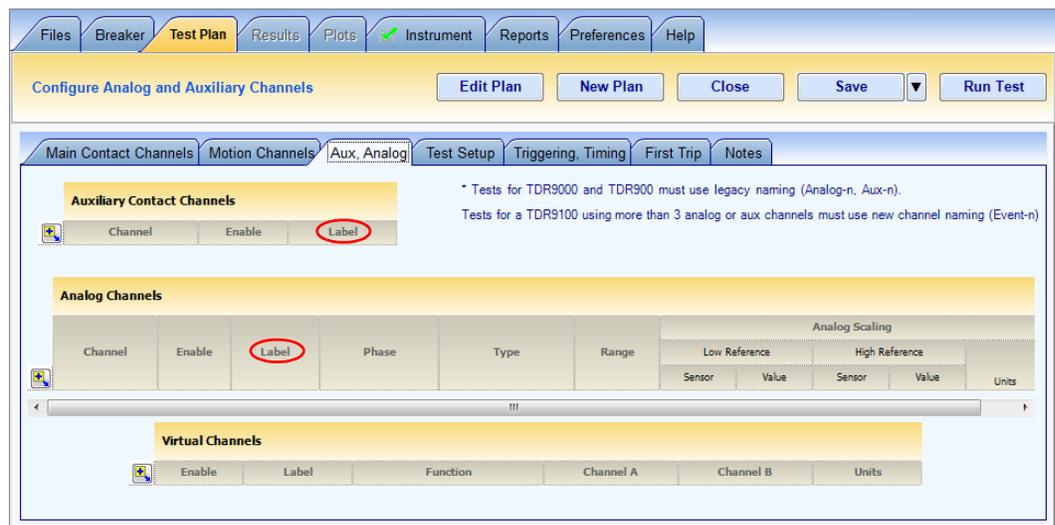


Figure 92 Aux, Analog SubTab of Test Plan Tab

Reassigning Event Channel IDs

Event channels can be reassigned using the Channel pull-down menu (Figure 94).

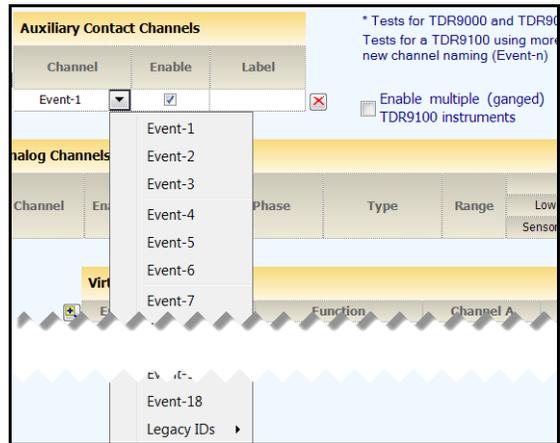


Figure 93 Reassigning Event Channels

Be careful not to assign the same Event channel number to two or more functions at the same time. Conflicting assignments are detected as an error at test run time.

Doble strongly recommends that you use Event-n channel IDs in TDR9100 test plans, even though legacy naming is available.

Assigning Legacy Channel IDs for Earlier TDR Instruments

You can assign legacy channel IDs (Aux-n, Analog-n) when creating test plans for other TDR models with 3A/3X arrangements ([Figure 94](#)).

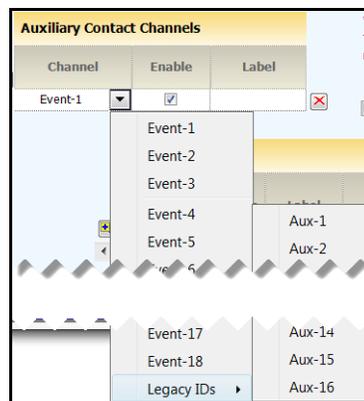
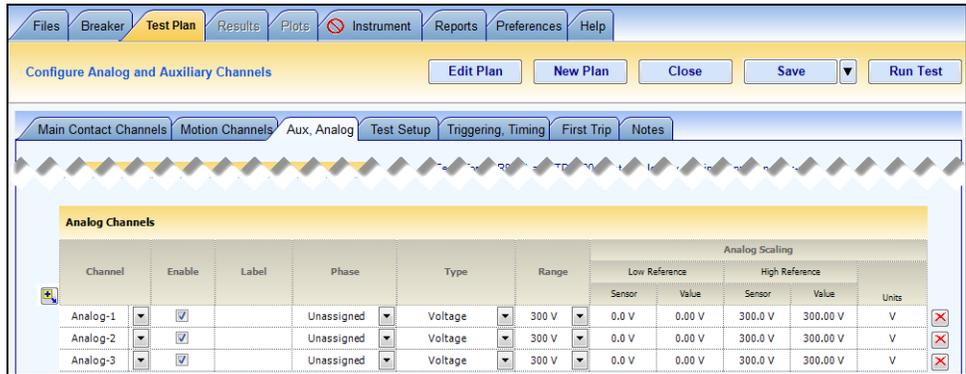


Figure 94 Assigning Legacy Channel IDs

Analog Channels

Figure 95 shows the Analog Channel parameters and specifications.



Channel	Enable	Label	Phase	Type	Range	Analog Scaling				Units	
						Low Reference		High Reference			
						Sensor	Value	Sensor	Value		
Analog-1	<input checked="" type="checkbox"/>		Unassigned	Voltage	300 V	0.0 V	0.00 V	300.0 V	300.00 V	V	<input type="checkbox"/>
Analog-2	<input checked="" type="checkbox"/>		Unassigned	Voltage	300 V	0.0 V	0.00 V	300.0 V	300.00 V	V	<input type="checkbox"/>
Analog-3	<input checked="" type="checkbox"/>		Unassigned	Voltage	300 V	0.0 V	0.00 V	300.0 V	300.00 V	V	<input type="checkbox"/>

Figure 95 Analog Channels

Analog Scaling

T-Doble scaling is a two-point, straight-line fit. The two points are defined as follows:

- *Low Reference Value*—Identifies the value T-Doble is to report (and plot) when the output of the sensor attached to the channel is at zero.
- *High Reference Value*—Identifies the value T-Doble is to report (and plot) when the output of the sensor attached to the channel is at full range.

You can enter any unit in the Units column of the Analog Channels table (see Figure 95). T-Doble automatically displays the correct value in the Values column.

If you know that there are two values on the transducer, and the high value doesn't correspond to full scale on the actual channel, you must extrapolate.

For example, assume you know that a pressure gauge has this output curve:

0 mV – 20 mV represents the range 10 - 25 mbar

Using an analog channel set to 0.2 V range (for example, 10 x the range of the 0.02 V sensor) and enter these values in the Analog Scaling fields:

- Low Reference Sensor—0.0 V
- Low Reference Value—10
- High Reference Sensor—0.2 V
- High Reference Value—250 (e.g. 25 mbar x 10)
- Unit—mbar

Voltage Range Selection

The TDR9100 supports the following ranges:

- 0.2 V peak
- 0.5 V peak
- 1.0 V peak
- 2.0 V peak
- 5.0 V peak
- 10.0 V peak
- 20.0 V peak
- 50.0 V peak
- 100 V peak
- 200 V peak
- 300 V peak

Note that the TDR900 and TDR9000 do not support all ranges. See the appropriate user guide for more information.

Current Selection for Probes

The Doble Autozero probe (Doble P/N 401-0055) is recommended for use with the TDR9100. It is a clip-on, Hall-effect probe with current ranges 20 A and 200 A. The Doble Autozero probe provides 2 V output on both ranges when current is at maximum.

T-Doble provides two current ranges to use with this probe:

- Low – 20 A
- High – 200 A

You can select the Doble Autozero Probe in T-Doble ([Figure 96](#)).

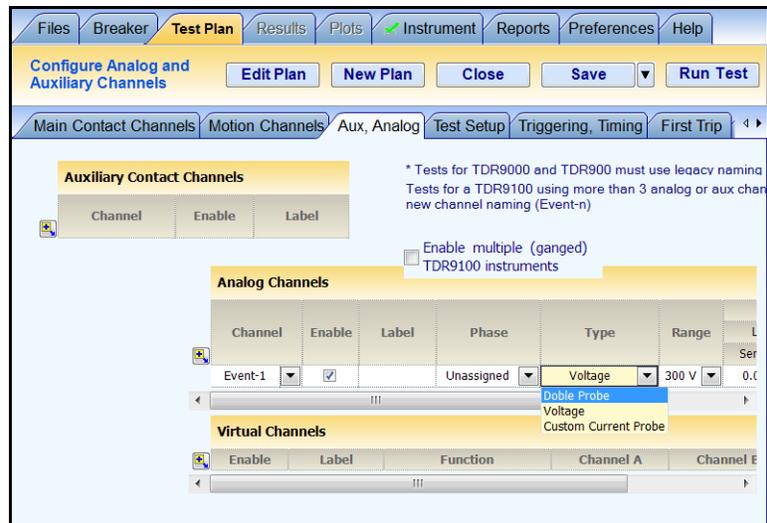


Figure 96 Selecting the Doble Autozero Probe

You can also use an analog channel to measure current with any probe that provides a voltage output. It is important to select appropriate matching voltage ranges in T-Doble and on the probe itself.

Auxiliary Contact Channels

[Figure 97](#) shows the parameters and specifications available for auxiliary contact channels. The portion of the test plan activates and labels the contact channels for auxiliary contacts being monitored.

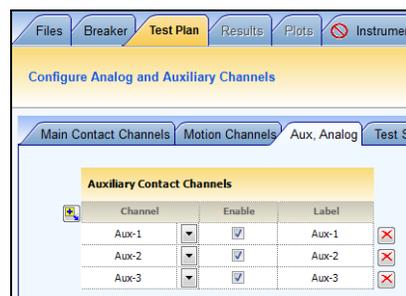


Figure 97 Auxiliary Contact Channel – Parameters and Specifications

Virtual Channels

The Virtual channels enable you to apply mathematical functions to selected analog channels. The following example uses division to represent the calculated resistance (Ω) derived from Event-1 (DC Voltage) and Event-2 (DC Current) (Figure 98).

Virtual Channels					
Enable	Label	Function	Channel A	Channel B	Units
<input checked="" type="checkbox"/>	Resistance	(select function)	Event-1	Event-2	Ohms
<input checked="" type="checkbox"/>		(select function)			
<input checked="" type="checkbox"/>		A / B			
		A + B			
		A - B			
		A * B			

Figure 98 Virtual Channels Table

6. Setting Up Tests

NOTE



First Trip tests are distinctively different from the other circuit breaker tests. If you wish to perform a First Trip test, go directly to [“First Trip Test” on page 137](#).

This chapter explains how to set up test parameters using the tables found on the Test Setup tab. It contains the following sections:

- [“Test Setup Tab” on page 116](#)
- [“Command Parameters” on page 117](#)
- [“Trip Test” on page 118](#)
- [“Close Test” on page 119](#)
- [“TripFree \(CO\) Test” on page 120](#)
- [“Reclosing \(O-C\) Test” on page 123](#)
- [“C-O Test” on page 126](#)
- [“O-CO and O-C-O Tests” on page 127](#)
- [“Record Only \(RO\) Test” on page 133](#)
- [“Trip/Close Ranges” on page 133](#)
- [“Recording Parameters” on page 134](#)
- [“Bounce Discriminator” on page 136](#)
- [“First Trip Test” on page 137](#)

Test Setup Tab

The Test Setup tab of the Test Plan page provides access to the main test parameters. See [Figure 99](#)

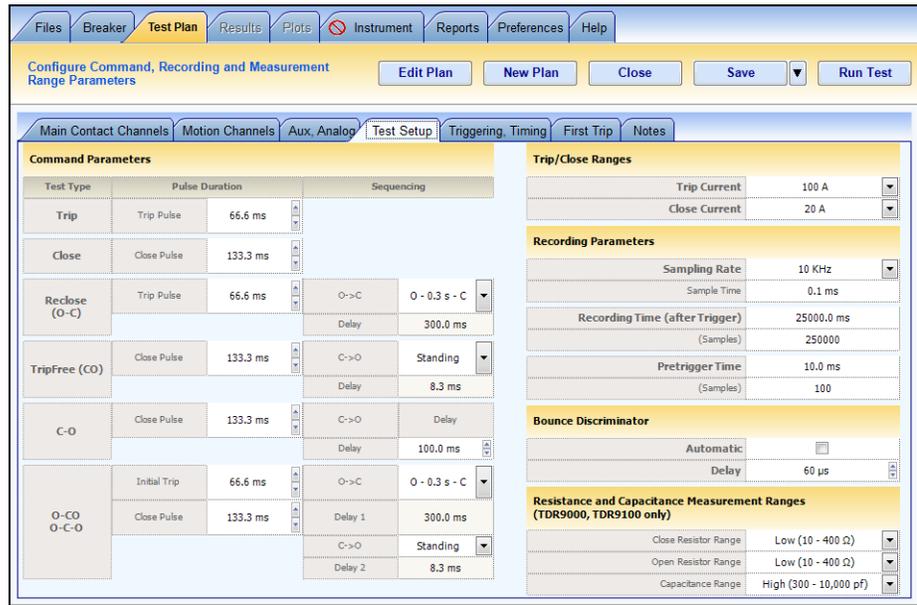


Figure 99 Test Setup Tab of Test Plan Page

Command Parameters

The Command Parameters table lists the default Pulse Duration and Sequencing parameters configured for each test. See [Figure 100](#) on [page 117](#).

Command Parameters				
Test Type	Pulse Duration		Sequencing	
Trip	Trip Pulse	66.6 ms		
Close	Close Pulse	133.3 ms		
Reclose (O-C)	Trip Pulse	66.6 ms	O->C	O - 0.3 s - C
			Delay	300.0 ms
TripFree (CO)	Close Pulse	133.3 ms	C->O	Standing
			Delay	8.3 ms
C-O	Close Pulse	133.3 ms	C->O	Delay
			Delay	100.0 ms
O-CO O-C-O	Initial Trip	66.6 ms	O->C	O - 0.3 s - C
	Close Pulse	133.3 ms	Delay	300.0 ms
			C->O	Standing
			Delay	8.3 ms

Figure 100 Command Parameters

General Note about Delay Parameters

Delay is the length of time after the inception of running a test before the test condition, such as a trip pulse, is implemented.

Only the O-CO and O-C-O tests use Delay 1 and Delay 2 parameters:

- Delay 1 sets the time for a first test condition to be implemented.
- Delay 2 sets the time for a second test condition to be implemented.

Trip Test

During the Trip test, a single, user-specified command is issued to open the circuit breaker. [Figure 101 on page 118](#) shows a waveform generated by the Trip test.

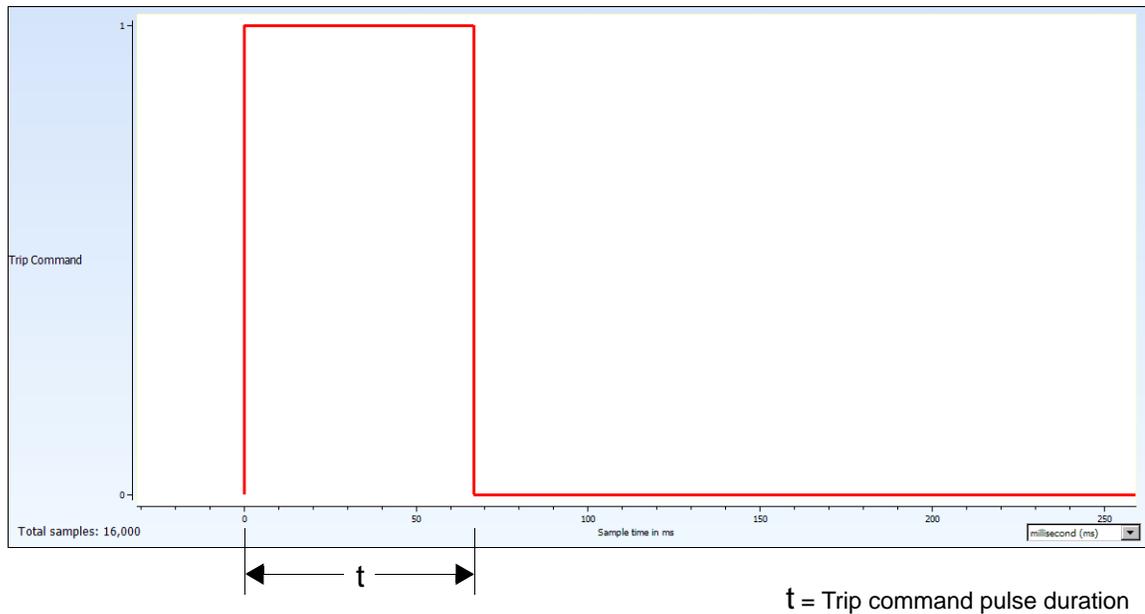


Figure 101 Trip Command Pulse

Table 4 Trip Test Command Parameters

Command Parameter	Definition
<i>Trip Pulse</i>	Determines the duration of the trip pulse sent to operate the trip circuit of the circuit breaker. Default values are: <ul style="list-style-type: none"> • 66.6 ms for 60 Hz • 80 ms for 50 Hz

Close Test

During the Close test, a single, user-specified command is issued to close the circuit breaker. [Figure 102 on page 119](#) shows a waveform generated by the Close test.

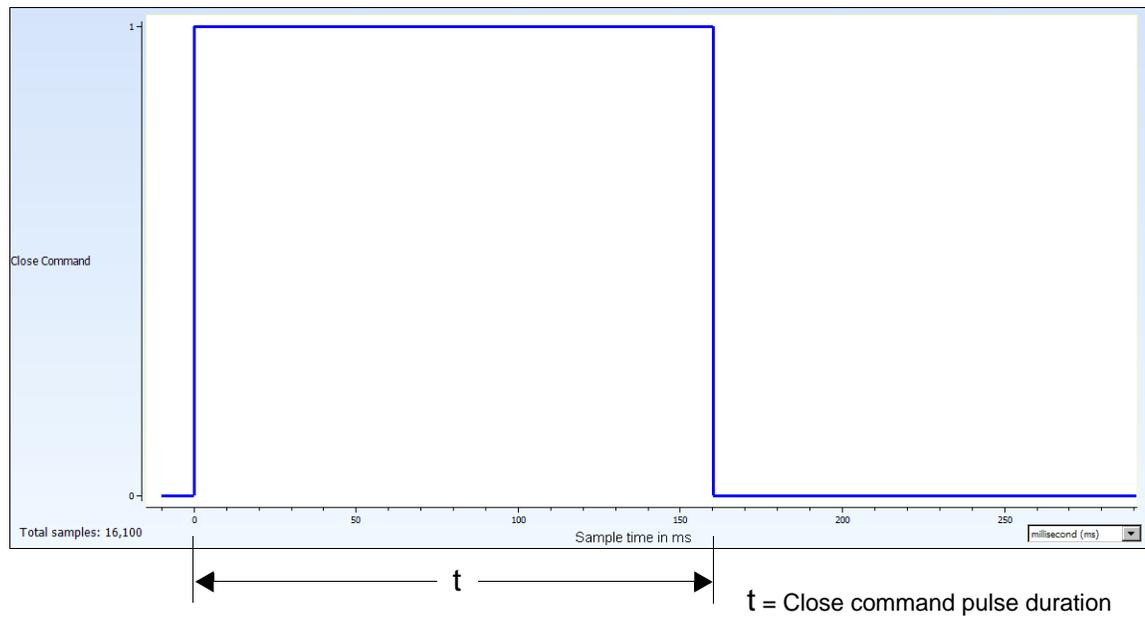


Figure 102 Close Command Pulse

Table 5 Close Test Command Parameters

Command Parameter	Definition
<i>Close Pulse</i>	Determines the duration of the close pulse sent to operate the close circuit of the circuit breaker. Default values are: <ul style="list-style-type: none"> • 133.3 ms for 60 Hz • 160 ms for 50 Hz

TripFree (CO) Test

During the TripFree test, dual, user-specified commands are issued to close the circuit breaker and open it shortly after. [Figure 103 on page 120](#) shows a waveform generated by the TripFree test.

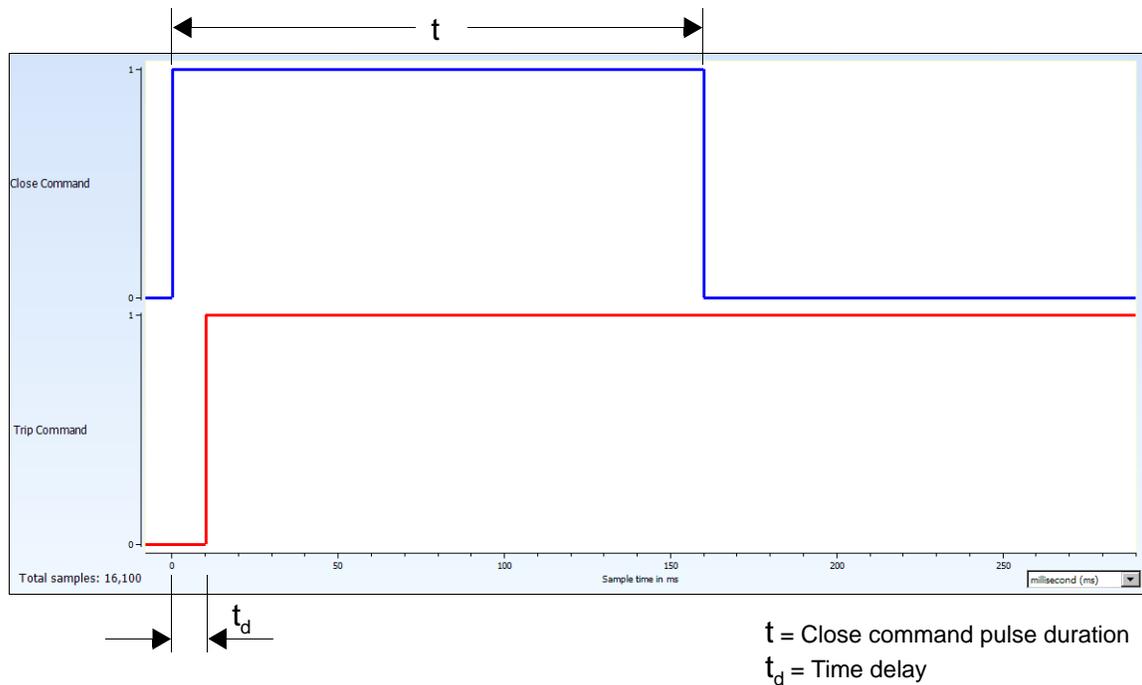


Figure 103 TripFree Command Pulse

Table 6 TripFree Test Command Parameters

Command Parameter	Definition
<i>Close Pulse</i>	Determines the duration of the close pulse sent to operate the close circuit of the circuit breaker. Default values are: <ul style="list-style-type: none"> • 133.3 ms for 60 Hz • 160 ms for 50 Hz

Table 6 TripFree Test Command Parameters (Continued)

Command Parameter	Definition
CO	<p>Determines when the trip pulse is initiated. There are three values:</p> <ul style="list-style-type: none"> • Standing—See “CO Parameter: Standing Option” on page 121 • First Touch—See “CO Parameter: First Touch Option” on page 121 • All Close, Any Phase—See “CO Parameter: All Close, Any Phase Option” on page 122

CO Parameter: Standing Option

The Standing option initiates 0.5 cycles (8.3 ms for 60 Hz and 10 ms for 50 Hz) after the close pulse and continues for the duration of the test (Figure 104). When Standing is selected, you cannot edit the Delay value.

Test Type	Pulse Duration		Sequencing	
TripFree (CO)	Close Pulse	133.3 ms	C->O	Standing
			Delay	8.3 ms

Figure 104 TripFree Standing

See Figure 103 on page 120 for a TripFree command pulse with a delay of 8.3 ms.

CO Parameter: First Touch Option

There is no delay. The trip pulse is applied when contact monitoring channel #1 (which is usually connected to contact #1 in Phase A) senses that the main contact is closed. The trip pulse continues for the duration of the test (Figure 105).

Test Type	Pulse Duration		Sequencing	
TripFree (CO)	Close Pulse	133.3 ms	C->O	First Touch

Figure 105 TripFree First Touch

Figure 106 shows how the Trip command is started when Contact 1 in Phase A makes a first touch.

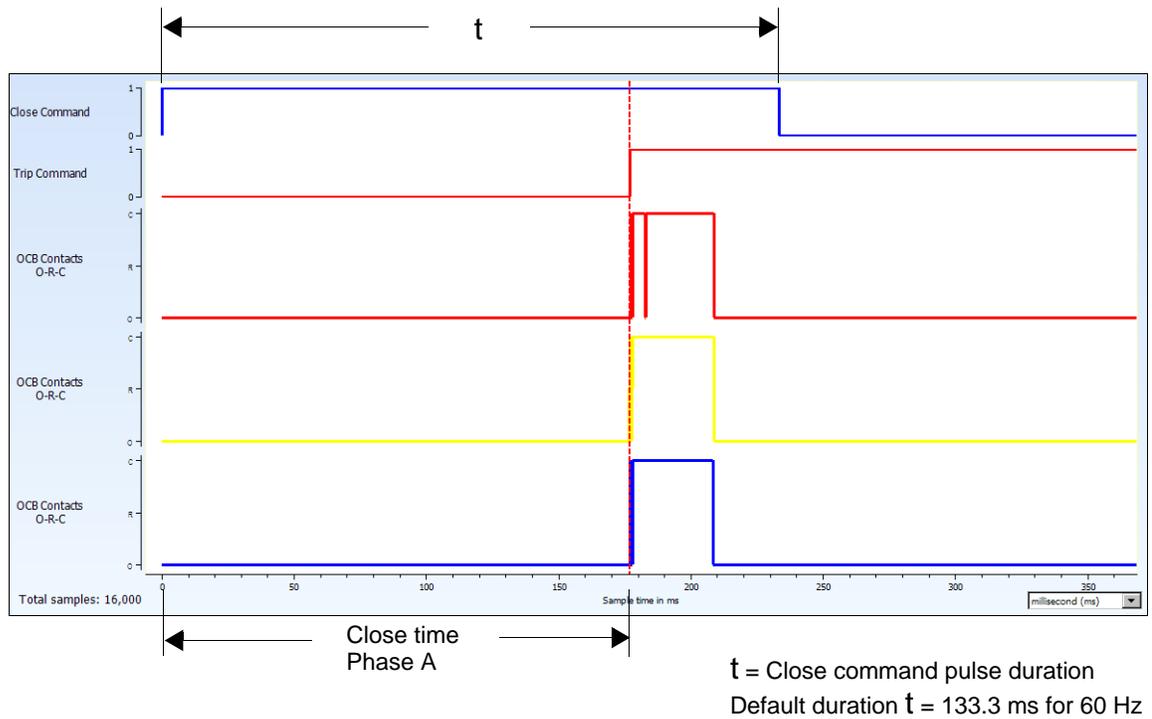


Figure 106 TripFree Started by Contact 1 First Touch

CO Parameter: All Close, Any Phase Option

There is no delay. The trip pulse is applied when all main contacts are closed for any phase. The first completed phase triggers the trip pulse.

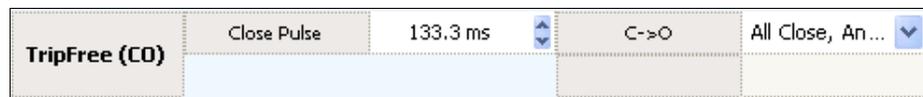


Figure 107 TripFree All Close, Any Phase

Reclosing (O-C) Test

During the Reclosing test, dual, user-specified commands are issued to open the circuit breaker and then close it shortly after. You can select a delay to specify the time to initiate the close pulse. Figure 108 shows a waveform generated by the Reclosing test.

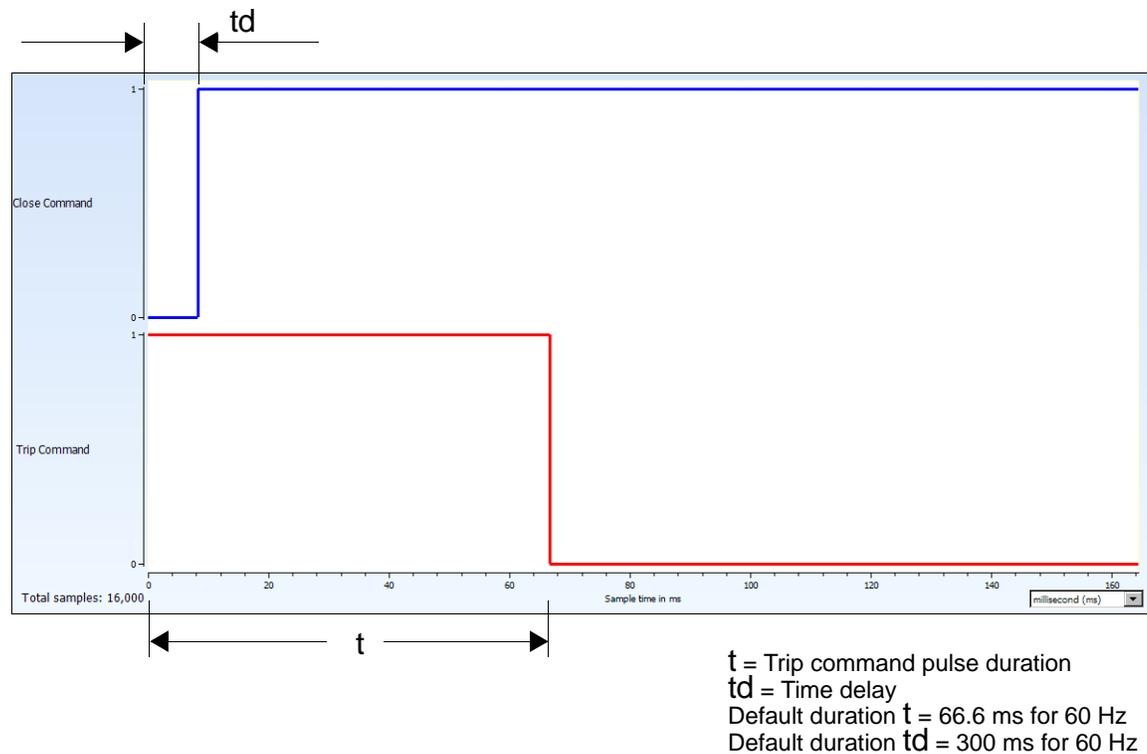


Figure 108 Reclosing Command Pulse

Table 7 Reclosing Test Command Parameters

Command Parameter	Definition
<i>Trip Pulse</i>	Determines the duration of the trip pulse sent to operate the trip circuit of the circuit breaker. Default values are: <ul style="list-style-type: none"> • 66.6 ms for 60 Hz • 80 ms for 50 Hz

Table 7 Reclosing Test Command Parameters (Continued)

Command Parameter	Definition
O-C	Determines when the close pulse is initiated. There are three values: <ul style="list-style-type: none"> • O - 0.3 s - C—See “O-C Parameter: O - 0.3 s - C Option” on page 124. • Delay—See “O-C Parameter: Delay Option” on page 125.

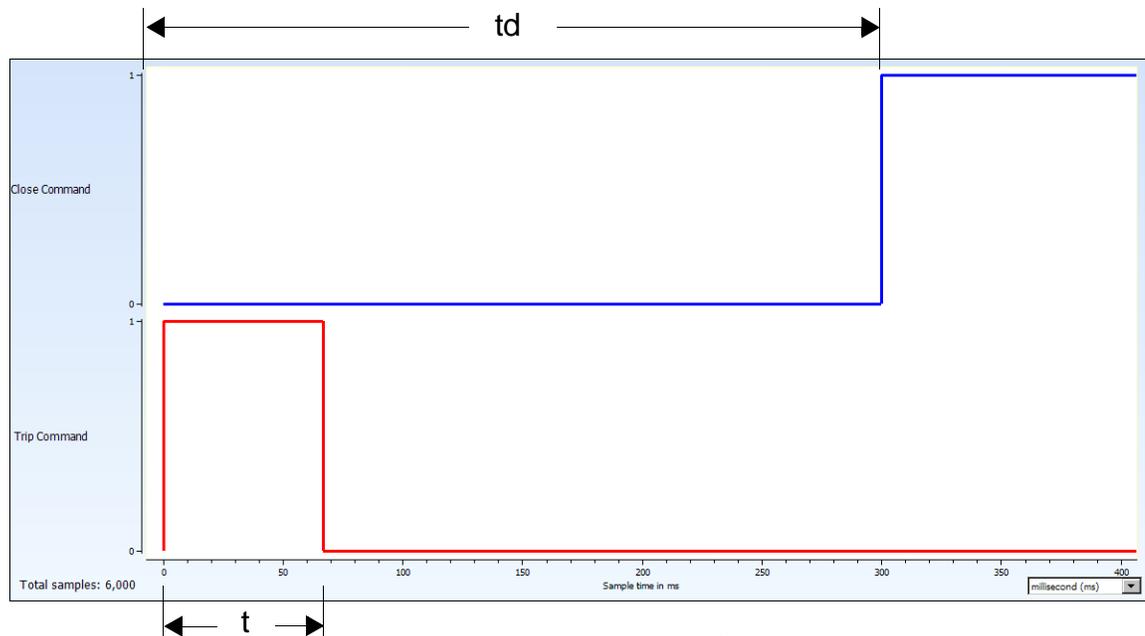
O-C Parameter: O - 0.3 s - C Option

The O - 0.3 s - C parameter performs a Reclosing test with a 300 ms delay after test initiation. This delay value cannot be edited. (Figure 109).

Test Type	Pulse Duration		Sequencing	
Reclose (O-C)	Trip Pulse	66.6 ms	O->C	O - 0.3 s - C
			Delay	300.0 ms

Figure 109 Reclosing O - 0.3 s - C

Figure 110 shows how the O - 0.3 s - C Close command is delayed.



t = Trip command pulse duration
 td = Time delay for close pulse
 Default duration t = 66.6 ms for 60 Hz
 Default duration td = 300 ms

Figure 110 Reclosing O - 0.3 s - C Operation

O-C Parameter: Delay Option

The Delay field appears when you select **Delay** in the O-C field. After test initiation, the close pulse is applied after the specified delay time (0.0 to 1600 ms; default value is 8.3 ms) and continues for the duration of the test (Figure 111).

Command Parameters			
Test Type	Pulse Duration		Sequencing
Reclose (O-C)	Trip Pulse	250.0 ms	O->C
			Delay
			300.0 ms

Figure 111 Reclosing with a User-defined Delay of 300 ms

Figure 112 shows a Reclosing delay with a default delay of 300 ms.

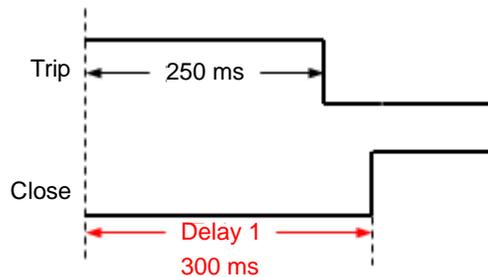
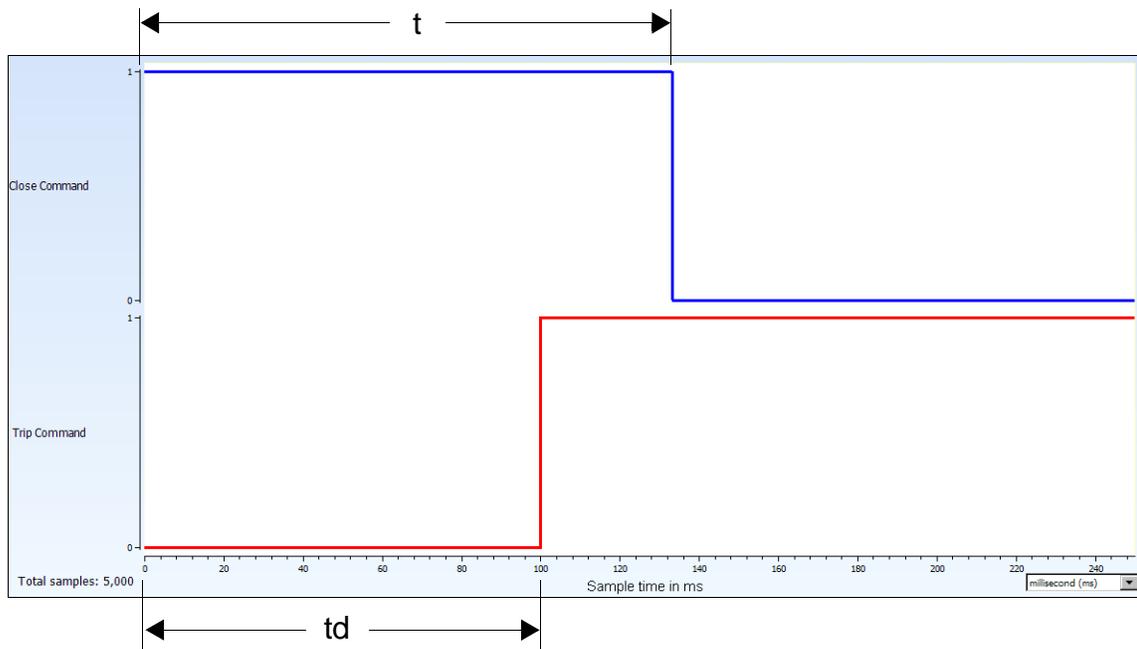


Figure 112 Reclosing Delay Operation

C-O Test

During the C-O test, dual, user-specified commands are issued to close the circuit breaker and then open it shortly after. The user can configure a delay to occur after test initiation, before the trip pulse is applied. Figure 113 shows a waveform generated by the C-O test.



t = Close command pulse duration
 td = Delay time for trip pulse initiation
 Default duration t = 133.3 ms for 60 Hz
 Default delay duration td = 100 ms

Figure 113 C-O Command Pulse

Table 8 C-O Test Command Parameters

Command Parameter	Definition
<i>Close Pulse Duration</i>	Determines the duration of the close pulse sent to operate the close circuit of the circuit breaker.
<i>C->O Sequencing</i>	Determines the delay of the trip pulse after test initiation (0.0 to 1600 ms; default is 100 ms).

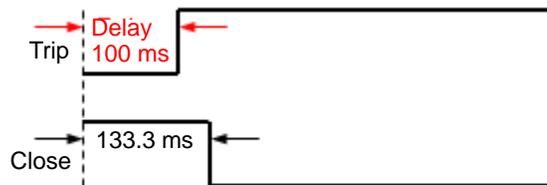
After test initiation, the trip pulse is applied after the specified time delay (0.0 to 1600 ms) and continues for the duration of the test (Figure 114).

Command Parameters				
Test Type	Pulse Duration		Sequencing	
C-O	Close Pulse	133.3 ms	C->O	Delay
			Delay	100.0 ms

Figure 114 C-O Delay of 100 ms

The delay length default value is 100 ms.

Figure 115 shows how the C-O command is delayed.

**Figure 115 C-O Delay Operation**

O-CO and O-C-O Tests

The O-CO and O-C-O tests are multi-operation tests controlled by dual, user-specified commands: open-close-open. Timing delays of 55 ms or greater can be configured and applied. The 55 ms minimum value is required by legacy equipment used by some Doble clients.

Figure 116 shows a waveform generated by the O-CO and O-C-O tests.

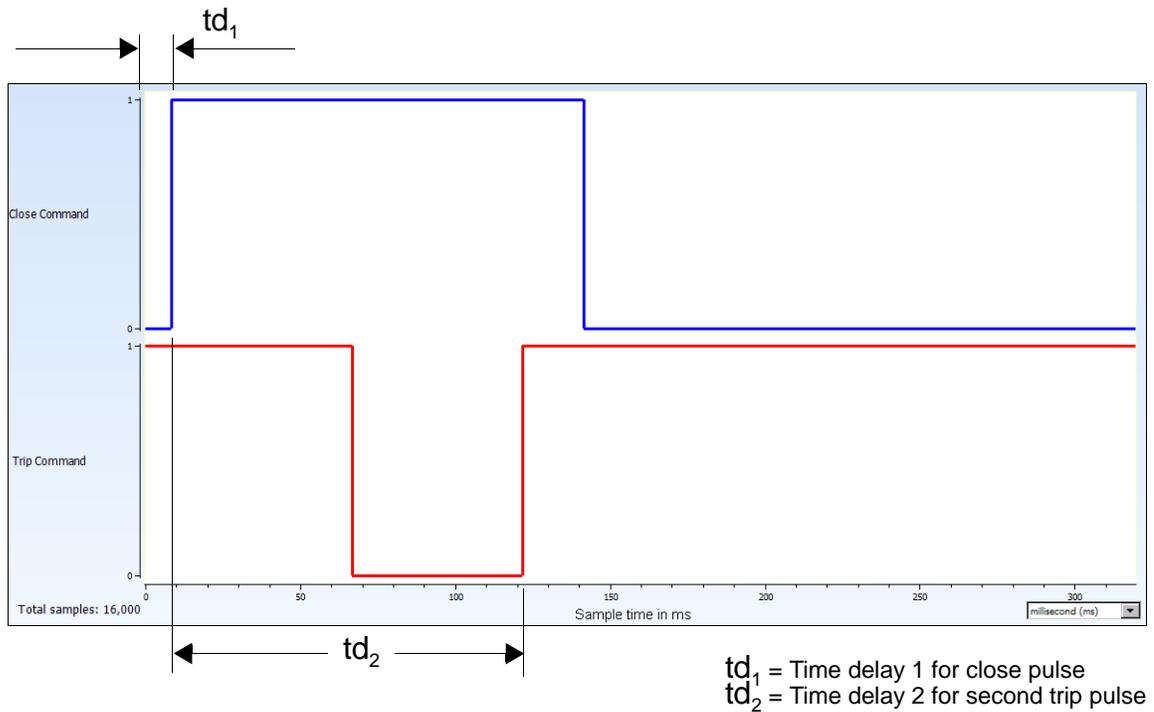


Figure 116 O-C-O Command Pulse

Table 9 O-CO and O-C-O Test Command Parameters

Command Parameter	Definition
<i>Trip Pulse</i>	Determines the duration of the trip pulse sent to operate the trip circuit of the circuit breaker.
<i>Initial Trip</i>	Determines the duration of the first trip pulse sent to operate the trip circuit of the circuit breaker. Default values are: <ul style="list-style-type: none"> • 66.6 ms for 60 Hz • 80 ms for 50 Hz
<i>Close Pulse</i>	Determines the duration of the close pulse sent to operate the close circuit of the circuit breaker.

Table 9 O-CO and O-C-O Test Command Parameters (Continued)

Command Parameter	Definition
O-C	<p>Determines when the close pulse is initiated:</p> <ul style="list-style-type: none"> • O - 0.3 s - C—Delay cannot be edited. • Delay—Initiates a Close after the time entered in the Delay Length field measured from test initiation (0.0 to 1600 ms; default is 8.3 ms). The Delay Length field appears when you select Delay in the O-C field.
CO	<p>Determines when the open pulse is initiated. There are four values:</p> <ul style="list-style-type: none"> • Standing—See “CO Parameter: Standing Option” on page 129 • First Touch—See “CO Parameter: First Touch Option” on page 130 • All Close, Any Phase—See “CO Parameter: All Close, Any Phase Option” on page 131 • Delay—See “CO Parameter: Delay Option” on page 132

CO Parameter: Standing Option

A trip command of a specified duration (8.0 to 1600 ms) is applied to the circuit breaker at time zero ([Figure 117](#)). The second trip command is applied to the circuit breaker delayed by 8.3 ms after the initiation of the close command and is left on for the remainder of the test. For the Standing option, the Delay 2 value is fixed at 8.3 ms and cannot be edited.

Command Parameters				
Test Type	Pulse Duration		Sequencing	
O-CO O-C-O	Initial Trip	250.0 ms	O->C	Delay
	Close Pulse	133.3 ms	Delay 1	300.0 ms
			C->O	Standing
			Delay 2	8.3 ms

Figure 117 O-C-O Standing

The minimum Delay 2 value is calculated as follows:

- 60 Hz—Delay 2 \geq 55 ms + (Trip pulse – 8.3 ms)
- 50 Hz—Delay 2 \geq 55 ms + (Trip pulse – 10 ms)

Figure 118 shows an O-C-O command pulse with a Reclose (O-C) Delay 1 of 300 ms and a standing TripFree (C-O) Delay 2 of 8.3 ms.

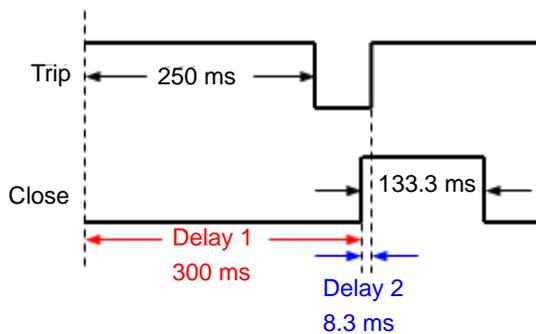


Figure 118 O-CO Standing Delay Operation

CO Parameter: First Touch Option

A trip command of a specified duration is applied to the circuit breaker at time zero (Figure 119). The second trip command is initiated when electrical closure is first detected on the main contact channel #1 (usually connected to contact #1 in Phase A), and is left on for the duration of the test.

Command Parameters				
Test Type	Pulse Duration		Sequencing	
O-CO O-C-O	Initial Trip	250.0 ms	O->C	Delay
	Close Pulse	133.3 ms	Delay 1	300.0 ms
			C->O	First Touch

Figure 119 O-C-O First Touch

The minimum Delay 1 value can be calculated as follows:

$$\text{Delay1} \geq \text{Trip Pulse} + 55 \text{ ms}$$

Figure 120 shows how O-C-O works when First Touch is selected for the TripFree operation (C-O). In this figure, the Reclose (O-C) Delay 1 value is 300 ms, and the Trip Command is initiated at the first contact detected on EHV Channel 1, Phase A.

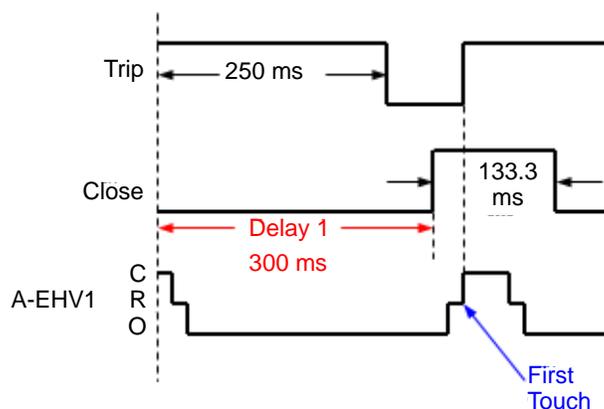


Figure 120 O-C-O First Touch Operation

CO Parameter: All Close, Any Phase Option

There is no delay. The trip pulse is applied when all main contacts are closed for any phase. The first completed phase triggers the second Trip pulse.

Command Parameters					
Test Type	Pulse Duration			Sequencing	
O-CO O-C-O	Initial Trip	250.0 ms		O->C	Delay
	Close Pulse	133.3 ms		Delay 1	300.0 ms
				C->O	All Close, Any...

Figure 121 TripFree All Close, Any Phase

Figure 122 shows how O-C-O works when All Close, Any Phase is selected for the Trip Free operation (C-O). In this figure, the Reclose (O-C) Delay 1 value is 300 ms, and the Trip Command is initiated when all of the contacts close in any phase. For this example, B and C phases are not shown, and it is assumed that A phase contacts close first. The Trip Command is initiated when closure is detected on EHV Channel 2, Phase A.

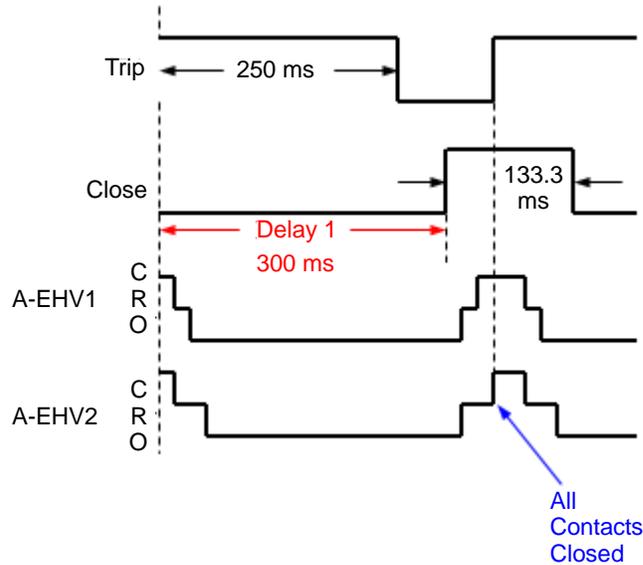


Figure 122 O-C-O All Close, Any Phase Operation

CO Parameter: Delay Option

After the initiation of the Close command, the specified time delay (Delay 2) occurs, and then the second trip command is applied to the circuit breaker and is left on for the remainder of the test.

Command Parameters				
Test Type	Pulse Duration		Sequencing	
O-CO O-C-O	Initial Trip	250.0 ms	O->C	Delay
	Close Pulse	133.3 ms	Delay 1	300.0 ms
			C->O	Delay
			Delay 2	100.0 ms

Figure 123 TripFree Delay

The TDR9100 imposes a maximum Delay 1 length based upon the duration of the Trip Pulse, as shown here:

$$\text{Delay 1 length} \leq 55 \text{ ms} + \text{Trip Pulse}$$

The minimum Delay 2 length can be calculated as follows:

$$\text{Delay 2 length} > 55 \text{ ms} + (\text{Trip pulse} - \text{Delay 1 length})$$

Figure 124 shows how the TripFree delay works.

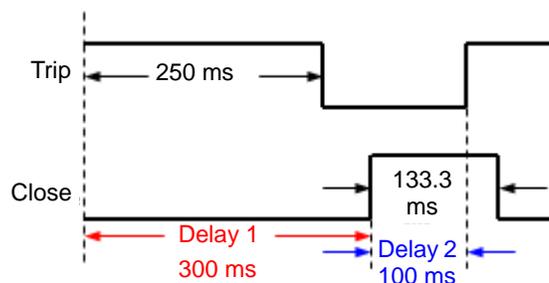


Figure 124 TripFree Delay Operation

Record Only (RO) Test

The Record Only test is a convenience for users who may wish to record activity on main contacts, resistor contacts, analog channels, and so on, without using the Trip/Close sequence commands.

For example, you can configure this test to record a Slow Close test. Record Only is selected from the Run Test menu.

Trip/Close Ranges

To maximize the resolution for all range selections, use the lowest practical range for the expected measurement. For example, if the expected maximum current is 14 amperes, select the 0-20 A range to achieve the greatest resolution without clipping. The Trip Current and Close Current ranges are identical: 0.2 A, 0.5 A, 1.0 A, 2.0 A, 5.0 A, 10 A, 20 A, 50 A, and 100 A.

Trip/Close Ranges	
Trip Current	20 A
Close Current	20 A

Figure 125 Trip/Close Range

Recording Parameters

Recording Parameters	
Sampling Rate	10 KHz
Sample Time	0.1 ms
Recording Time (after Trigger)	1600.0 ms
(Samples)	16000
Pretrigger Time	10.0 ms
(Samples)	100

Figure 126 Recording Parameters

To control the test recording, you can configure the Sampling Rate, Recording Time, Pretrigger Time, and Samples values. When one of these values is configured, the information associated with it adjusts automatically.

Sampling Rate

The Sampling Rate field sets the frequency at which the conditions sensed on the TDR9100 measurement channels are sampled. A higher sampling rate results in finer resolution of measurement, but also generates larger results files and longer data upload times. The default Sampling Rate is 10 kHz. The related Sample Time field displays the time period between consecutive samples at the set sampling rate.

When the Sampling Rate value changes:

- Sample Time (sample period) is recalculated
- Recording Time (recording duration after trigger) is adjusted
 - Samples (number of samples in the recording) remains the same
- Pretrigger Time (recording duration before trigger) is adjusted
 - Samples (number of samples in the recording) remains the same

Recording Time

The Recording Time field sets the length of time during which data will be recorded after the triggering event occurs. The default Recording Time is 1600 ms. The related Samples field displays the number of samples resulting from the set Recording Time at the set Sampling Rate.

When Recording Time value changes, Samples (number of samples in the recording after the trigger event) is adjusted.

Pretrigger Time

The Pretrigger Time field sets a length of time during which data will be recorded before the triggering event occurs. The default Pretrigger Time is 10 ms. Pretrigger Time can be used with any test type, but is often used with externally triggered tests where the available trigger signal will occur after something else of interest is expected to occur.

When Pretrigger Time changes, Samples (number of samples in the recording before the trigger event) is adjusted.

Samples

Both the Recording Time and the Pretrigger Time values can also be configured by adjusting their related Samples fields.

- When Samples is adjusted under Recording Time, Recording Time is adjusted
- When Samples is adjusted under Pretrigger Time, Pretrigger Time is adjusted



NOTE: The maximum sample length of a recording is 524,288 samples per channel. [Table 10](#) shows the relationship between sampling rate and maximum recording time.

Table 10 Sampling Rates and Maximum Recording Times

Sampling Rate	Maximum Samples	Maximum Total Recording Time (Before and After Trigger)	
		In Seconds	In Minutes
20 kHz	524288	26.2	-
10 kHz		52.4	-
1000 Hz		524.3	8.7
100 Hz		5242.9	87.3

Bounce Discriminator

The Bounce Discriminator is a digital filter that distinguishes between real contact activity and cross-coupled signals with 2 μs resolution. When a bounce is detected, it triggers the Bounce Discriminator, which sets up a window in time equal to the Bounce Discriminator filter time. Bounces with durations equal to or greater than the Bounce Discriminator filter time are passed through and stored in memory as valid contact data, while bounces with durations less than the Bounce Discriminator filter time are rejected and not recorded.

The Bounce Discriminator filter time can range from 4 μs to 100 μs. Select the Automatic option to set the Bounce Discriminator filter time to 60 μs, which is optimal for most applications.



Figure 127 Bounce Discriminator

First Trip Test

The First Trip test uses the analog and auxiliary channels of the TDR9100 to capture operational data for circuit breakers that are in service and have been idle for long periods of time. The test detects lubrication problems and other incipient failure modes. Because breakers often operate properly after the lubricant has been exercised by a test, only the First Trip test can detect incipient lubrication problems.

CT secondaries can be used as the signal source instead of the main contact test cables, because the main contacts are energized. In consequence, phase current waveforms replace the usual main contact and resistor contact timing measurements.

Breakers Eligible for First Trip Testing

The TDR9100 can perform First Trip testing on IPO circuit breakers as well as those with a single mechanism for the three phases. As long as safe access is provided, additional signals such as motion and velocity can be included in the test. However, because of safety factors, it is not common practice to measure motion and velocity during First Trip testing.

Data Integrity and Interpretation

To preserve the integrity of data, First Trip tests are performed on circuit breakers that are in service. Clip-on Doble probes and voltage probes monitor the DC battery voltage, phase currents, trip coil currents, and auxiliary contacts. An external signal triggers the recording when the circuit breaker is operated.

First Trip test results are analyzed by comparison to subsequent test results.

Safety Considerations for First Trip Tests

First Trip testing involves making connections inside the control cabinet of a live circuit breaker.

WARNING!

Do not use main contact test cables (EHV or OCB) during First Trip tests for any reason!

Please keep the following recommendations in mind:

- **Doble recommends that you operate the circuit breaker remotely and use the external trigger feature of the TDR9100.** For this reason, the instructions in this guide assume that you are using the external trigger.
- **Doble does not recommend connecting a motion transducer to an energized breaker.** To include the measurement of the motion characteristics of a circuit breaker in the First Trip tests, *while the breaker is de-energized*, find a spot on the circuit breaker's mechanism and permanently install a motion transducer for use in a future First Trip test.
- **Take every opportunity when the circuit breaker is de-energized to make adjustments**, such as adjusting wiring to accommodate clip-on probes.

Configuring a First Trip Test

It is advisable to have a separate test plan for a First Trip test.

To configure a First Trip test, enter data in the following parts of the T-Doble interface:

- Breaker page, Nameplate tab—Include at least the manufacturer, model number, serial number, special ID, if any, and location. In the Description field, Doble recommends that you indicate that this test plan is for a First Trip test.
- Test Plan page, First Trip tab—Make these selections:
 - Trip Command (Recording Trigger)**
Aux Contact Channels to use an auxiliary contact channel
 - Transition**
 - Open–Closed
 - Closed–Open
 - Wet–Dry
 - Dry–Wet
 - Any change

The trigger event is the change of state the TDR9100 is expecting to see before recording the test data. During a First Trip test, the closing of the 52CS/T contacts initiates the recording. Or, the 52X/Y/a/b auxiliary contacts may be used as a trigger source with pretrigger time included to ensure that the entire event is captured in the recorded test results.

- “Aux Contact” trigger source—To use the “Aux Contact” trigger source, click the **First Trip** tab. In the Channel column, select **Aux Contact Channels** and select an existing channel (see [Figure 128](#)). Or, select, **Add New Channel** and create a new channel.

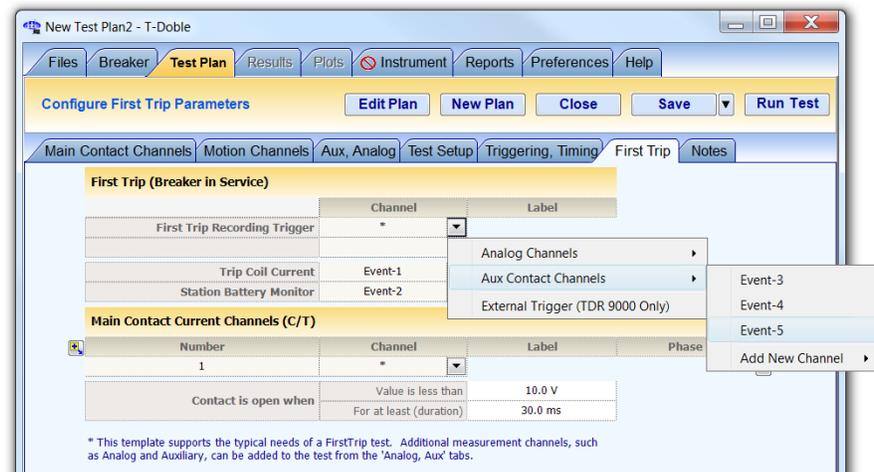


Figure 128 First Trip (Breaker in Service)

Select the pre-trigger time or leave it at the default (see [“Recording Parameters” on page 134](#)). However, to capture the entire recording, it is recommended that pre-trigger time be longer than the opening time of the AUX contact.

- For each current or voltage waveform to be measured, activate an analog channel and give it a label and a phase in the Main Contact Current Channels (C/T) table of the First Trip tab ([Figure 129](#)). All analog currents are measured using Doble probes. The DC supply voltage is measured with an analog voltage channel. Activate only the channels being used.

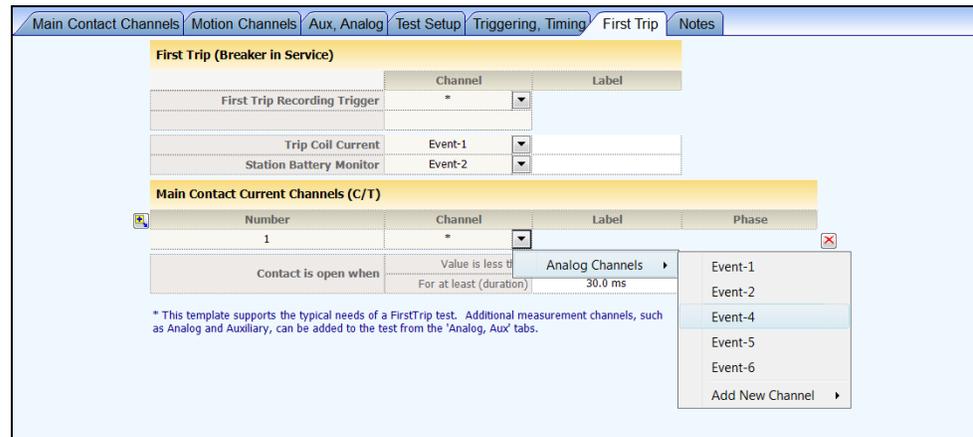


Figure 129 Main Contact Current Channels

Instrument Connections for First Trip Tests

Table 11 lists the connections to the TDR9100 required for a minimum set of channels. This is an external trigger test, so no Trip/Close control cable is used. Additional pretrigger time may be required, depending on the auxiliary contact used for the external trigger.

Table 11 Minimum Set of Channels

Item	Signal	Type	Instrument Connection
1	Phase Current* (from CT secondary)	Analog	Event
2	Trip coil current	Analog	Event
3	DC Supply voltage	Analog	Event
4	52X, 52Y, 52A, 52B, or 52CS/T contact state	Auxiliary Contact	Event

*Optionally, measure all three phase currents if channels are available.

Making Circuit Breaker Connections

Leads for measuring the main contact current are connected via clip-on probe to the current transformer (CT) secondary for the phase being measured. If testing a live-tank breaker where a separate free-standing CT is used, it should be possible to position the TDR9100 so that cable lengths suffice to make the connection.



NOTE: Before using the Doble Current Probe (P/N 401-0055), please review [“Doble Probe” on page 164](#) for information about proper use, including zeroing and overriding the power-save mode.

To make connections to the breaker:

1. Connect the test set ground to the TDR9100 and then to the ground grid.
2. Connect the AC power cord to the TDR9100 and then to the supply receptacle.
3. For each phase current being measured:
 - a. Connect an analog test cable to the Event Analog channel on the TDR9100 according to the test plan.
 - b. Connect the cable to a Doble Current Probe.
 - c. Clip the probe onto the CT secondary. See [“Doble Probe” on page 164](#) for important information about correct use of the Doble Current Probe.
4. For the selected trip coil:
 - a. Connect an analog test cable to the Event Analog channel on the TDR9100 according to the test plan.
 - b. Connect the cable to a Doble Current Probe.
 - c. Clip the probe to the trip coil circuit.
5. For the DC supply voltage measurement:
 - a. Connect an analog test cable to the Event Analog channel on the TDR9100 according to the test plan.
 - b. Connect the cable across the DC supply switch.
6. For the external trigger input and other auxiliary contact timing measurements:

- a. Connect an event test cable to an Event Auxiliary channel on the TDR9100 according to the test plan.
- b. Connect the cable across the selected relay contacts.
- c. For the auxiliary contact acting as the external trigger for the test, ensure that the selected channel has been set as the external trigger in the test plan.

Disconnecting After a First Trip

To disconnect after a First Trip test (if no further tests will be performed):

1. Turn the TDR9100 power switch to OFF.
2. Disconnect all cables and probes from the circuit breaker, CTs, and control circuits. Lay all cables on the ground.
3. Disconnect all test cables from the TDR9100.
4. Unplug the TDR9100 AC power cord from the supply receptacle and then from the TDR9100.
5. When all other connections have been removed, disconnect the ground cable from the ground grid and then from the TDR9100.

7. Triggering and Timing Setup

This chapter describes the parameters found on the Triggering, Timing tab of the Test Plan page. It contains the following sections:

- [“Test Triggering Setup” on page 143](#)
- [“Timing Reference Setup” on page 145](#)
- [“Selecting a Timing Reference for Tabulating Test Results” on page 146](#)

Test Triggering Setup

The Test Triggering feature ([Figure 130](#)) enables you to initiate a test or recording using either the default internal trigger, or an external trigger such as a command from a remote control-room.

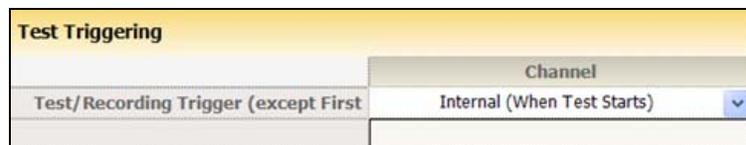


Figure 130 Test Triggering

There are three trigger types:

- Internal (when test starts). This is the default.
- Analog (external).
- Aux Contact (external).

Internal Triggers

When an internal trigger is used, tests are initiated by the TDR9100 and T-Doble software, based on the “Run Test” function and the condition of the TDR9100 safety switch or safety bypass flag. Internal trigger mode can be used for all test types, including breaker control (Trip/Close sequence) tests and Record Only tests.

Analog (External) Triggers

Any analog Event channel can be selected and used to initiate a test based on detecting an external voltage level (Figure 131). To do this, select (or add) an analog Event channel as the test/recording trigger, and configure a threshold setting. Once the system is armed through the “Run Test” function, the test is initiated if the value detected on that channel exceeds the set threshold. When the analog Event channel is configured on the Aux, Analog tab, the threshold can either be a voltage value (Figure 131) or a current value (Figure 132).



Test Triggering	
	Channel
Test/Recording Trigger (except First Trip)	Event-1
Threshold (max: 300V)	10.00 V

Figure 131 Analog Event (Voltage) External Trigger Settings



Test Triggering	
	Channel
Test/Recording Trigger (except First Trip)	Event-1
Threshold (max: 300V)	2.00 A

Figure 132 Analog Event (Current) External Trigger Settings

Aux Contact (External) Triggers

Any Auxiliary Contact Event channel can be selected and used to initiate a test (Figure 133). To do this, select (or add) an auxiliary contact Event channel as the test/recording trigger, and configure a state transition for detection of the triggering event. The transition can be one of five types:

- Open to Close
- Closed to Open
- Wet to Dry
- Dry to Wet
- Any Change



Figure 133 Aux Contact Event External Trigger Settings

NOTE



The AUX Contact Trigger In channel is designed to work in a substation using station battery voltages of 38 V DC or higher. Voltages less than 38 V DC may not meet the threshold requirements of the “wet” state.

For more information, see [“Auxiliary Contact Channels” on page 113](#). [“Pretrigger Time” on page 135](#) describes the pre-trigger data functionality available for this test.

NOTE



For a test tabulation of an externally triggered test to be meaningful, the T0 (trigger event) and the circuit breaker activation must coincide.

When any external trigger is used, the internal command parameters (whether default values or values set by the operator) are effectively disabled, because the command to operate originates externally.

Testing using an external trigger gives the user a way to verify that the remote command of the circuit breaker is functioning correctly.

Timing Reference Setup

The Timing Reference Setup table sets the initiation point for each timing event. Each event can be configured separately, as shown in [Figure 134](#).

Timing Reference Setup		
Test Type	Timing Reference	Detail
Trip	Internal (When Test Starts)	▼
Close	Internal (When Test Starts)	▼
Reclose (O-C)	Internal (When Test Starts)	▼
TripFree (CO)	Internal (When Test Starts)	▼
C-O	Internal (When Test Starts)	▼
O-CO	Internal (When Test Starts)	▼

Figure 134 Timing Reference Setup

The Detail fields set these possible parameters of the selected initiation point:

- Test Initiation—Internal (When Test Starts)
- Threshold—Trip Current, Close Current, and Analog Channel
- Transition (Change of State)—Auxiliary Contact Channel

These settings affect how timing results are tabulated; you can use these settings for any type of test.

Selecting a Timing Reference for Tabulating Test Results

Use the Timing Reference Setup table ([Figure 135](#)) to select a reference for tabulation.

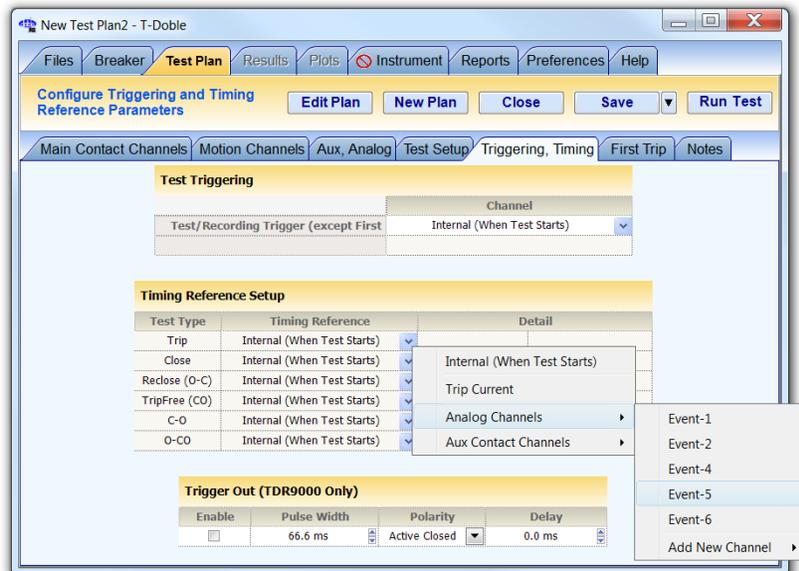


Figure 135 Selecting a Timing Reference for Tabulation

Main contact timing tabulation can be initiated from the following timing event selections:

- Test Initiation (T0)
- Trip Current
- Close Current
- Analog Channels
- AUX Contact Channels

NOTE



Changing the close timing event affects only the tabulated test results for a Close test; the plots are not affected.

Test Initiation

Timing a Close test from test initiation is achieved using the close pulse and Timing Event parameters (Figure 136).

Test Type	Pulse Duration
Close	Close Pulse 133.3 ms

Figure 136 Close Parameters

Figure 137 shows how timing works for test initiation. The times t_1 and t_2 indicate the following:

- t_2 —The time required to close the main contact. The close time is measured from the test initiation.
- t_1 —The time required to close the resistor contact. The close time is measured from the test initiation. (If the Relative to Test Initiation option is selected in Resistor Contact Timing Specification, see “Resistor Timing – Close” on page 69.)

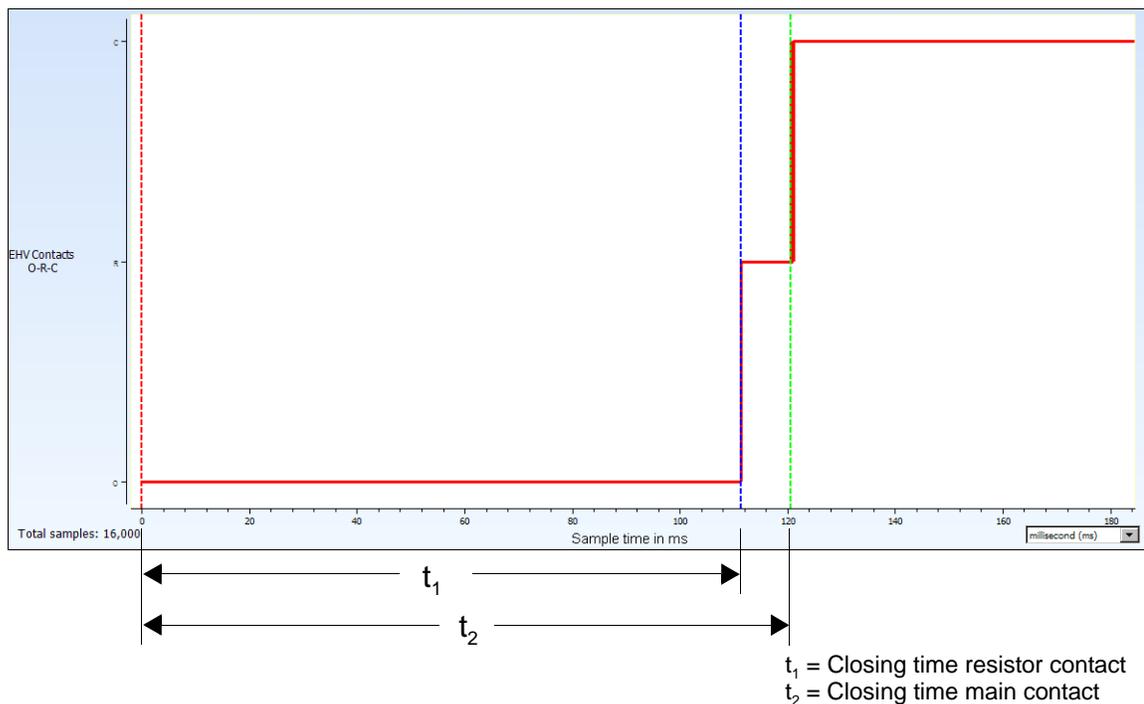


Figure 137 Close Time

Close Current Magnitude

Timing a close test based on close current magnitude is achieved through a combination of the Close Pulse, Timing Event, and Timing Trigger parameters (Figure 138).

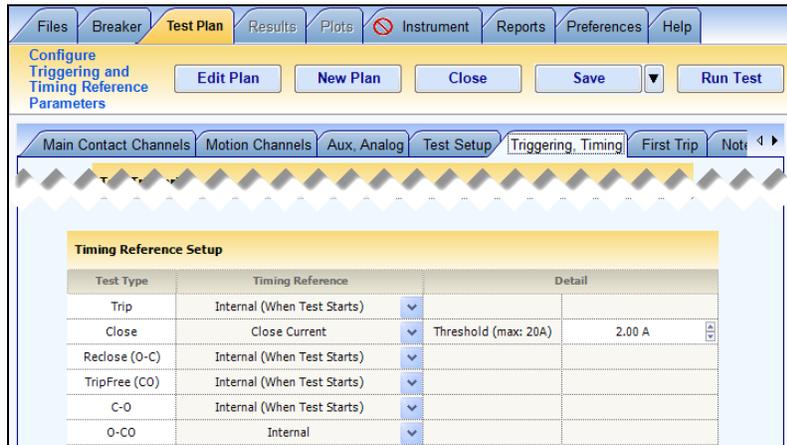


Figure 138 Select Close Current and Threshold Value

The timing trigger value is set by selecting a threshold current (A).

The selection made calculates the timing of the main contact (t_2) and resistor contact (t_1) (Figure 139 on page 150) after the close current reaches the specified threshold value (1.5 A in this example), if the Relative to Test Initiation option is selected as shown in “Resistor Timing – Close” on page 69.

It is important to select a threshold current that is less than the maximum value of the close current.

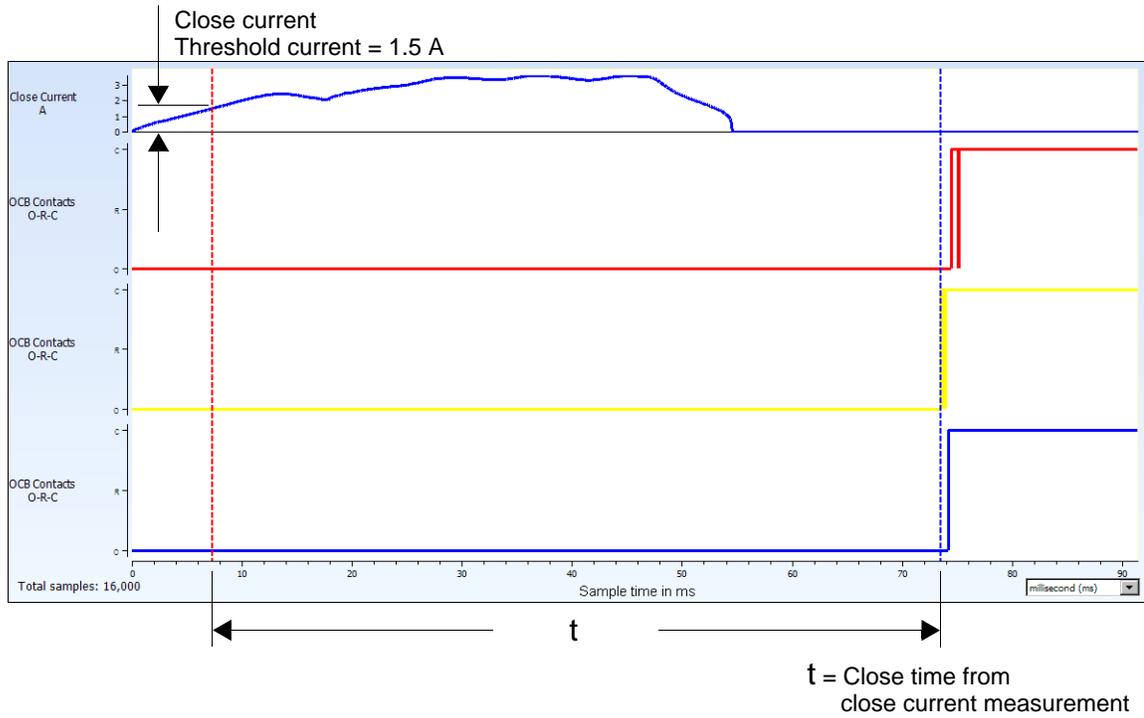


Figure 139 Close Timing from Close Current Measurement

Analog: Voltage or Current Magnitude

Timing a close test based on voltage or current magnitude for a particular channel is achieved through the combination of the Close Pulse, Timing Event, Timing Trigger, and Timing Channel parameters (Figure 140).

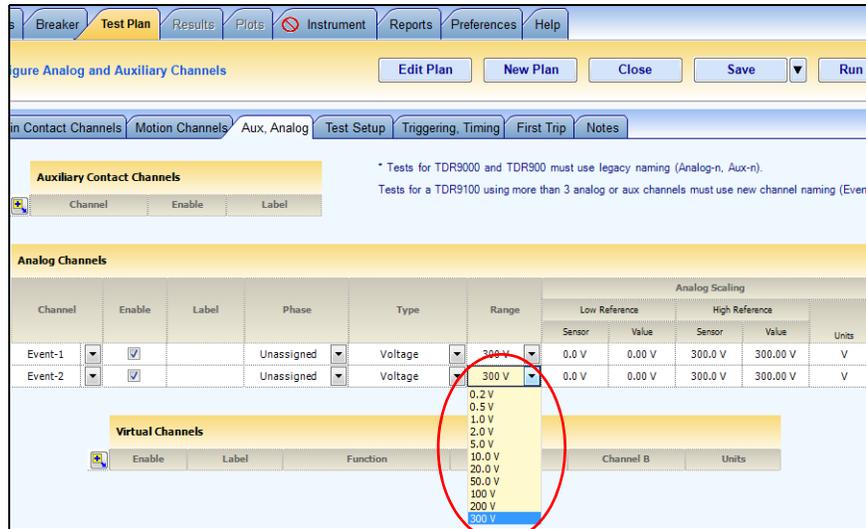


Figure 140 Select Magnitude of Analog Measurement

The measurements in [Figure 141](#) were calculated using an external current probe with a selected range of 20 A. The timing of the main contact (t_2) and resistor contact (t_1) is calculated in this way:

1. The t_0 option is selected in “Resistor Timing – Close” on page 69.
2. The designated channel reaches the threshold current (10 A in this example) of the full scale current selected for that channel ([Figure 141](#)).
3. The calculation is made.

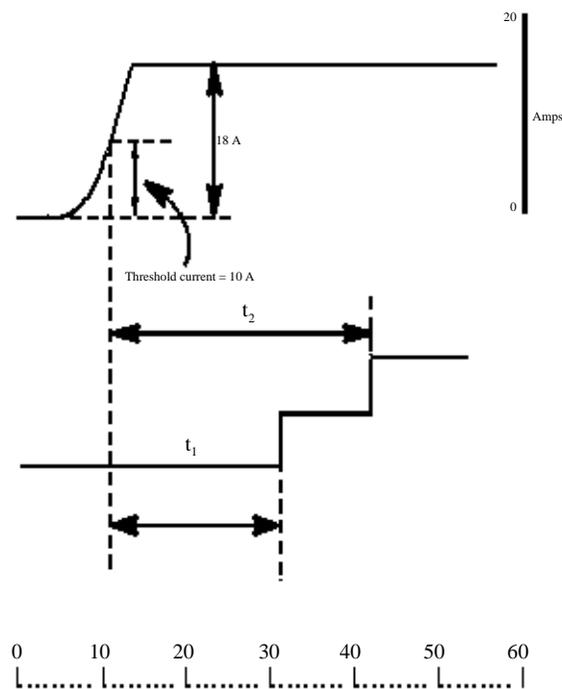


Figure 141 Close Timing from Current Measurement

If external shunt is used, let us say 5 V = 100 A, then the timing starts when the shunt output reaches 2.5 V, which corresponds to 50 A.

Figure 142 shows an example for voltage. The timing of the main contact (t_2) and resistor contact (t_1) is calculated in this way:

1. The Relative to Test Initiation option is selected in “Resistor Timing – Close” on page 69.
2. The designated channel reaches the threshold current (140 V in this example) of the full scale current selected for that channel.
3. The calculation is made.

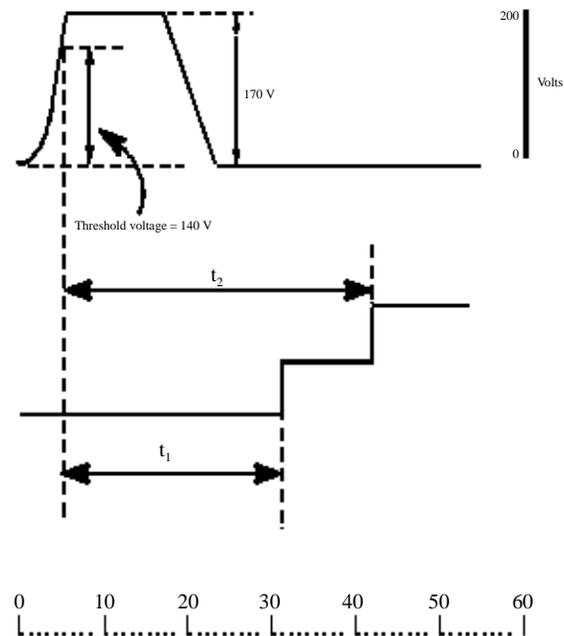


Figure 142 Close Timing from Voltage Measurement

Auxiliary Contact Transition

Timing a Close test based on the transition of a contact for a particular channel is achieved through the combination of the Close Pulse, Timing Event, and Timing Reference parameters. Figure 143 shows how to select the channel.

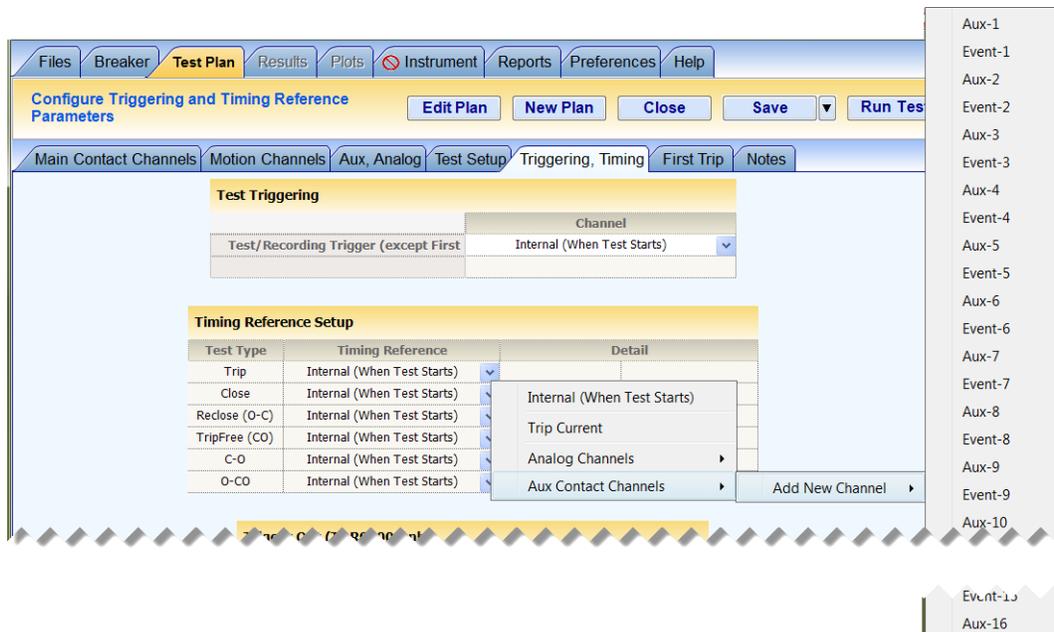


Figure 143 Select Contact Channel

To calculate the timing of the main contact (t_2) and resistor contact (t_1):

1. The T0 option is selected in “Resistor Timing – Close” on page 69.
2. The first transition of the selected auxiliary contact occurs.
3. The calculation is made. See Figure 144.

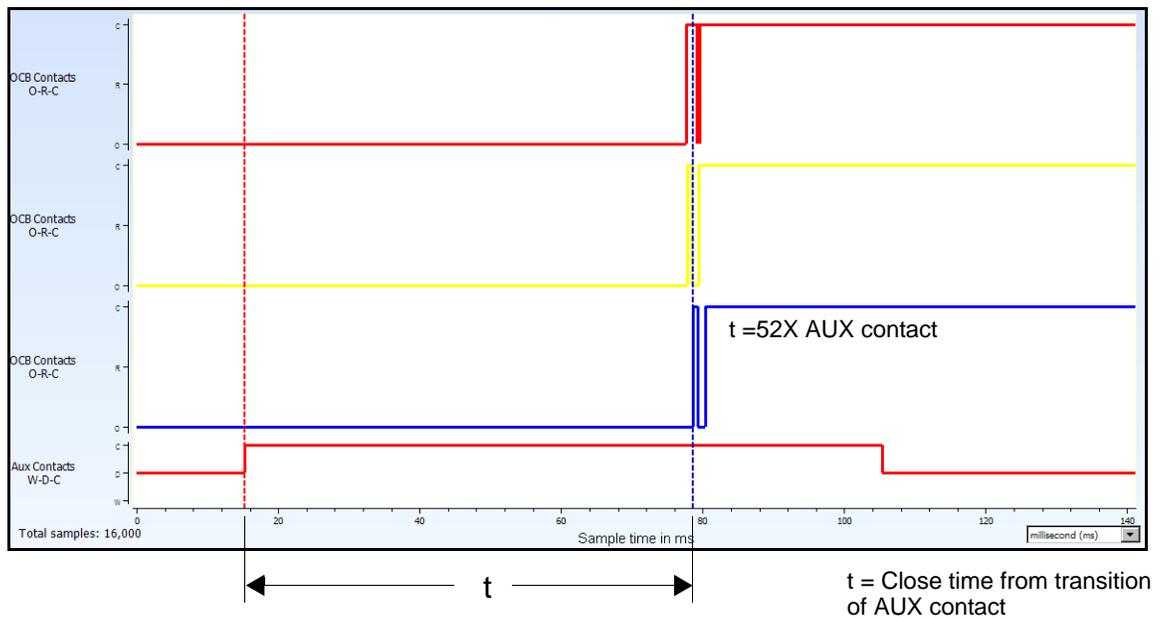


Figure 144 Closing Time Measured from Transition of AUX Contact

8. Running a Test

This chapter provides the minimum information required to make connections between a circuit breaker and the TDR9100 Circuit Breaker Test System, run a test, and save the test results. It contains the following sections:

- [“Front Panel Reference” on page 158](#)
- [“Set up the Hardware in this Order!” on page 160](#)
- [“Step 1: Preparing the Circuit Breaker” on page 160](#)
- [“Step 2: Making TDR9100 Connections” on page 161](#)
- [“Step 3: Making Circuit Breaker Connections” on page 166](#)
- [“Step 4: Creating a Test Plan” on page 178](#)
- [“Step 5: Removing Safety Grounds” on page 178](#)
- [“Step 6: Applying Power” on page 180](#)
- [“Step 7: Running the Test” on page 181](#)
- [“Step 8: Disconnecting After Testing is Complete” on page 183](#)

Front Panel Reference

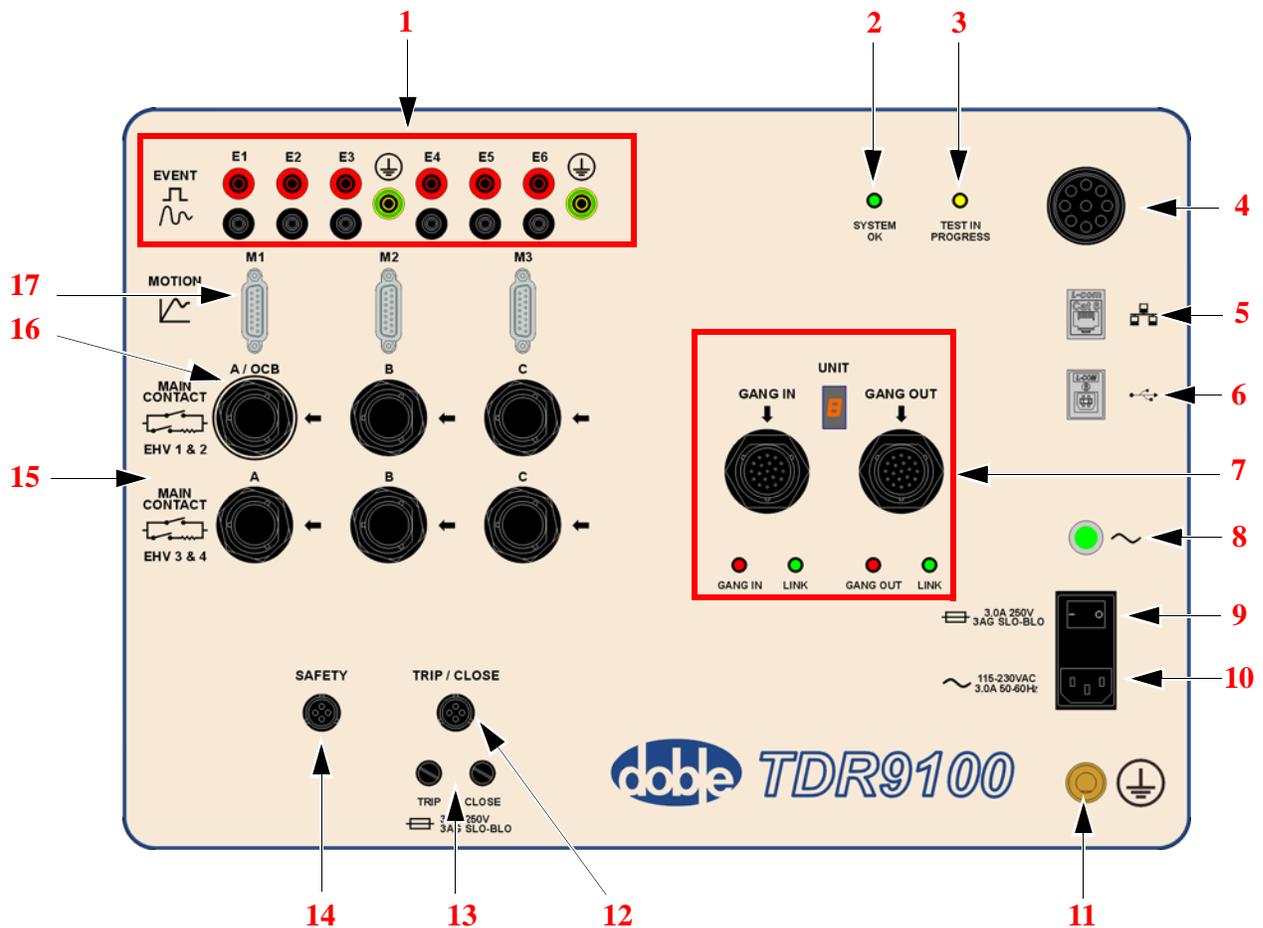


Figure 11.1 TDR9100 Front Panel

Table 12 describes the connections and controls present on the TDR9100 Front Panel. For technical detail, see [Appendix E, "TDR9100 Circuit Breaker Test System Specifications."](#)

Table 12 TDR9100 Front Panel Connections and Switches

Item	Description
1	Shrouded 4 mm banana jack connectors. Programmable for: <ul style="list-style-type: none"> • Auxiliary contact timing measurement • General-purpose analog voltage measurement
2	DC power sources valid operation LED
3	LED indicating that a test is in progress
4	Speaker
5	Ethernet port
6	USB port
7	Ganging connectors and indicators (not supported in all software versions)
8	Main power indicator light
9	<ul style="list-style-type: none"> • IEC standard power cord connector, 3-pronged male • AC fuses
10	Power ON/OFF switch
11	System safety ground twist-lock connector for the ground cable
12	Trip/Close control connector, 4-pin male
13	Trip and Close fuses
14	Safety switch cable or Safety Bypass Flag connector, 4-pin female
15	EHV main contact test cable connectors, circular 12-pin male
16	OCB cable connector (upper left main contact connector only)
17	Motion transducer cable connectors, 15-pin female

Set up the Hardware in this Order!

It is important that you set up your hardware in the order given in this chapter. This order ensures that the equipment is properly grounded before you work around or near an energized power system:

1. Prepare the circuit breaker. See [page 160](#).
2. Make connections to the TDR9100. See [page 161](#).
3. Make connections to the circuit breaker. See [page 166](#).
4. Remove safety grounds. See [page 178](#).

Step 1: Preparing the Circuit Breaker

Minimize Electrostatic Interference

Although the system successfully performs in the presence of electrostatic interference, reduction of such interference is important.

In order to minimize electrostatic interference:

- The TDR9100 is designed to test circuit breakers with one side of the circuit breaker at ground potential at all times.
- The main contact test cables act as antennae for electrostatic pickup, electromagnetic pickup, or both. In order to minimize this exposure, the TDR9100 uses shielded cable.

Procedure

To prepare the circuit breaker:

1. Trip the circuit breaker.
2. Open, lock, and tag the isolating disconnect switches on both sides of the circuit breaker.
3. Connect safety grounds to a cleaned (brushed) spot on the ground grid and then to each terminal of the circuit breaker to be tested.
4. Remove DC power from the Trip and Close circuits on the circuit breaker control panel.

Step 2: Making TDR9100 Connections

WARNING!

To reduce problems associated with electrostatic discharge, always confirm that appropriate service disconnects are secured. Then, connect cables to the TDR9100 in this order:

1. Safety ground cable
2. Power supply cable
3. Communication cable
4. Ganging cables (optional)
5. Other cables required for the test to be performed

Only after all connections are made to the TDR9100 can you make connections to the testing breaker.

Follow all safety procedures.

Grounding the TDR9100

To ground the TDR9100 and attach the power cable:

1. Plug the ground cable into the TDR9100 ground receptacle. (See **11** in [Figure 11.1 on page 158.](#)) Connect the other end to the substation ground.
2. Plug the safety switch cable into the SAFETY receptacle. (See **14** in [Figure 11.1 on page 158.](#)) If you plan to use an external trigger, plug in the Safety Bypass flag.
3. Ensure that the available utility AC supply voltage is correct for use with the TDR9100 (100 - 240 V AC, 50 or 60 cycles).
4. Attach the power cord. (See **9** in [Figure 11.1 on page 158.](#))

Connecting the TDR9100 to the Controller PC

To connect the TDR9100 to the controller PC:

1. Connect the controller PC to the TDR9100 using one of the following cables:
 - Ethernet
 - USB(See **6** and **5** in [Figure 11.1 on page 158.](#))
2. Turn the controller PC power switch **ON**.

3. Double-click the T-Doble icon ([Figure 145 on page 162](#)) or select **Start/All Programs/ Doble Engineering/T-Doble**.



Figure 145 T-Doble Icon

Main Contact OCB and EHV Connections

To make main contact connections for OCB or EHV circuit breakers, use the attachment accessories provided. Two types of connections are possible:

- OCB main contact test cable to OCB connector and then to appropriate circuit breaker terminals.
See **16** in [Figure 11.1 on page 158](#). Connect alligator clip leads as labeled: A,B,C Common or 1,2,3 Common.
- EHV main contact test cables to EHV connectors and then to appropriate circuit breaker terminals.
See **15** in [Figure 11.1 on page 158](#). Connect alligator clip leads as labeled: PH A, Contact 1,2, Common, etc.

Event Connections: Auxiliary Contact Channels

The TDR9100 auxiliary contact channels support inputs from external devices. Auxiliary contacts can be wetted with voltages from 48 to 300 V peak. The auxiliary contact channels are configured in T-Doble on the Aux, Analog tab of the Test Plan page. For more information, see [“Auxiliary Contact Channels” on page 113](#).

NOTE



The auxiliary contact measurement channels *are not* polarity sensitive.

To connect an auxiliary contact:

1. Attach one end of the Doble-supplied auxiliary contact cable to a pair of auxiliary contact channel banana jacks. (See **1** on [Figure 11.1 on page 158](#).)

2. Use the attachment accessories provided to attach the other end of the cable across the device to be monitored. Make the connection directly across the device, or at the terminal block.

Event Connections: Analog Channels: Current and Voltage

The TDR9100 monitors both current and voltage using the analog channel connectors. The analog channels accept:

- Voltage input (up to 300 V peak)
- Doble current probe input (0-2 V output)
- Custom current probe input (voltage output)

NOTE



Analog measurement channels *are* polarity sensitive.

Voltage

The analog channels accept voltage inputs up to 300 V peak. To configure them, open the Test Plan page and select the Aux, Analog tab. For more information, see [“Analog Channels” on page 111](#).

To connect a voltage input:

1. Attach the TDR9100 end of the Doble-supplied analog cable to a pair of Analog Channel banana jacks. (See **1** on [Figure 11.1 on page 158](#).)

The TDR9100 end has a shield connector. Be sure to attach the shield (green and yellow) banana plug to the chassis ground (green and yellow) banana jack. (See **15** on [Figure 11.1 on page 158](#).)

Multiple shields can be stacked.

2. Use the attachment accessories provided to attach the other end of the cable across the device to be monitored, either directly across the device or at the terminal block.

Doble Probe

Doble current probe (PN 401-0055) inputs can be configured for 20 A or 200 A. To configure them, open the Test Plan page and select the Aux, Analog tab. See [Figure 146](#).

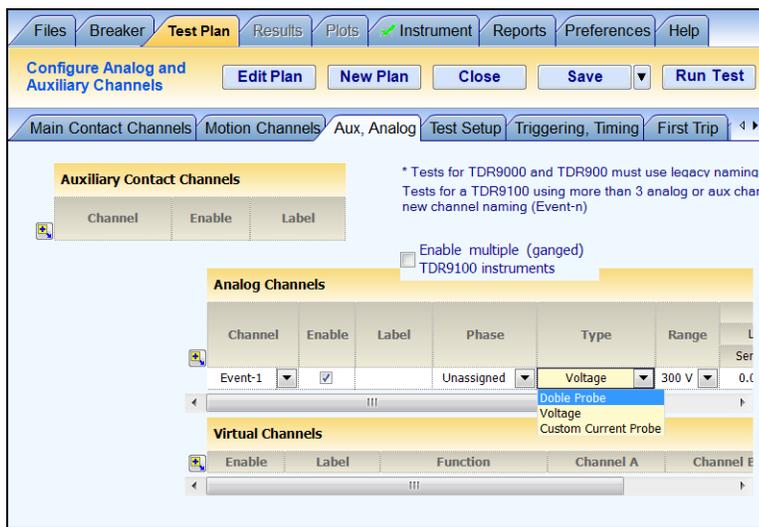


Figure 146 Configuring a Doble Probe

You must zero the Doble current probe whenever a new test plan is loaded or a channel is activated.

NOTE



To conserve battery power, Doble's current probe powers down after ten minutes. To disable this feature, press the *Zero* button while turning the probe on. The green LED flashes several times to indicate the battery saver feature is disabled.

Make sure that the probe is not attached to, or placed near, current-carrying wires during the zeroing process.

To connect and zero the probe:

1. Plug the TDR9100 end of the analog cable into the desired Analog Channel connector. (See 1 on [Figure 11.1 on page 158](#).)

The Analog Channel inputs are polarity sensitive. Be sure to attach the shield (green and yellow) banana plug to the chassis ground (green and yellow) banana jack. (See 11 on [Figure 11.1 on page 158](#).) The banana jacks for multiple shields can be stacked.

2. Plug the free end of the analog cable into the current probe.
3. Turn the probe on: set the selector switch to the desired range.

4. Press the **Zero** button on the probe.
5. Repeat this procedure for any additional probes.
6. Leave the probe on and securely clamp the probe around the wire that carries the current to be monitored.

Current Shunt or Probe

To set up a current shunt or probe:

1. Connect the TDR9100 end of the Doble-supplied analog cable to a pair of Analog Channel banana jacks. (See **1** on [Figure 11.1](#) on page 158.)

The Analog Channel inputs are polarity sensitive.

2. Make sure to attach the shield (green and yellow) banana plug to the chassis ground (green and yellow) banana jack. (See **11** on [Figure 11.1](#) on page 158.)

Multiple shields can be stacked.

3. Use the attachment accessories provided to attach the other end of the cable across the shunt.
4. To configure the current shunt, open the Test Plan page of T-Doble and select the **Aux, Analog** tab.
5. In the Type column, select **Custom Current Probe** ([Figure 147](#)).

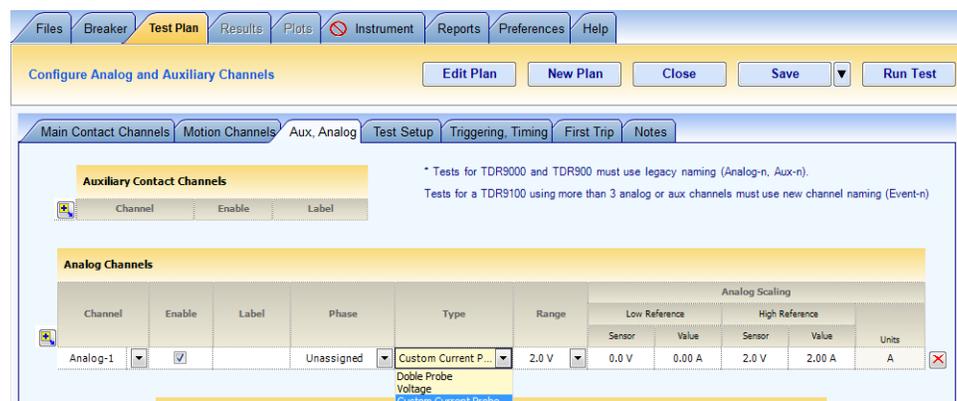


Figure 147 Current Shunt Setting in Analog Channels Table

6. Make all other appropriate settings.

[Figure 147](#) shows the settings for a current shunt with 2 V for 2 A.

Trip/Close Connections

For a description of Trip/Close connections, please see [step 1](#) and [step 2](#) in “[Step 3: Making Circuit Breaker Connections](#)” on page 166.

Motion Connections

To make a transducer connection to a Motion connector:

1. Connect the male end (pin contacts) of the Motion Transducer cable to one of the three Motion connectors. (See **17** in [Figure 11.1 on page 158](#).)
2. Connect the female end of the Motion Transducer cable (socket contacts) to the transducer.

Step 3: Making Circuit Breaker Connections

WARNING!



For greater safety, Doble recommends that you pull the circuit breaker's control power switches, fuses, or both, before you make any connections. After connections are complete, restore the control power.

To make circuit breaker connections:

1. Connect the TDR9100 end of the breaker control cable to the TRIP/CLOSE connector on the TDR9100. (See **12** in [Figure 11.1 on page 158](#).) Connect the other end of the breaker control cable to the circuit breaker.
2. Use one of the following methods of connection:
If the manual trip and close switch connections are accessible, connect the:
 - a. Trip leads across the terminals of the manual Trip switch on the circuit breaker control panel (local connection schemes may vary).
 - b. Close leads across the terminals of the manual Close switch on the circuit breaker control panel (local connection schemes may vary).

If the manual trip or close switch connections are inaccessible:

- a. Connect one of the clips for the Trip/Close cable +DC voltage supply
- b. Connect the other clip to the input side of the respective trip or close coil.

Either method of connection causes the TDR9100 to act as a series switch that applies +DC voltage to the appropriate coil for operation.

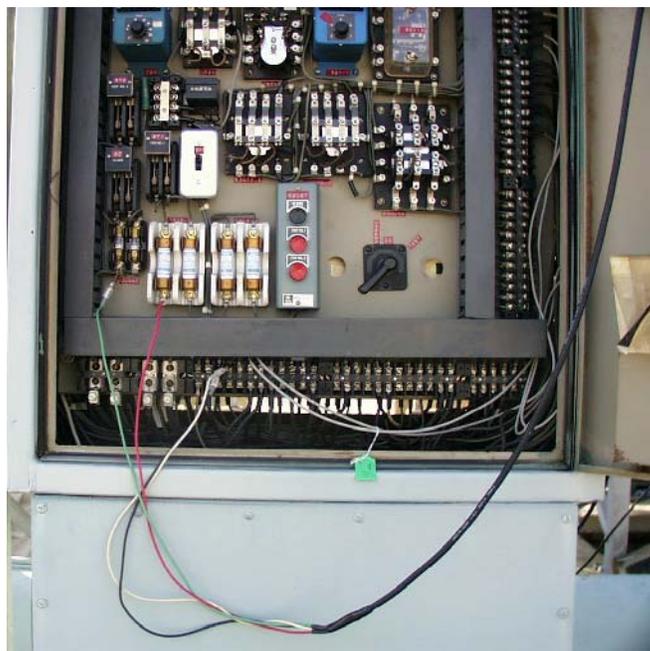


Figure 148 Step 1: Circuit Breaker Control Cabinet Preparation

Main Contact Connections

There are two types of main contact connections:

- [OCB \(Overall\) Circuit Breaker](#)
- [EHV \(Live Tank\) Circuit Breaker](#)

OCB (Overall) Circuit Breaker

To make OCB connections:

1. Connect an OCB main contact test cable to the appropriate circuit breaker terminals as listed in [Table 13 on page 168](#).



It is important to provide good connections between the contact monitoring cables and the terminals. To relieve the clips of cable weight and ensure better contact especially in windy conditions, wrap the cables around the porcelain.

Table 13 OCB Dead Tank Connections

Alligator Clip Color	Phase	Terminal
Red	A	1
Yellow	B	3
Blue	C	5
Black	COM	2, 4, 6

- For safety reasons, ground one side, usually the common side, of the circuit breaker using an appropriate grounding conductor. **This step is required.**

Doble does not supply grounding jumpers for this step.

- Determine the location for the transducer. Note that:
 - It may be necessary to remove covers or panels to access the location.
 - The location must not bind the transducer or mechanism when the circuit breaker is operated.

Figure 149 shows a typical mounting of the rotary/linear transducer.

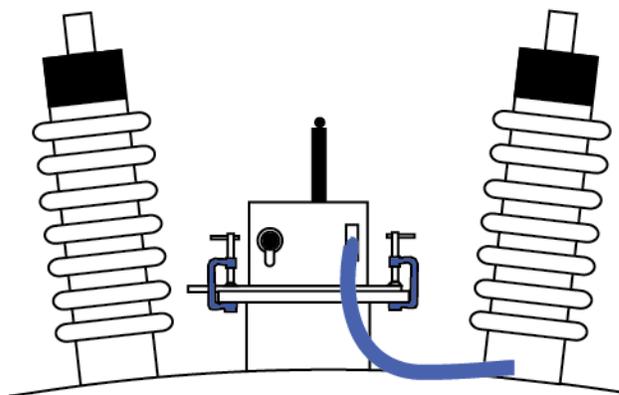


Figure 149 Rotary/Linear Transducer

4. Install a mounting platform for the transducer.

Mounting clamps and platforms are not supplied as standard equipment with the TDR9100. Optional mounting kits are available for specific circuit breaker models. General-purpose mounting adapters and clamps are available from Doble. They facilitate transducer mounting for a wide variety of circuit breaker models.

In some applications, the transducer can also be mounted directly to the circuit breaker tank.

5. Connect the transducer rod or rotary adapter to the circuit breaker mechanism.

A #10 (0.190)-32 UNF-2A threaded rod is supplied as standard equipment with a TR3190 rotary/linear transducer. Other thread sizes are available as optional equipment from Doble.

WARNING!

For dead tank bulk oil circuit breakers: Install and remove the transducer rod while the mechanism is up. If the circuit breaker is activated accidentally, the rod can only move down.

6. Mount the transducer on the tank or platform (installed in [step 4](#)) using clamps or other hardware.

For reasons of safety, and to assure high-quality data, be sure to attach the mounting hardware firmly to the circuit breaker tank or frame, so that it does not move during testing.

If only one transducer is used, it is customary to install it on Tank 2. Doble recommends that tests also be performed with transducers mounted on Tanks 1 and 3.

7. Position the transducer on the mounting platform so the connecting rod is centered in its pathway.

8. Verify that the connecting rod has clearance to move through the entire stroke of the circuit breaker's operation without binding or collision.

9. Rotate the transducer clamping knob until the small moving wheels pinch the connecting rod against the bull wheel.

Figure 150 shows the cable connections for the dead tank test.

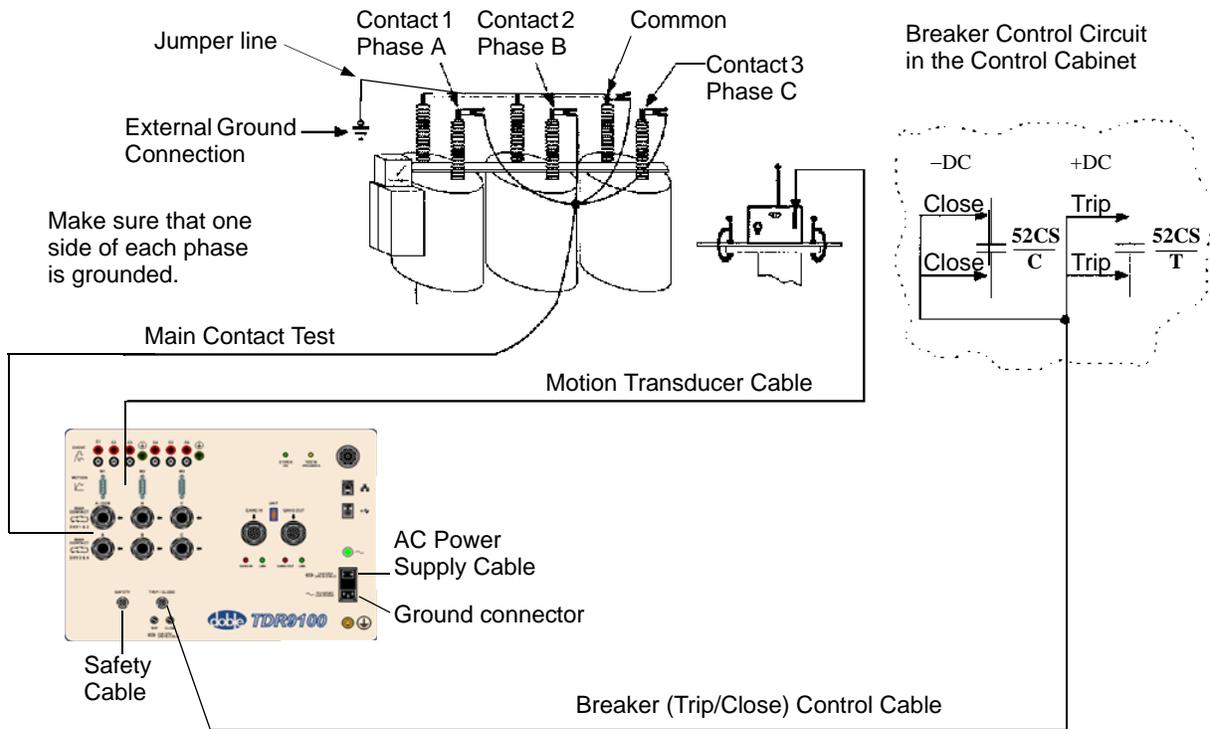


Figure 150 TDR9100 Cable Diagram – Dead Tank

EHV (Live Tank) Circuit Breaker

This section describes two types of EHV connections:

- Main contact
- Motion

Main Contact

In T or Y module circuit breakers, the common (COM) connection is usually made on the center tank of each module. The contact connections (1-4) are made on the appropriate terminals. Doble recommends that one side of the circuit breaker be grounded for safety.

To make EHV connections, connect the EHV main contact test cables to the appropriate circuit breaker terminals as listed in [Table 14 on page 171](#).

NOTE

It is important to provide good connections between the contact monitoring cables and the terminals. To relieve the clips of cable weight and ensure better contact especially in windy conditions, wrap the cables around the porcelain.

Table 14 EHV Connections

Alligator Clip Color	Phase	Contact
Yellow	Red	1
Red	Red	2
Black	Red	COM
Yellow	Red	3
Red	Red	4
Black	Red	COM
Yellow	Yellow	1
Red	Yellow	2
Black	Yellow	COM
Yellow	Yellow	3
Red	Yellow	4
Black	Yellow	COM
Yellow	Blue	1
Red	Blue	2
Black	Blue	COM
Yellow	Blue	3
Red	Blue	4
Black	Blue	COM

Motion

Measuring motion may be difficult for most live tank circuit breakers because of the inaccessibility of the moving components. In many cases, the transducer cannot be attached directly to the moving contact portion of a live tank circuit breaker mechanism.

In such cases, attach the transducer to another part of the mechanism that moves in a secondary relationship to the main drive mechanism being measured through transducer scaling. Often, this mounting location is found near the semaphore, which indicates the status of the circuit breaker.

For a full discussion of:

- Transducer transducer scaling—See “[Transducer Scaling](#)” on page 104.
- Transducer configuration—See “[Configuring the TR3190 Digital Rotary/Linear Transducer](#)” on page 174.

Figure 151 shows the cable interconnections for the live tank test.

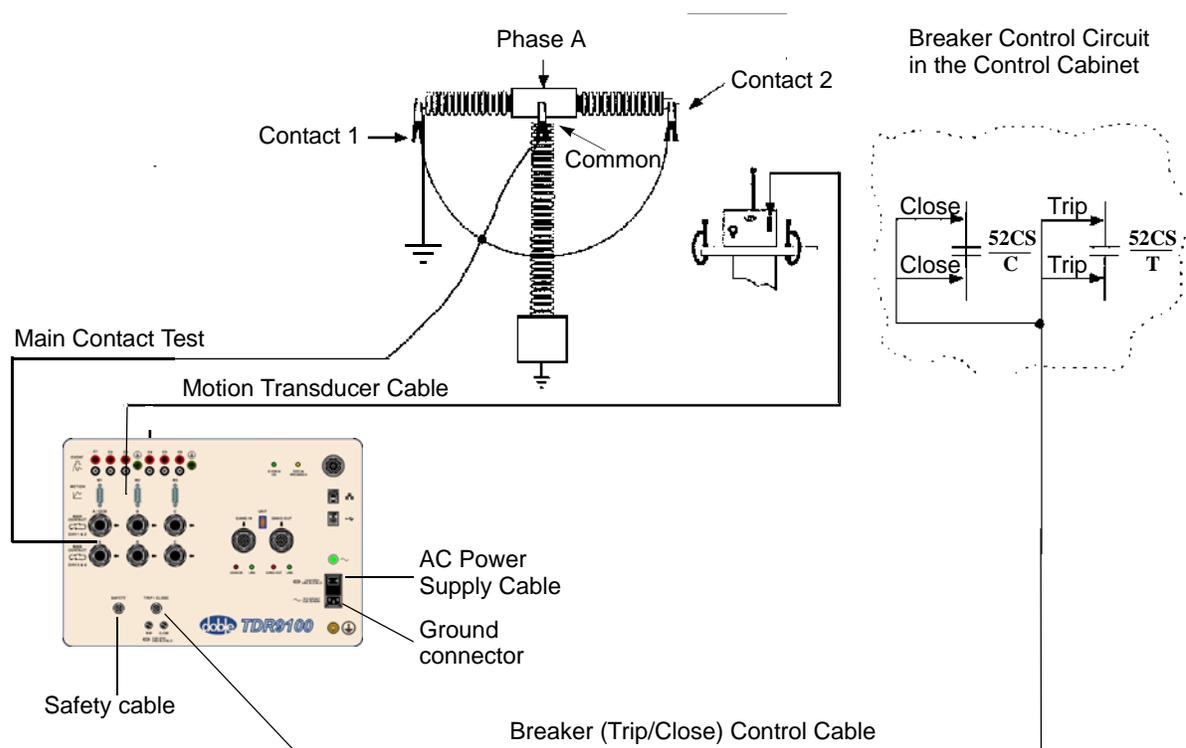


Figure 151 TDR9100 Cable Diagram – Live Tank

Figure 152 shows an installation with live tank circuit breaker contact monitor cabling in place.

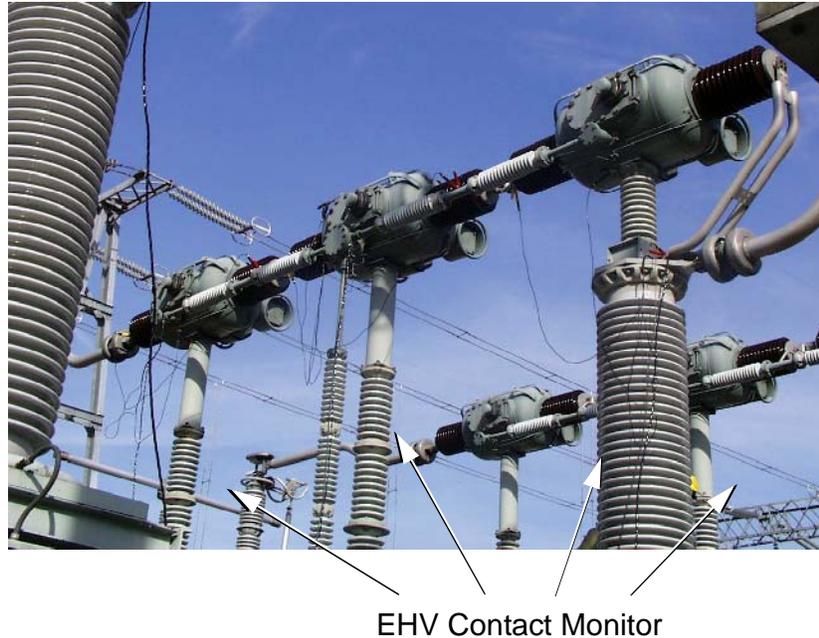


Figure 152 Installation with Circuit Breaker Contact Monitor Cabling

Event Connections

This section explains how to make connections from the analog or auxiliary contact channels of the TDR9100.

Analog

For analog connections, use the attachment accessories provided to attach the other end of the analog cable across the device to be monitored, either directly across the device or at the terminal block.

Generally, voltage measurements are made from the high side of the load to the neutral rail.

Aux

For auxiliary connections, use the attachment accessories provided to attach one end of the Doble-supplied auxiliary contact cable across the device to be monitored, either directly across the device or at the terminal block.

System Control Connections

Two kinds of control connections are made from the TDR9100:

- External Trigger (In)
- Trip/Close (Out)

External Trigger Setup

To make External Trigger connections with an auxiliary or analog channel, use the attachment accessories provided to attach the auxiliary or analog contact cable across the device to be monitored, either directly across the device or at the terminal block.

Trip/Close

To make Trip/Close connections from the TDR9100:

1. Connect the free end of the breaker control cable to the circuit breaker.
2. Connect the:
 - a. Trip leads across the terminals of the manual Trip switch on the circuit breaker control panel.
 - b. Close leads across the terminals of the manual Close switch on the circuit breaker control panel (local connection schemes may vary).

Motion Connections

	<p>WARNING! When using a linear rod, make sure that the circuit breaker is in a safe position before beginning transducer installation. A safe position exists when an accidental circuit breaker operation draws the rod <i>away from</i>, not toward, the person performing the installation. This is usually the closed position.</p>
---	---

Configuring the TR3190 Digital Rotary/Linear Transducer

The TR3190 Digital Rotary/Linear Transducer is used to measure rotary or linear motion. The setup for each measurement follows.

Figure 153 shows the three components of the TR3190 (TR3160LR). They include:

- Transducer
- Chuck holder plate
- Rotary chuck

The chuck holder plate is mounted in different locations, depending on whether a rotary or linear measurement is intended.

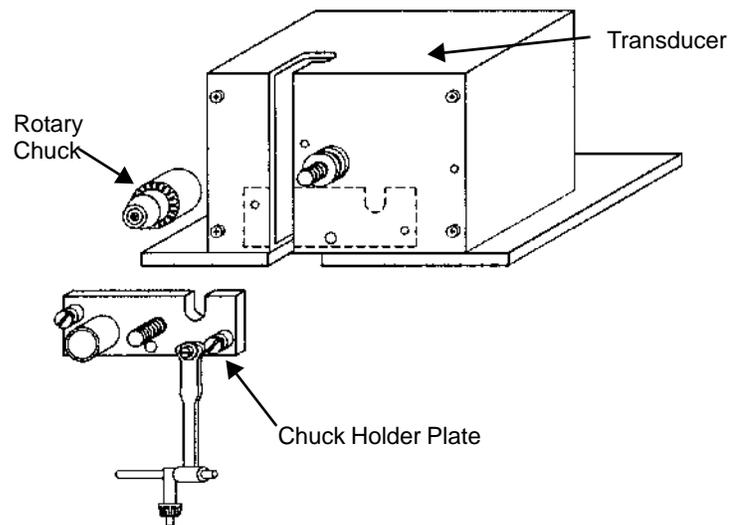


Figure 153 TR3190 (TR3160LR) Transducer Components

The chuck holder plate is shipped in the configuration shown in Figure 154 on page 175.

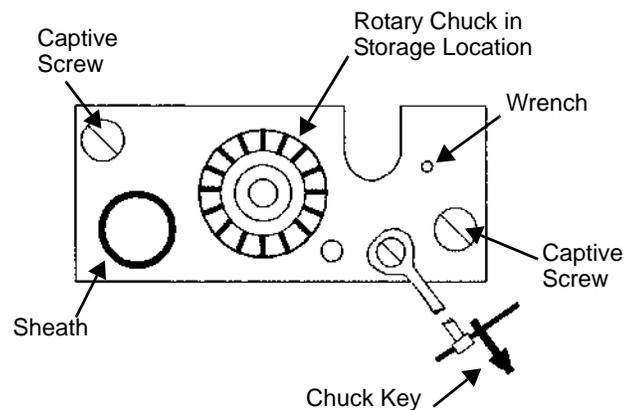


Figure 154 Chuck Holder Plate Configuration

This plate provides four different functions:

- When mounted in the ROTARY position:
 - It depresses a micro-switch that indicates to the TDR9100 that a rotary measurement is being performed.
 - It covers the gate area, which serves as a reminder that it must be moved to the LINEAR position prior to inserting the travel rod to perform a linear measurement.
- It includes a metal sheath that covers the rotary shaft to ensure that the threads do not come in contact with any foreign objects that could cause thread damage during storage or operation.
- It has a cutout that is used as a wrench to hold the rotary shaft, while the rotary chuck is loosened or tightened.
- It provides a storage location for the rotary chuck when a linear measurement is made.

Rotary Motion

To configure for rotary motion:

1. Remove the rotary chuck from its storage location on the chuck holder plate by rotating it counterclockwise.
For added torque, insert the chuck key into the rotary chuck.
2. Remove the chuck holder plate from the transducer by loosening the two captive screws.
3. Position the wrench portion of the chuck holder plate on the rotary shaft. (See [Figure 155](#).)

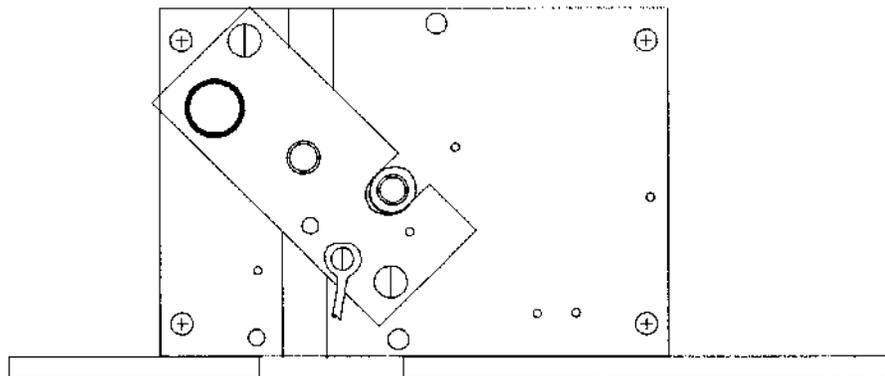


Figure 155 Chuck Holder Plate Mounting to Tighten Rotary Chuck

4. Thread the rotary chuck onto the rotary shaft and hand tighten, using the chuck holder plate to keep the rotary shaft from moving.
5. Insert the chuck key into the rotary chuck.
6. Hold the chuck holder plate against the transducer. Using the chuck key to provide additional torque, rotate the chuck clockwise to tighten it onto the rotary shaft.
7. Remove the chuck key from the rotary chuck.
8. Remove the chuck holder plate from the rotary shaft and use the two captive screws to secure it in the ROTARY position on the transducer ([Figure 156 on page 177](#)).

Configuration is complete.

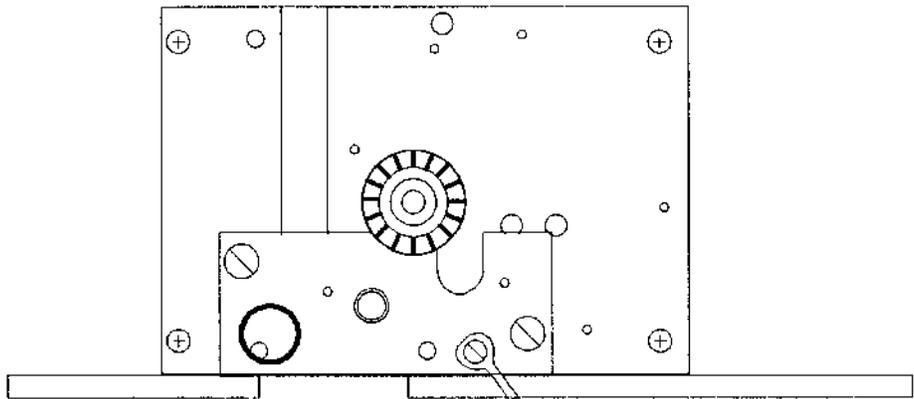


Figure 156 Chuck Holder Plate mounted in ROTARY position

Linear Motion

To configure for linear motion:

1. Remove the chuck holder plate from the transducer by loosening the two captive screws.
2. If the rotary chuck is:
 - Mounted to the rotary shaft—Go to [step 3](#).
 - Otherwise—Go to [step 6](#).
3. Position the wrench portion of the chuck holder plate on the rotary shaft. (See [Figure 157 on page 178](#).)
4. Rotate the rotary chuck counterclockwise and remove it from the rotary shaft. If necessary, use the chuck key to provide additional torque as described in [step 6 on page 177](#).

5. as shown in [Figure 154](#) Store the rotary chuck on the chuck holder plate as shown in [Figure 154 on page 175](#).

NOTE



If the rotary chuck is mounted on the rotary shaft during a linear measurement, the added mass of the chuck can induce internal slippage to the transducer causing measurement error.

6. Mount the chuck holder plate in the LINEAR position on the transducer using the two captive screws to secure it. See [Figure 157](#).

Configuration is complete.

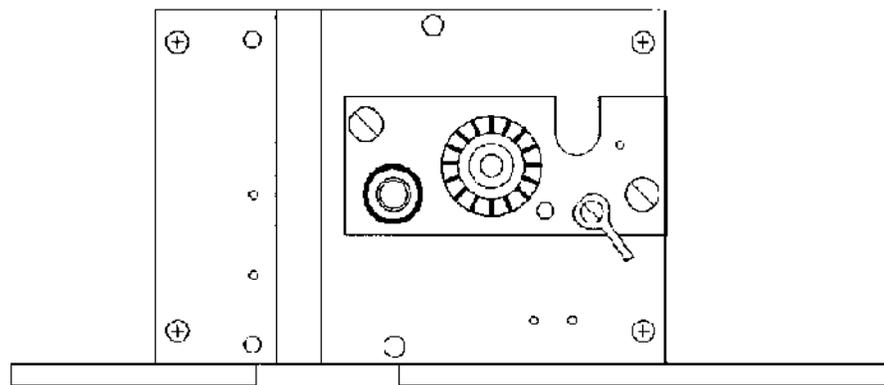


Figure 157 Chuck Holder Plate Mounted in LINEAR Position

Step 4: Creating a Test Plan

For instructions, go to [Chapter 6, “Setting Up Tests.”](#) Continue on [“Step 5: Removing Safety Grounds” on page 178.](#)

Step 5: Removing Safety Grounds

Before you can run the test, you must decide which ground connections to remove from one side of the circuit breaker. Usually, it does not matter which side, but two situations require special consideration:

- [“Neutral-grounded Transformers” on page 179](#)
- [“High Voltages” on page 179](#)

Neutral-grounded Transformers

If there is no disconnect switch between a neutral-grounded transformer and the circuit breaker:

- Remove the ground connections from the side of the circuit breaker that is farther from the transformer.
- Leave in place the ground connections between the transformer and the circuit breaker ([Figure 158](#)).

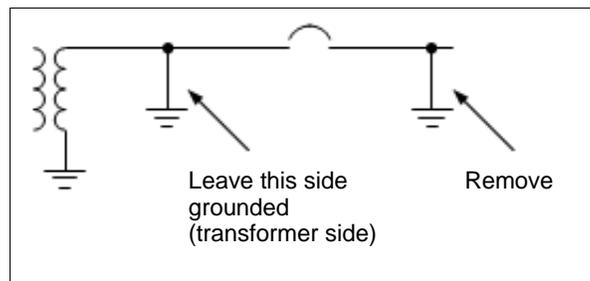


Figure 158 Neutral-Grounded Transformer and Ground Connections

High Voltages

When an energized high voltage conductor is near the circuit breaker, an induced voltage can occur on the isolated sections of bus connected to either side of the circuit breaker. To minimize the danger, leave the grounds on the side of the breaker that:

- Has the longest section of bus, or
- Is closest to the energized circuit

See [Figure 159](#) for details.

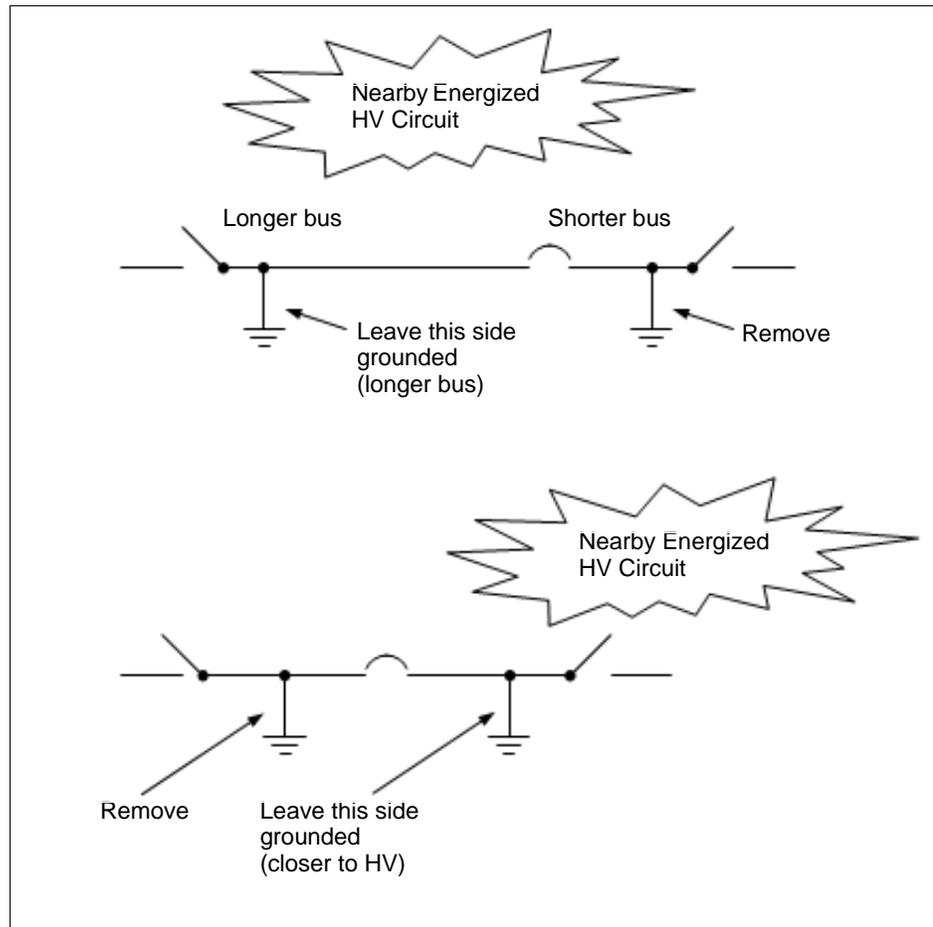


Figure 159 High Voltages and Ground Connections

Step 6: Applying Power

To apply power before running the test:

1. Restore DC power to the circuit breaker Trip and Close circuits.
2. Apply AC power to the TDR9100.
3. Wait about two minutes. Then confirm that:
 - The System On LED is illuminated (item 2 on [page 158](#))
 - The correct unit number is displayed (item 7 on [page 158](#))
 - The Link LEDs should be flashing (item 7 on [page 158](#))
 - The green AC power indicator is illuminated (item 8 on [page 158](#))

Step 7: Running the Test

Safely Activating a Test

The TDR9100 provides two ways of activating a test:

- Safety Switch—*For the greatest possible safety*, connect the safety switch cable, stretch it to a full 25 ft (7.6 m) from the circuit breaker, make sure all team members are far from the circuit breaker, and press the safety switch to activate the test.
- T-Doble—With the Safety Bypass Flag installed, select **OK** in the T-Doble user interface.

NOTE

If the Safety Switch is not pressed within 60 s, the test is aborted and the following message appears.



Figure 160 Test Aborted—Slow Switch Press

If the Safety Switch is released before the alarm ceases, the test is aborted and the following message appears.



Figure 161 Test Aborted—Premature Switch Release

Procedure

To run a test:

1. Click the **Run Test** button.

The Select Test window appears.



Figure 162 Select Test Window

2. Select the test of interest.

The TDR9100 begins to beep, indicating that it is ready to begin testing.



WARNING! This is the last warning before circuit breaker operation. Make sure all safety issues are in compliance.

3. Activate the test.

The test begins and the Test Progress window appears.



Figure 163 Test Progress Window

Data collection times vary depending on the types and number of channels in use. This process can take several minutes.

When the test finishes, T-Doble displays the results on the Plots tab, except for the results of the Capacitance test. Capacitance results are displayed on the Results tab. For more information, see [Chapter 9, “Displaying and Interpreting Test Results.”](#)

Step 8: Disconnecting After Testing is Complete

1. Turn the power switch of the TDR9100 to **OFF**.
2. Disable the circuit breaker power by pulling the DC power switches, fuses, or both.
3. Replace all safety grounds that were removed to perform tests.

WARNING!

- **Be sure to replace all safety grounds before proceeding.**
- **Make sure that appropriate service disconnects are secured.**
- **Follow all safety procedures.**
- **Disconnect the cables from the circuit breaker first and the TDR9100 second.**

4. Remove the main contact test cables from the circuit breaker.
Do not pull the cables. Remove the cables at the connection.
5. Remove all additional test leads from the circuit breaker.
6. Remove safety grounds from the circuit breaker. If OCB testing was performed, remove common-side jumpers.
7. Unplug the following cables from the TDR9100:
 - a. Contact Monitor
 - b. Motion Transducer
 - c. Breaker Control
 - d. Remote Safety Switch
8. Unplug the AC power cord from the power receptacle.
9. Unplug the AC power cord from the TDR9100.
10. Remove the System Safety Ground from the TDR9100.
11. Unlock and remove the tags from the isolating disconnects.

- 12.** Remove the ground cable from the connection to the ground grid.
- 13.** Restore the circuit breaker to service.

9. Displaying and Interpreting Test Results

This chapter explains how to select and print tabulated data, and how to display and interpret graphic displays of data. It contains the following sections:

- [“Displaying Results” on page 186](#)
- [“Viewing Tabular Results” on page 186](#)
- [“Viewing Graphical Results” on page 189](#)
- [“Saving Test Results” on page 202](#)
- [“Trip Test Results” on page 202](#)
- [“Close Test Results” on page 206](#)
- [“Reclosing Test Results” on page 209](#)
- [“TripFree Test Results” on page 212](#)
- [“O-C-O Test Results” on page 215](#)
- [“Creating Reports” on page 218](#)

Editing the Nameplate

After a test is run and saved, new fields are added to the Nameplate tab. You can optionally add new information in these fields:

- Serial Number—Test instrument serial number
- Calibration—calibration date
- Ambient temperature at time of test
- Humidity at time of test

Figure 164 Nameplate With Additional Fields

Displaying Results

Once a test is run, the Results and Plots pages become active (Figure 165).

- Using the Results page, you can view data in tabular form.
- On the Plots page, you can view one test result at a time, or you can overlay test results of a similar type and view them together.

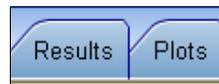


Figure 165 Navigation Tabs Available After a Test

Viewing Tabular Results

The Results page provides the test results in numeric form, and it indicates whether the result was within the manufacturer's specifications. Result data is provided on these tabs:

- Main Contacts
- Resistor Contacts

- Motion
- Motion at Main Open/Close
- Motion at Resistor Open/Close
- Advanced
- First Trip
- Capacitances
- Notes



Figure 166 Results Page

Figure 167 displays sample results from the Main Contacts tab. It provides this information:

- Measured values (Main Contact Timing, Synchronization)
- Manufacturer’s limits (Main Contact Timing, Synchronization)
- Pass  or Warning  status

Main Contact Timing Measurements						
Timing Reference: From Test Initiation			Close Timing			
Channel ID	Label	Phase	Contact Timing	Synchronization		
				In Breaker		
OCB-A	CONTACT1	Phase A	5.00 cy 			
OCB-B	CONTACT2	Phase B	4.99 cy 	0.04 cy		
OCB-C	CONTACT3	Phase C	4.96 cy 			
			Close Limits			
			Maximum	6.00 cy	0.20 cy	
			Minimum	0.00 cy		

Figure 167 Sample Main Contacts Data

Figure 168 displays sample results from the Motion Measurements tab. It provides this information:

- Measured values (Zone Average Velocity, Travel)
- Manufacturer’s limits (Zone Average Velocity, Travel)

Motion Measurements								
Channel and Phase	Zone Type	Zone Velocities		Travel				
		Close		Total Travel	Overtravel	Rebound	Contact Wipe	
		Close Zone 1	Close Zone 2					
Motion-1 (TRAVEL 2) Phase B	Measured	Dist; Dist	Dist; Dist	199.5 mm 	0.2 mm	0.1 mm	16.8 mm	
	Limits	Max	4,500 m/s	*	240.0 mm	*	*	*
		Min	3,700 m/s	*	160.0 mm	*	*	*

Figure 168 Sample Motion Measurements Data

Figure 169 displays sample results from the Motion at Main Open/Close tabs. It provides measured values (Travel, Average Velocity, and Time).

Motion Measurements, Main Contacts Open/Close						
Channel	Label	Phase	At Main Contact Open			Motion Reference Channel
			Travel from Start Position (Contact Wipe)	Average Velocity*	Time from Initiation**	
OCB-A	OCB-A	Phase A	19.0 mm	3.704 m/s	22.8 ms	LINKAGE
OCB-B	OCB-B	Phase B	21.0 mm	4.233 m/s	22.8 ms	MECHANISM
OCB-C	OCB-C	Phase C	19.0 mm	3.704 m/s	22.8 ms	LINKAGE

* Velocity is averaged over a range of 9 samples centered on the event.
 ** Measured relative to the time of test triggering

Figure 169 Sample Motion at Main Open/Close Data

Viewing Graphical Results

The Plots page enables you to display graphical results in a variety of ways.



Figure 170 Results Tab of Plots Page

Setting Plotting Preferences

The Plotting tab of the Preferences window controls the appearance of plots.

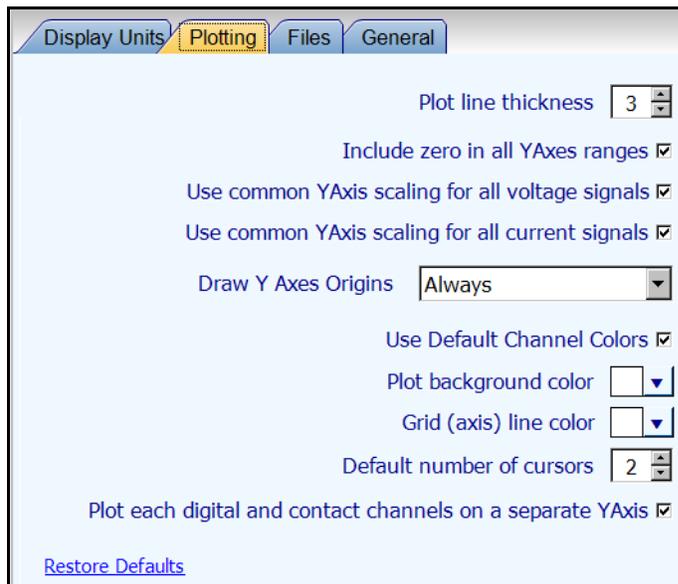


Figure 171 Plotting Tab of Preferences Page

Table 15 describes the plotting values you can set.

Table 15 Plotting Preferences

Setting	Description	Default Setting
Plot line thickness	1 (thin) to 5 (thick)	3
Include zero in all Y axes ranges	Select or deselect.	Selected
Use common Y axis scaling for all voltage signals	Select or deselect.	Selected
Use common Y axis scaling for all current signals	Select or deselect.	Selected
Draw Y Axes Origins	Options are Never , Always , or When span overlaps zero .	Never

Table 15 Plotting Preferences (Continued)

Setting	Description	Default Setting
Use Default Channel Colors	Select or deselect. Sets channel colors as follows: <ul style="list-style-type: none"> • Phase A—Red • Phase B—Yellow • Phase C—Blue 	Selected
Plot background color	Select a color for the background of the graph.	
Grid (axis) line color	Select a color for the gridlines of the graph.	
Default number of cursors	Select the number of cursors to appear automatically on the graph. Range is from 1 to 8.	2
Plot each digital and contact channel on a separate Y axis	Select or deselect	Deselected
Restore Defaults link	Click to restore system default plotting values.	N/A

Using the Plots Toolbar

The icons at the top of the Test Results and Overlay tabs enable you to view and manipulate your data in various ways.

**Figure 172 Toolbar on Plots Page**

One other display control exists on this page, but it is not in the tool bar. To change the displayed unit of measurement on the X axis, select **millisecond (ms)** or **Cycle (cy)** from the drop-down box at the bottom right of the window.



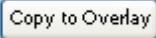
Figure 173 Selection Box for Unit of Measurement

Table 16 explains the purpose of each icon.

Table 16 Icons Used to Set Plotting Preferences

Icon	Description
	Unzoom and restore all traces. Displays graph as it appeared originally after the test was run.
	Unzoom all visible traces. If you have deleted some traces and added others, unzooms and displays only those selected traces.
	Zoom in.
	Zoom out.
	Show data cursors.
	Move cursors into view.
	Show or hide cursor readouts.
	Copy plot image or data to clipboard.
	Save image of plot to file in selected format.
	Print plot.
	Set up page for printing.
	Print preview.

Table 16 Icons Used to Set Plotting Preferences (Continued)

Icon	Description
 Legend	Show or hide signal legend.
	Copy the current data to the overlay plot.

Zooming In and Out

To enlarge a portion of the traces:

1. Click and hold any corner of the trace area to be enlarged, drag the mouse to the diagonally opposite corner of the trace, and release the mouse button.

The window displays the selected area, enlarged.

2. To zoom out, click the **Unzoom and restore all traces** button, or the **Unzoom all visible traces** button.

Activating and Moving Cursors

T-Doble provides cursors, or vertical markers, to determine either the value of a trace or the time elapsed at one or more locations on the plots. Note that:

- By precisely positioning cursors, you can view trace times and values and compare them to manufacturer specifications.
- If two cursors appear, the times and trace values at each cursor location appear. You can display or hide the delta value, which is the difference in the measured results for the two cursor locations. An example of a delta value is the left cursor value minus the right cursor value.

2. If you cannot see the cursors, click the **Move cursors into view** button .
3. Click the **Show Delta Values** link to display the delta values.
If two -- and only two -- cursors are active, a Delta values column appears in the table. It does not appear for one cursor, nor does it appear for three or more cursors.
4. Reposition a cursor by dragging it with the mouse or by using the keyboard arrow keys to make precision moves. (See [Table 17.](#))

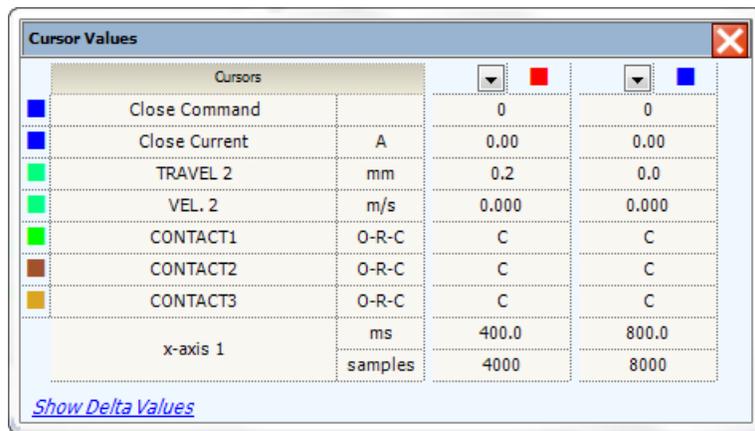
Table 17 Precision Cursor Movement

Key	Cursor Direction
Left arrow	Moves 1 sample left.
Right arrow	Moves 1 sample right.

5. To remove the cursors, click the **Show Data Cursors** button  again.

Reading the Cursor Values Table

The Cursor Values table ([Figure 176](#)) provides readouts for all active cursors.



Cursors			
Close Command		0	0
Close Current	A	0.00	0.00
TRAVEL 2	mm	0.2	0.0
VEL. 2	m/s	0.000	0.000
CONTACT1	O-R-C	C	C
CONTACT2	O-R-C	C	C
CONTACT3	O-R-C	C	C
x-axis 1	ms	400.0	800.0
	samples	4000	8000

[Show Delta Values](#)

Figure 176 Cursor Values Table

Contact Timing

NOTE



The compound states described for R and O-R-C may be the result of contact bounce during circuit breaker operation.

- **O**—Indicates the contact was open at the time selected.
- **C**—Indicates the contact was closed at the time selected.
- **R**—Indicates the contact was in Resistor state at the time selected.
- **O-C**—Indicates the contact was in a state of change at the time shown, and the selected sample time contained instances of the circuit breaker in the Open and Closed states.
- **C-O**—Indicates the contact was in a state of change at the time shown, and the selected sample time contained instances of the circuit breaker in the Closed and Open states.
- **O-R-C**—Indicates the contact was in a state of change at the time shown, and the selected sample time contained instances of the circuit breaker in the Open, Resistor, and Closed states.
- **R-C**—Indicates the contact was in a state of change at the time shown, and the selected sample time contained instances of the circuit breaker in the Resistor and Closed states.
- **O-R**—Indicates the contact was in a state of change at the time indicated, and the selected sample time contained instances of the circuit breaker in the Open and Resistor states.

Trip and Close

All trip and close current values are positive.

Auxiliary Channels

The following auxiliary and analog contact values appear:

- **C**—Contact was closed at the time selected.
- **O**—Contact was open at the time selected.
- **D**—Contact was open dry at the time selected. Voltage is not present.
- **W**—Contact was open wet at the time selected. Voltage is present.

All current and voltage values are displayed as follows:

- DC—All values are positive.
- AC—All values are bipolar.

Advanced Cursor Functions

The Cursor Values Table provides additional cursor functions (Figure 177).

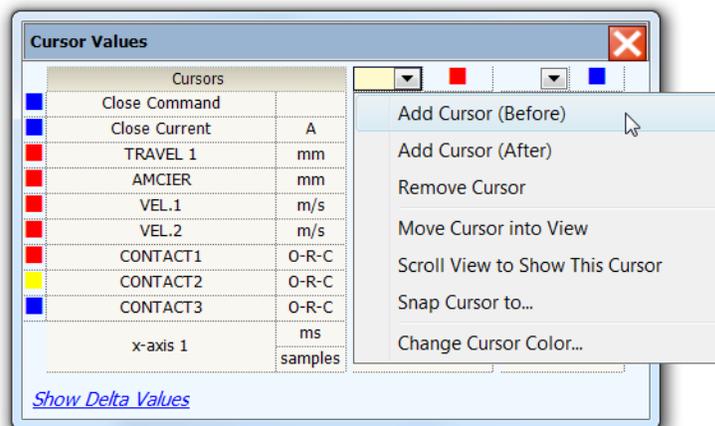


Figure 177 Advanced Cursor Functions Provided in Cursor Values Table

For each cursor, a pull-down menu provides the following functions:

- Add Cursor (Before) – activate another single cursor in a position before this cursor in the timeline
- Add Cursor (After) – activate another single cursor in a position after this cursor in the timeline
- Remove Cursor – removes this cursor from the plot display
- Move Cursor into View – if this cursor is out of view due to zooming, move it into the current view
- Scroll View to Show This Cursor – if this cursor is out of view due to zooming, scroll the plot display to the cursor location
- Snap Cursor to... - move the cursor precisely to a particular place in a specified signal plot defined by one of the following:
 - A zero crossing
 - A threshold (voltage or current)
 - A transition (contact state)

- Next minimum
- Next maximum
- Change Cursor Color – allows user to select a different color for the this cursor line

Viewing Trace Information

Basic trace display properties are set in the Preferences page. (See “Setting Plotting Preferences” on page 190.) To view trace information:

1. Click the **Legend** button  Legend.

The Plot Legend window appears (Figure 178).

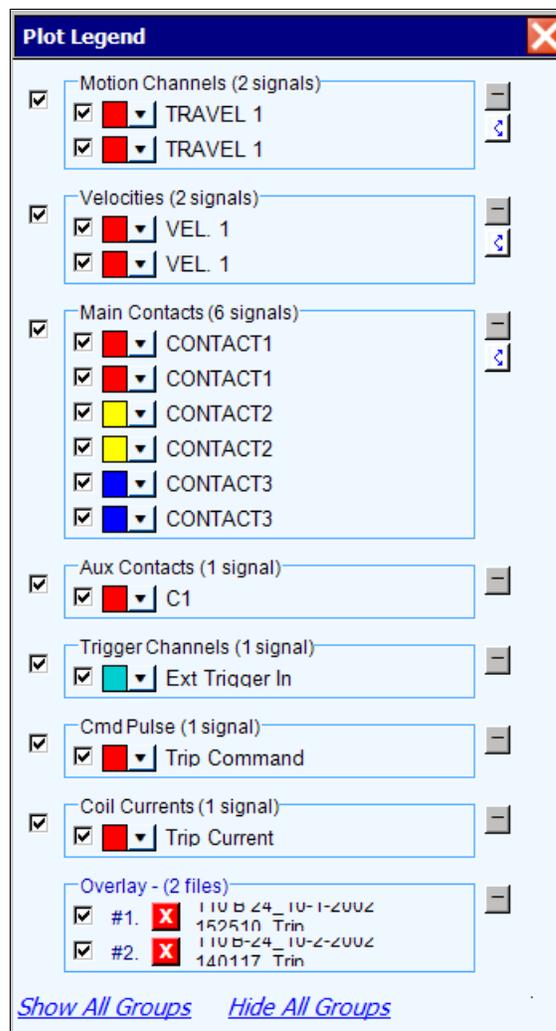


Figure 178 Plot Legend Window for Two Overlaid Signals

Displaying and Hiding Traces

In the Plot Legend window, you can display and hide traces in the following ways:

- To display the legend for all traces in a group—Click the plus sign  to the right of the group. To hide the legend for all traces in a group, click the minus sign .
- To hide a trace or group of traces, uncheck the box next to its name in the legend. To show a trace or group of traces, check the box next to its name in the legend.
- To hide an overlaid set of traces—Deselect the check mark to the left of the filename in the Overlay section of the Plot Legend window. See [Figure 178](#).
- To remove an overlaid set of traces—Click the red or white X to the left of the filename in the Overlay section of the Plot Legend window. See [Figure 178](#).
- To hide all traces—Click **Hide All Groups**.
- To show all traces—Click **Show All Groups**.

Reordering Trace Information

In the Plot Legend window, you can reorder trace information in these ways:

- Split trace information—Click the Separate Traces button  next to a set of traces in the legend. Each trace is now displayed in its own section in both the Plot Legend window and the plot.
- Combine traces—Click and hold the mouse in a section of an individual trace legend, drag it over the legend you wish to combine with, and release. The two signals are combined into one in both the Plot Legend window and the plot.
- Move traces up and down—Click and hold the mouse in a section of the individual trace legend, drag it to the desired location in the Plot Legend window, and release. The traces on the graph and legend move accordingly.

Changing Trace Colors

To set colors for each trace, click the arrow to the left of the trace name and select a color.

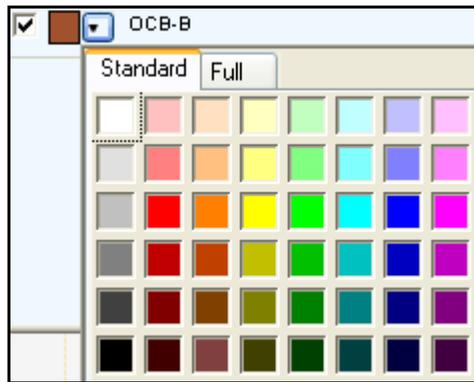


Figure 179 Selecting a Trace Color

Overlaying Plots

To overlay test results:

1. Display one set of test results.
2. Click the **Copy to Overlay** button in the toolbar.
3. Click the **Overlay** tab.
4. Click the **Files** tab and select the set of test results you wish to overlay.
5. Click the **Overlay** button.

The two sets of test results are displayed on the Overlaid tab. [Figure 180](#) shows an example. You can add more overlays by following the same steps.

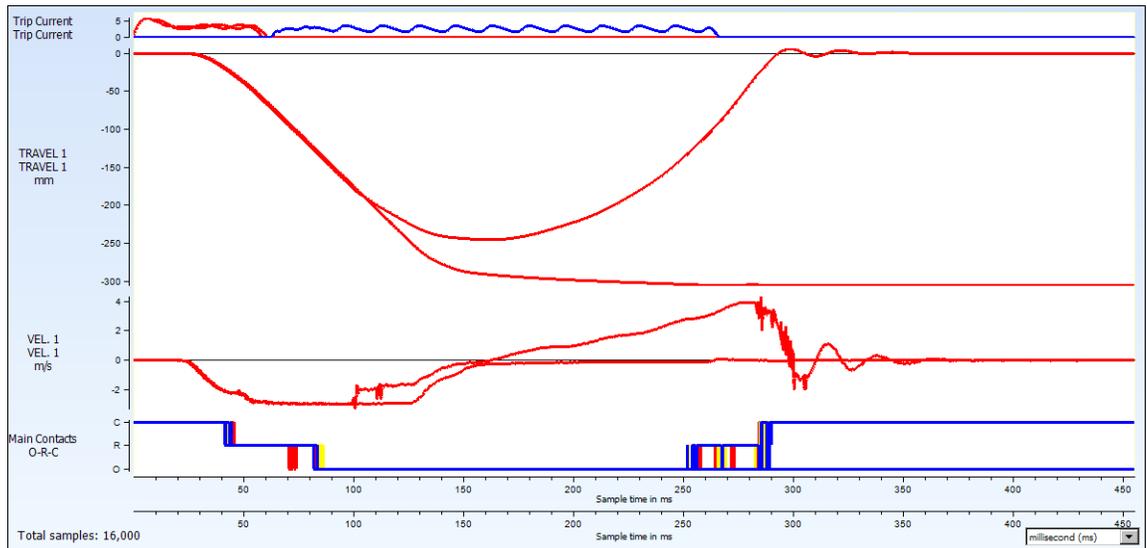


Figure 180 Overlaid Test Results

Editing Breaker Specifications

You may wish to make comparisons by changing breaker specifications. To do this, go to the Breaker page and edit the specifications as necessary. T-Doble instantly compares your data to the breaker specifications and displays a Pass or Warning value in the test results. The original test plan and test results files remain intact.

If you wish to save these altered results, do one of the following:

- Save all data—Click the **Save** icon , select **Save As**, edit the filename and directory as desired, and select **OK**. All data is saved in the TDRX file format.
- Save a graphic image—On the Plots tab, click the **Save** icon , select a graphics file format and a directory, and click **Save**.
- Copy the data—On the Plots tab, click the **Copy** icon  and select:
 - **Copy Picture** to paste the graph into another document
 - **Copy Data** to paste the data in tab-delimited format into another document

Saving Test Results

You can save test results automatically or manually.

- Automatically—On the Files tab of the Preferences page, make sure that **Automatically save file after every test** is selected. This option stores new test results as soon as the test is run.

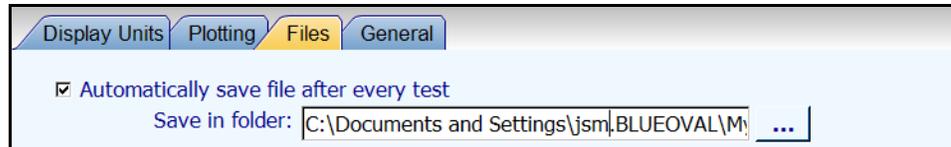


Figure 181 Automatically Saving Test Results

Doble recommends that you keep this option selected at all times.

- Manually—Do one of the following:
 - Click the **Save** or **Save As** button, as appropriate, in the Results or Plots page.
 - In the Plots page only, click the **Save** icon , select a graphics file format and a directory, and click **Save**.

Trip Test Results

This section provides a complete set of sample results for a Trip test.

Plotted Results

Location: Test Results tab of Plots page

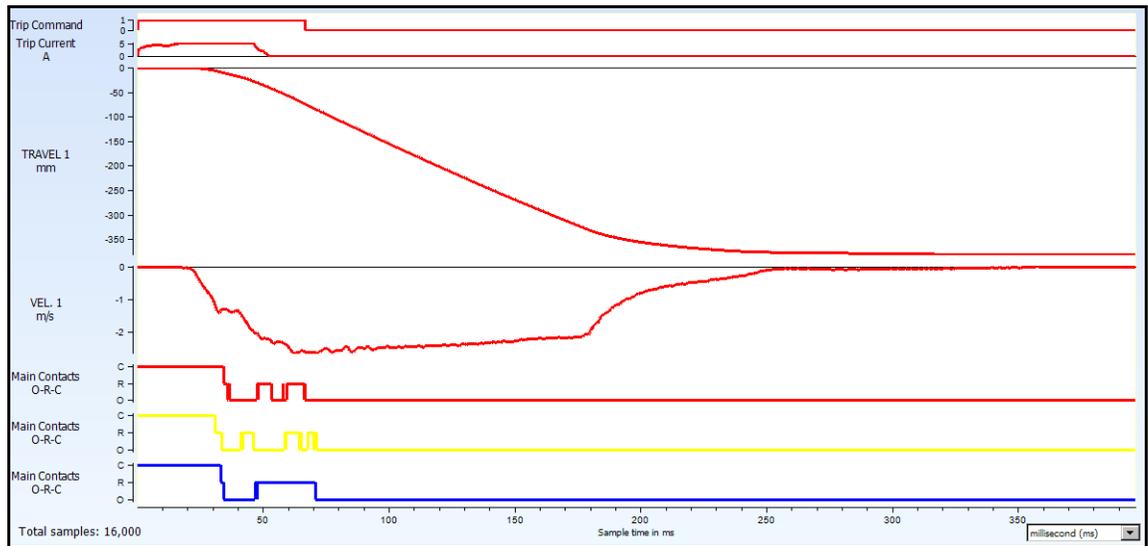


Figure 182 Plotted Results of Trip Test

Main Contact Data

Location: Main Contacts tab of Results page

The Main Contact Timing Measurements table presents the following data:

- Measured values (Main Contact Opening Time, Synchronization)
- Manufacturer’s limits (Main Contact Opening Time, Synchronization)
- Pass  or Warning  status

Main Contact Timing Measurements						
Timing Reference: From Test Initiation			Main Contact Timing			
Channel ID	Label	Phase	Opening Time	Synchronization		
				In Breaker		
OCB-A	CONTACT1	Phase A	24.3 ms		0.5 ms	
OCB-B	CONTACT2	Phase B	24.6 ms			
OCB-C	CONTACT3	Phase C	24.8 ms			
			Trip Limits			
			Maximum	28.0 ms	2.0 ms	
			Minimum	1.0 ms		

Figure 183 Main Contact Timing Data of Trip Test

Resistor Data

Location: Resistor Contacts tab of Results page

The Resistor Contact Timing Measurements table presents this data:

- Measured values
 - Resistor Open Timing and Synchronization from Test Initiation
 - Resistor Open Timing and Synchronization Relative to Main Contact)
- Manufacturer’s limits (Resistor Opening Time)
- Pass  or Warning  status

Resistor Contact Timing Measurements									
Channel ID	Label	Phase	Resistance	Resistor Close Timing From Test Initiation			Resistor Close Timing Relative to Main Contact		
				Closing Time	Synchronization In Breaker		Closing Time	Synchronization In Breaker	
OCB-A	CONTACT1	Phase A	447.0 Ω	55.1 ms	1.0 ms		11.7 ms		0.2 ms 
OCB-B	CONTACT2	Phase B	445.0 Ω	54.1 ms	1.0 ms		11.9 ms		
OCB-C	CONTACT3	Phase C	441.0 Ω	54.7 ms	1.0 ms		11.7 ms		
				Close Limits			Close Limits		
			Maximum	*	*	*	15.0 ms	5.0 ms	
			Minimum	*	*	*	8.0 ms		

Figure 184 Resistor Contact Timing Data for Close Test

Motion Data

Location: Motion tab of Results page

The Motion Measurements table presents this data:

- Measured values (Zone Average Velocity, Travel)
- Manufacturer’s limits (Zone Average Velocity, Travel)
- Damping (Trip Test only)
- Pass  or Warning  status

Motion Measurements												
Channel and Phase	Zone Type	Zone Velocities				Travel						
		Open		Open		Total Travel	Overtravel	Rebound	Damping			
		Open Zone 1	Open Zone 2	Open Zone 1	Open Zone 2							
Motion-1 (TRAVEL 1)	Measured	11.89 f/s		*	*	15.126 in		0.000 in		0.000 in		371.9 ms
	Limits	Max	12.00 f/s	*	*	15.500 in	0.125 in	0.625 in				
Phase A	Min	11.00 f/s	*	*	*	14.500 in	0.000 in	0.000 in				

Figure 185 Motion Data for Trip Test

Motion at Main Open/Close Data

Location: Motion at Main Open/Close tab of Results page

The Motion Measurements, Main Contacts Open/Close table provides these measured values:

- Travel from start position until main contact part (main contact wipe)
- Velocity averaged over a range of 9 samples centered at main contact part
- Time from initiation until main contact part

Motion Measurements, Main Contacts Open/Close						
Channel	Label	Phase	At Main Contact Open			Motion Reference Channel
			Travel from Start Position (Contact Wipe)	Average Velocity*	Time from Initiation**	
OCB-A	CONTACT1	Phase A	36.4 mm	4.410 m/s	26.6 ms	TRAVEL 1
OCB-B	CONTACT2	Phase B	38.2 mm	4.480 m/s	27.0 ms	TRAVEL 1
OCB-C	CONTACT3	Phase C	40.9 mm	4.516 m/s	27.6 ms	TRAVEL 1

* Velocity is averaged over a range of 9 samples centered on the event.
 ** Measured relative to the time of test triggering

Figure 186 Main Contact Open/Close Data for Trip Test

Motion at Resistor Open/Close Data

Location: Motion at Resistor Open/Close tab of Results page

The Motion Measurements, Main Contacts Open/Close table provides these measured values:

- Travel from start position until resistor contact part (resistor contact wipe)
- Velocity averaged over a range of 9 samples centered at resistor contact part
- Time from initiation until resistor contact part

Motion Measurements, Resistor Contacts Open/Close						
Channel	Label	Phase	At Resistor Contact Open			Motion Reference Channel
			Travel from Start Position (Contact Wipe)	Average Velocity*	Time from Initiation**	
OCB-A	CONTACT1	Phase A	144.8 mm	3.669 m/s	75.7 ms	TRAVEL 1
OCB-B	CONTACT2	Phase B	143.4 mm	3.669 m/s	75.3 ms	TRAVEL 1
OCB-C	CONTACT3	Phase C	139.4 mm	3.634 m/s	74.2 ms	TRAVEL 1

* Velocity is averaged over a range of 9 samples centered on the event.
 ** Measured relative to the time of test triggering

Figure 187 Resistor Contact Open/Close Data for Trip Test

Close Test Results

This section provides a complete set of sample results for a Close test.

Plotted Results

Location: Test Results tab of Plots page

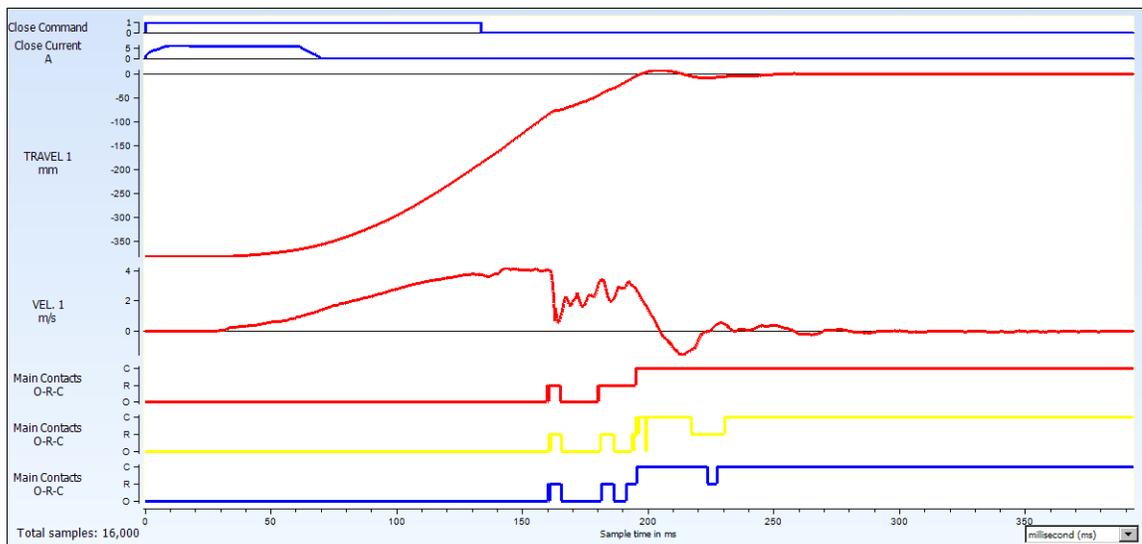


Figure 188 Plotted Results of Close Test

Main Contact Data

Location: Main Contacts tab of Results page

The Main Contact Timing Measurements table presents the following data:

- Measured values (Main Contact Close Timing, Synchronization)
- Manufacturer's limits (Main Contact Close Timing, Synchronization)
- Pass  or Warning  status

Main Contact Timing Measurements						
Timing Reference: From Test Initiation			Close Timing			
Channel ID	Label	Phase	Contact Timing	Synchronization		
				In Breaker		
OCB-A	CONTACT1	Phase A	158.3 ms		0.3 ms	
OCB-B	CONTACT2	Phase B	158.0 ms			
OCB-C	CONTACT3	Phase C	158.1 ms			
			Close Limits			
			Maximum	250.0 ms	4.2 ms	
			Minimum	150.0 ms		

Figure 189 Main Contact Timing Data of Close Test

Resistor Data

Location: Resistor Contacts tab of Results page

The Resistor Contact Timing Measurements table presents this data:

- Measured values:
 - Resistor Close Timing and Synchronization from Test Initiation
 - Resistor Close Timing and Synchronization Relative to Main Contact
- Manufacturer's limits (Resistor Close Timing)
- Pass  or Warning  status

Resistor Contact Timing Measurements											
Channel ID	Label	Phase	Resistance	Resistor Close Timing From Test Initiation			Resistor Close Timing Relative to Main Contact				
				Contact Timing	Synchronization		Contact Timing	Synchronization			
					In Breaker			In Breaker			
OCB-A	CONTACT1	Phase A	*	114.1 ms	✓	5.1 ms	✓	44.2 ms	✓	4.9 ms	✓
OCB-B	CONTACT2	Phase B	*	112.4 ms	✓	5.1 ms	✓	45.6 ms	✓	4.9 ms	✓
OCB-C	CONTACT3	Phase C	*	109.0 ms	✓			49.1 ms	✓		
				Close Limits			Close Limits				
			Maximum	*	140.0 ms		5.4 ms	60.0 ms		5.4 ms	
			Minimum	*	100.0 ms			30.0 ms			

Figure 190 Resistor Contact Timing Data for Close Test

Motion Data

Location: Motion tab of Results page

The Motion Measurements table provides these measured values:

- Measured values (Zone Average Velocity, Travel)
- Manufacturer’s limits (Zone Average Velocity, Travel)
- Contact Wipe (Open Test Only)
- Pass  or Warning  status

Motion Measurements								
Channel and Phase	Zone Type	Zone Velocities		Travel				
		Close		Total Travel	Overtravel	Rebound	Contact Wipe	
		Close Zone 1	Close Zone 2					
Motion-1 (TRAVEL 2)	Measured	4.130 m/s	✓	199.7 mm	✓	0.1 mm	0.1 mm	15.2 mm
	Limits	Max	4.500 m/s	*	240.0 mm	*	*	*
Phase B	Min	3.700 m/s	*	160.0 mm	*	*	*	

Figure 191 Motion Data for Close Test

Motion at Main Open/Close Data

Location: Motion at Main Open/Close tab of Results page

The Motion Measurements, Main Contacts Open/Close table provides these measured values:

- Travel from start position to main contact touch
- Velocity averaged over a range of 9 samples centered at main contact touch
- Time from initiation until main contact touch

Motion Measurements, Main Contacts Open/Close						
Channel	Label	Phase	At Main Contact Close			Motion Reference Channel
			Travel from Start Position	Average Velocity*	Time from Initiation**	
OCB-A	CONTACT1	Phase A	174.2 mm	2.281 m/s	144.3 ms	TRAVEL 3
OCB-B	CONTACT2	Phase B	172.3 mm	2.632 m/s	143.6 ms	TRAVEL 3
OCB-C	CONTACT3	Phase C	175.4 mm	2.281 m/s	144.9 ms	TRAVEL 3

* Velocity is averaged over a range of 9 samples centered on the event.
** Measured relative to the time of test triggering

Figure 192 Main Contact Open/Close Data for Close Test

Motion at Resistor Open/Close Data

Location: Motion at Resistor Open/Close tab of Results page

The Motion Measurements, Main Contacts Open/Close table provides these measured values:

- Travel from start position to resistor contact touch
- Velocity averaged over a range of 9 samples centered at resistor contact touch
- Time from initiation until resistor contact touch

Motion Measurements, Resistor Contacts Open/Close						
Channel	Label	Phase	At Resistor Contact Close			Motion Reference Channel
			Travel from Start Position	Average Velocity*	Time from Initiation**	
OCB-A	CONTACT1	Phase A	141.3 mm	3.860 m/s	133.6 ms	TRAVEL 3
OCB-B	CONTACT2	Phase B	138.6 mm	3.684 m/s	132.9 ms	TRAVEL 3
OCB-C	CONTACT3	Phase C	142.4 mm	3.684 m/s	133.9 ms	TRAVEL 3

* Velocity is averaged over a range of 9 samples centered on the event.
** Measured relative to the time of test triggering

Figure 193 Resistor Contact Open/Close Data for Close Test

Reclosing Test Results

This section provides a complete set of sample results for a Reclosing test.

Plotted Results

Location: Test Results tab of Plots page

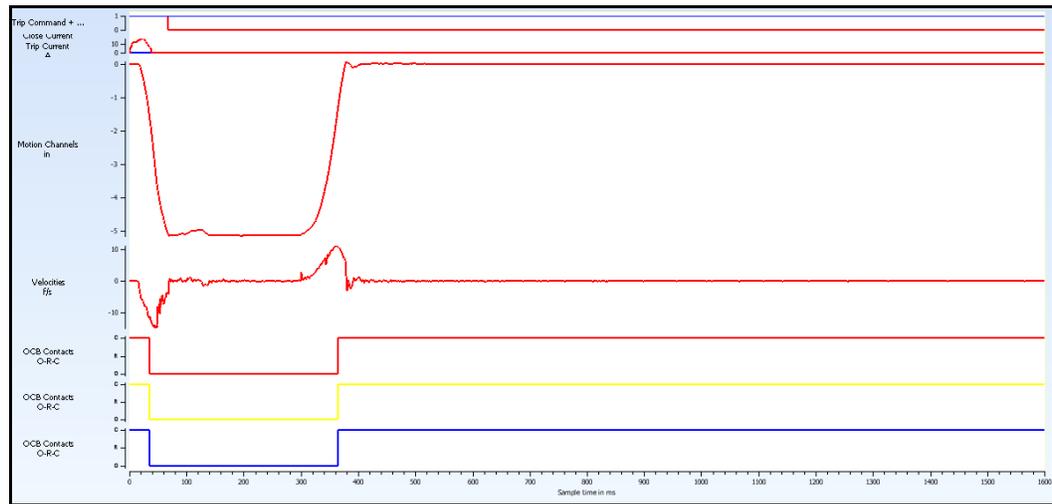


Figure 194 Plotted Results of Reclosing Test

Main Contact Data

Location: Main Contacts tab of Results page

The Main Contact Timing Measurements table presents the following data:

- Measured values:
 - Main Contact Reclosing Open-Close Timing
 - Total Reclosing Timing
 - Reclosing Synchronization
 - Initial Trip Timing
 - Initial Trip Synchronization
- Manufacturer's limits:
 - Main Contact Reclosing Open-Close Timing
 - Total Reclosing Timing
 - Reclosing Synchronization
- Pass  or Warning  status

Main Contact Timing Measurements									
Timing Reference: From Test Initiation			Reclose Open-Close Timing		Total Reclose Timing			Initial Trip Timing	
Channel ID	Label	Phase	In Breaker	Contact Timing		Synchronization		Contact Timing	Synchronization
						In Breaker			
OCB-A	CONTACT1	Phase A	328.8 ms	364.5 ms	✓	0.6 ms		34.8 ms	0.9 ms
OCB-B	CONTACT2	Phase B		365.1 ms	✓			35.3 ms	
OCB-C	CONTACT3	Phase C		364.6 ms	✓			35.7 ms	
			Reclose Open-Close Limits		Reclose Limits				
			Maximum	*	383.3 ms	*			
			Minimum	*	350.0 ms				

Figure 195 Main Contact Timing Data of Reclosing Test

Motion Data

Location: Motion tab of Results page

The Motion Measurements table presents data for the Open portion of the Reclosing test:

- Measured values (Zone Average Velocity, Travel)
- Manufacturer’s limits (Zone Average Velocity, Travel)
- Pass  or Warning  status

Data is not provided for the Close portion of the Reclosing test on the Motion tab.

Motion Measurements						
Channel and Phase		Zone Velocities				Travel
		Open				Total Travel
		Open Zone 1	Open Zone 2			
		Dist; Dist	Dist; Dist			
Motion-1 (TRAVEL 1) Phase A	Zone Type					
	Measured	12.89 f/s	✓	*	5.216 in	✓
	Limits	Max	14.00 f/s		*	5.500 in
Min		12.00 f/s		*	5.000 in	

Figure 196 Motion Data for Reclosing Test

Motion at Main Open/Close Data

Location: Motion at Main Open/Close tab of Results page

The Motion Measurements, Main Contacts Open/Close table presents data for the Open portion of the Reclosing test:

- Travel from start position until main contact part (main contact wipe)
- Velocity averaged over a range of 9 samples centered at main contact part
- Time from initiation until main contact part

Data is not provided for the Close portion of the Reclosing test on the Motion at Main Open/Close tab.

Motion Measurements, Main Contacts Open/Close						
Channel	Label	Phase	At Main Contact Open			Motion Reference Channel
			Travel from Start Position	Average Velocity*	Time from Initiation**	
OCB-A	CONTACT1	Phase C	47.1 mm	6.703 m/s	17.2 ms	TRAVEL 2
OCB-B	CONTACT2	Phase B	46.4 mm	6.562 m/s	17.1 ms	TRAVEL 2
OCB-C	CONTACT3	Phase A	47.1 mm	6.703 m/s	17.2 ms	TRAVEL 2

Figure 197 Motion at Main Open/Close for Reclosing Test

TripFree Test Results

This section provides a complete set of sample results for a TripFree test.

Plotted Results

Location: Test Results tab of Plots page

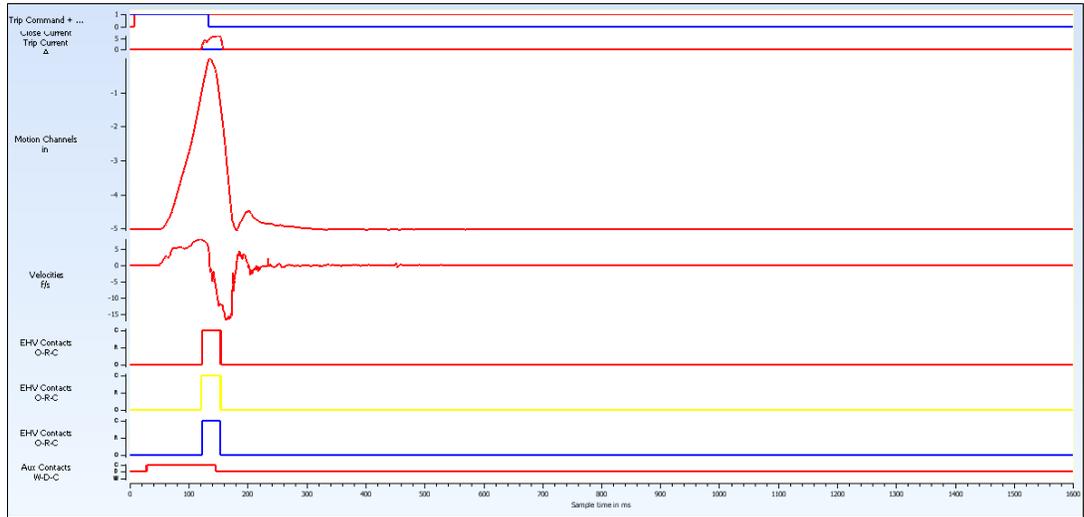


Figure 198 Plotted Results of TripFree Test

Main Contact Data

Location: Main Contacts tab of Results page

The Main Contact Timing Measurements table presents the following data:

- Measured values:
 - TripFree Close-Open [Dwell] Timing
 - Total TripFree Timing
 - Total TripFree Synchronization
 - Initial Close Timing
 - Initial Close Synchronization
- Manufacturer's limits (TripFree Close-Open [Dwell] Timing)
- Pass  or Warning  status

Main Contact Timing Measurements												
Timing Reference From Test Initiation			TripFree Dwell Timing			Total TripFree Timing			Initial Close Timing			
Channel ID	Label	Phase	In Module	In Phase	In Breaker	Contact Timing			Synchronization			
DHV-A1	A-EHV 1	Phase A		32.0 ms		154.2 ms				122.2 ms		
DHV-B1	B-EHV 1	Phase B		33.2 ms	33.2 ms	154.6 ms			0.0 ms	121.4 ms		0.0 ms
DHV-C1	C-EHV 1	Phase C		31.9 ms		153.0 ms				121.9 ms		
			TripFree Dwell Limits									
			Maximum			*						
			Minimum			*						

Figure 199 Main Contact Timing Data of TripFree Test

Motion Data

Location: Motion tab of Results page

The Motion Measurements table presents data for the Close portion of the TripFree test:

- Measured values (Zone Average Velocity, Travel)
- Manufacturer’s limits (Zone Average Velocity, Travel)
- Pass  or Warning  status

Data is not provided for the Open portion of the TripFree test on the Motion tab.

Motion Measurements					
Channel and Phase			Zone Velocities		Travel
			Close		Total Travel
			Close Zone 1	Close Zone 2	
Motion-1 (TRAVEL 1)	Zone Type		Dist; Dist	Dist; Dist	
	Measured		See note	See note	106.8 mm 
Phase A	Limits	Max	*	*	127.0 mm
		Min	*	*	76.2 mm

Note: In a TripFree or C-O test, zone velocities are not measured for distance-distance or distance-time zones

Figure 200 Motion Data for TripFree Test

Motion at Main Open/Close Data

Location: Motion at Main Open/Close tab of Results page

The Motion Measurements, Main Contacts Open/Close table presents data for the Close portion of the TripFree test:

- Travel from start position until main contact touch
- Velocity averaged over a range of 9 samples centered at main contact touch
- Time from initiation until main contact touch

Data is not provided for the Open portion of the TripFree test on the Motion at Main Open/Close tab.

Motion Measurements, Main Contacts Open/Close						
Channel	Label	Phase	At Main Contact Close			Motion Reference Channel
			Travel from Start Position	Average Velocity*	Time from Initiation**	
OCB-A	CONTACT1	Phase A	73.8 mm	2.258 m/s	72.4 ms	TRAVEL 1
OCB-B	CONTACT2	Phase B	72.4 mm	2.293 m/s	71.8 ms	TRAVEL 1
OCB-C	CONTACT3	Phase C	73.5 mm	2.293 m/s	72.3 ms	TRAVEL 1

* Velocity is averaged over a range of 9 samples centered on the event.
 ** Measured relative to the time of test triggering

Figure 201 Main Contact Open/Close Data for TripFree Test

O-C-O Test Results

This section provides a complete set of sample results for an O-C-O test.

Plotted Results

Location: Test Results tab of Plots page

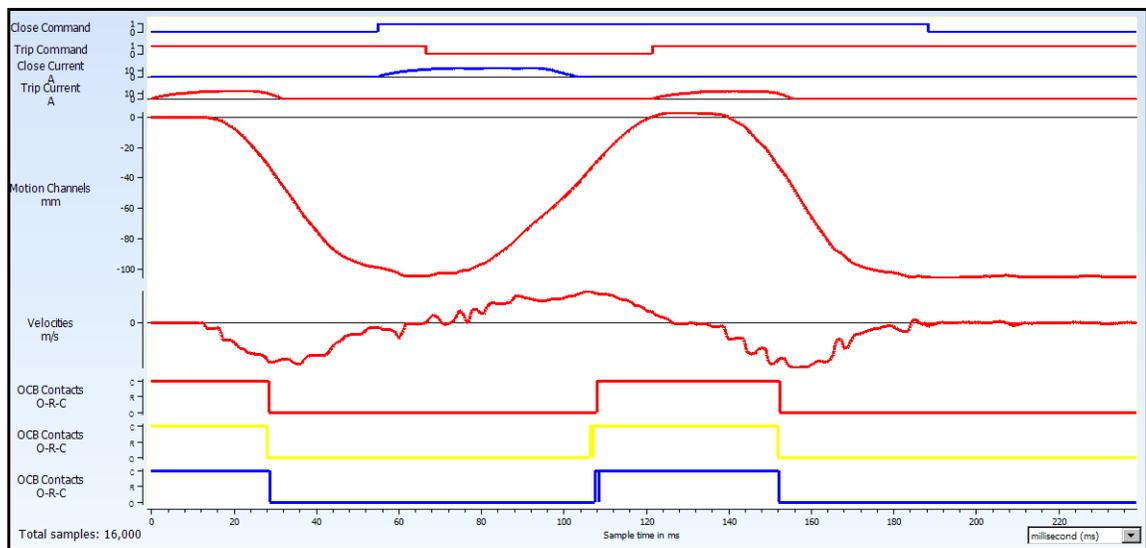


Figure 202 Plotted Results of O-C-O Test

Main Contact Data

Location: Main Contacts tab of Results page

The Main Contact Timing Measurements table presents the following data:

- Measured values:
 - Total O-C-O Timing
 - Total O-C-O Synchronization
 - Initial Trip Timing
 - Initial Trip Synchronization
 - Initial Close Timing
 - Initial Close Synchronization

Main Contact Timing Measurements								
Timing Reference: From Test Initiation			Total O-C-O Timing		Initial Trip Timing		Initial Close Timing	
Channel ID	Label	Phase	Synchronization		Synchronization		Synchronization	
			Contact Timing	In Breaker	Contact Timing	In Breaker	Contact Timing	In Breaker
OCB-A	CONTACT1	Phase A	429.9 ms		12.4 ms		104.8 ms	
OCB-B	CONTACT2	Phase B	429.3 ms	0.6 ms	11.9 ms	0.5 ms	104.7 ms	0.1 ms
OCB-C	CONTACT3	Phase C	429.7 ms		12.2 ms		104.8 ms	

Figure 203 Main Contact Timing Data of O-C-O Test

Motion Data

Location: Motion tab of Results page

The Motion Measurements table presents data for the Initial Open portion of the test:

- Measured values (Travel)
- Manufacturer's limits (Travel)
- Pass  or Warning  status

Data is not provided for the Close or Second Open portions of the O-C-O test on the Motion tab.

Motion Measurements			
Channel and Phase	Travel		
	Total Travel		
Motion-1 (TRAVEL 1)	Zone Type	Measured	71.5° 
	Limits	Max	47.0°
Min		43.0°	

Figure 204 Motion Data for O-C-O Test

Motion at Main Open/Close Data

Location: Motion at Main Open/Close tab of Results page

The Motion Measurements, Main Contacts Open/Close table provides data for the Initial Open portion of the test:

- Travel from start position to main contact open
- Velocity averaged over a range of 9 samples centered at main contact open
- Time from initiation to main contact open

Data is not provided for the Close or Second Open portions of the O-C-O test on the Motion at Main Open/Close tab.

Motion Measurements, Main Contacts Open/Close						
Channel	Label	Phase	At Main Contact Open			Motion Reference Channel
			Travel from Start Position	Average Velocity*	Time from Initiation**	
OCB-A	CONTACT1	Phase A	32.7 mm	3.916 m/s	28.5 ms	TRAVEL 1
OCB-B	CONTACT2	Phase B	30.7 mm	3.739 m/s	28.0 ms	TRAVEL 1
OCB-C	CONTACT3	Phase C	33.1 mm	3.951 m/s	28.6 ms	TRAVEL 1

* Velocity is averaged over a range of 9 samples centered on the event.
 ** Measured relative to the time of test triggering

Figure 205 Main Contact Open/Close Data for O-C-O Test

Creating Reports

You can tailor a report that meets your requirements, print it, save it to one of several file formats, or export it to Microsoft Excel. To do this:

1. Click the **Reports** tab.

The Report Selectors subtab opens (see [Figure 206](#)).

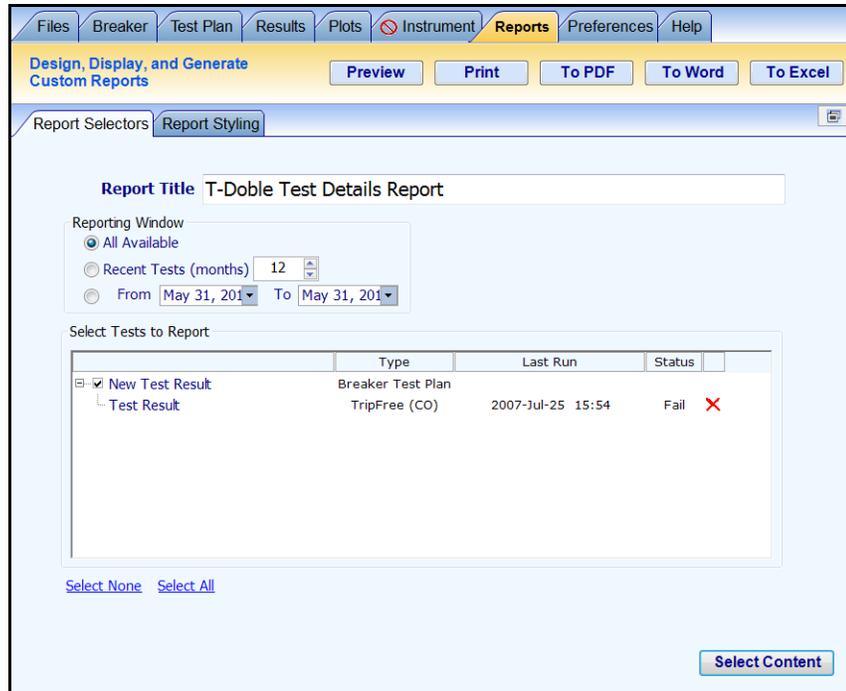


Figure 206 Design Page of Reports Tab

2. Describe the purpose of this window.
3. Click Select Content at the bottom of the window.

The content selection window appears ([Figure 207](#)).

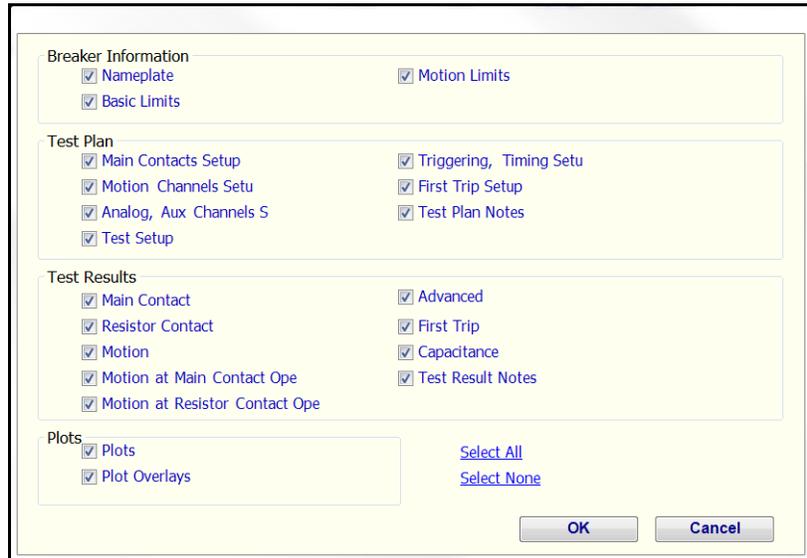


Figure 207 Content Selection Window

4. From the Breaker Information, Test Plan, Test Results, and Plots sections, select the elements you wish to include in the report, and click **OK**.
5. Click the **Report Styling** tab (Figure 208).

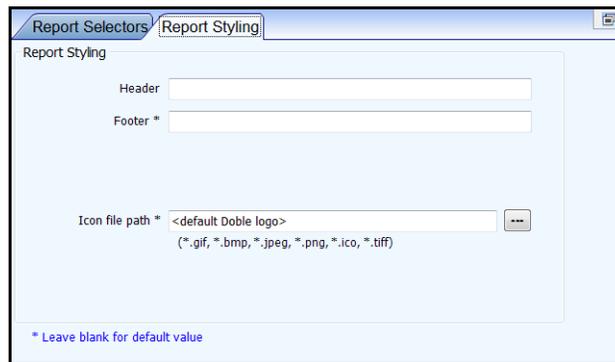


Figure 208 Report Styling Tab

6. Enter any desired header and footer text, and select an icon file if desired. The icon appears in the upper right-hand corner of the first page of the report.

7. Click one of these buttons:

- Preview—Displays the report online exactly as it will appear in print
- Print—Prints the report
- Excel—Exports report data to an Excel spreadsheet

Figure 209 shows a sample Excel spreadsheet containing report data. The sample here contains 18 tabs; the Test Setup tab is displayed.

	A	B
	Trip/Close Ranges	
1		
2	Trip Current	20 A
3	Close Current	20 A
	Recording Parameters	
5		
6	Sample Time	0.1 ms
7	Sampling Rate	10,000 Hz
9	Recording Time (after Trigger)	500.0 ms
10	(Samples)	5000
12	Pretrigger Time	0.0 ms
13	(Samples)	0
	Bounce Discriminator	

Figure 209 Sample Excel Spreadsheet

A. Maintenance

This appendix provides maintenance procedures for the TDR9100. It contains the following sections:

- [“TDR Instrument Rules for Safe Operation” on page 221](#)
- [“Cleaning the TDR9100” on page 222](#)

TDR Instrument Rules for Safe Operation

WARNING!



Always follow these guidelines to operate the system safely.

- *Always* install the Safety Ground cables when using the system in the field.
- Power the TDR9100 using the correct electrical line voltage to avoid electrical short circuits, overheating, and shocks. If in doubt, check the electrical rating label attached to each unit.
- Do not, for any reason, cut or remove the grounding prong from the power cord.
- Turn power OFF and disconnect from line power before reaching into the TDR9100.
- Never insert metal objects, such as screwdrivers or paper clips, inside the TDR9100 while power is ON.
- Unplug the TDR9100 if it is not to be used for an extended period of time. Also unplug it before cleaning it.
- If the TDR9100 is dropped, have it checked by a qualified service technician before placing it back in service. Dropping the TDR9100 can disturb the insulation system.
- Do not place the TDR9100 in excessively warm or humid locations.

Cleaning the TDR9100

As part of normal maintenance, sponge the outer case and front panel of the TDR9100 with a mild soap solution and wipe them dry with a clean cloth or paper towel. *DO NOT* use household cleaners containing chlorinated or abrasive compounds. *DO NOT* spray liquids directly onto the TDR9100.

NOTE



Do not use flammable liquids, such as gasoline or lighter fluid, for cleaning electrodes, electrical components, or moving parts. Disconnect the TDR9100's power cord and all other external cables before cleaning or removing the TDR9100 cover.

B. Error Messages

If T-Doble detects a conflict between test plan specifications and the actual hardware setup, a `Test Cancelled` error message appears. See [Figure 210](#).

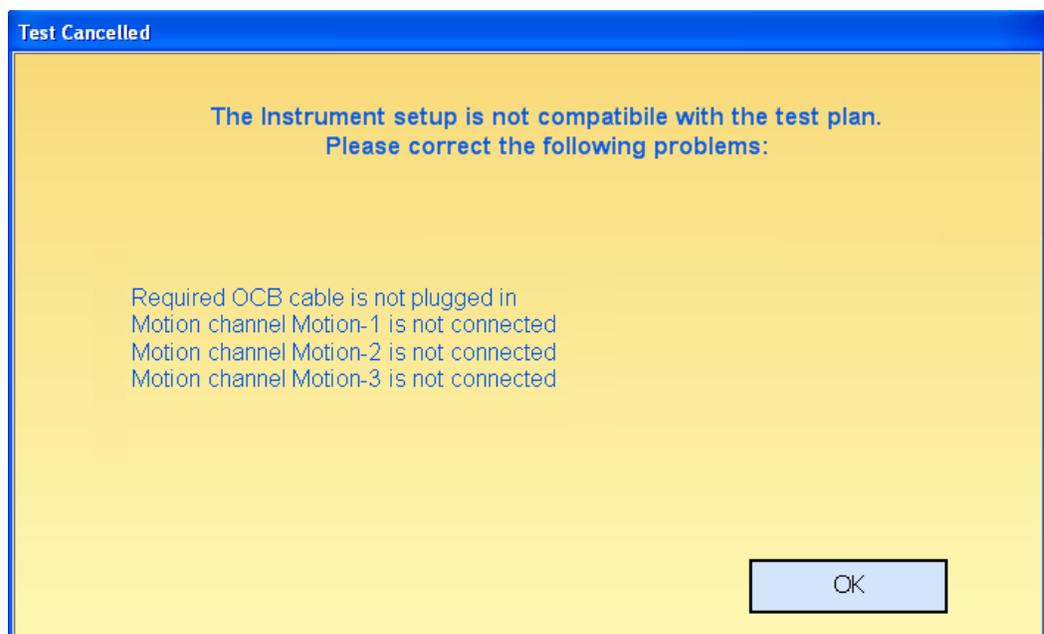


Figure 210 “Test Cancelled” Error Message

At other times, a Test Failed error message appears. The information at the bottom of the window varies according to the nature of the hardware problem. [Figure 211](#) shows an example.



Figure 211 “Test Failed” Error Message

You may be able to resolve the problem by following this procedure:

1. Ensure that the equipment under test does not exceed TDR9100 operating limits.
2. Investigate the specific items mentioned in the text of the error message.
3. Call Customer Service.

C. Concepts of Operation

This appendix explains the concepts of TDR9100 operation. It contains the following sections:

- [“Channel Types” on page 225](#)
- [“Circuit Breaker Control” on page 227](#)
- [“System Operation” on page 227](#)

Channel Types

The TDR9100 is a multi-purpose data recorder outfitted with various signal sources and receiver channels. It supports these channel types:

- Main and Resistor Contact timing
- Resistor Contact resistance measurement
- Grading Capacitor capacitance measurement
- Motion (transducer input) channels
- Auxiliary contact timing channels
- Analog (voltage) channels

All channels are collected and forwarded to the controller for processing. Data processing creates measurements, compares them to specifications (circuit breaker vendor limits or learned results shared between utilities), and produces Pass/Warning decisions.

Main Contact Timing

Contact timing is performed by providing a voltage source (isolated in pairs for EHV) to the contacts and comparing the voltage across the contacts to references internal to the TDR9100. A voltage below the lower threshold (on the order of 5% of the source voltage) is logged as a Close state. A voltage above the higher threshold (on the order of 95% of the source voltage) is logged as an Open state. The state is sampled at one of four selectable sample rates and stored in a circular buffer for transfer to the computer.

A hardware discriminator qualifies state transitions to eliminate noise and cable capacitance that might be perceived as switch bounce. The discrimination time is set to 60 μ s and is sampled at 2 MHz.

Resistor Contact Timing

Resistor contact timing is measured much the same as main contact timing. When the measured voltage falls between the lower threshold and the higher threshold, the channel is determined to be in the *resistive* state.

Motion Channels

Motion channels accept inputs from Doble motion transducers. The transducers output two quadrature signals generated from optical sensors that switch on and off based on a *picket fence* of lines passing between the sensors and a light source. Each transition is equal to a movement of 0.0125 in/0.318 mm (0.09° for rotary motion) imposed on the transducer. The transitions are counted and sampled. The direction of movement is identified by which quadrature signal leads and which lags at any moment in time. The distance curve is generated by providing a running sum of the transitions vs. time, using the initial position as *zero*. The velocity curve is generated by taking the change in distance vs. time.

Auxiliary Contact Channels

The auxiliary contact channels measure and display the timing of three different states: Open-Wet, Open-Dry, and Closed. An isolated wetting voltage is provided for each channel that is not externally wetted to allow for the differentiation of open vs. closed and to clean any oxide buildup on the contacts. Both the open/close decision and the wet/dry decision are made based on the voltage across the channel inputs. The states are sampled at the selected sample rate.

Analog Channels

The analog channels are general purpose voltage recordings. The inputs are isolated from each other and sampled by a 12-bit serial A/D converter. The A/D converter clock is 80 kHz. Eight consecutive samples are averaged and sampled by the system at the selected sample rate.

Circuit Breaker Control

The system includes a Trip/Close module capable of activating the control coils of the circuit breaker under test. The command signals are capable of switching 100 A of current on both the Trip channel and the Close channel. These levels can be sustained for tens of milliseconds, with lower current values sustainable for tenths of seconds. Each channel is protected with a slow-blow fuse.

The Trip and Close command signals are programmed into timers, configured via user inputs, when the operator initiates a test. Before a Trip or Close command leaves the TDR9100, each command signal is interrupted by a relay that has three control mechanisms:

- When the test is initiated, the firmware outputs a logic enable signal to the relay control circuitry.
- Once the safety switch is pressed, voltage is supplied to one side of the relay coil.
- The firmware detects the safety switch closure and outputs a signal, which completes the relay coil circuit allowing the command signals out to the breaker.

System Operation

The system is composed of two functional components: the TDR9100 and T-Doble, the controller software that runs on a controller PC.

Test Execution

The operator initiates the test, which turns on all of the test voltages and starts the sampling of all the activated channels. Samples are stored in a circular buffer. When the predefined trigger signal is detected, the samples are transferred from the circular buffer to a permanent buffer pending the end of the test, at which point the information is transferred to the controller.

Data Transfer

The amount of data transferred to the controller is proportional to the number and type of channels activated. Each main contact channel, analog channel, or auxiliary contact channel is a single channel. The internal Trip and Close coil current channels are individual channels.

Data is compressed and transferred to the controller at rates that vary with the communication method (USB or Ethernet). The different channel types compress to varying degrees depending on content: timing channels compress very well; analog channels do not.

Results Processing

T-Doble receives the test data and decompresses it. Calculations are performed on a channel-by-channel basis resulting in switching times, maximum values, and average values during specific times. The results of these calculations are compared to the circuit breaker specifications included in the test plan. A Pass/Warning comparison is performed and the results are reported on all channels with specifications.

Results are made available in both tabular and graphical formats. Numerous utilities such as zooming, overlaying, and on-screen measurements are made available as part of the graphics package.

D. Parts

Cable Bags and Individual Cables

TDR9100 Basic Cable Bag and Individual Components

Table 18 TDR9100 Cable Bag and Individual Components

Picture	Description	P/N	No.
	Basic cable bag containing: <ul style="list-style-type: none">• Breaker control cable• Ground cable• Safety switch• Ethernet crossover (X-over) cable• USB cable• CD of T-Doble software• TDR9100 Quick Start Guide	071-0073-01	1
Components sold individually:			
	Breaker Control Cable	02B-0013-06	1

Table 18 TDR9100 Cable Bag and Individual Components

Picture	Description	P/N	No.
	Ground Cable, 30 ft	02C-0019-01	1
	Safety Switch, 25 ft	02B-0050-10	1
	Ethernet crossover (X-over) cable RJ45	181-0646	1
	USB Cable, type A-B	181-0585	1

Table 18 TDR9100 Cable Bag and Individual Components

Picture	Description	P/N	No.
	T-Doble software on CD. Download from http://www.doble.com/support/download_tdoble-trx.html or call Doble.		
	Canvas cable bag, large	2FB-3449-01	1

Ganging Cables

Table 19 Ganging Cables

Picture	Description	P/N	No.
	Ganging cable, 60 ft	05B-0965-01	1
	Ganging cable, 10 ft	05B-0965-02	1

Main Contact (OCB) Cable

Table 20 Main Contact (OCB) Cable and Ganging Cables

Picture	Description	P/N	No.
	<p>OCB Cable:</p> <ul style="list-style-type: none"> • 60 ft overall length • 45 ft trunk length • 15 ft branch length 	05B-0620-01	1

EHV Cable Bag #1 and Individual Cables

Table 21 EHV Cable Bag #1 and Individual Components

Picture	Description	P/N	No.
	<p>Cable bag containing three EHV cables for channels 1-2.</p> <ul style="list-style-type: none"> • Each cable is labeled red, yellow, or blue. • Two breaks per phase each. • One common connection. • Standard length: 60 ft. 	020-0127-01	1
Components sold individually:			
	EHV, ch 1-2, red label	05B-0621-01	1
	EHV, ch 1-2, yellow label	05B-0621-02	1
	EHV, ch 1-2, blue label	05B-0621-03	1
Sample Photo			

Table 21 EHV Cable Bag #1 and Individual Components

Picture	Description	P/N	No.
	Cable bag, large	2FB-3449-01	1

EHV Cable Bag #2 and Individual Cables**Table 22 EHV Cable Bag #2 and Individual Components**

Picture	Description	P/N	No.
	<p>Cable bag containing three EHV cables for channels 3-4.</p> <ul style="list-style-type: none"> • Each cable is labeled red, yellow, or blue. • Two breaks per phase each. • One common connection. • Standard length: 60 ft. 	020-0127-02	1
Components sold individually:			
	EHV, ch 3-4, red label	05B-0621-04	1
	EHV, ch 3-4, yellow label	05B-0621-05	1
	EHV, ch 3-4, blue label	05B-0621-06	1
Sample Photo			

Table 22 EHV Cable Bag #2 and Individual Components

Picture	Description	P/N	No.
	Cable bag, large	2FB-3449-01	1

Cable Bag with 3 Auxiliary and 3 Analog Cables

Table 23 Cable Bag with 3 Auxiliary and 3 Analog Cables

Picture	Description	P/N	No.
	<p>Cable bag containing 2 kits:</p> <p>Cable kit 071-0024-01:</p> <ul style="list-style-type: none"> • 3 auxiliary cables labeled red, yellow, and blue • 3 analog cables labeled red, yellow, and blue <p>Plug adapters and clips kit 071-0023-01:</p> <ul style="list-style-type: none"> • 3 red plug adapters • 3 black plug adapters • 3 red crocodile clips • 3 black crocodile clips • 6 white crocodile clips 	T9940	1

Table 23 Cable Bag with 3 Auxiliary and 3 Analog Cables

Picture	Description	P/N	No.
Components sold individually:			
 <p>Sample Photo</p>	Auxiliary cable, red label	05B-0635-01	1
	Auxiliary cable, yellow label	05B-0635-02	1
	Auxiliary cable, blue label	05B-0635-03	1
 <p>Sample Photo</p>	Analog cable, red label	05B-0634-01	1
	Analog cable, yellow label	05B-0634-02	1
	Analog cable, blue label	05B-0634-03	1
	Cable bag, small	2FB-3450-01	1
	Plug adapter, black	212-0540	3
	Plug adapter, red	212-0541	3
	Crocodile clip, black	212-0542	3
	Crocodile clip, red	212-0543	3
	Crocodile clip, white	212-0544	6

Cable Bag with 6 Analog Cables

Table 24 Cable Bag with 6 Analog Cables

Picture	Description	P/N	No.
	Cable bag containing: <ul style="list-style-type: none"> • 2 analog cables, red label • 2 analog cables, yellow label • 2 analog cables, blue label • 6 red plug adapters • 6 black plug adapters • 6 red crocodile clips • 6 black crocodile clips 	T9950	1
Components sold individually:			
 Sample Photo	Analog cables, red label	05B-0634-01	2
	Analog cables, yellow label	05B-0634-02	2
	Analog cables, blue label	05B-0634-03	2
	Cable bag, small	2FB-3450-01	1
	Plug adapter, black	212-0540	6
	Plug adapter, red	212-0541	6
	Crocodile clip, black	212-0542	6
	Crocodile clip, red	212-0543	6

Transducers and Transducer Cables

TR3170 Gold Rotary Transducer Kit

Table 25 TR3170 Gold Rotary Transducer Kit

Picture	Description	P/N	No.
	Complete kit containing: <ul style="list-style-type: none"> • TR3170 Gold Rotary Transducer • 40-ft cable 	TR3170	1
	Motion cable, 40 ft	181-0107	1
	Cable bag, small	2FB-3450-01	1

TR3171 AHMA 4/8 Transducer/Adapter

Table 26 TR3171 AHMA 4/8 Transducer/Adapter

Picture	Description	P/N	No.
	Complete kit containing: <ul style="list-style-type: none"> • TR3171 AHMA 4/8 Transducer/Adapter • 40-ft. cable • Software CD 	TR3171	1
	Motion cable, 40 ft	181-0107	1

Table 26 TR3171 AHMA 4/8 Transducer/Adapter (Continued)

Picture	Description	P/N	No.
	Cable bag, small	2FB-3450-01	1

TR3186 ABB HMB 4/8 Rotary Transducer

Table 27 TR3186 ABB HMB 4/8 Rotary Transducer

Picture	Description	P/N	No.
	Complete kit containing: <ul style="list-style-type: none"> • TR3186 ABB HMB-4/8 Rotary Transducer Assembly • 40-ft cable 	TR3186	1
	Motion cable, 40 ft	181-0107	1
	Cable bag, small	2FB-3450-01	1

TR3189 ABB HMB 4/8/11 Rotary Transducer

Table 28 TR3189 ABB HMB 4/8/11 Rotary Transducer

Picture	Description	P/N	No.
	Complete kit containing: <ul style="list-style-type: none"> • TR3189 ABB HMB 4/8/11 Linear Transducer Assembly • 40-ft cable • User documentation 	TR3189	1
	Motion cable, 40 ft	181-0107	1
	Cable bag, small	2FB-3450-01	1
	Installation instructions	72A-2658-01	1

TR3190 Digital Rotary and Linear Transducer

Table 29 TR3190 Digital Rotary and Linear Transducer

Picture	Description	P/N	No.
	Complete kit containing: <ul style="list-style-type: none"> • TR3190 Digital Rotary Linear Transducer • Travel Rod • 40-ft cable 	TR3190	1
No picture	Travel Rod	Call Doble	1
	Motion cable, 40 ft	181-0107	1
	Cable bag, small	2FB-3450-01	1

Transducer Cables

Table 30 Transducer Cables

Picture	Description	P/N	No.
	Motion cable, 40 ft	181-0107	1
	Motion cable, 60 ft	181-0512	1
	Motion cable, 100 ft	181-0510	1

Adapters and Clips

Crocodile Clip and Plug Adapter Kit and Individual Components

Table 31 Crocodile Clips and Plug Adapters

Picture	Description	P/N	No.
	Terminal Kit from Event/Analog Cable Set	017-0023-01	1
Components sold individually:			
See photo above	Plug, adapter, black, 4 mm socket	212-0540	3
	Plug, adapter, red, 4 mm socket	212-0541	3
	Clip, crocodile, black, 4 mm socket	212-0542	3
	Clip, crocodile, red, 4 mm socket	212-0543	3
	Clip, crocodile, white, 4 mm socket	212-0544	6

Mechanical Adapter Kit

Table 32 Mechanical Adapter Kit

	TR3185 Mechanical adapter	030-1422-02	1
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Miscellaneous Items

Picture	Description	P/N	No.
No image available	Doble Current Probe	401-0055	1
	Safety Bypass Flag	05C-0648-01	1
	Fuse, 3.0A, 250V, 3AG, SLO-BLO	384-0002	2
	Power cord Call Doble for replacement.		

E. TDR9100 Circuit Breaker Test System Specifications

This appendix provides the specifications for the TDR9100 and its operations.



NOTE! Specifications are subject to change without notice. For more information, email TDRInfo@doble.com.

General Specifications

Table 33 TDR9100 General Specifications

Characteristic	Description
Recordings	<ul style="list-style-type: none">• 25 seconds, all channels, 20 kHz (max resolution)• 50 seconds, all channels, 10 kHz• 8 minutes, all channels, 1 kHz• 80 minutes, all channels, 100 Hz (min resolution)
Communication	USB or Ethernet
Safety	<ul style="list-style-type: none">• Safety Ground• Safety Switch (local and remote)• Audible Indication (test in progress)

Physical Specifications

Table 34 TDR9100 Physical Specifications

Characteristic	Description
Dimensions	53.5 x 41 x 22 cm
Weight	24 lbs (11 kg)
Power Supply	100 V to 240 V, 50/60 Hz
Temperature	<ul style="list-style-type: none"> • 0 °C to 50 °C operating • -25 °C to 70 °C storage
Humidity	Up to 95% relative humidity, non-condensing

Main Contact and Resistor Contact Timing

Table 35 TDR9100 Main Contact and Resistor Contact Timing

Characteristic	Description
Number of Phases	3
Breaks Per Phase	4
OCB Configuration	3 contacts
EHV Configuration	12 contacts
Resolution	50 µs
Resistor Detection Range	10 Ohms to 10 kOhms
Voltage Isolation to Chassis	1000 V

Trip/Close Initiation Control

Table 36 TDR9100 Trip/Close Initiation Control

Characteristic	Description
Maximum Input Current	± 100 A (momentary)
Maximum Input Voltage	± 300 V
Voltage Isolation to Chassis	1000 V

Motion Channels

Table 37 TDR9100 Motion Channels

Characteristic	Description
Number of Channels	3
Connector	15-pin D
Voltage Isolation to Chassis	1000 V

Event Channels

Table 38 TDR9100 Analog Measurement Channels

Characteristic	Description
Maximum Input Voltage	± 300 V
Maximum Voltage to Chassis	± 1000 V
Auxiliary Contact Mode	
Open Circuit Voltage	29 V \pm 10%
Close Circuit Current	28 mA \pm 10%
Open Detection	$>+3.5$ V and $< +35$ V
Closed Detection	$<+3$ V and > -3 V

Table 38 TDR9100 Analog Measurement Channels

Characteristic	Description
Wet Detection	> +38 V or <-4 V
Analog Measurement Mode	
Input Impedance	1 M Ohms
Resolution	12 Bit
Ranges	300 V, 200 V, 100 V, 50 V, 20 V, 10 V, 5 V, 2 V, 1 V, 0.5 V and 0.2 V
Accuracy	± 1% Reading, ± 1% Full Scale Offset
Bandwidth	DC to 5000 Hz

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