TDR900™ and TDR9000™ Circuit Breaker Test System and T-Doble

User's Guide

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Preface

The *TDR900 and TDR9000 Circuit Breaker Test System User's Guide* introduces both testing systems, describes how to perform tests, and explains how to interpret test results. It also provides troubleshooting and maintenance procedures, application notes, theory and conceptual information, and other supporting documentation.

Who Should Read This Guide

This guide is intended for anyone who works with the TDR9000™ Circuit Breaker Test System, or the TDR900™ 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. The two most commonly-used icons are shown here, but any icon you may see in the text is intended to draw your attention to especially important information.

NOTE

Notes provide supplemental information of special importance. This information may apply to only some circumstances.

WARNING!

Warnings provide information that is intended to prevent physical harm to you or other users of the instrument. The information may also prevent damage to equipment. ALWAYS read and obey warning information.

1. Two Instruments in One Manual

This manual explains provides instructions and supporting data for the TDR900 and TDR9000 two circuit breaker testing systems, and explains how to use the T-Doble software.

TDR900 Circuit Breaker Test System

The TDR900™ Circuit Breaker Test System is a single box solution that meets user testing requirements. The TDR900 provides testing of up to four breaks per phase, for a total of 12 main contacts simultaneously. The control circuit breaker trip and close commands allow the user to perform these operations:

- Trip (O)
- Close (C)
- TripFree (CO)
- Reclose (O-C and O-0.3 s-C)
- C-O
- O-CO, O-C-O, and O-0.3 s-CO
- First Trip
- Record Only

The following sections of this manual deal exclusively with the TDR900:

- Chapter 9: “TDR900 Hardware and Supported Tests”
- Chapter 10: “TDR900: Running a Test”
- Appendix F: “TDR900 Circuit Breaker Test System Specifications”

TDR9000 Circuit Breaker Test System

The TDR9000™ Circuit Breaker Test System is a modular instrument that users can modify to meet their testing requirements. The TDR9000 provides testing of up to eight breaks per phase, for a total of 24 main contacts simultaneously. The control circuit breaker trip and close commands allow the user to perform these operations:

- Trip (O)
- Close (C)
- TripFree (CO)
- Reclose (O-C and O-0.3 s-CO)
- C-O
- O-CO, O-C-O, and O-0.3 s-CO
- First Trip
- Record Only
- Capacitance

The following sections of this manual deal exclusively with the TDR9000:

- Chapter 11: "TDR9000 Hardware and Supported Tests"
- Chapter 12: "TDR9000 Setting Up and Running Tests"
- Appendix G: "TDR9000 Circuit Breaker Test System Specifications"

T-Doble Software

T-Doble enables you to create or modify circuit breaker 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 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.

When installed on any laptop or other computer that is used to perform tests, T-Doble can perform the following functions:

- Create individual circuit breaker test plans using a Library test plan as its basis. Each circuit breaker test adds to the database of test results available for analysis. Completed individual circuit breaker tests contain not only the test results gathered, but also a record of the circuit breaker test plan used.
- Display the results of an individual circuit breaker test graphically and tailor the presentation of results to highlight behaviors of interest.

- Automatically update test results when editable fields are changed.
- Overlay the results from different tests for comparison. The software compares test results against circuit breaker specifications and present a *Pass* or *Fail* determination for each measurement for which a comparative value is set in the test plan.

Instructions for using T-Doble appear throughout this manual, and are adapted as appropriate for the requirements of the TDR9000 and TDR900.

2. Safety Considerations

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

Grounding the Instrument

General requirements:

- *Always* first solidly ground or earth the apparatus under test, the TDR instrument, and any other external equipment being used.
- *Always* install the Safety Ground cables when using the system in the field.
- *Never* cut or remove the grounding prong from the power cord.
- When the TDR instrument is permanently housed in a vehicle, ground the vehicle chassis and bind the instrument 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 instrument or transducers.
- Do not use the instrument or transducers as a step or platform.
- Do not store the instrument or transducers in temperatures lower than –13 °F (–25 °C) or greater than 158 °F (70 °C).
- Do not operate the instrument or transducers in temperatures lower than 32 °F (0 °C) or greater than 122 °F (50 °C).
- Do not store the instrument or transducers in excessively humid environments.
- Do not expose the instrument or transducers to rain, snow, sand, or dust.
- Always transport the instrument 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 6-32.

- 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.***

Personnel Required for Field Testing

The TDR instrument should not be operated by a crew of less than two people. Designate one person as the *Test Set Operator* and the other as the *Safety Observer*.

The role of testing personnel can be defined as follows:

- Test Set Operator—Supervises the test and operates the TDR instrument.
- Safety Observer—Observes the performance of the test, oversees the test setup, watches for any potential safety hazards, and gives warnings and guidance as required.

Personnel safety considerations include:

- Hold a pre-test meeting for everyone who will be working near the area where testing will be performed. Frequently, other crews will be working on non-test-related tasks in close proximity to the equipment being tested.
- Review the tests to be performed; the apparatus and the voltage test levels involved; and potential hazards of the work and individual assignments
- Remind personnel to be aware of the activity taking place around them and to be aware that non-test personnel may enter the test area.
- Agree on a consistent and uniform set of visual and verbal signals that will be used during testing.
- While making the various types of connections involved in the different tests, it may be necessary for personnel to climb up on the apparatus.

  Be sure that no one remains on the apparatus while a test is in progress.

WARNING!

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

Do not handle contact monitor cable test connections while a test is running. Up to 48 V DC can be present.

Safely Testing the TDR900 or TDR9000

To ensure a safe testing environment:

- Use the correct voltage to power the instrument 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 instrument.
- Never insert metal objects, such as screwdrivers or paper clips, inside the instrument while power is ON.
- Unplug the instrument if it is not to be used for an extended period of time, or before cleaning.
- If the instrument is dropped, have it checked by a qualified service technician before placing it back in service. Dropping the instrument can disturb the insulation system.

3. Circuit Breaker Testing Theory

This chapter covers two major topics:

- "Basic Circuit Breaker Interruption Principles" on page 3-1
- "How to Time Switching Devices" on page 3-23

Basic Circuit Breaker Interruption Principles

When a switch carrying AC current opens, an arc forms. This arc is initiated when the last metal-to-metal contact breaks (time T_1 in Figure 3.1).

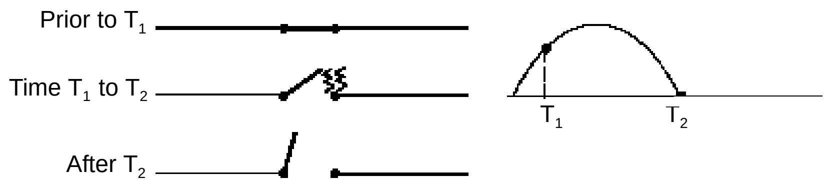


Figure 3.1 Arc Principles

The arc is a conductor. As the contact in motion moves away from the stationary contact, the arc stretches. This stretching and cooling enables the arc to quench at a point where the current is zero, represented by time T_2 in Figure 3.1, subsequent to contact parting. The alternating current crosses zero twice each cycle. At these zero crossings, the arc extinguishes. It remains extinguished if the dielectric strength of the insulating medium between the contacts is greater than the transient recovery voltage across the contacts. (See "Transient Recovery Voltage" on page 3-15 for more information.)

If the dielectric strength across the contacts is insufficient to withstand the transient recovery voltage, a restrike occurs and the arc is re-established. At the next zero crossing the arc again extinguishes. This process continues until the dielectric strength is sufficient to withstand voltage across the contacts.

Interruption in Air

The following sections explain circuit breaker interruption in air, including:

- Air-Magnetic Circuit Breakers
- Air-Blast Circuit Breakers

Air-Magnetic Circuit Breakers

Figure 3.2 and Figure 3.3 on page 3-3 explain current interruption in an air-magnetic circuit breaker. Air-magnetic circuit breakers use a magnetic field to lengthen the arc and force it into a labyrinth of insulating plates where it is stretched, dispersed, and cooled by the interleaved arc plates.

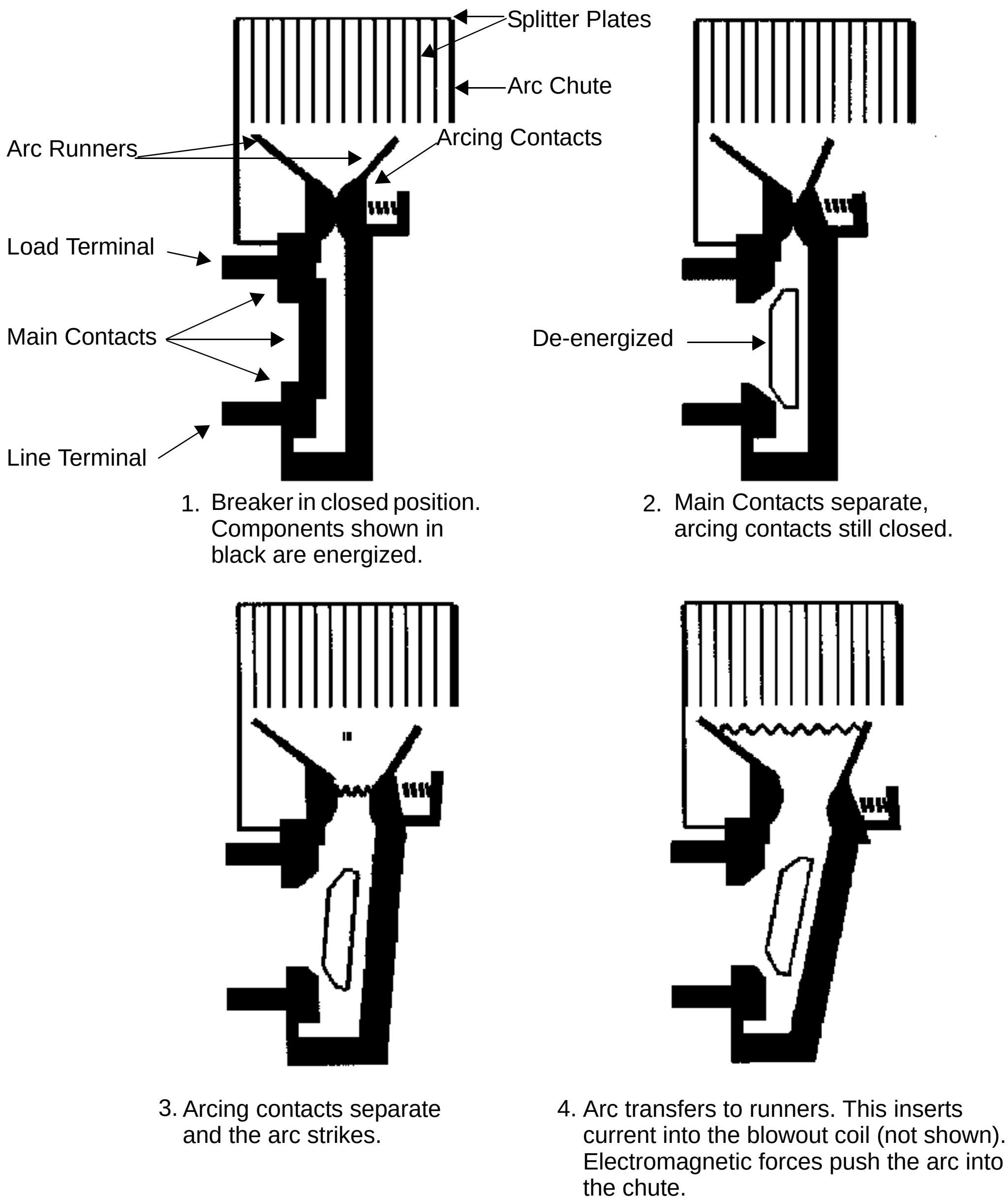
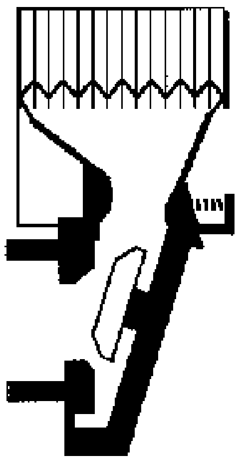
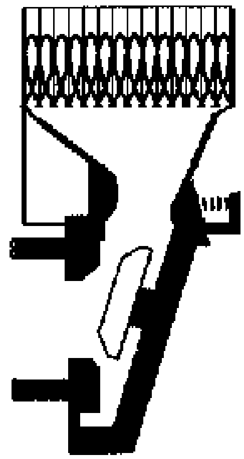


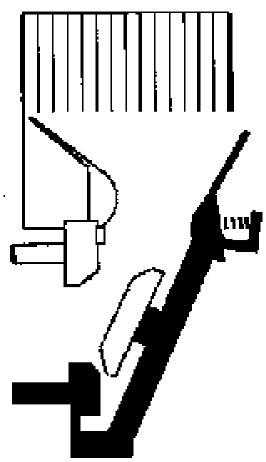
Figure 3.2 Air-Magnetic Breaker Operation



5. Arc transfers to splitters to form a number of short series arcs.



6. Small arcs are attached into loops. This cools the arc and increases resistance to a point where, at an early current zero, the arc is quenched.



7. Current is interrupted. Visible break.

Figure 3.3 Air-Magnetic Breaker Operation (Continued)

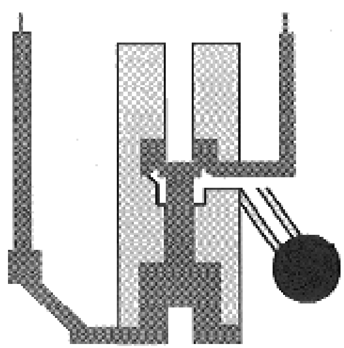
Air-Blast Circuit Breakers

This section describes two techniques employed by air-blast circuit breakers.

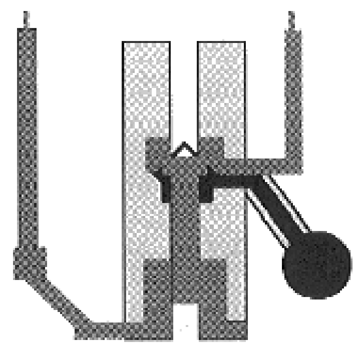
Technique 1

Figure 3.4 and Figure 3.5 on page 3-5 explain the process that occurs for current interruption in an air-blast circuit breaker.

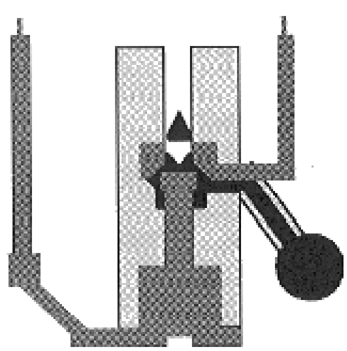
This technique is used in the circuit breakers rated up to 46 kV.



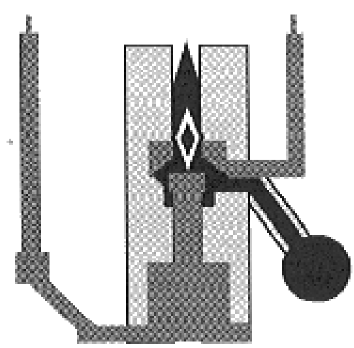
1. Cross section of a circuit breaker showing the path of current when the circuit breaker is in the closed position.



2. The trip coil is energized and releases a pilot air valve which allows the air to flow from the breaker tank. This air flows to the contact chamber and displaces the interrupting contacts.

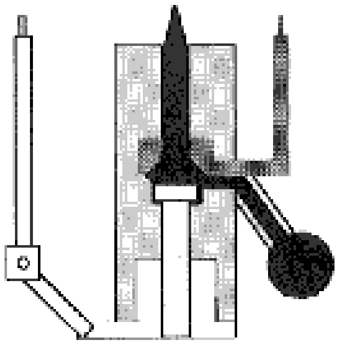


3. Air blast continues to force air past the interrupting contacts as the arc is initiated.

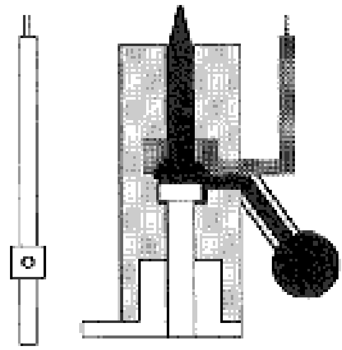


4. When the air travels and streams alongside the arc, the arc is enveloped and the arc products are directed to a cooling chamber.

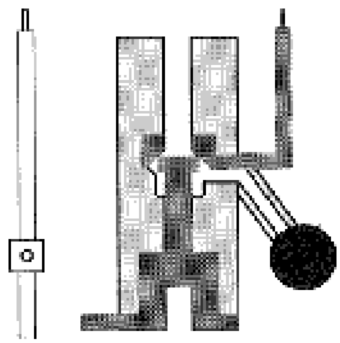
Figure 3.4 Air-Blast Circuit Breaker Operation



5. As the air blast continues, the energy of the arc is absorbed by further cooling and the dielectric strength is increased.



6. The arc is extinguished at the end of 1/2 cycle. After a time delay, the isolating contacts open.



7. When the isolating contacts are open, the air valve shuts off the air blast supply and the interrupting contacts reset through spring pressure.

Figure 3.5 Air-Blast Circuit Breaker Operation (Continued)

Technique 2

The basic principle illustrated in Figure 3.6 is used in circuit breakers rated up to 765 kV. Under normal conditions, current-carrying conductors are surrounded by compressed air.

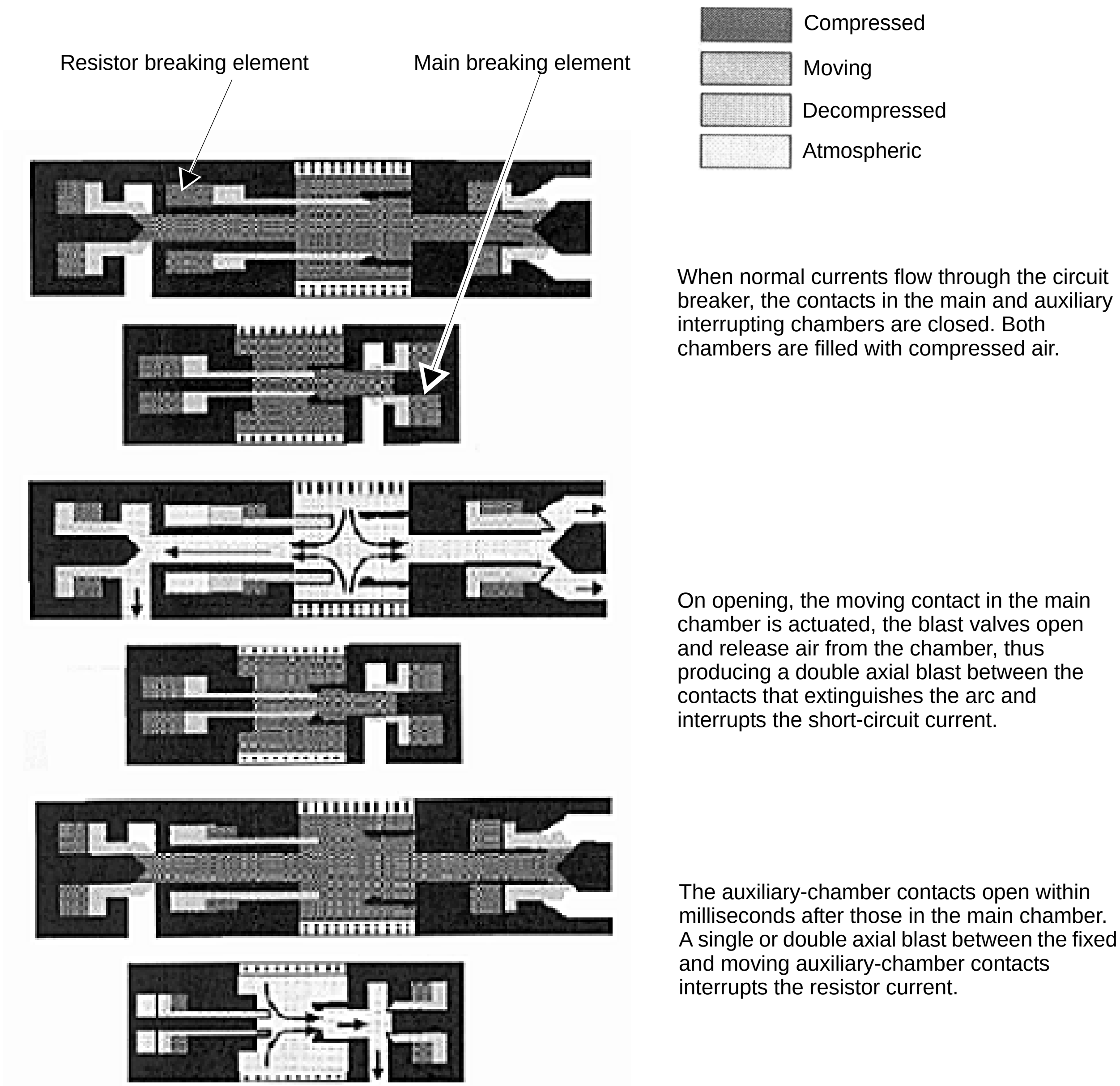


Figure 3.6 Air Blast Circuit Breaker – General Operation (Courtesy of GEC Alsthom T&D Inc.)

Interruption in Oil

Oil circuit breakers use oil to provide insulation. During the presence of the arc, oil produces hydrogen and other gases as by-products. The hydrogen helps to cool the surface of the arc.

The heart of the oil circuit breaker is the arc control device. At the earliest instance when the current is zero after contact separation, the arc control device causes the path of the resulting arc to lose its memory concerning its conducting state.

Figure 3.7 shows the crossblast interrupter method, in which the arc is drawn in front of a series of lateral vents. The heat of the arc vaporizes the oil, and the gases formed increase in pressure and force the arc to blow into the vents. Before the arc can escape from the vents, it short-circuits itself at the entry point to the vents.

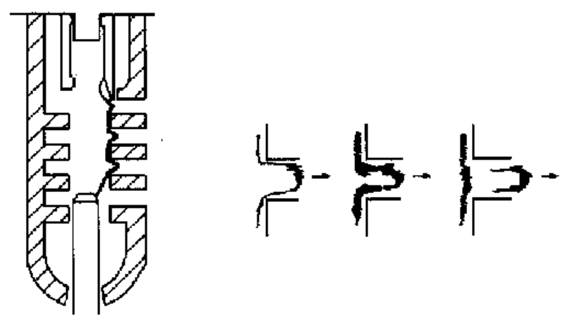


Figure 3.7 Circuit Breaker Interruption in Oil

This process continues throughout the arcing period at intervals of the order of tens of microseconds, though these time intervals are not constant because the relevant events both inside and outside the arc control device are changing continuously.

Ultimately, when the pressure inside the arc control device becomes sufficiently high, and the length of the arc is also sufficiently extended at a power frequency of current zero, the arc is extinguished.

The arc always burns inside a bubble of gas, and this bubble extends and expands through the vents to the outside of the arc control device. The hot gases emerging from the vents are initially still ionized and it is essential to ensure by correct vent design that no breakdowns occur between the vents external to the arc control device. This is particularly important for EHV interrupters where multiple series vent arrangements are invariably used.

Oil circuit breakers are used up to 345 kV.

Interruption in Vacuum

Figure 3.8 gives a size comparison between a Westinghouse 10-cm-diameter vacuum interrupter rated 500 MVA (15 kV / 22 kA) and the arc chute of a Westinghouse air circuit breaker of comparable rating. (Reprinted from Reference 2. Permission granted by Marcel Dekker, Inc.)

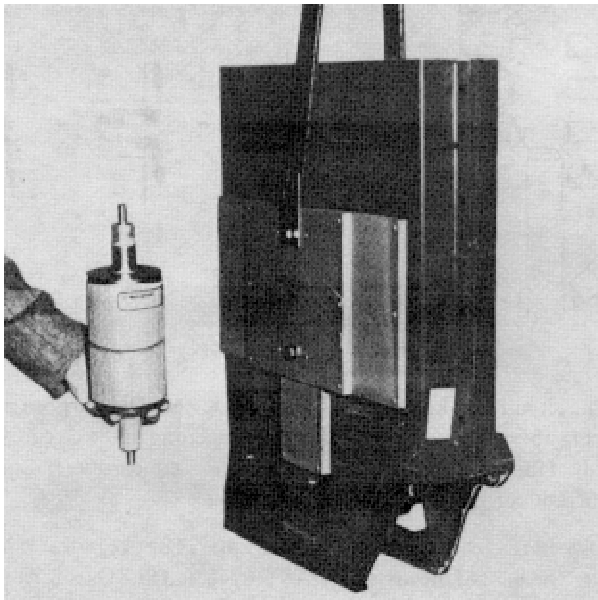


Figure 3.8 Size Comparison Westinghouse 10-cm-Diameter Vacuum Interrupter/Arc Chute of a Westinghouse Air Circuit Breaker

Figure 3.9 gives a general vacuum interrupter cross section. (Reprinted from Reference 2. Permission granted by Marcel Dekker, Inc.)

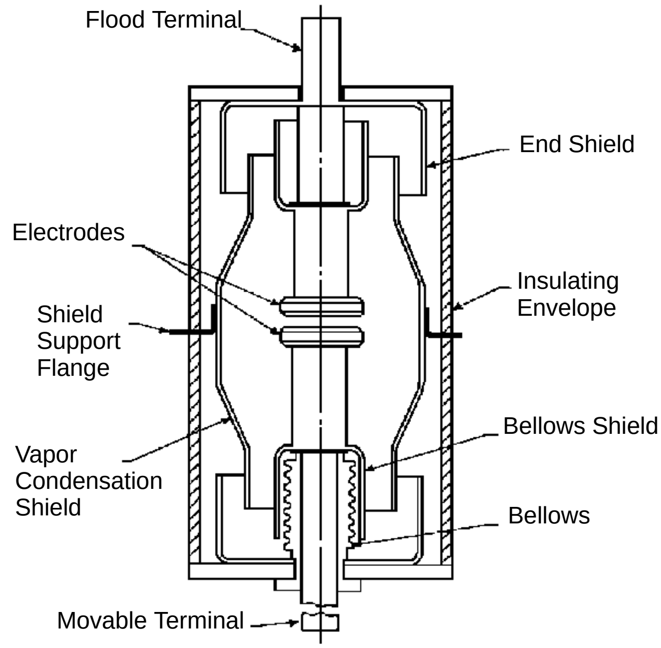


Figure 3.9 Vacuum Interrupter Schematic

The ambient gas pressure within the evacuated envelope is 1.33E-09 bar. Under normal circuit conditions the interrupter is closed and contacts butt together.

Arcing is established within the interrupter by separating the movable contact from the stationary contact. This arc burns in the metal vapor evaporated from local hot spots on the contact surfaces. The metal vapor continually leaves the intercontact region and recondenses on the contact surfaces and the surrounding metal vapor condensation shield.

The shield is usually isolated from both contacts and serves to protect the glass or ceramic envelope from vapor deposition. When the current waveform crosses zero, vapor production ceases and the original vacuum condition is rapidly restored with the contacts in the open position. The circuit voltage is withstood internally by the intercontact gap and externally by the insulating envelope.

Vacuum interrupters are currently manufactured for use in circuit breakers rated up to 72.5 kV.

Interruption in SF_6

One of the most important electrical characteristics of SF_6 (sulfur hexafluoride) is its dielectric strength. Figure 3.10 shows a graph demonstrating the dielectric strength of SF_6 and N_2. (Reprinted from Reference 2. Permission granted by Marcel Dekker, Inc.)

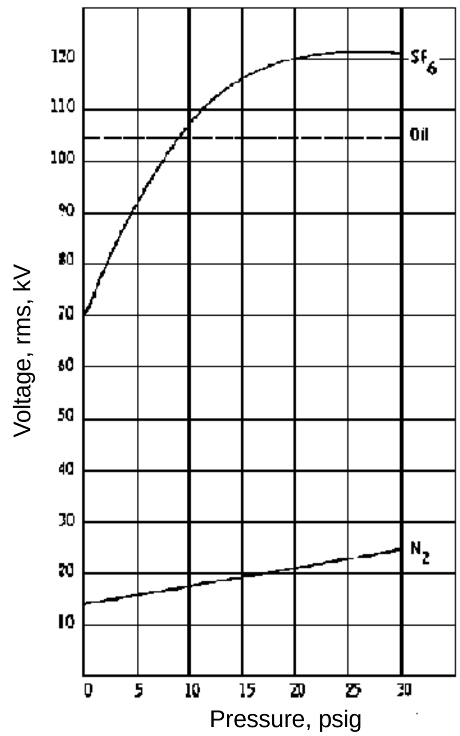


Figure 3.10 60 Hz Dielectric Strength of SF_6 vs. N_2

At any given pressure the dielectric strength of SF_6 is generally three to five times that of air.

The remainder of this discussion gives the specific information on how Double-Pressure, Puffer Type, and Self-Extinguishing SF_6 circuit breakers operate.

Double-Pressure SF_6 Circuit Breakers

Figure 3.11 shows the structure of a Double-Pressure SF_6 circuit breaker (Reprinted from Reference 2. Permission granted by Marcel Dekker, Inc.).

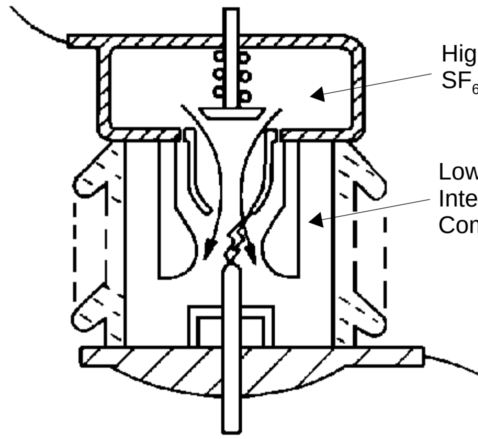


Figure 3.11 Double-Pressure SF_6 Circuit Breaker Operation

This is the early design of SF_6 circuit breakers. Its operation is similar in principle to that of air-blast circuit breakers: It is comprised mainly of these two elements:

- A high-pressure metal reservoir containing most of the SF_6 gas
- An interrupter compartment containing the circuit breaker contacts surrounded by SF_6 gas at lower pressure

For the current breaking operation, the circuit breaker contacts part while the high-pressure gas is released from its reservoir to the interrupter compartment, where it blows out the arc. After the current interruption, the gas is pumped back to its reservoir.

Self-Extinguishing SF_6 Circuit Breakers

Figure 3.12 shows the structure of a Self-Extinguishing SF_6 circuit breaker. (Reprinted from Reference 2. Permission granted by Marcel Dekker, Inc.)

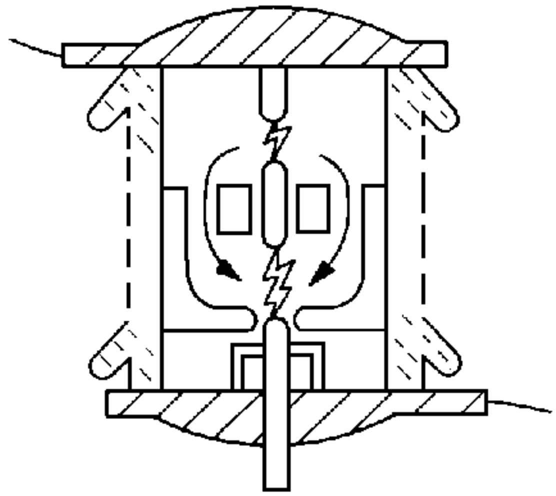
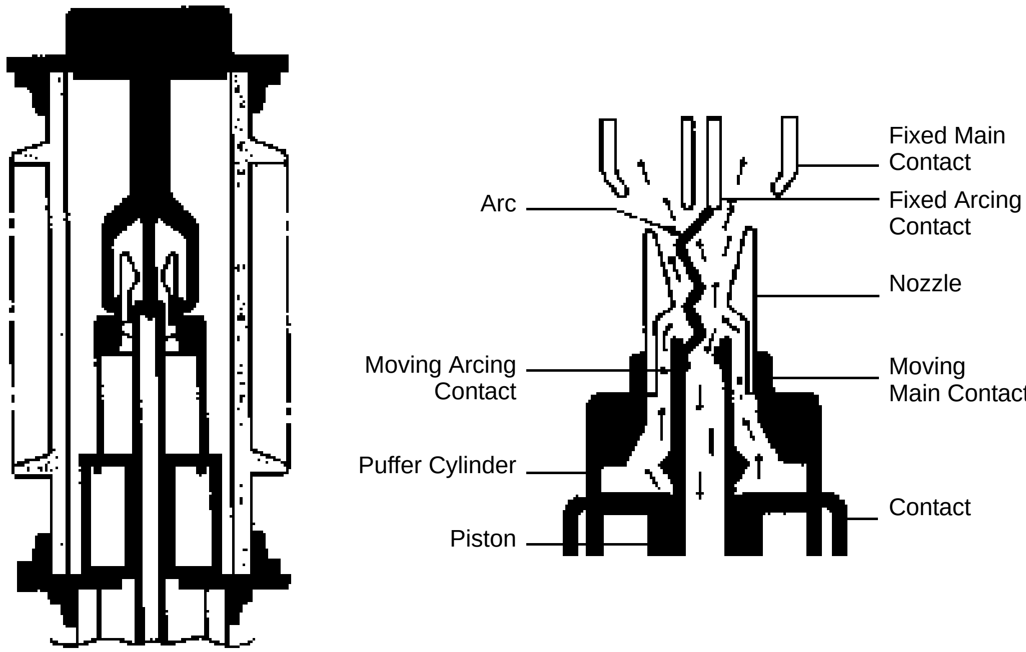


Figure 3.12 Self-Extinguishing SF_6 Circuit Breaker Operation

The interrupting chamber is divided into two main compartments, one of which is the arc compartment. Both have the same gas pressure, about 5 bar, while the circuit breaker is closed or open. When the circuit breaker is being opened, the contacts separate and an arc is drawn between them. The heat generated by the arc heats the gas in the arc compartment and rapidly increases its pressure. The gas blasts from the arc compartment to the second, adjacent compartment. This rapid expansion cools the arc column and extinguishes it at a current zero point. A third compartment (not shown) is incorporated to augment the gas pressure while interrupting smaller currents. Using this arrangement, the arcing time is independent of the current magnitude; and the currents are interrupted at their natural zero.

Puffer-Type SF_6 Circuit Breakers

Figure 3.13 shows the structure of a Puffer-Type SF_6 circuit breaker (courtesy of Mitsubishi Electric). These circuit breakers are applied to voltages up to 765 kV.



Closed Position **Interrupting Principle**

Figure 3.13 Puffer Type SF_6 Circuit Breaker Operation

The SF_6 gas in the cylinder is compressed by the downward movement of the cylinder and is forced into the nozzle area where the arc is drawn between the stationary arc contact and the moving arc contact. The nozzle concentrates the gas flow to the area of the arc, resulting in very effective arc extinction.

Live Tank vs. Dead Tank

In the dead-tank design, shown in Figure 3.14, the interrupting elements are enclosed in a grounded metal tank and the conductors enter the interrupting chamber through bushings.

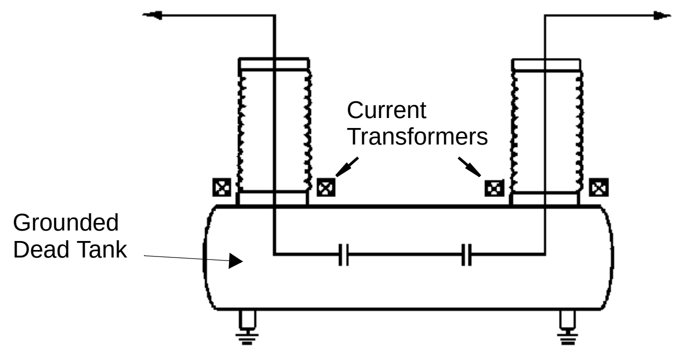


Figure 3.14 Dead-Tank Circuit Breaker Schematic

In the live-tank design, as shown in Figure 3.15, the circuit breaker interrupters are mounted in a container at line potential and are insulated from ground potential using porcelain insulating columns. The major advantage of the live tank is its lower cost, especially at a higher voltage rating.

A major disadvantage is that it requires externally mounted current transformers, which are more expensive and require more substation space than bushing current transformers.

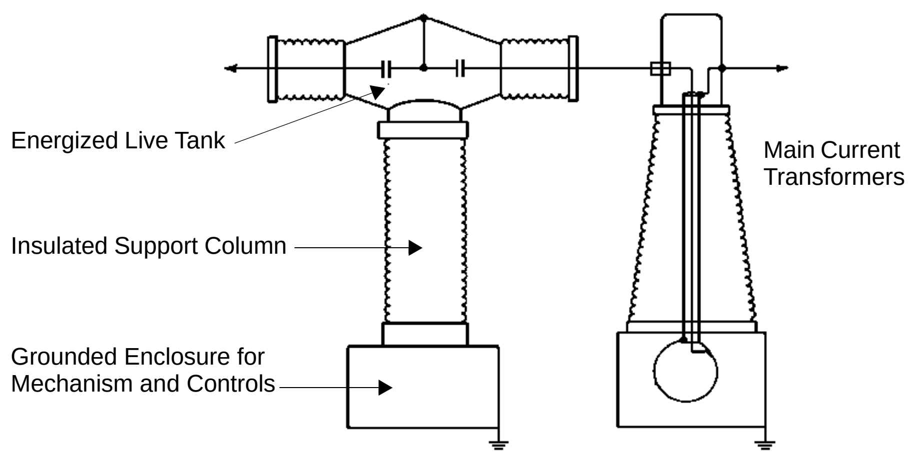


Figure 3.15 Live-Tank Circuit Breaker

Transient Recovery Voltage

Figure 3.16 shows the Transient Recovery Voltage scheme. (Reprinted from Reference 2. Permission granted by Marcel Dekker, Inc.)

When the current through the circuit breaker is interrupted, the entire system adjusts to its new operating state. The voltage transients produced separately by the left subsystem, $V_L(t)$, and the right subsystem, $V_R(t)$, stress the recently conducting arc plasma. The transient recovery voltage (TRV) is defined as the difference between the voltage on the left and right sides of the circuit breaker.

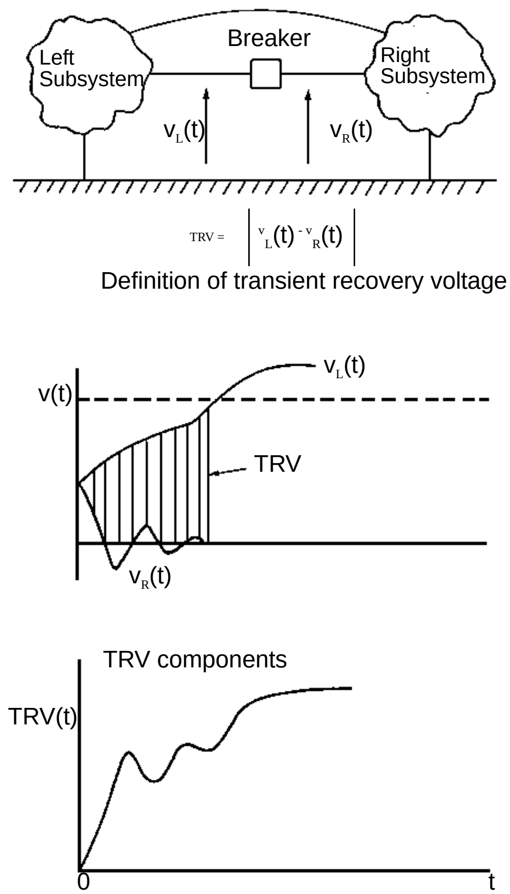


Figure 3.16 Transient Recovery Voltage Scheme

When the basic interrupter of the circuit breaker does not meet the interruption requirements, auxiliary devices, including an insertion resistor, shunt capacitor, or open-gap grading capacitor, are used to modify the TRV.

Insertion Resistor on Close

Figure 3.17 shows how an insertion resistor is used to modify the TRV (courtesy of ABB Power T&D Company, Inc.).

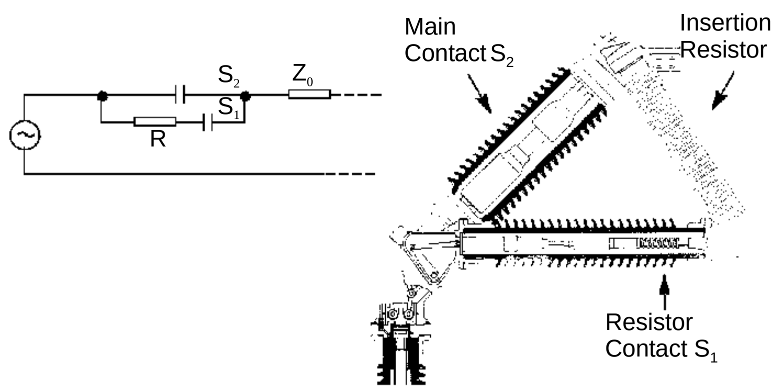


Figure 3.17 Transient Recovery Voltage: Insertion Resistor Operation

Many circuit breakers, especially those used in transmission circuits, employ resistors for operation. They were originally used during opening operations and still, if present, provide a useful function at these times.

Such resistors serve one of two functions: In a multibreak circuit breaker they are used to help to distribute the transient recovery voltage more uniformly across the several breaks. They can also be used to reduce the severity of the transient recovery voltage at the time of interruption by introducing damping into the oscillation. When the fault current has been switched by S_2, a remaining current flows through R. This must be interrupted subsequently by opening the auxiliary interrupter S_1.

The primary use of the resistors in modern circuit breakers is to reduce voltage transients on closing. If the source is stiff, a high percentage of the source voltage is impressed across the line at the time the circuit breaker closes to energize a transmission line. If the other end of the transmission line is open, or if it is terminated in a high impedance load such as an unloaded transformer, the voltage wave essentially doubles at the far end. Such high switching surges put severe stress on components at that location. Transmission circuit breakers with insertion resistors help to minimize this transient effect. Switch S_1 is closed first; the voltage across it is shared by R. The voltage impressed on the line is reduced by the factor Z_0R+Z_0 and all the waves generated as a consequence are correspondingly reduced. The switch, S_2, is closed a short time later, after the surges on the line have subsided.

Shunt Capacitor

Figure 3.18 shows how a shunt capacitor is used to modify the TRV (Courtesy of ABB Power T&D Company, Inc.).

A shunt capacitor is connected across the phase-to-ground voltage. This has no effect on the magnitude of the recovery voltage, but does affect the initial rate of rise of the transient voltage.

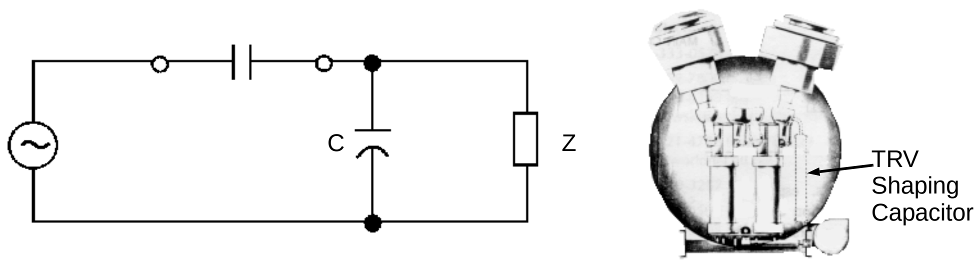


Figure 3.18 Transient Recovery Voltage: Shunt Resistor Operation

Open-Gap Grading Capacitor

Figure 3.19 shows how an open-gap grading capacitor is used to modify the TRV (courtesy of Mitsubishi Electric).

A capacitor is applied across the open contacts of a circuit breaker. Most multibreak circuit breakers use grading capacitors across the contacts to obtain the proper voltage division for interruption and surge voltage control.

The grading capacitor acts the same as a shunt capacitor in affecting the initial rate of the transient voltage.

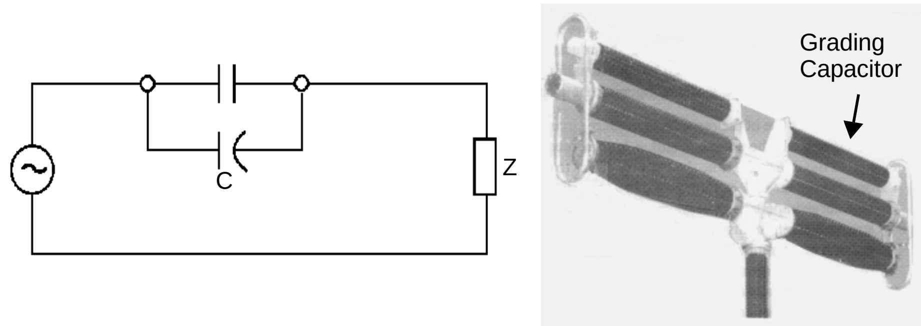


Figure 3.19 Transient Recovery Voltage: Open-Gap Grading Capacitor Operation

Gang Operation vs. Independent Pole Operation

Gang operation is a term used for a circuit breaker mechanism that operates all three poles together.

As the voltage level increases, the distance between phases must also be increased in order to maintain the necessary dielectric strength in air. It is very difficult to maintain contact synchronism when using gang operation. The length and the mass of the interconnecting rod also becomes a problem. Therefore, multiple single pole mechanisms are used in most circuit breakers above 345 kV.

When a high voltage circuit breaker consisting of three single pole mechanisms is used (Independent Pole Operation), it is necessary to employ a phase disagreement circuit to eliminate the possibility of having one or more phases closed while one or more phases are open.

Single phase tripping and reclosing for single phase-to-ground faults may be used in a circuit breaker with Independent Pole Operation. Power can be transmitted in the two unfaulted phases, while the third phase interrupts the fault and then recloses to restore the circuit. If the reclosing is not successful, the other two phases must be opened. This scheme may aid in maintaining system synchronism and stability in addition to maintaining power flow.

Circuit Switchers and Breakers with Isolating Contacts

A circuit switcher is an outdoor switching device that incorporates both an interrupter and an air disconnect switch. Because circuit switchers typically have lower interrupting ratings, they are more limited in their applications. However, they are an economical solution when higher ratings are not required.

Circuit switchers employ SF_6, vacuum, or other types of interrupters to break a circuit, and either the interrupter or the air switch to make the contact. The sequence of operation varies with the type of circuit switcher.

Figure 3.20 shows how the interrupter breaks the circuit.

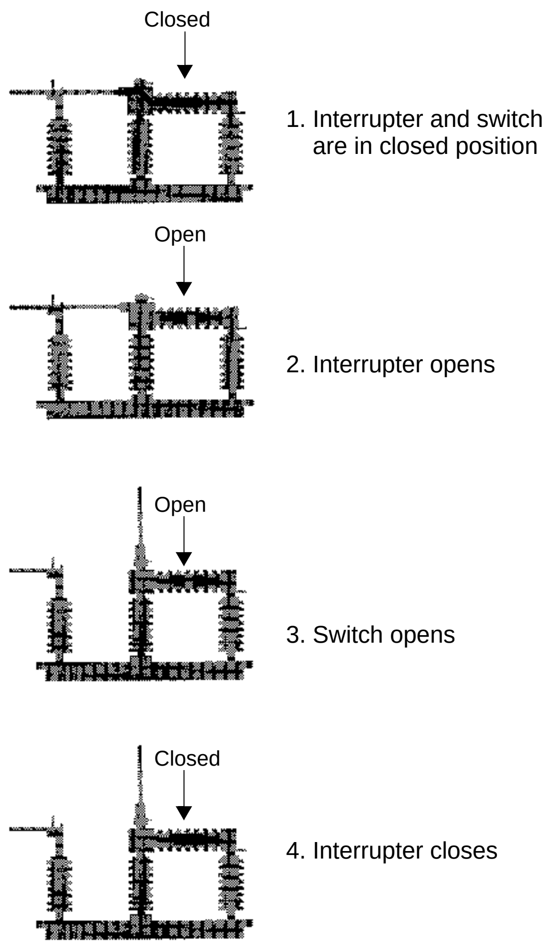
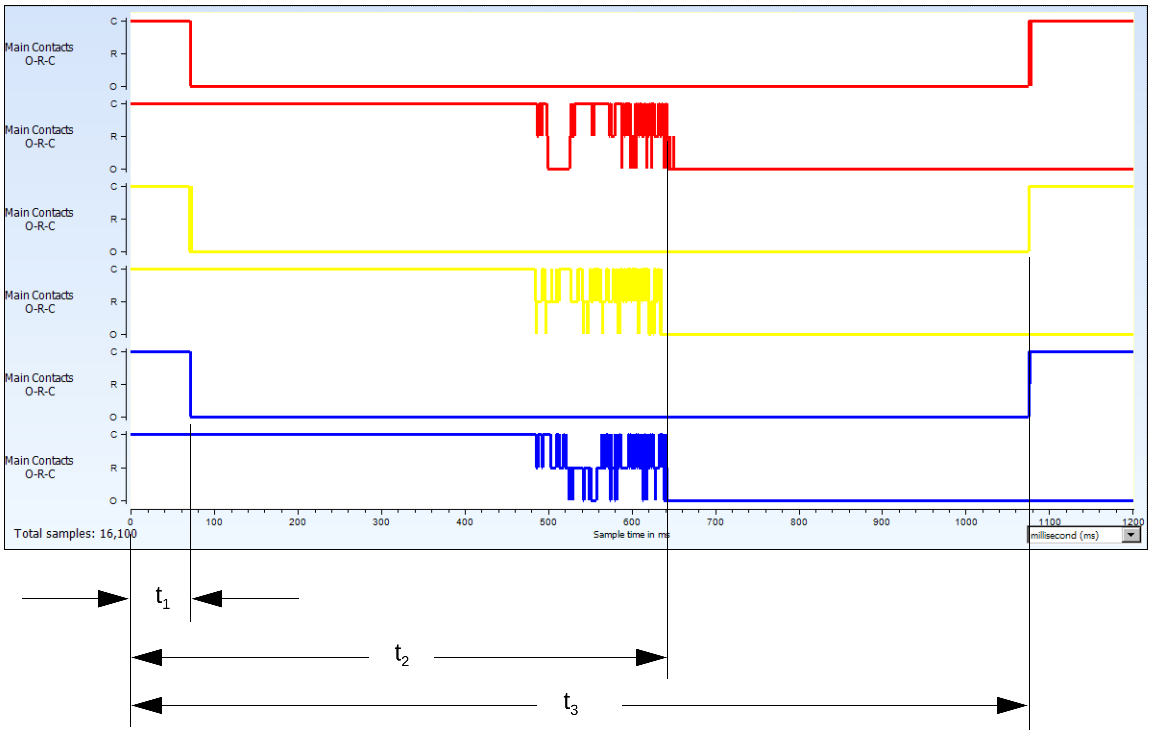


Figure 3.20 Circuit Switcher Opening Operation

Both the switch and the interrupter are closed (1), carrying current. When activated, the interrupter opens (2), breaking the current, while the switch is still closed. The switch then opens (3) for full visual confirmation of circuit isolation.



t_1 = Opening time of interrupter
t_2 = Opening time of switch
t_3 = Closing time of interrupter

Figure 3.21 Waveforms for Circuit Switcher Opening Operation

Figure 3.22 shows how the switch closes the circuit.

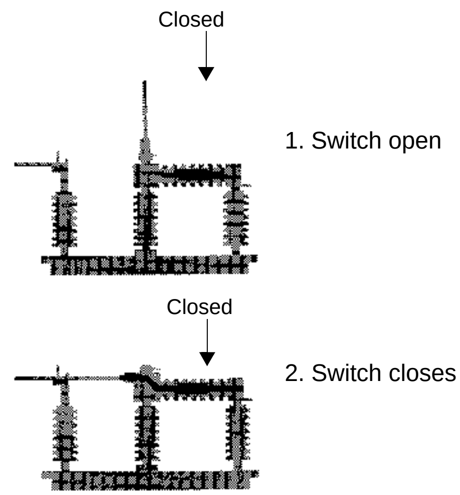


Figure 3.22 Circuit Switcher Closing Operation

The final closing of the switch activates the mechanism.

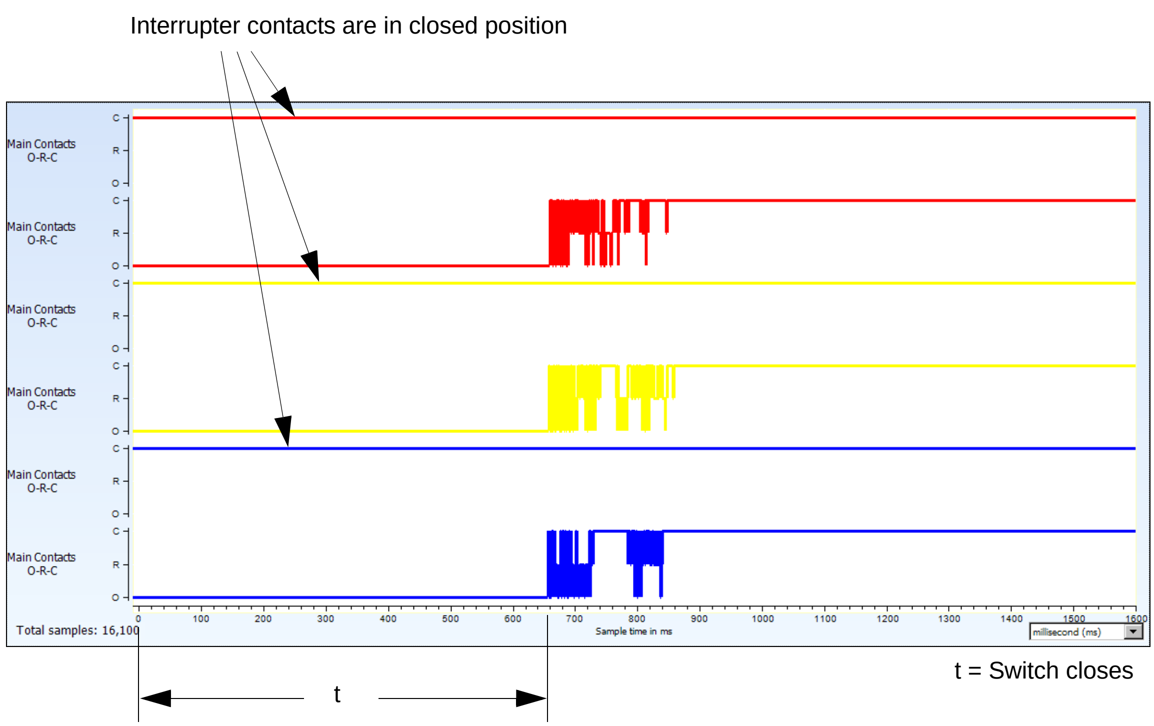


Figure 3.23 Waveforms for Circuit Switcher Closing Operation

Some circuit breakers have isolators (#6, Figure 3.24) in conjunction with their main interrupting contacts (#1, Figure 3.24), as well as arcing contacts (#2, Figure 3.24) and auxiliary arcing chambers. The BBC DR 36 is such a circuit breaker. Because the main, arcing, and resistor chamber contacts all have distinct timing characteristics, it is necessary to use a timing device that allows for several different sets of contact timing specifications.

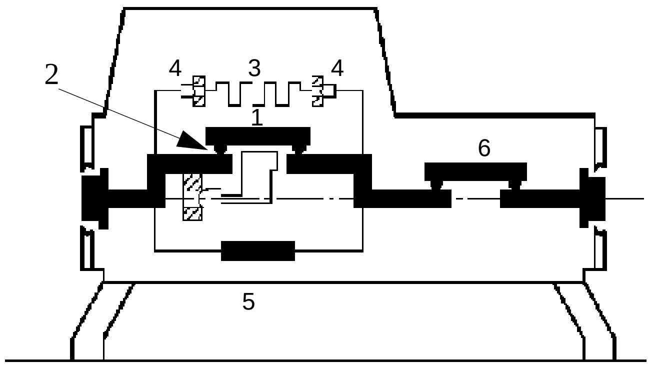


Figure 3.24 Circuit Breaker with Isolating Contacts

How to Time Switching Devices

Figure 3.25 displays a typical circuit used to monitor contact status.

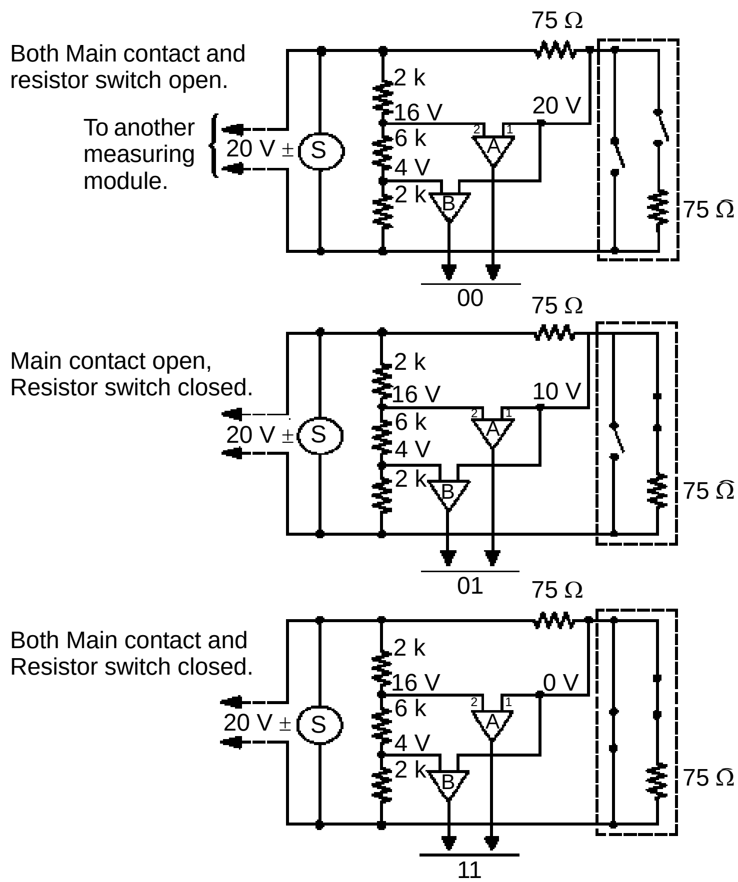


Figure 3.25 Contact Monitoring

The source voltage (20V) is applied across the voltage divider comprised of the contact assembly and the internal resistor (75 Ω). This voltage divider determines the contact voltage signal, which depends on the status of the contact assembly. The contact voltage signal is compared with a scaled replica of the source voltage. The output of the comparator depends on the relationship between inputs, as shown on Figure 3.26.

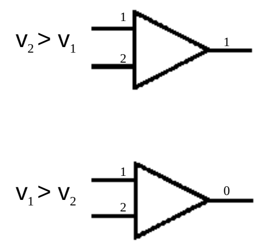


Figure 3.26 Voltage Comparator Output

Figure 3.27 shows how changing the contact assembly status (both open, main contact open-resistor switch closed, both closed) changes the contact voltage signal applied to the input 1 of the comparators, which results in different combinations of the outputs. These different combinations of output signals are further interpreted to assign a corresponding status to the contact assembly.

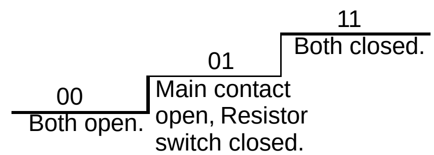


Figure 3.27 Effect of Contact Assembly Status on Output Voltage

Due to the physical geometry of a multiple module live tank circuit breaker, there is a stray capacitance-to-ground present in each circuit breaker head. Additional capacitance is added by the measurement cables attached to the circuit breaker. Figure 3.28 shows C_1, C_2, C_3 as the total capacitances-to-ground present during the measurement. These typically are 4000 to 8000 pF.

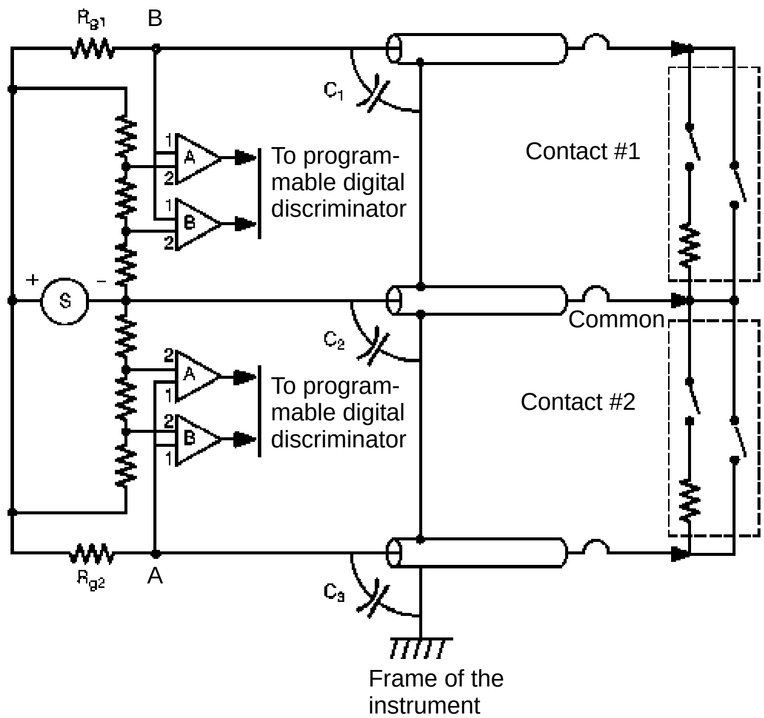


Figure 3.28 Capacitance-to-Ground for a Circuit Breaker

Figure 3.29 shows what happens when the diagram is simplified and analyzed at the moment when contact #2 closes and contact #1 is still open.

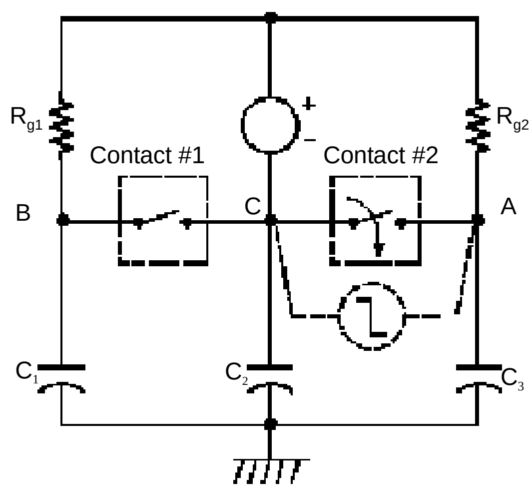


Figure 3.29 Capacitance-to-Ground: Contact #2 Closed, Contact #1 Open

When contact #2 closes, the potential at point A goes from $+V_s$ to zero. Consequently, to simplify the analysis, replace the closing of contact #2 with a voltage source, which represents a step-down function.

Figure 3.30 shows a redrawn diagram that excludes the instrument power supply (S) from the circuit, because the power supply has no effect on the transient process.

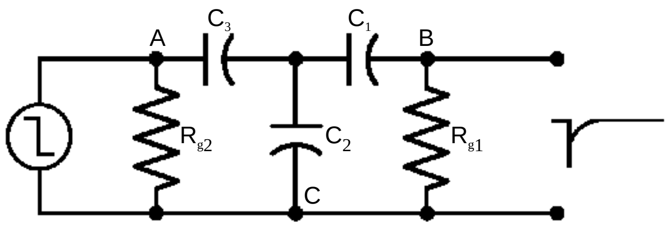


Figure 3.30 Capacitance-to-Ground: Contact #2 Closed, Contact #1 Open (Simplified)

When contact #2 is still open (step-down voltage is not applied to point A), all capacitors are charged according to the circuit parameters (C_2 in series with $C_1//C_3$. See Figure 3.29 on page 3-25.) As soon as the step-down voltage is applied, the capacitors discharge (C_1 in series, with $C_2//C_3$) and, because of the current through Rg1, the voltage at point B drops. When the discharge process is completed and the capacitors are charged according to the new circuit condition, the potential at point B returns (no current through Rg1).

The voltage at point B is monitored by the comparators that follow the open-to-close transition of contact #1. The temporary voltage drop can be misinterpreted as a change in the state of contact #1. This phenomenon results in *cross-talk* between the contact operation measurement channels. Occurring within the module and between all the modules in a phase, the cross-talk produces erroneous contact state transition information.

Although it is desirable to distinguish between real contact activity and cross coupled signals with 2 µs resolution, this is neither a practical nor realistic task because fast contact bounces and cross-talk appear as identical events. The cross-talk is dealt with by using a digital discriminator, a digital filter circuit located on each main contact channel. Located downstream from the comparator circuit, the digital discriminator qualifies the data before it is stored in memory. It operates upon any type of contact activity, and qualifies both main contacts and resistor switch data.

The filter time can range from 4 to 100 µs and is set by the test plan in 2 µs increments.

The Digital Discriminator circuit is triggered when a bounce is first detected, and sets up a *window* in time equal to the Filter Time. Bounces with durations equal to or greater than the Digital Filter Time are passed through and stored in memory as valid contact data, while bounces with durations less than the Filter Time are rejected and not recorded. The TDR instrument does, however, flag these events so they are not used when calculating the resistor value.

Contact Penetration (Insertion) and Wipe

The main distinction between the contact penetration, sometimes referred to as contact insertion, and the contact wipe is that penetration is obtained through mechanical measurement and contact wipe is obtained through electrical measurement.

The value of contact penetration is obtained as follows: with the circuit breaker closed, a mark is made on the moving contact as shown in Figure 3.31.

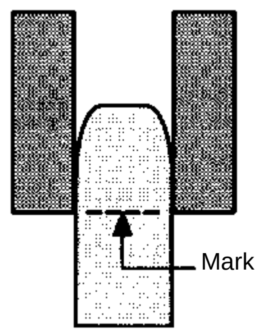


Figure 3.31 Contact Penetration Value Preparation

With the circuit breaker open, the distance between the mark and the top of the moving contact is measured as shown in Figure 3.32. This distance is the value of contact penetration or contact insertion.

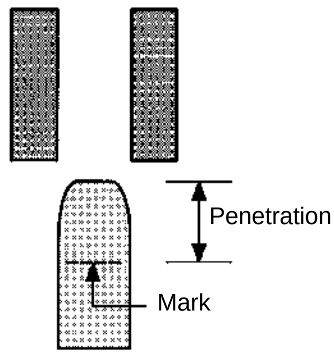


Figure 3.32 Contact Penetration Measurement

During the measurement of contact wipe, the measurement starts when the moving contact makes an electrical contact with the stationary contact and ends when the moving contact stops (Figure 3.33).

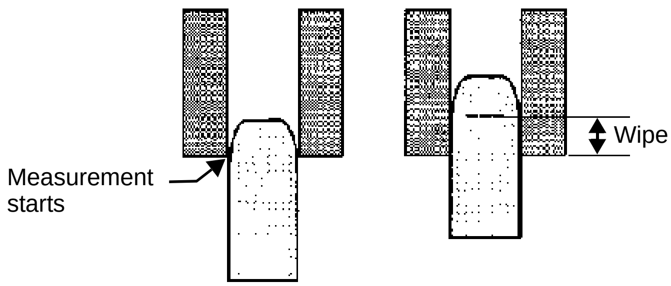


Figure 3.33 Contact Penetration Measurement Endpoints

Figure 3.32 on page 3-28 and Figure 3.33 show that, because of the chamfer on the moving contact, the mechanical and electrical measurements may yield different results.

Before the manufacturer's specification is used, it is important to know how this value is obtained. If the only specification available is the result of mechanical measurement (penetration), the benchmark for future trending analysis should be obtained by using the electrical wipe that was measured by the TDR instrument.

4. Preliminary Setup and Breaker Data

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

Preliminary setup involves these steps:

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.

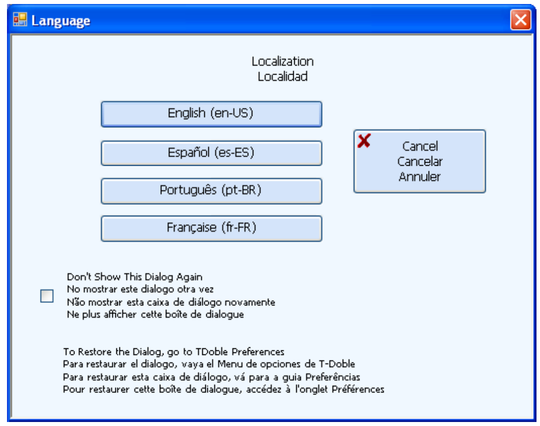


Figure 4.1 Language Window

2. Select **English**.

The Doble splash screen appears.

Figure 4.2 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 all 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 instrument 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 4.3 Tabs Providing Access to T-Doble Main Pages

Selecting the Instrument

The Instrument page enables you identify and to select a TDR900 or TDR9000 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.

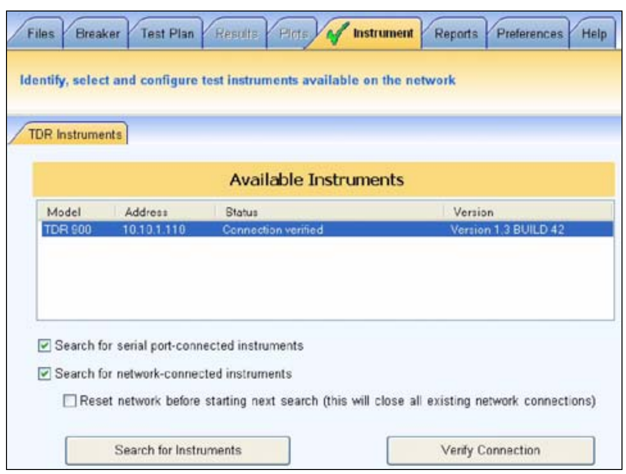


Figure 4.4 Instrument Page Listing Connected Instruments

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

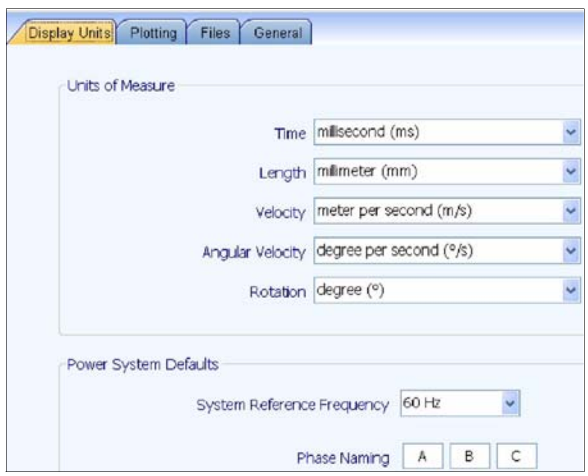


Figure 4.5 Display Units Tab of Preferences Page

Plotting Tab

The Plotting tab provides such settings as line thicknesses, axis characteristics, colors, and so on. "Setting Plotting Preferences" on page 8-5 for more information.

Files Tab

The Files tab provides settings related to saving and importing files. See Saving Test Results for a discussion of how to save data."

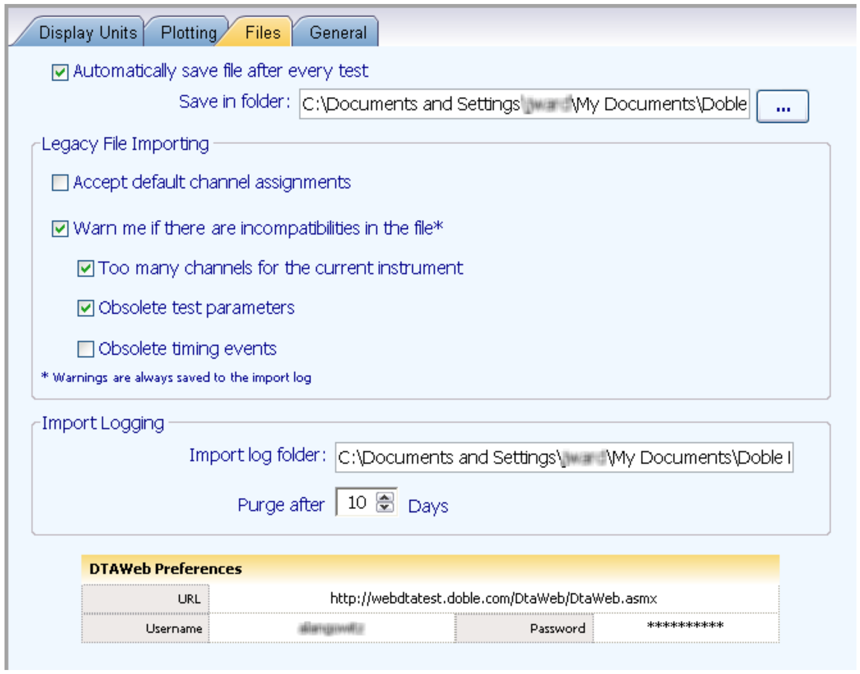


Figure 4.6 Files Tab of Preferences Page

General Tab

The General tab provides options governing the opening and closing of T-Doble windows and of T-Doble itself.

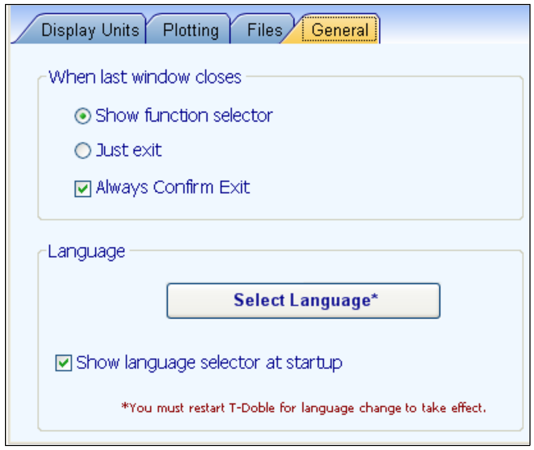


Figure 4.7 General Tab of Preferences Page

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.

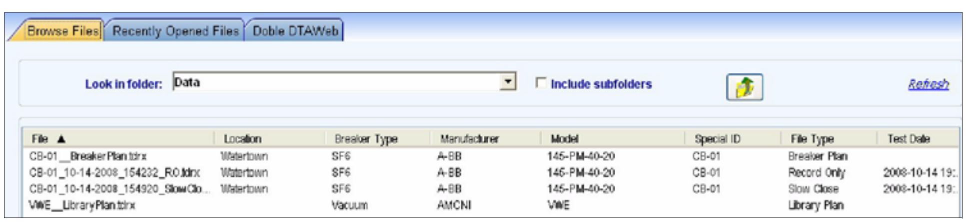


Figure 4.8 Files Page and Browse Files Tab

Entering Breaker Data

The Breaker page enables you to select and enter all data related to the circuit breaker you wish to test. It contains the following tabs:

- "Start Here Tab" on page 4-7
- "Nameplate Tab" on page 4-8
- "Basic Limits Tab" on page 4-9
- "Motion Limits Tab" on page 4-30

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.

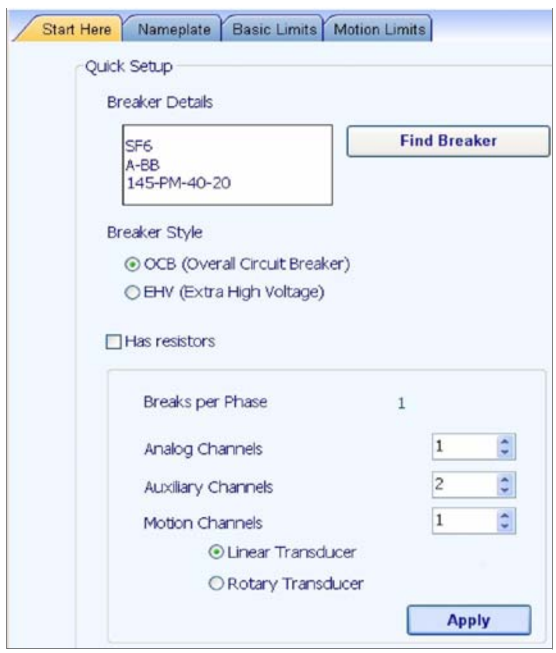


Figure 4.9 Start Here Tab of Breaker Page

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** or **EHV**).
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 4.10 shows the Nameplate tab.

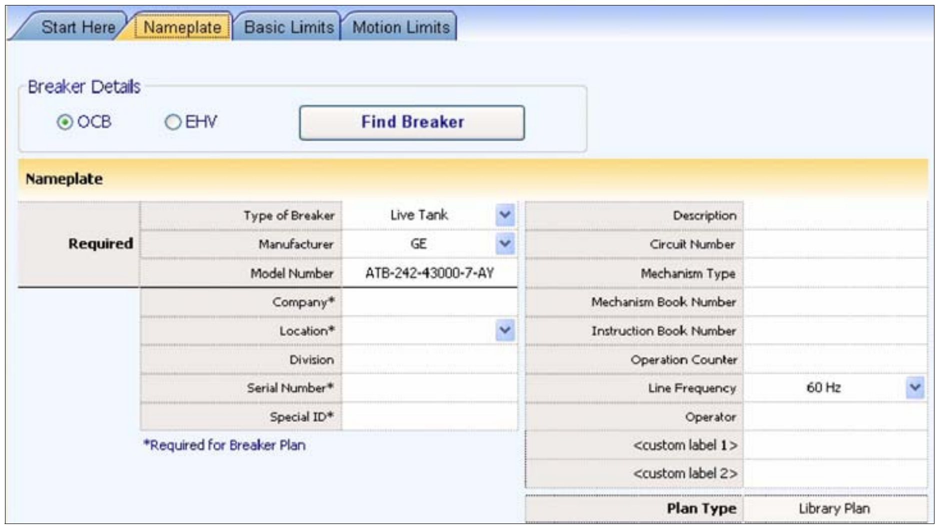


Figure 4.10 Nameplate Tab of the Breaker Page

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 4.11 shows timing limits for an OCB overall test, or for breakers with one break per phase.

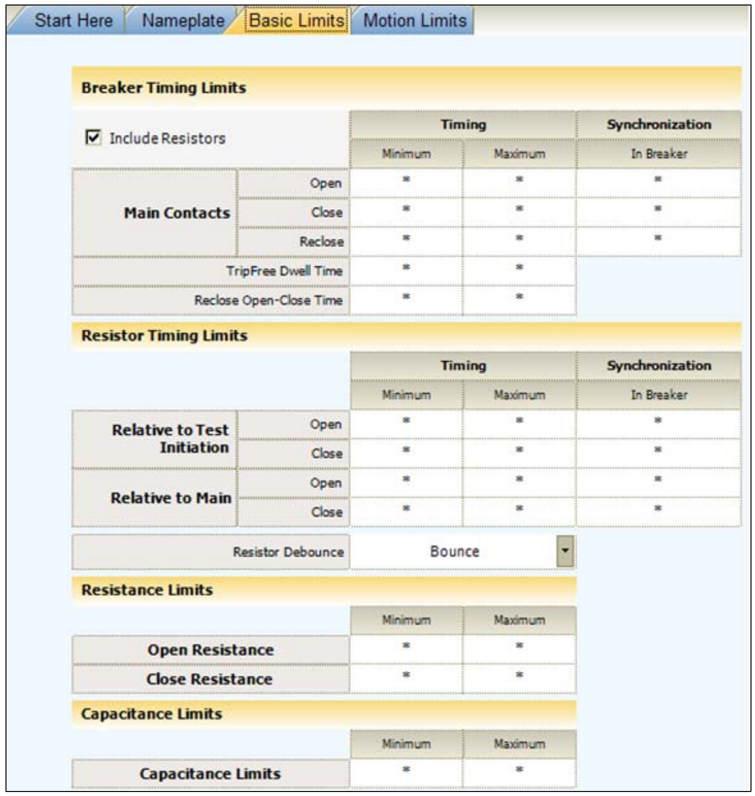


Figure 4.11 Basic Limits Tab of Breaker Page

Breaker Timing Limits

Figure 4.12 shows the timing limits for EHV breakers with multiple breaks per phase.

Breaker Timing Limits

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

Figure 4.12 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 4.13 shows contact opening time (the time between test initiation and the last contact to part).

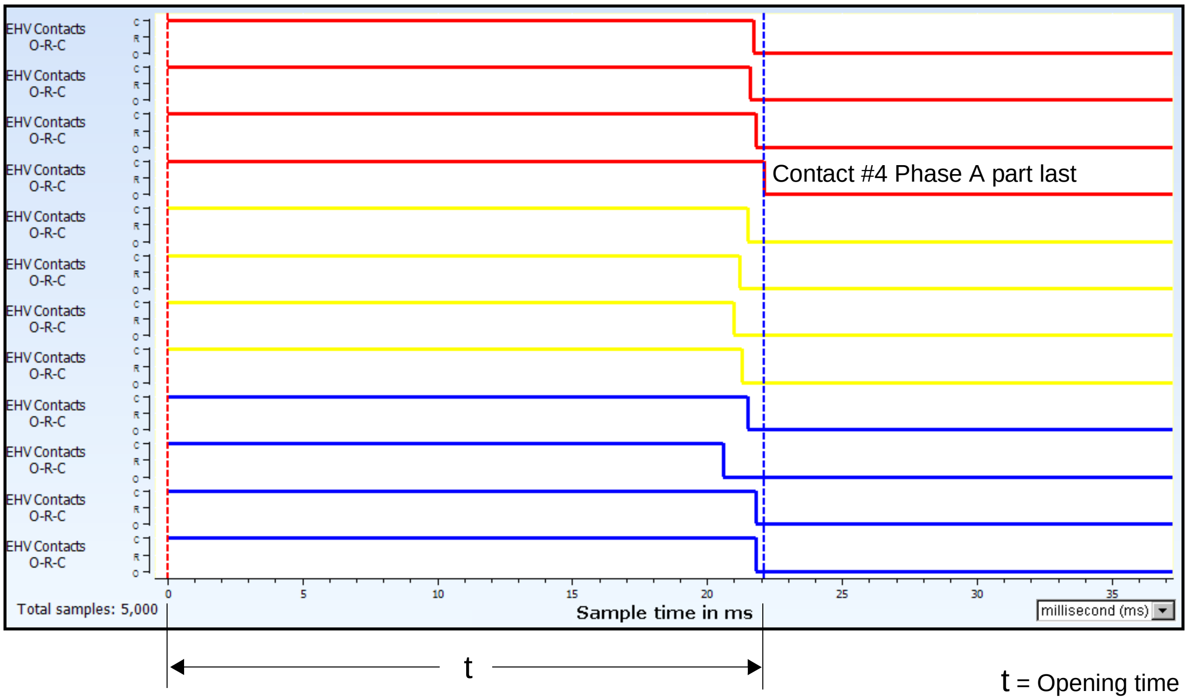


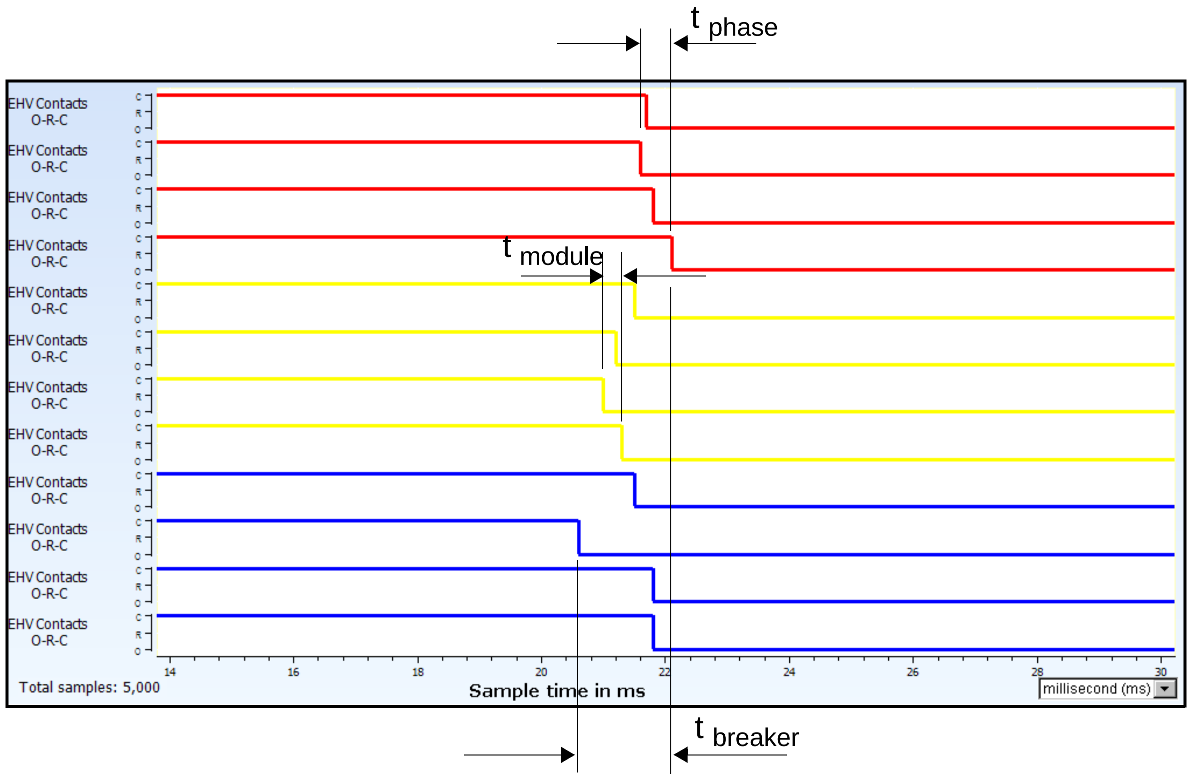
Figure 4.13 Main Contacts Opening Time

Figure 4.14 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 4.14 Open Synchronization in Module, Phase, and Breaker

Figure 4.15 provides test results of a sample synchronization.

Main Contact Timing Measurements

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

Figure 4.15 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 4.16 shows contact closing time (the time between test initiation and last contact to close).

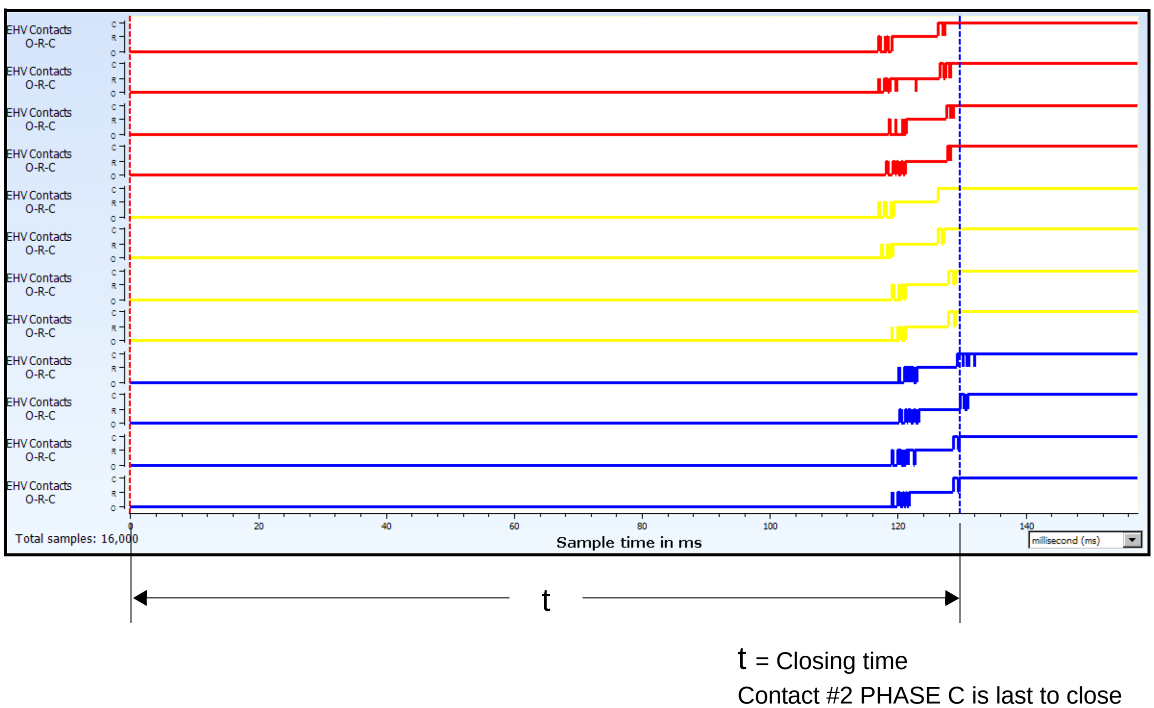


Figure 4.16 Module-Level Contact Close Synchronization

Figure 4.17 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

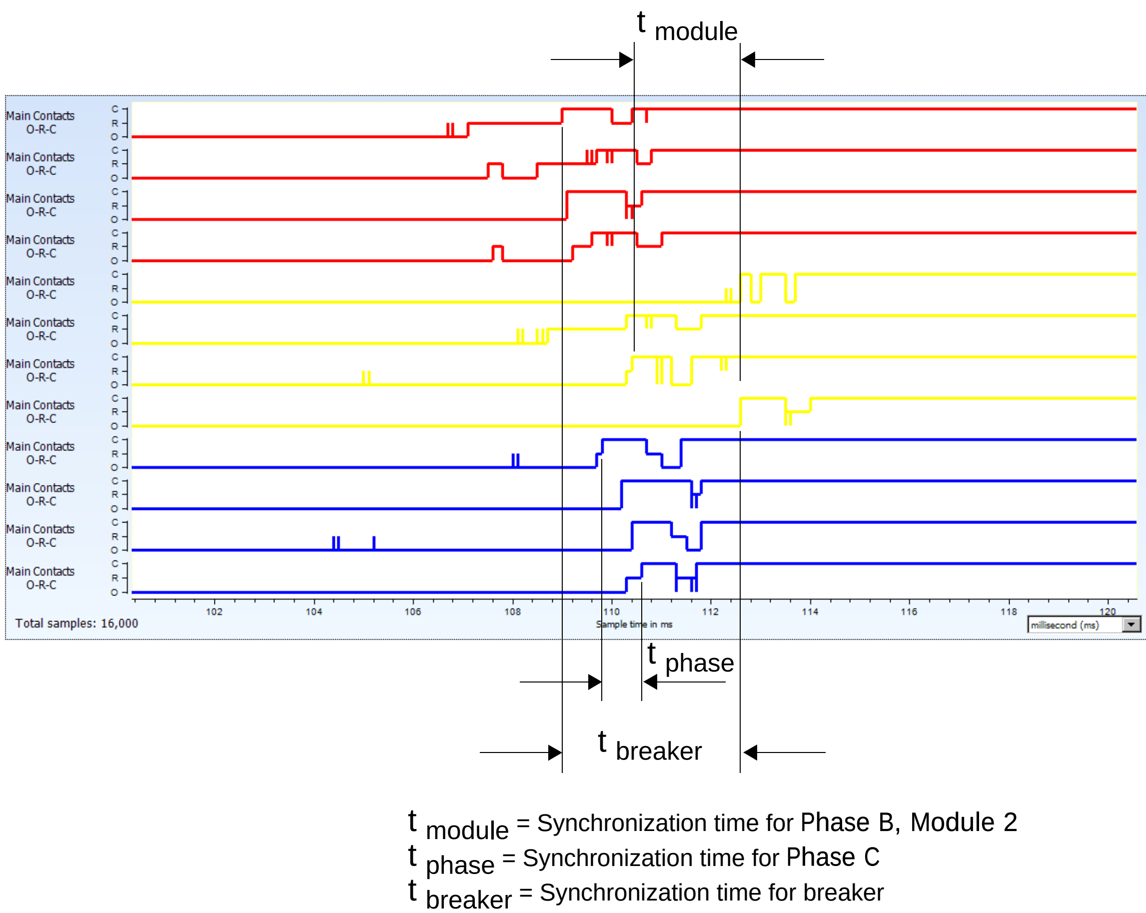


Figure 4.17 Close Synchronization in Module, Phase, and Breaker

Main Contacts: Reclose

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 4.18 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

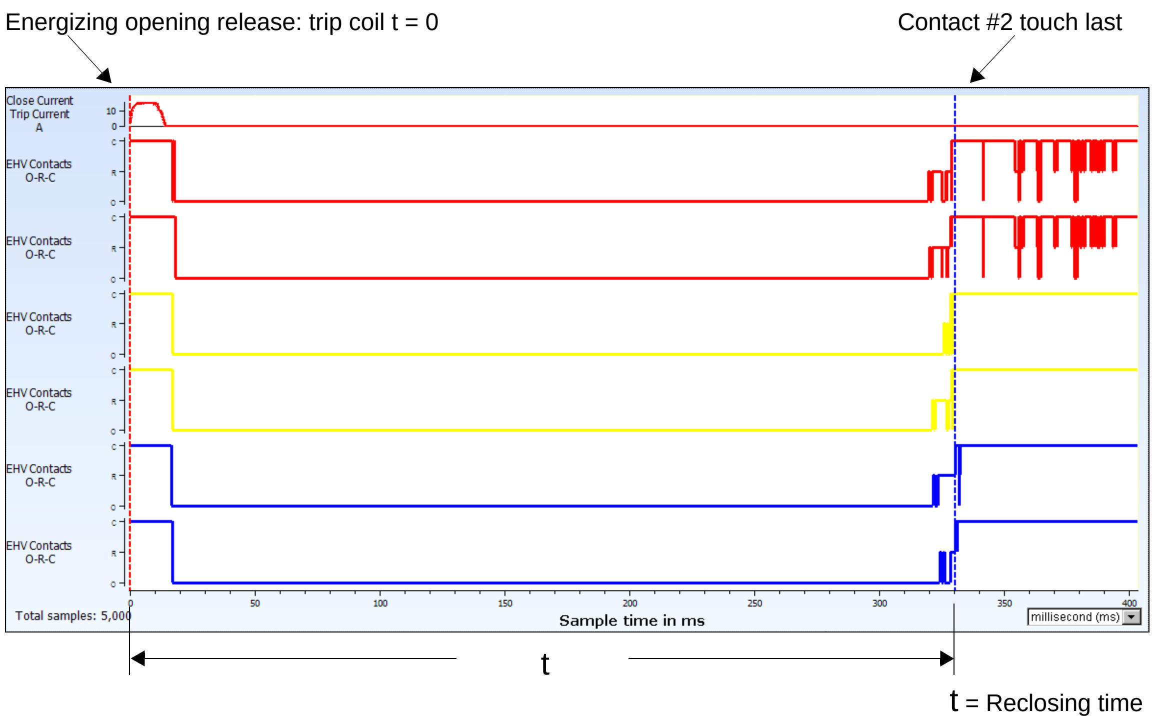


Figure 4.18 Main Contact Timing – Reclosing

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 4.19 shows the TripFree dwell time.

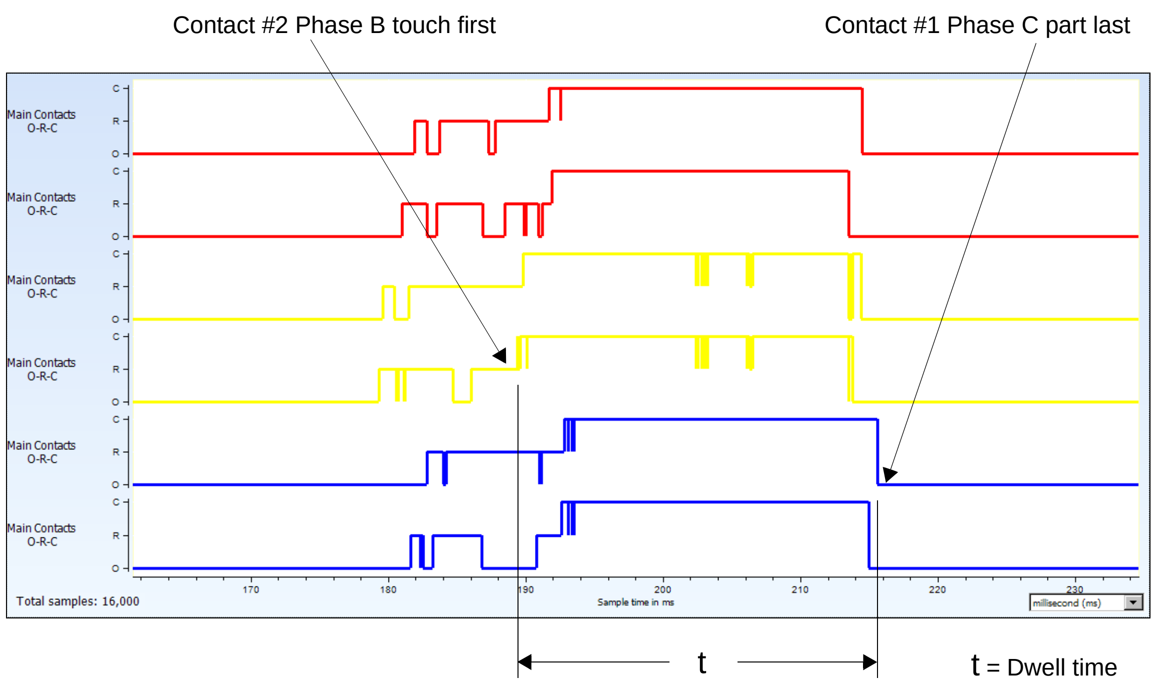


Figure 4.19 TripFree Dwell Time

Main Contacts: Reclose Open-Close Time

IEEE designation: O – 0.3 s - C

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.

Reclose open-close time parameters include:

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

Figure 4.20 shows the Reclose open-close time.

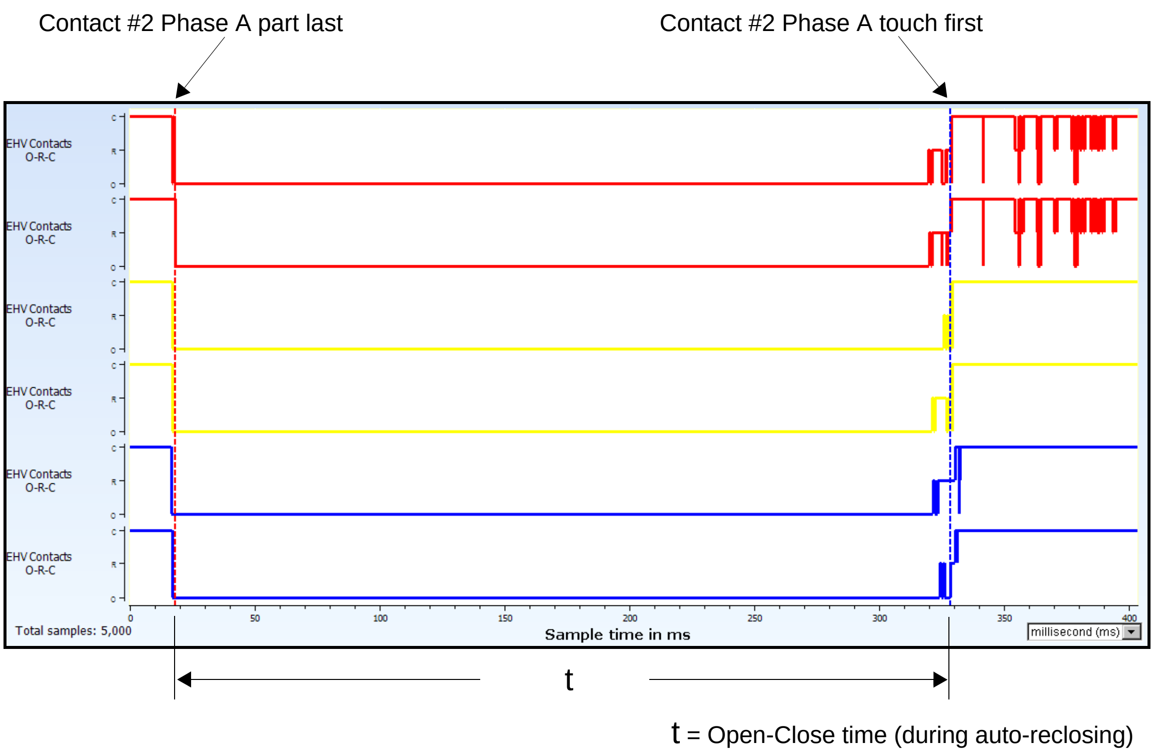


Figure 4.20 Reclose Open-Close Time

Resistor Timing Limits

Figure 4.21 shows the resistor timing limits available for the circuit breaker resistor contacts.

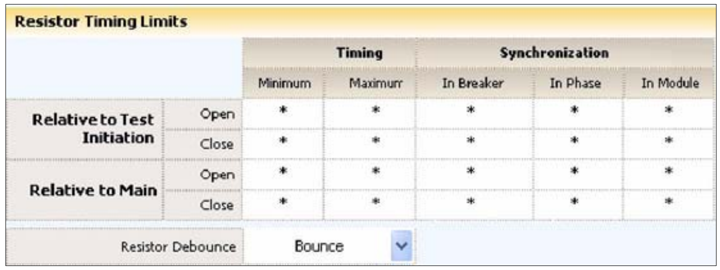


Figure 4.21 Resistor Timing Limits

Resistor Timing – Open

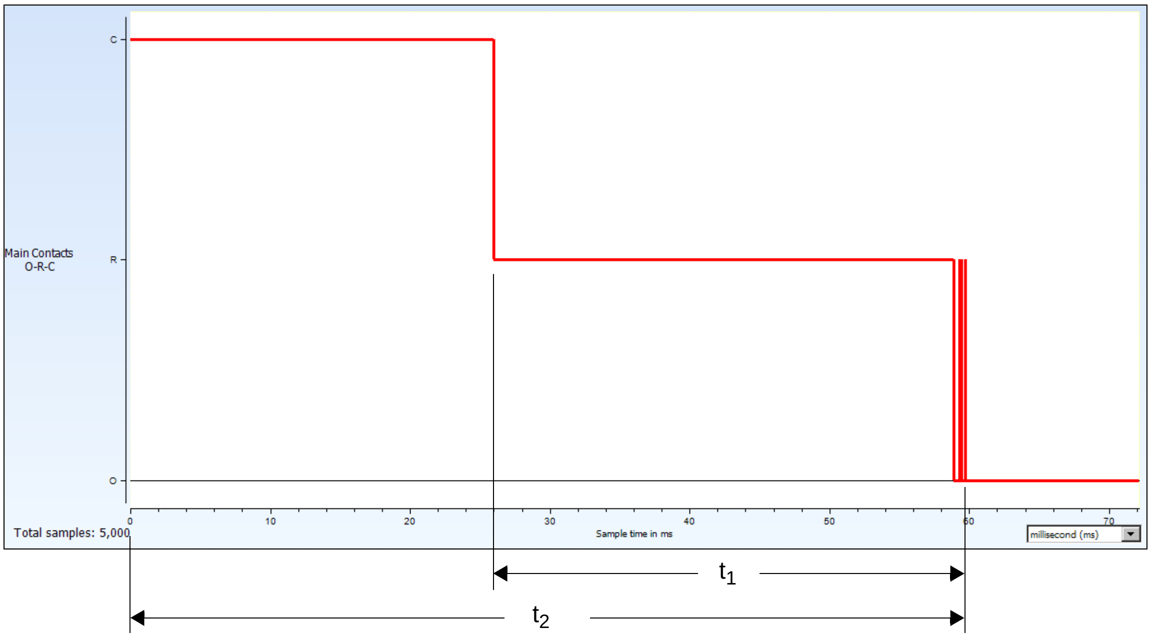
You can time resistor switches in two ways using these options:

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

Parameters include:

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

Figure 4.22 shows Opening time relative to main and test initiation.



t_1=Opening time relative to main

t_2=Opening time relative to test initiation

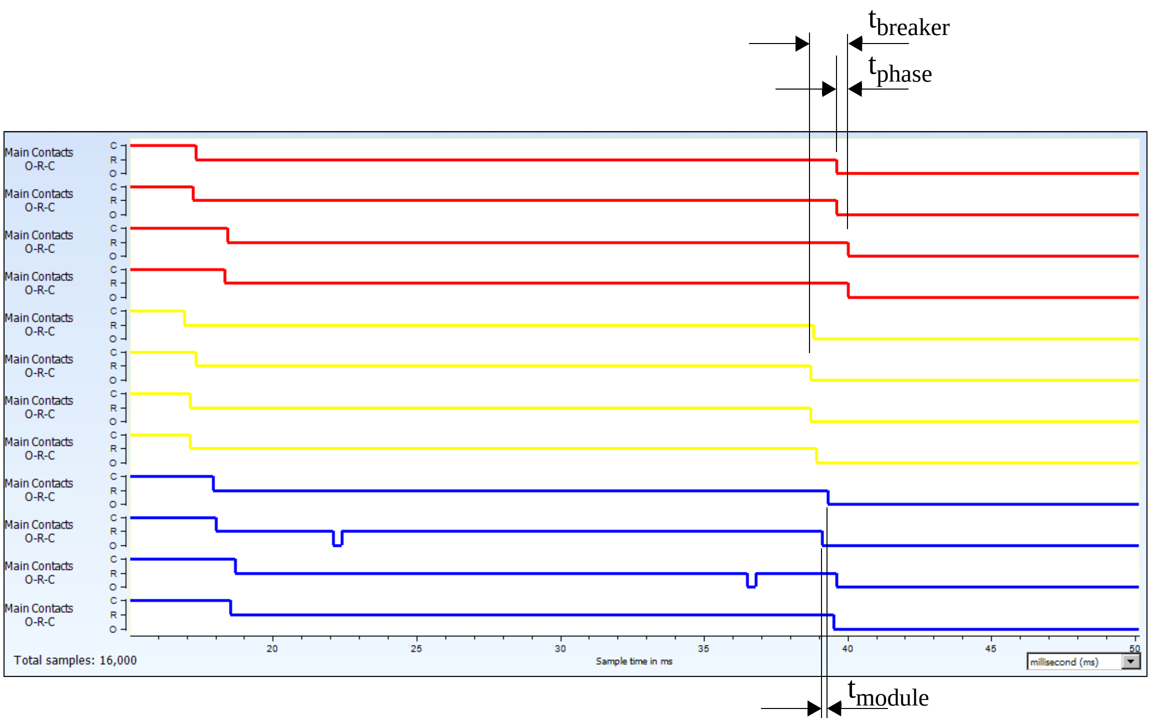
Figure 4.22 Opening Time – Resistor Switch

Figure 4.23 shows how contact and resistor switch timing open synchronization occurs on a module-by-module level.

Module Maximum allowable difference in time between the opening of the two resistor switches in any module

Phase Maximum allowable difference in time between the opening of the two resistor switches in a phase

Breaker Maximum allowable difference in time between the opening of the two resistor switches in a circuit breaker



t_{module}=Synchronization time for Phase C, Module #1

t_{phase}=Synchronization time for Phase A

$t_{breaker}$=Synchronization time for breaker

Figure 4.23 Resistor Switch Open Synchronization

Resistor Timing – Close

Some circuit breakers utilize insertion resistors during closing in order to control the transient overvoltages that occur during the closing operation. (For more information, see "Transient Recovery Voltage" on page 3-15). The timing of the closure of the resistor switches may be measured during the circuit breaker timing test.

You can time resistor switches 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 switches to close if measured relative to test initiation, or minimum time that resistors are in the circuit (the time interval between resistor switch closure and main contact closure) when measured relative to main contacts.
- Maximum—Maximum time for the resistor switches 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 4.24 shows closing time from test initiation until resistor contact touch.

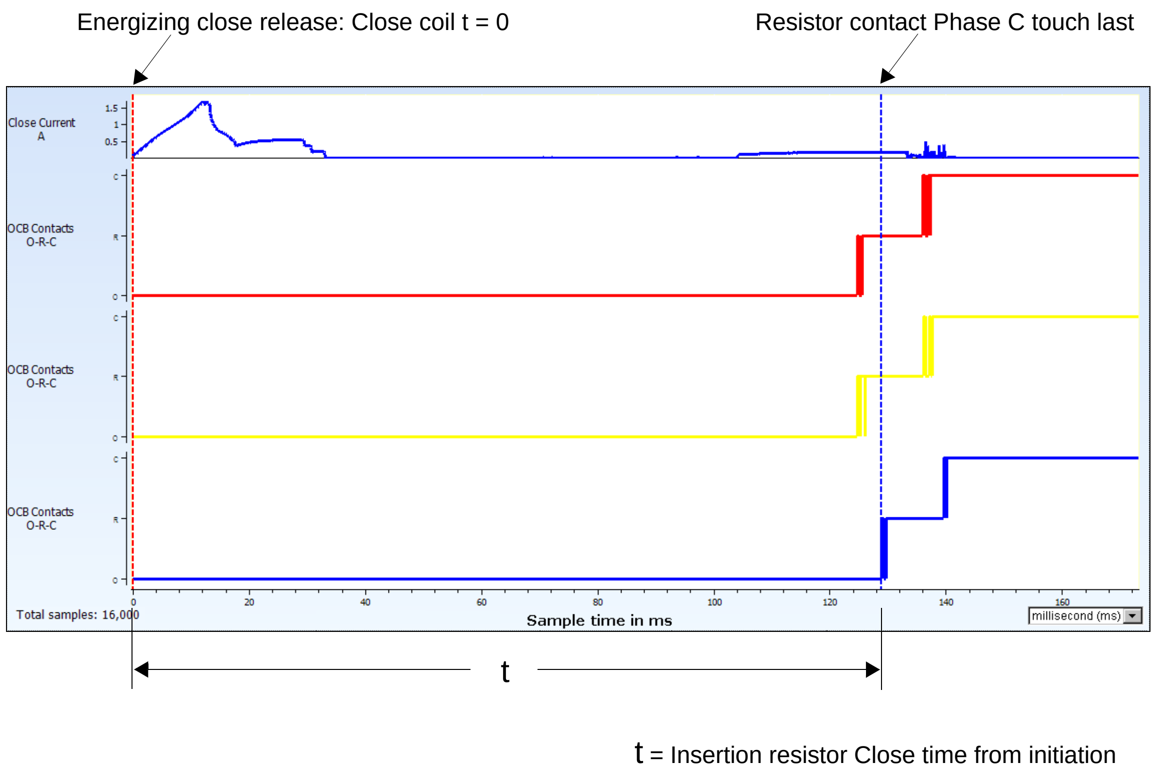


Figure 4.24 Resistor Switch Timing Measure Relative to Test Initiation

Figure 4.25 shows timing from resistor contact touch until main contact close.

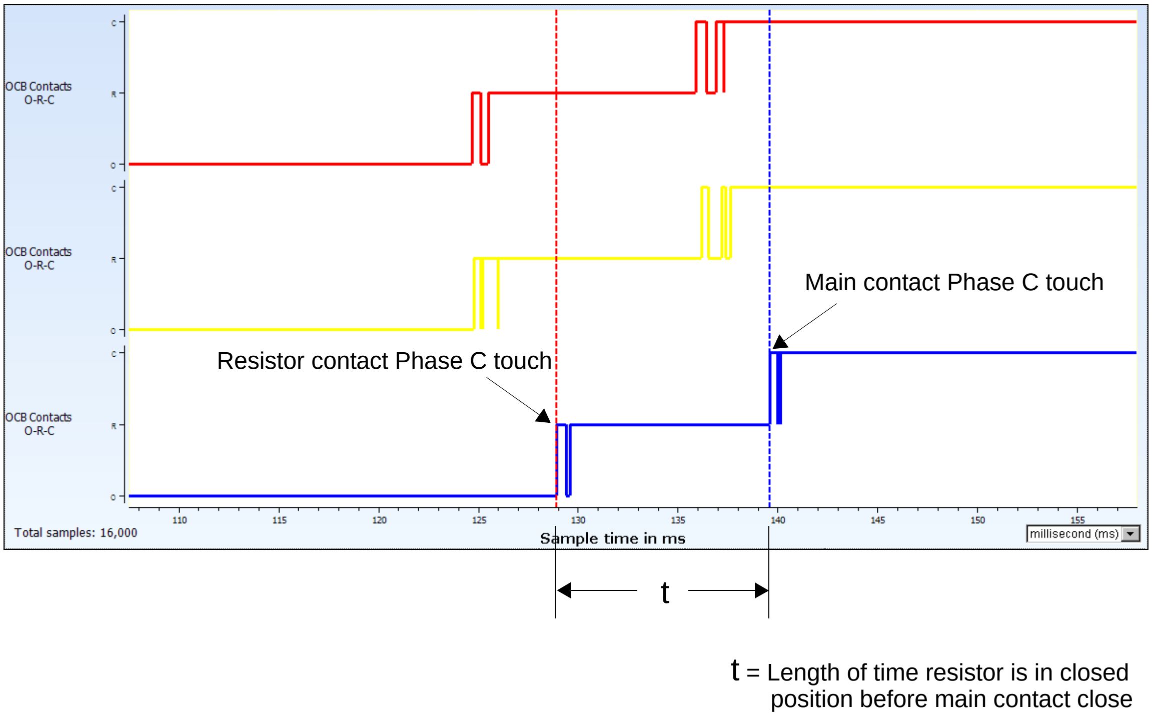


Figure 4.25 Resistor Switch Timing Relative to Main Contact Closure, Phase C

Figure 4.26 shows how contact and resistor switch timing close synchronization occurs on a module-by-module level.

Module Maximum allowable difference in time between the closing of the two resistor switches in any module

Phase Maximum allowable difference in time between the closing of the two resistor switches in a phase

Breaker Maximum allowable difference in time between the closing of the two resistor switches in a circuit breaker

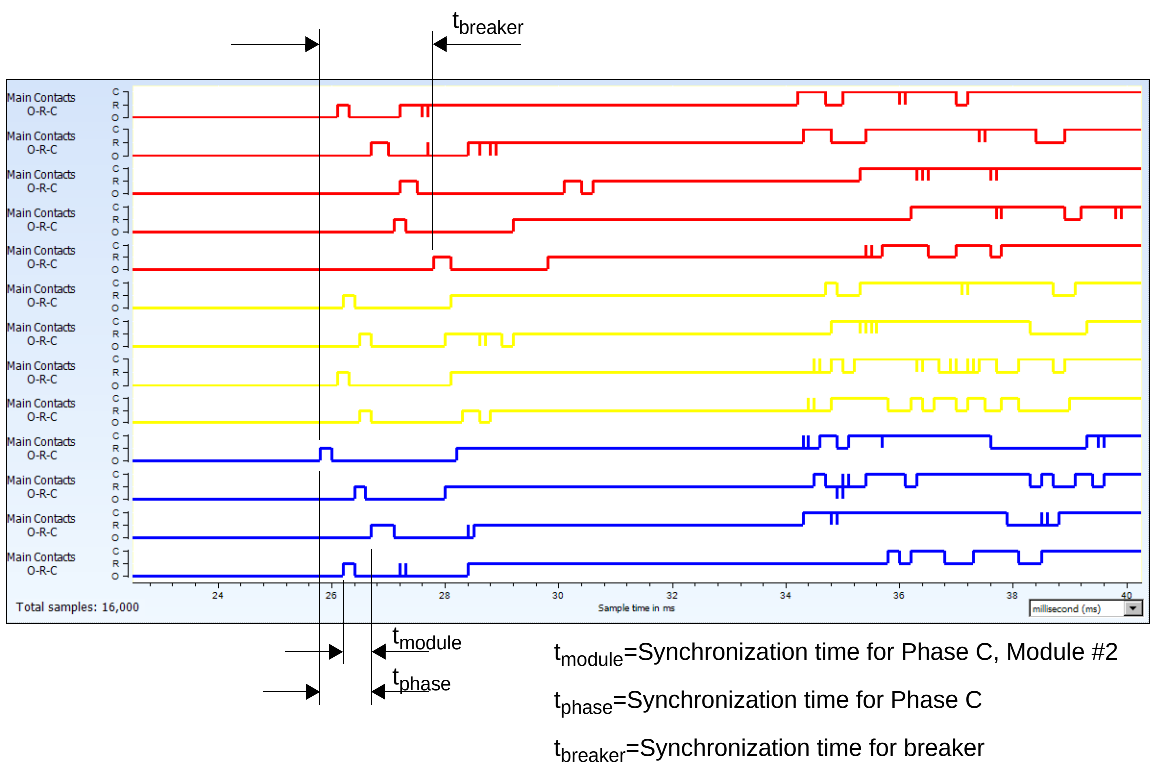


Figure 4.26 Resistor Switch – Close Synchronization

Resistor Debounce Values for First Touch Tabulation

The Resistor Debounce field sets the minimum amount of time the instrument's 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.

The Resistor Debounce field provides these options: 100 µs, 200µs, 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 switch closure during a Close operation, and by the last resistor switch open during an Opening operation.**

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

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

  In such a case, the Resistor Debounce time can be reduced from the default value of 200 µs to 100 µs to observe the resistor switch (despite its bouncing) and obtain a tabulated value. This is acceptable if the bouncing is a normal part of this particular circuit breaker's operation. 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 switch timing.
- If Bounce is selected, the first identifiable transition to the resistor level is used for the resistor switch tabulation and it is not necessary to have a resistor level for any minimum amount of time.

Figure 4.27 and Figure 4.28 illustrate the effects of resistor debounce values.

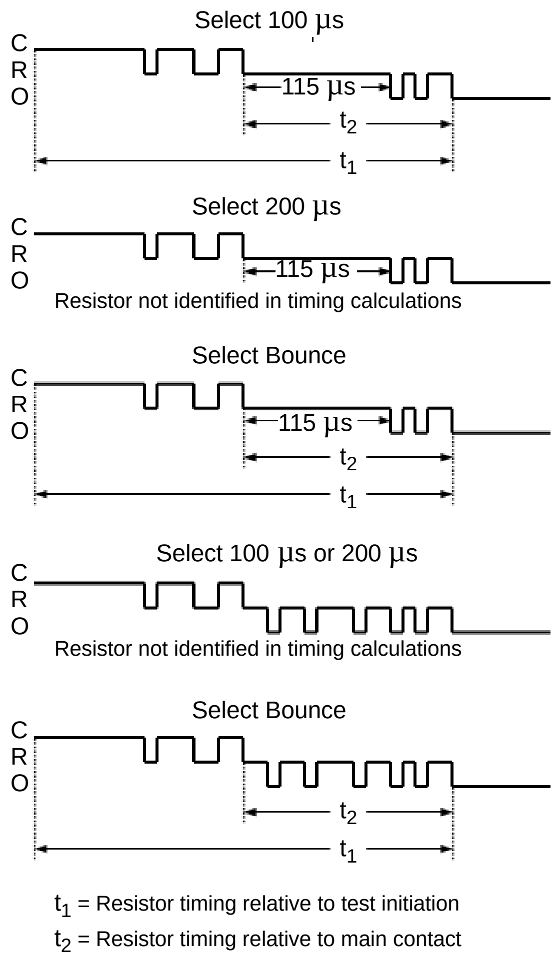


Figure 4.27 Resistor Debounce Effects – Open Test

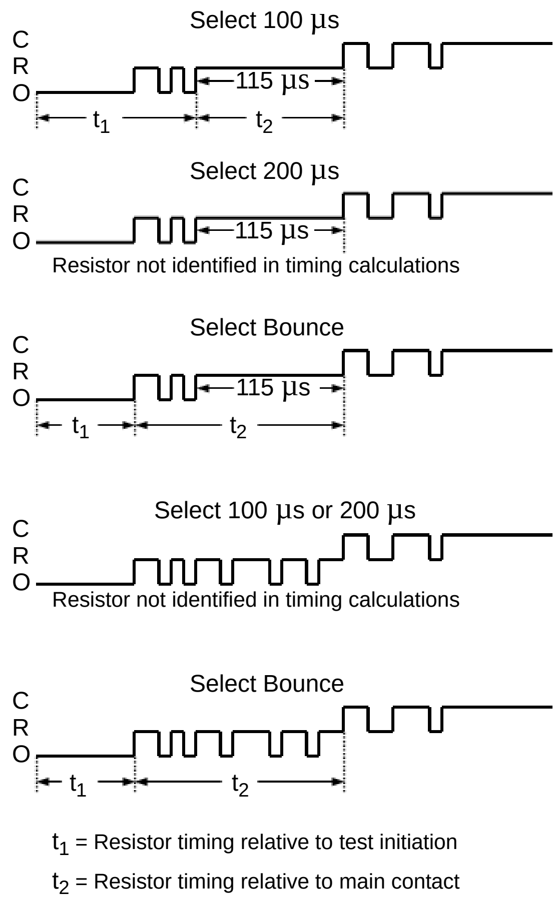


Figure 4.28 Resistor Debounce Effects – Close Test

NOTE

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

The Relative to Main option tabulates resistor switch 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 4-19** **and** **"Resistor Timing – Close" on page 4-22****.**

Resistance Limits (TDR9000 Only)

Resistance Limits		
	Minimum	Maximum
Open Resistance	*	*
Close Resistance	*	*

Figure 4.29 Resistance Limits

The Resistance parameters are as follows:

- Open Resistance: Minimum—Minimum allowable value for the Opening Resistor in Ω
- Open Resistance: Maximum—Maximum allowable value for the Opening Resistor in Ω
- Close Resistance: Minimum—Minimum allowable value for the Closing Resistor in Ω
- Close Resistance: Maximum—Maximum allowable value for the Closing Resistor in Ω

The TDR instruments measure resistance values from 10 to 7 kΩ.

Capacitance Limits (TDR9000 Only)

The TDR instrument can measure the capacitance of grading capacitors that are connected across the main contact of a circuit breaker in the range of 75 to 10,000 pF.

Capacitance parameters are as follows:

- Minimum—The minimum expected capacitance
- Maximum—The maximum expected capacitance

Figure 4.30 shows the Capacitance parameters.

Capacitance Limits		
	Minimum	Maximum
Capacitance Limits	*	*

Figure 4.30 Capacitance Channel Tables

To set capacitance ranges, go to “TDR9000 Only: Resistance and Capacitance Ranges” on page 6-29.

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 Tab of the Test Plan Page. (See Transducer Scaling for an explanation of transfer functions).

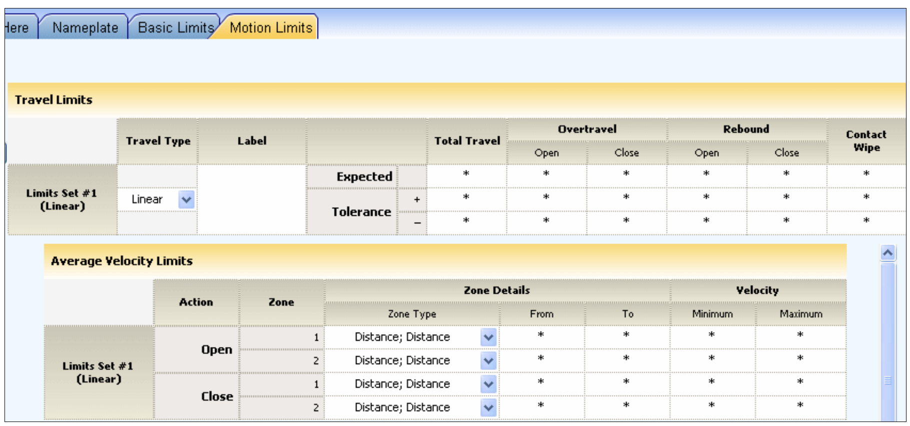


Figure 4.31 Motion Limits Tab of Breaker Page

Travel Limits

Figure 4.32 shows the Travel limits available for a circuit breaker.

Figure 4.32 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 5-2.
- Tolerance—You can specify positive and negative tolerances. Negative tolerance for contact wipe must never be greater than the specified contact wipe.

The TDR instrument 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 4.33):

- Mount the transducer on phase A.
- Connect the motion transducer cable to the M1 connector.
- Activate Motion Channel 1 on the Motion Channels tab of the Test Plan page, and label it A.
- Connect Contact Monitor Cable 1 to Phase A.

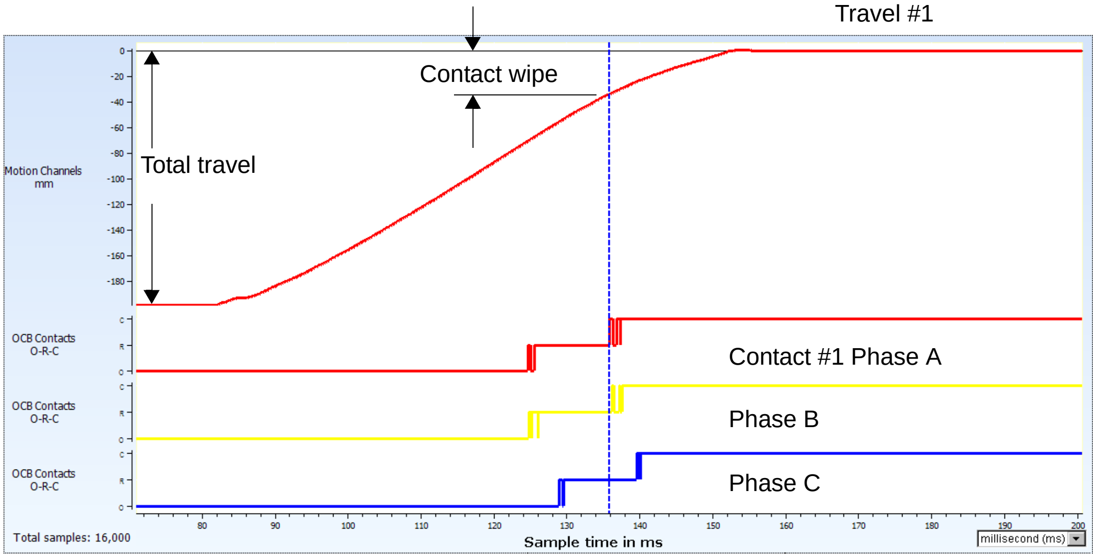


Figure 4.33 Contact Wipe Measurement

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

Figure 4.34 shows timing for contact wipe during the total travel operation.

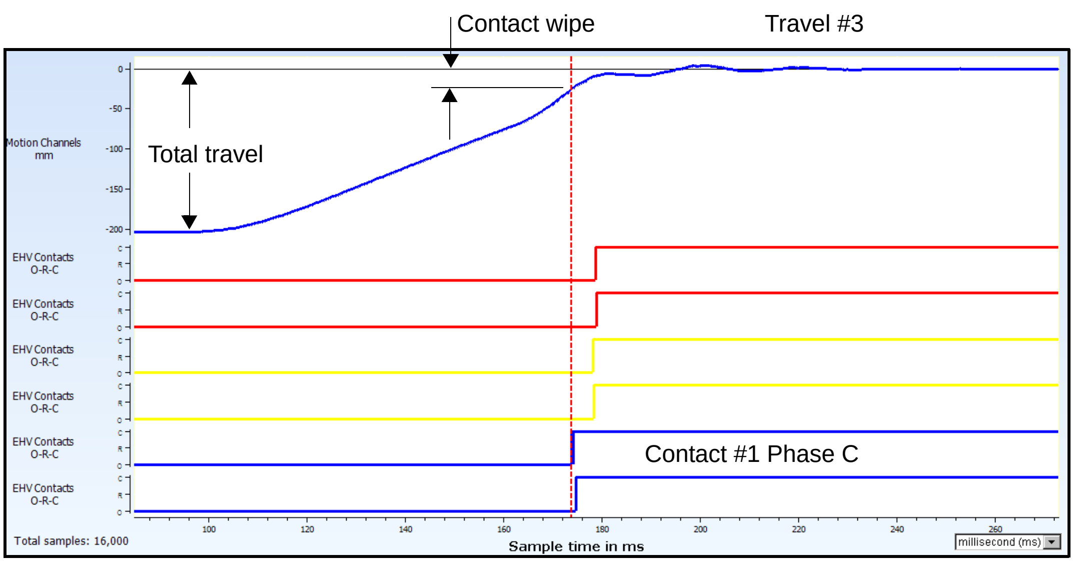


Figure 4.34 Contact Wipe and Total Travel for Multiple Breaks

Figure 4.35 shows timing for contact wipe during trip operation.

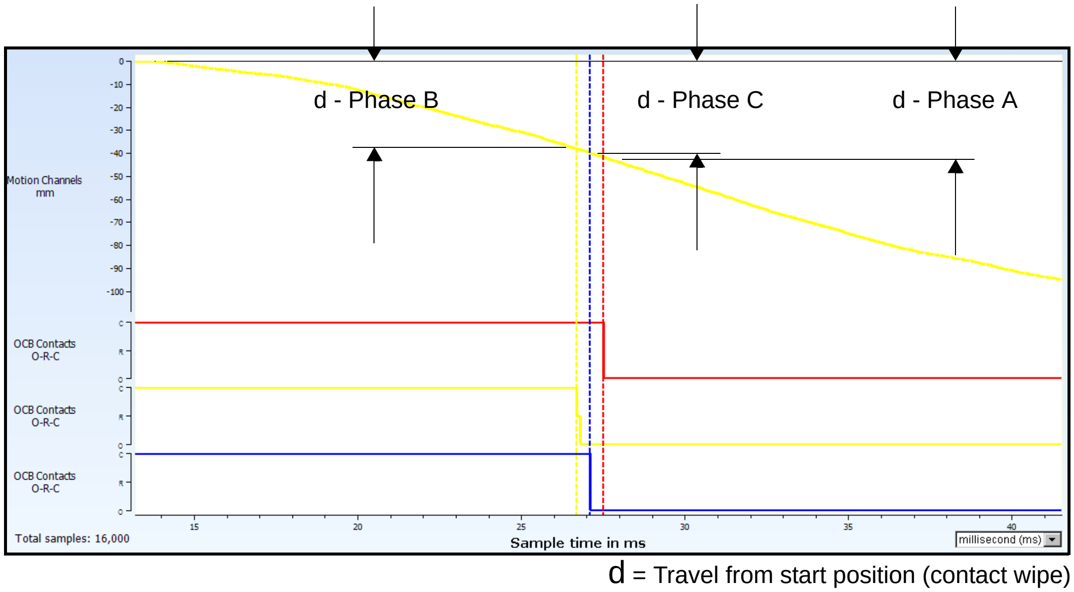


Figure 4.35 Contact Wipe During Trip Operation

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 4.36 shows how overtravel and rebound operate during a circuit breaker opening operation.

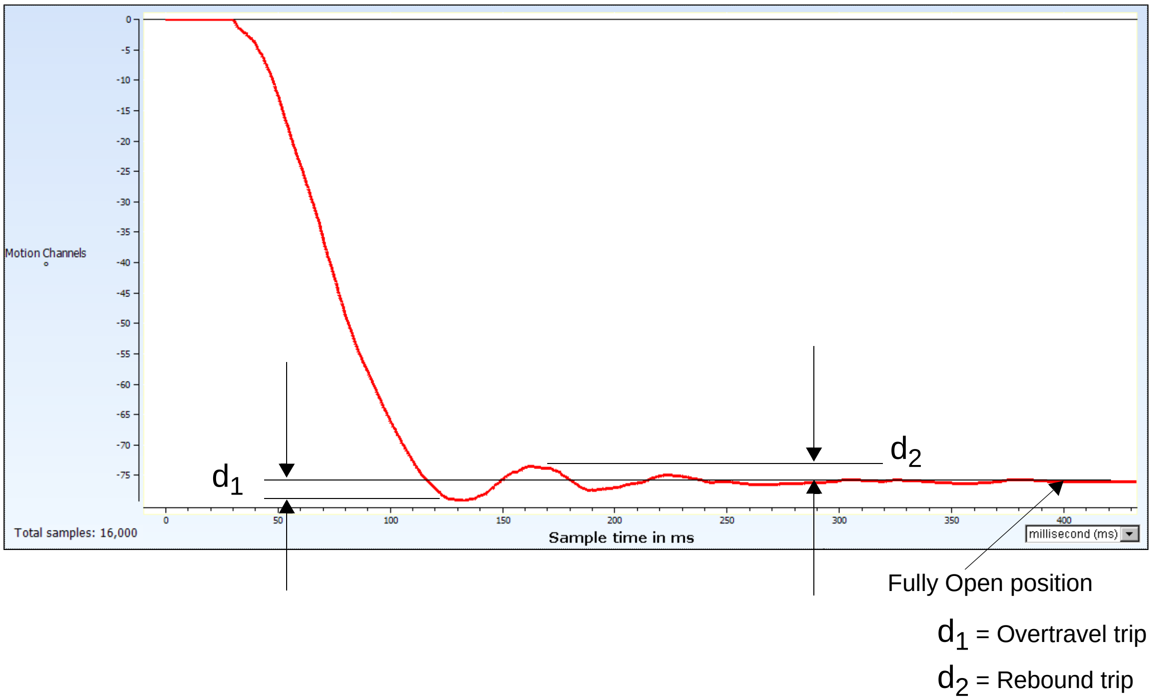


Figure 4.36 Overtravel/Rebound Open

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 4.37 shows how overtravel and rebound operate for a circuit breaker closing operation.

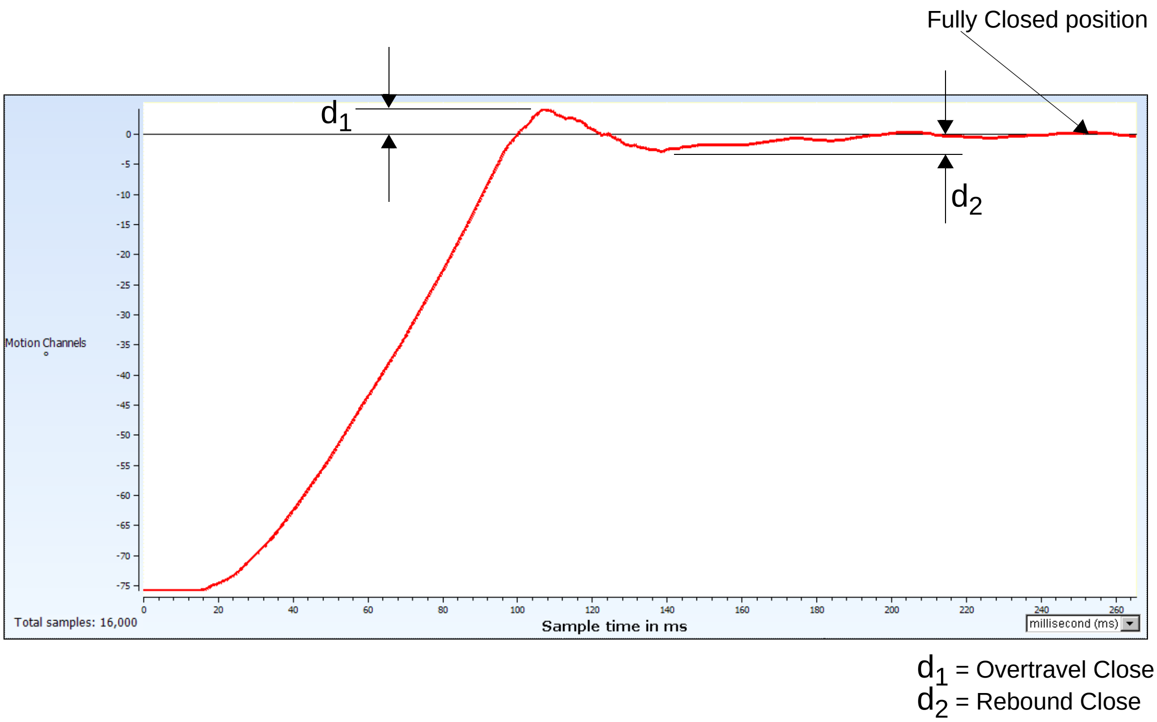


Figure 4.37 Overtravel/Rebound Closed

Average Velocity Limits

Figure 4.38 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 4.38 Average Velocity Limits

Average Velocity – Open

You must enter a zone before the instrument 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 (Figure 4.48 on page 4-44).

- 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 4.39.)

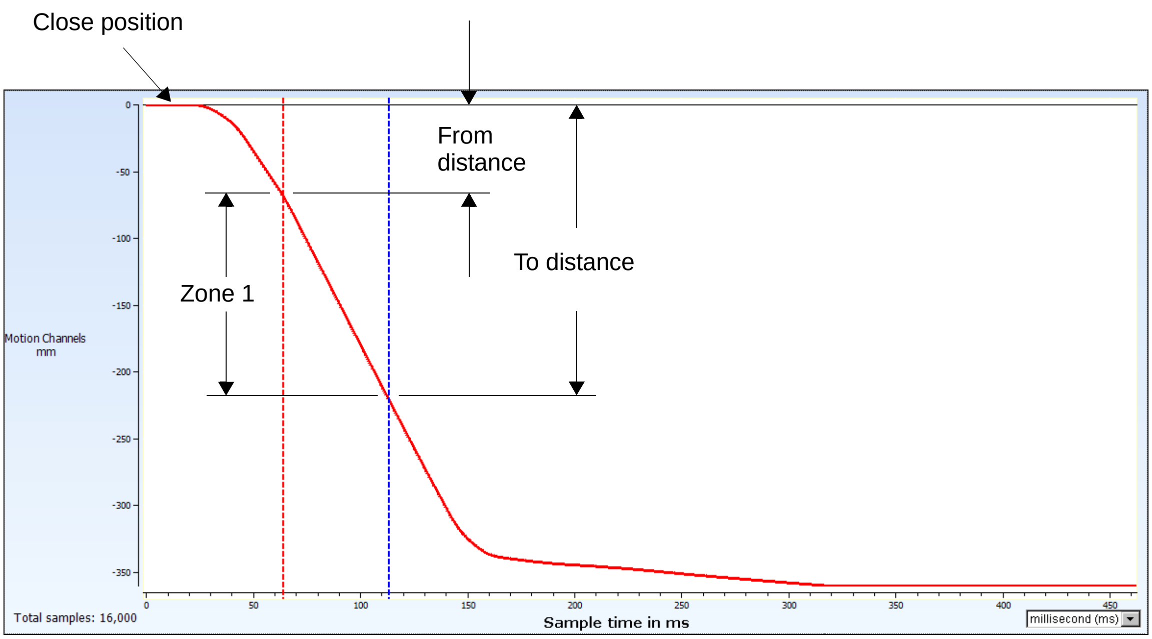


Figure 4.39 Average Velocity Distance to Distance

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 4.40.)

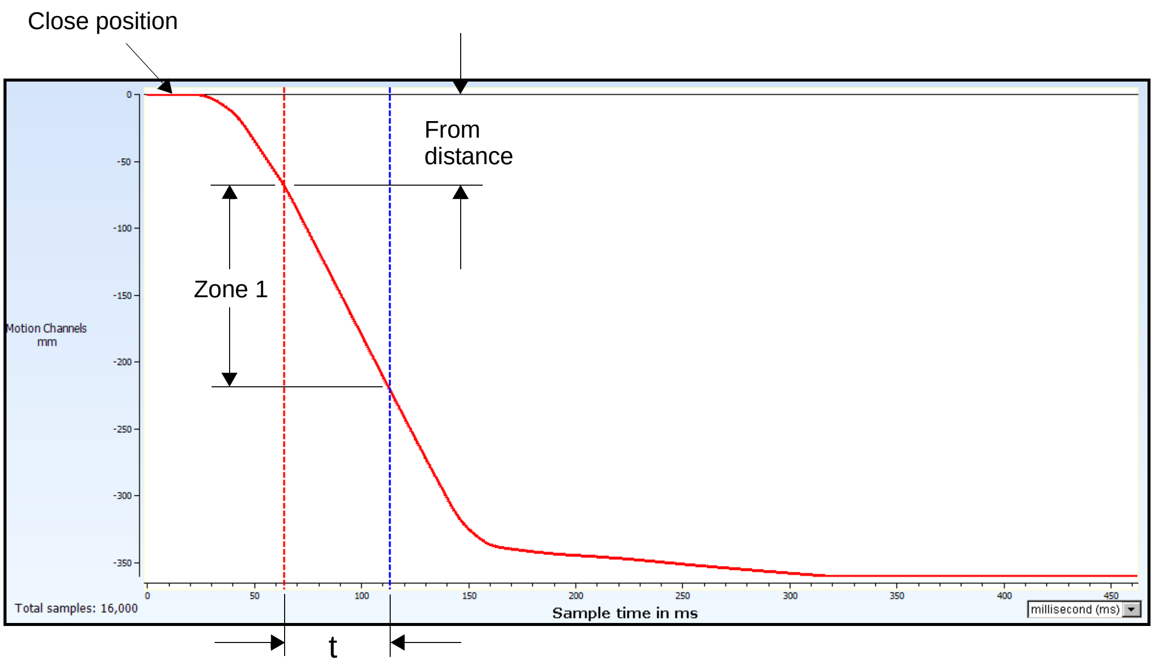


Figure 4.40 Average Velocity Distance to Time Trip Operation

- Time to Time—The circuit breaker average velocity is calculated between the two times specified. In Figure 4.41, the end time (*TO*) must be greater than the start time (*FROM*).

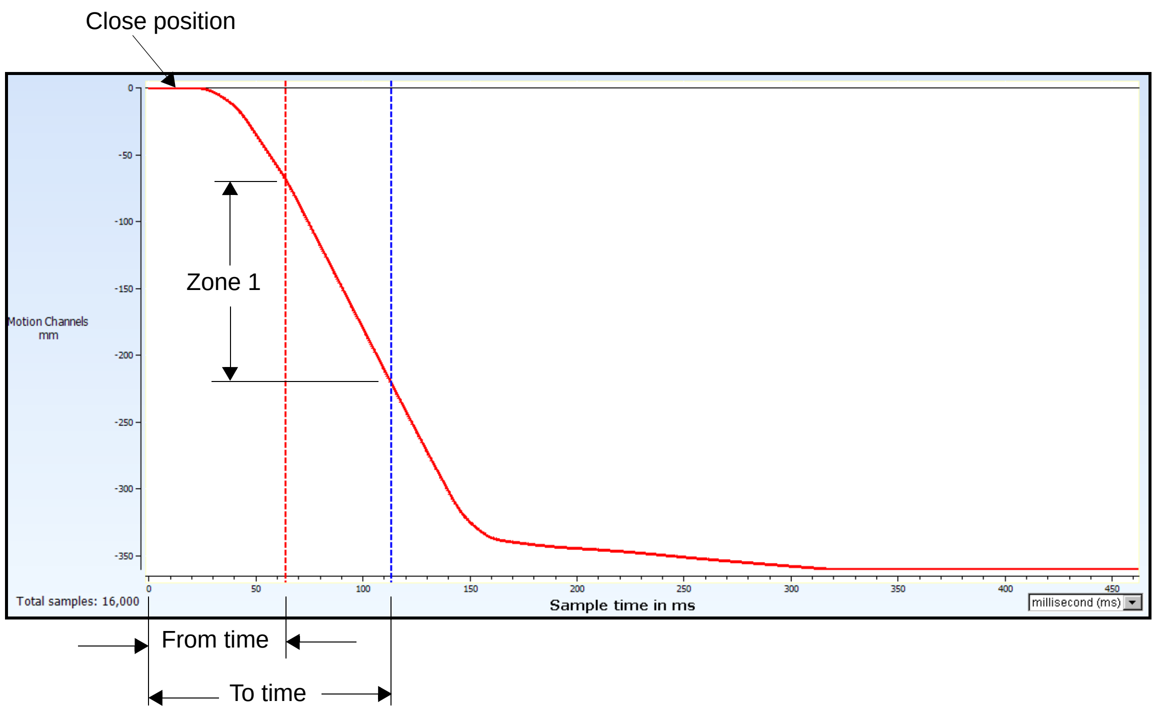


Figure 4.41 Average Velocity Time to Time

- 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 instrument uses the main contact data for the phase in which the motion channel is activated. (See Figure 4.42.)

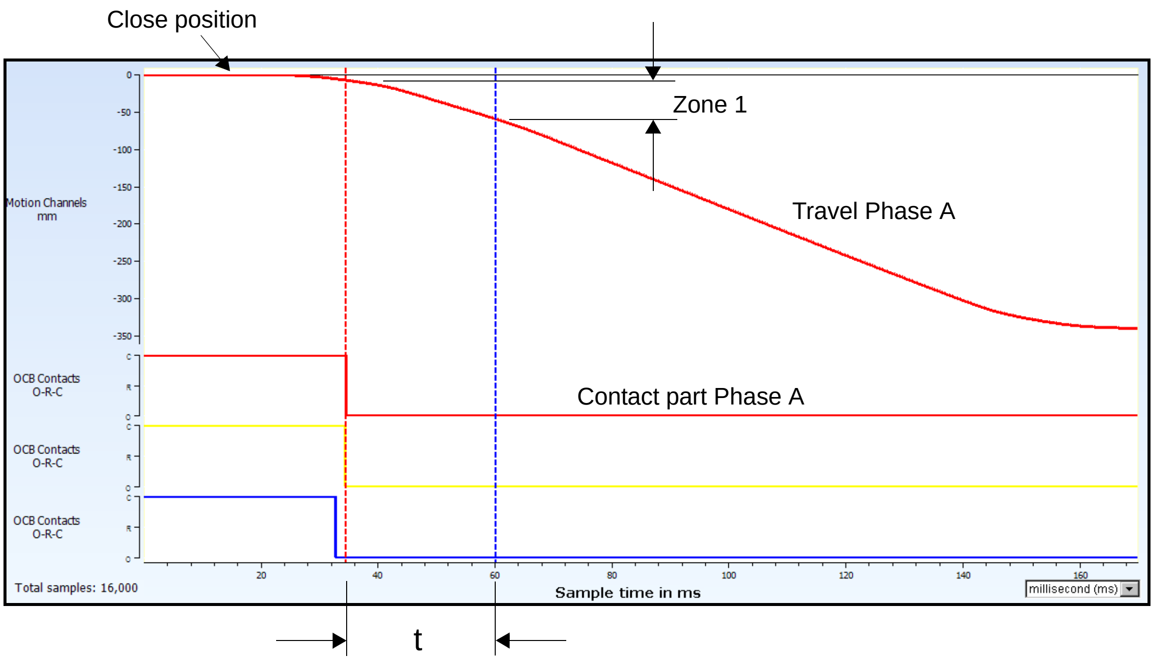


Figure 4.42 Average Velocity Contact Open to Time OCB Overall One Break per Phase

NOTE

For the EHV circuit breaker (Figure 4.43), the instrument uses the data for Main Contact 1 from the phase for which the motion channel is activated to calculate the average velocity. In Figure 4.43, Motion Channel 3 (corresponding to Phase C) is active. Therefore, Phase C Contact #1 is used for the average velocity calculation.

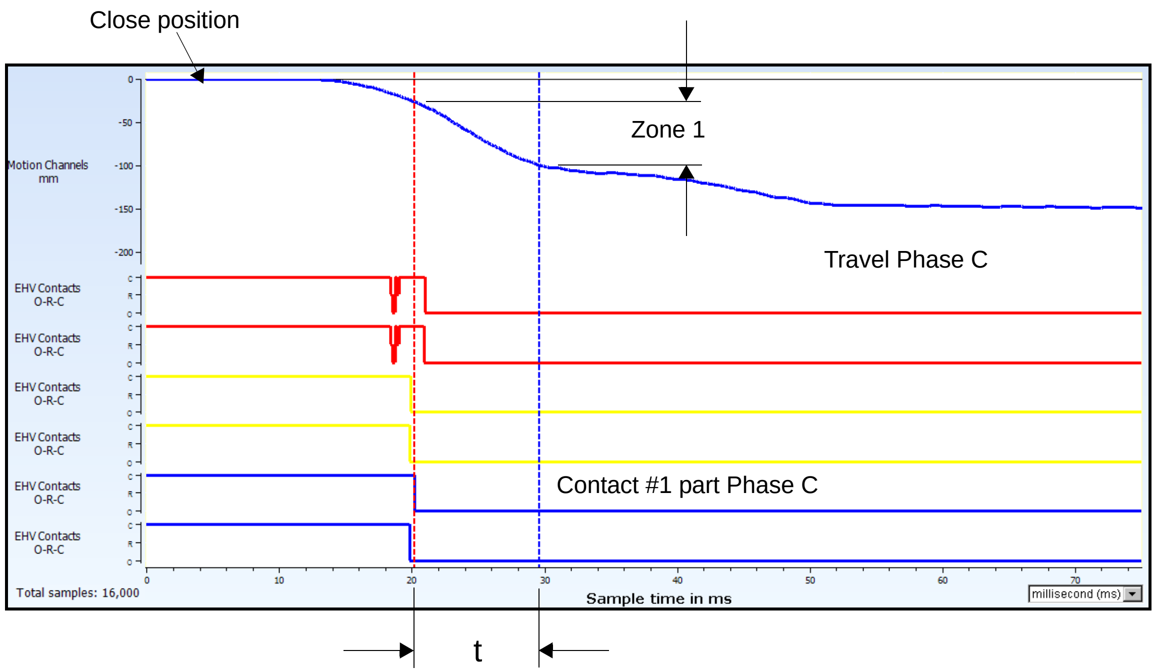


Figure 4.43 Average Velocity Contact Open to Time, Motion Channel #3 (Phase C) Active

- Open to Distance—The circuit breaker’s average velocity is calculated for the interval between when the main contacts part and the point in time that corresponds to the specified distance.

Figure 4.44 and Figure 4.45 show the operation of this zone type.

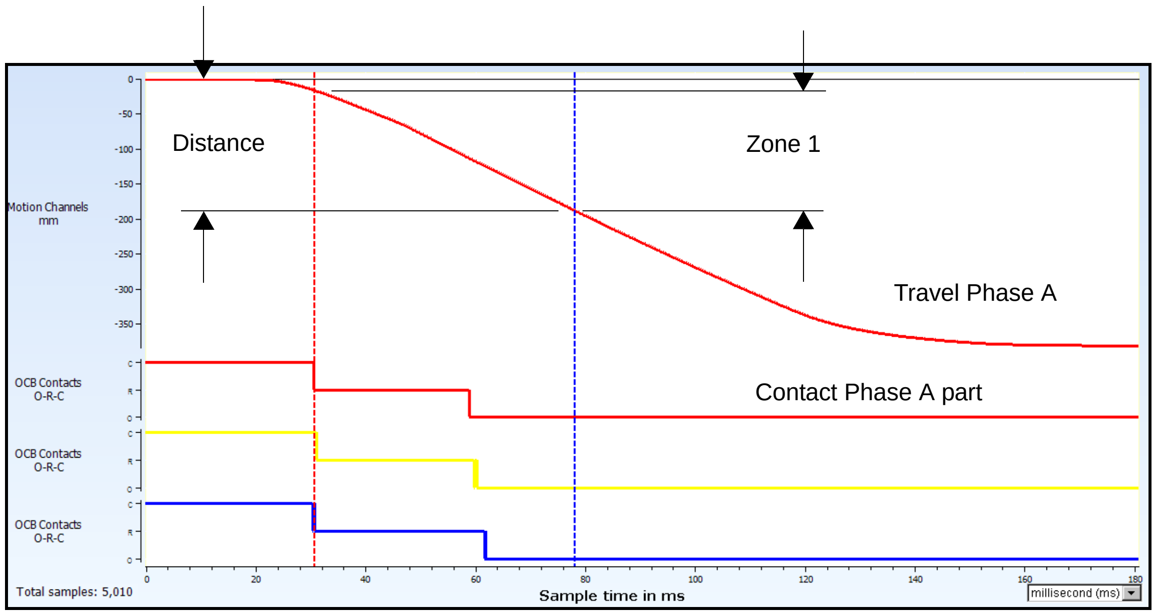


Figure 4.44 Average Velocity Contact Open to Distance for Single Break per Phase, Motion Channel #1 (Phase A) Active

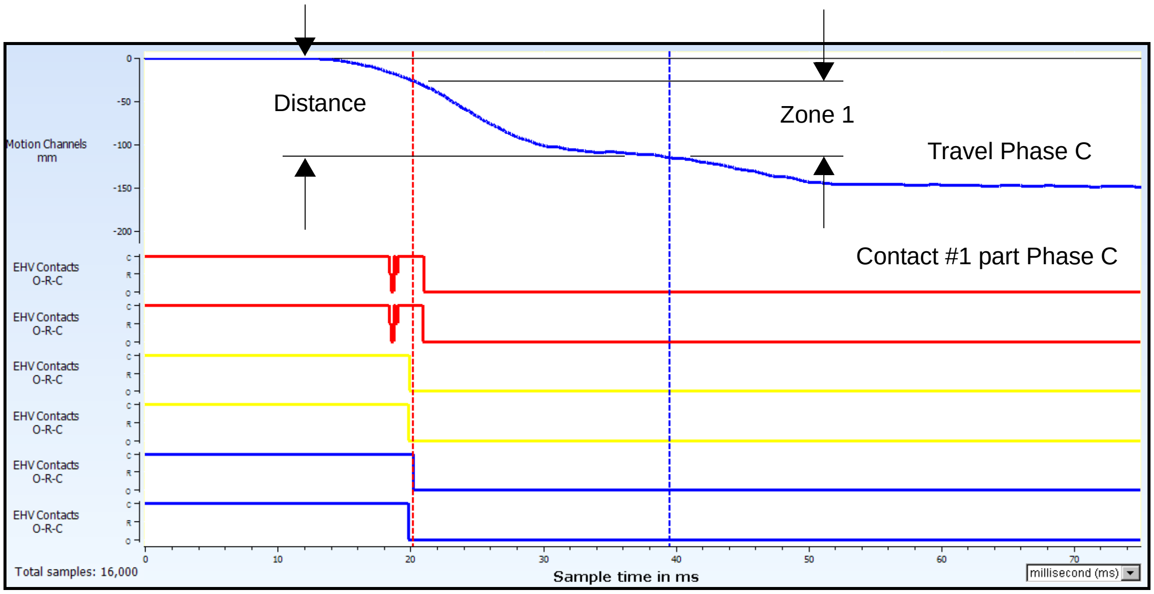


Figure 4.45 Average Velocity Contact Open to Distance for Multiple Breaks Per Phase, Motion Channel #3 (Phase C) Active

- 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.

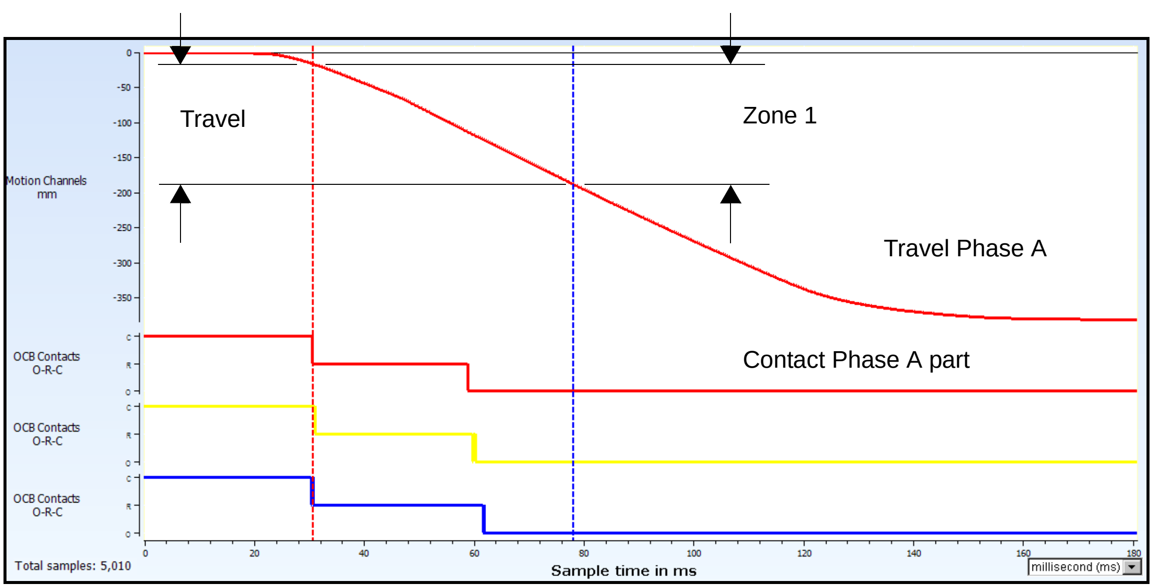


Figure 4.46 Average Velocity Contact Open to Travel for Single Break per Phase, Motion Channel #1 (Phase A) Active

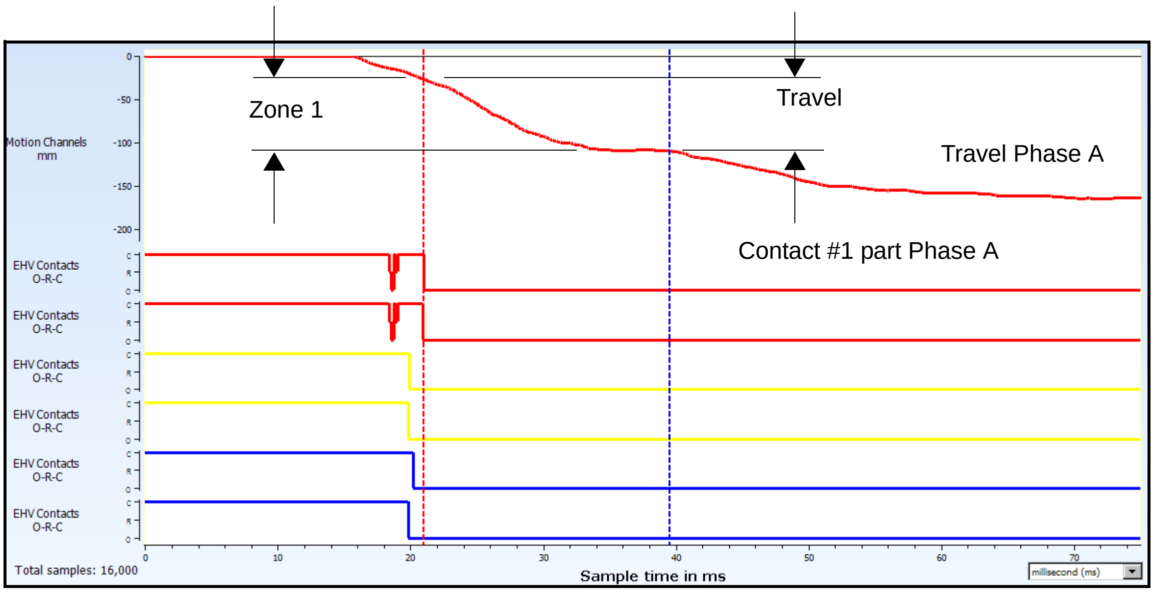


Figure 4.47 Average Velocity Contact Open to Travel for Multiple Breaks Per Phase, Motion Channel #1 (Phase A) Active

Velocity Open Zone 2

Zone 2 is independent of Zone 1 (Figure 4.48).

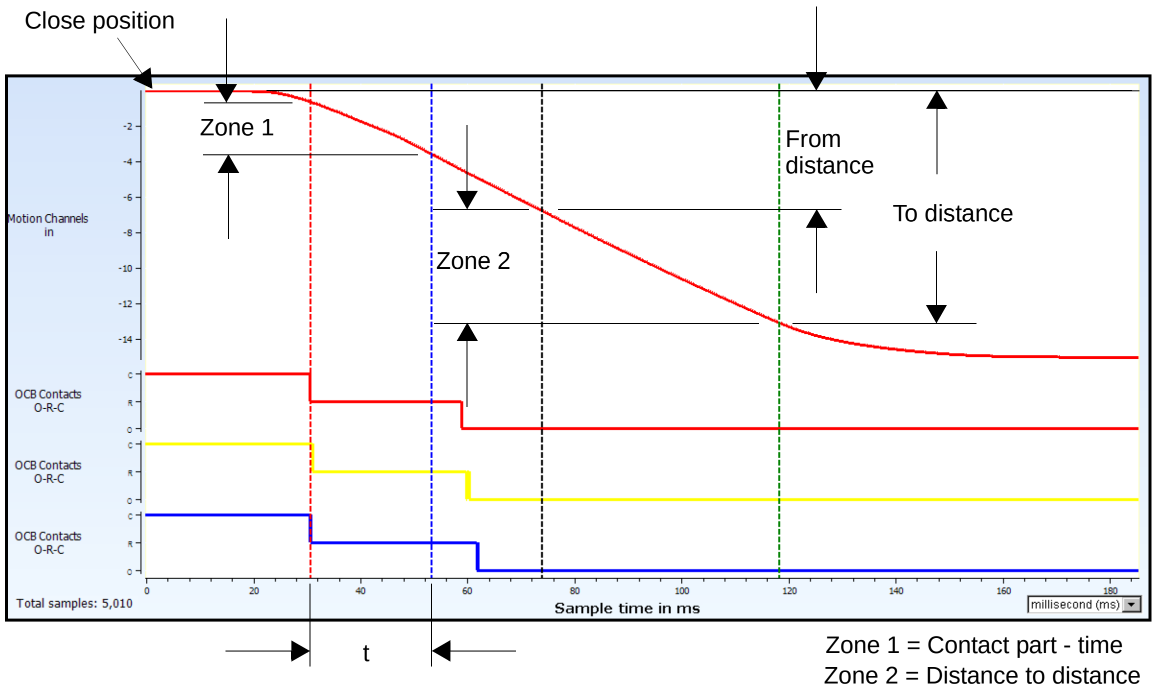


Figure 4.48 Average Velocity for Zone 1 and Zone 2, Motion Channel #1 (Phase A) Active

Average Velocity – Close

You must enter a zone before the instrument 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 4.56).

- 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 4.49. The end distance (*TO*) must be smaller in magnitude than the start distance (*FROM*).

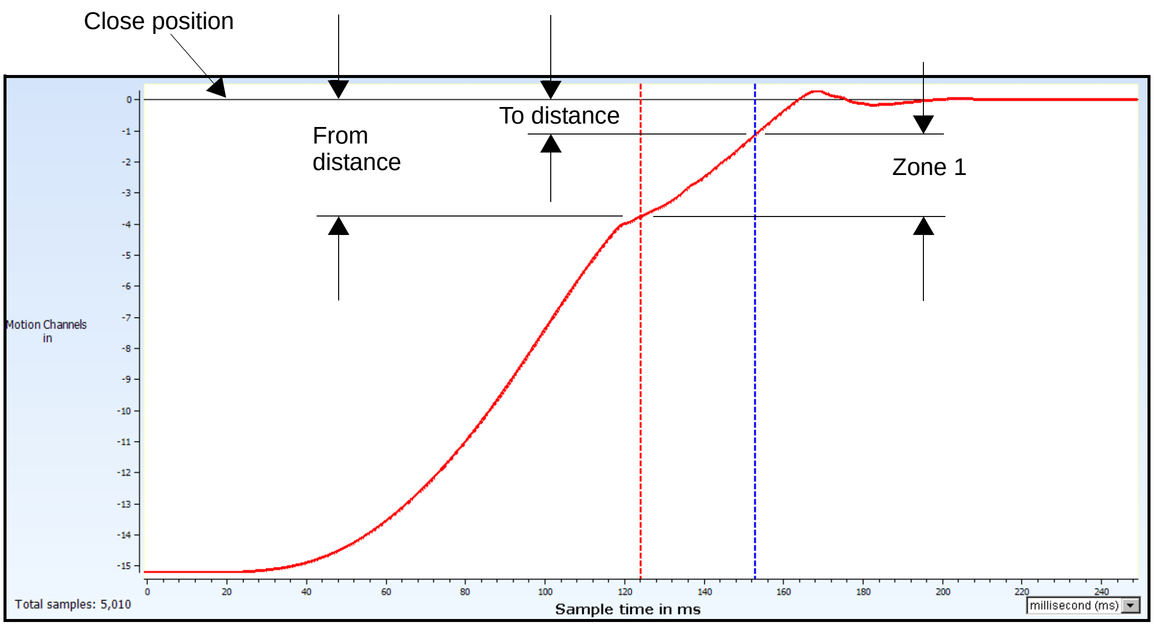


Figure 4.49 Average Velocity Distance to Distance Close Operation

- 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 4.50.

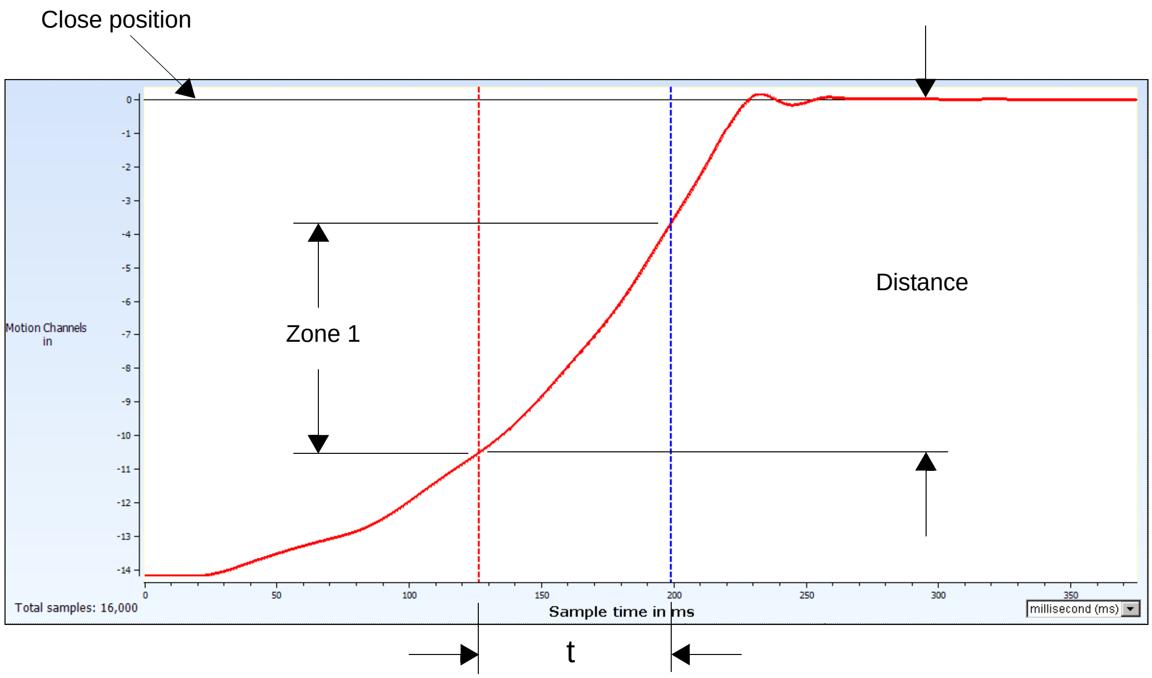


Figure 4.50 Average Velocity Distance to Time Close Operation

- Time to Time—The circuit breaker average velocity is calculated between the two times specified. In Figure 4.51, the end time (*TO*) must be greater than the start time (*FROM*).

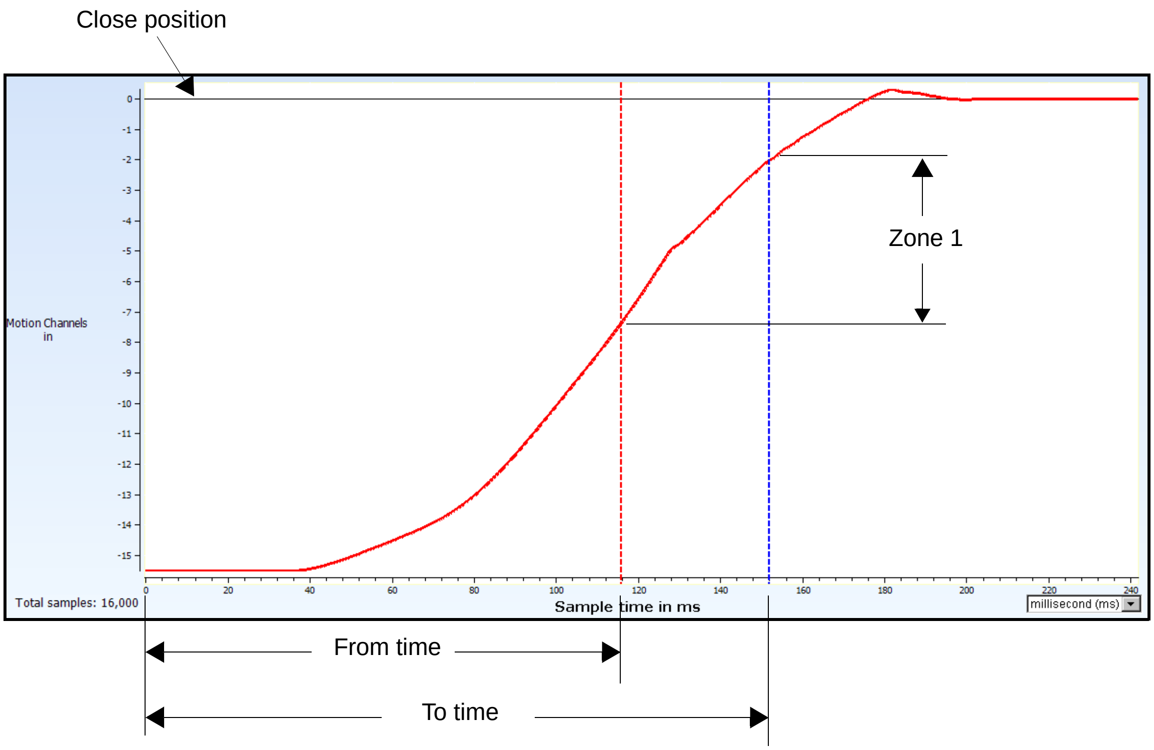


Figure 4.51 Average Velocity Time to Time Close Operation

- 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 4.52).

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

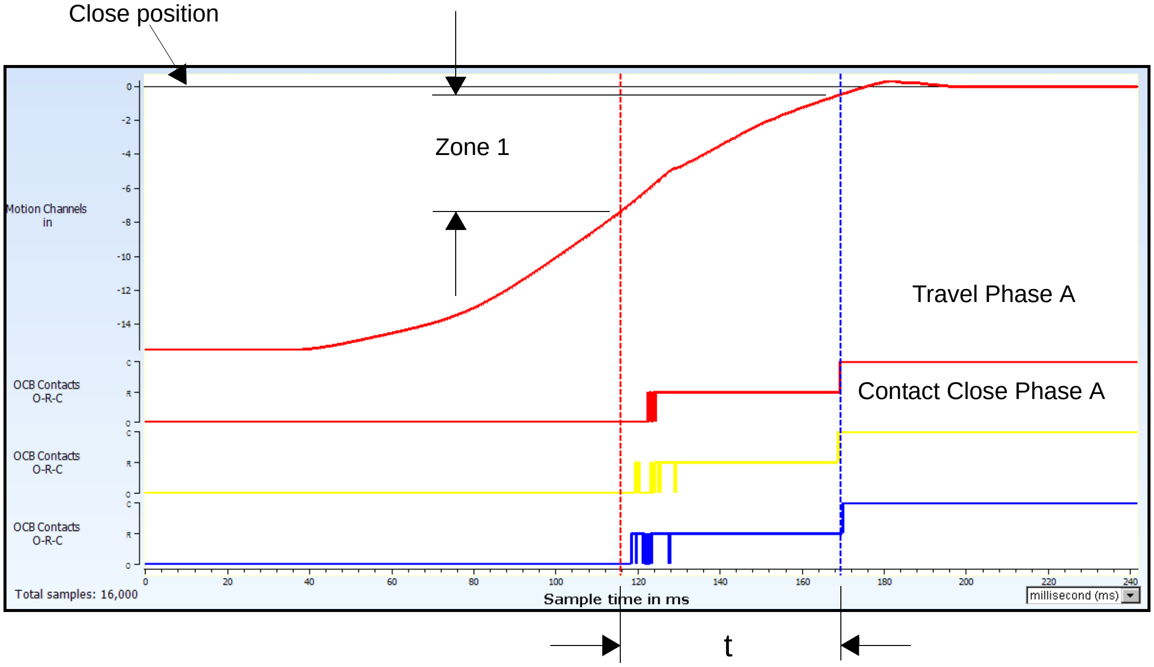


Figure 4.52 Average Velocity Time to Contact Close, Motion Channel #1 (Phase A) Active

For the EHV circuit breaker, the instrument uses the data for Main Contact 1 from the phase of the active motion channel. Figure 4.53 shows the average velocity for a Close operation referencing time to contact closure.

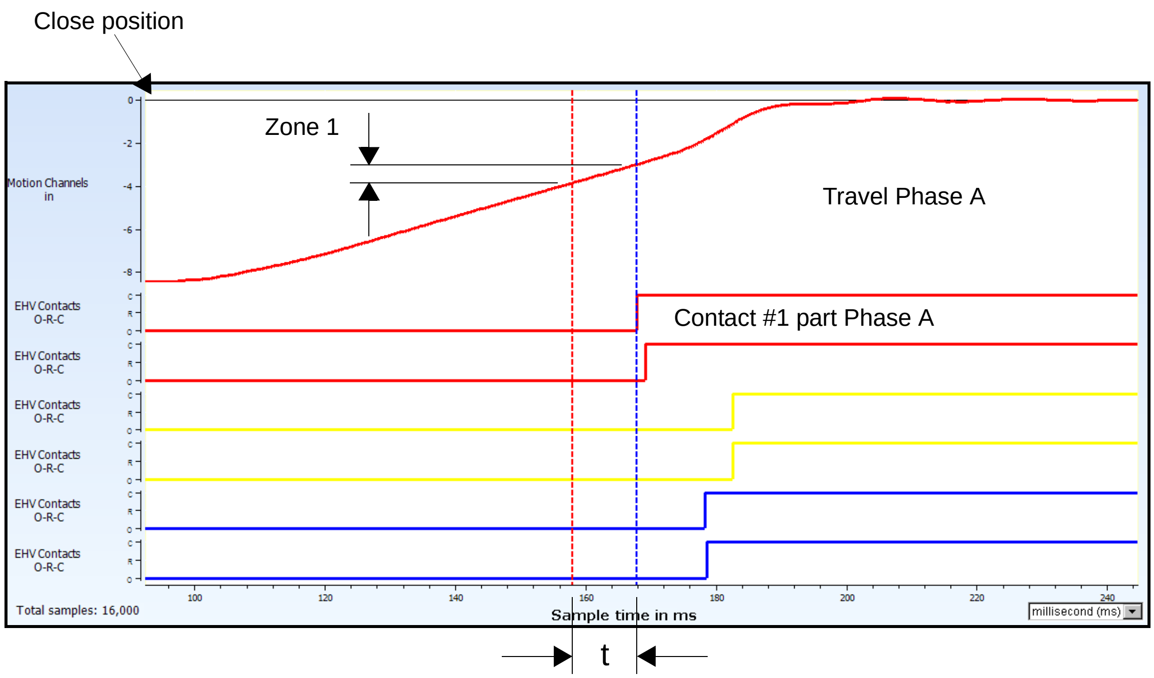


Figure 4.53 Average Velocity Time to Contact Close, Motion Channel #1 (Phase A) Active (EHV)

- 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 4.54 shows the average velocity for a close operation referencing distance to contact close.

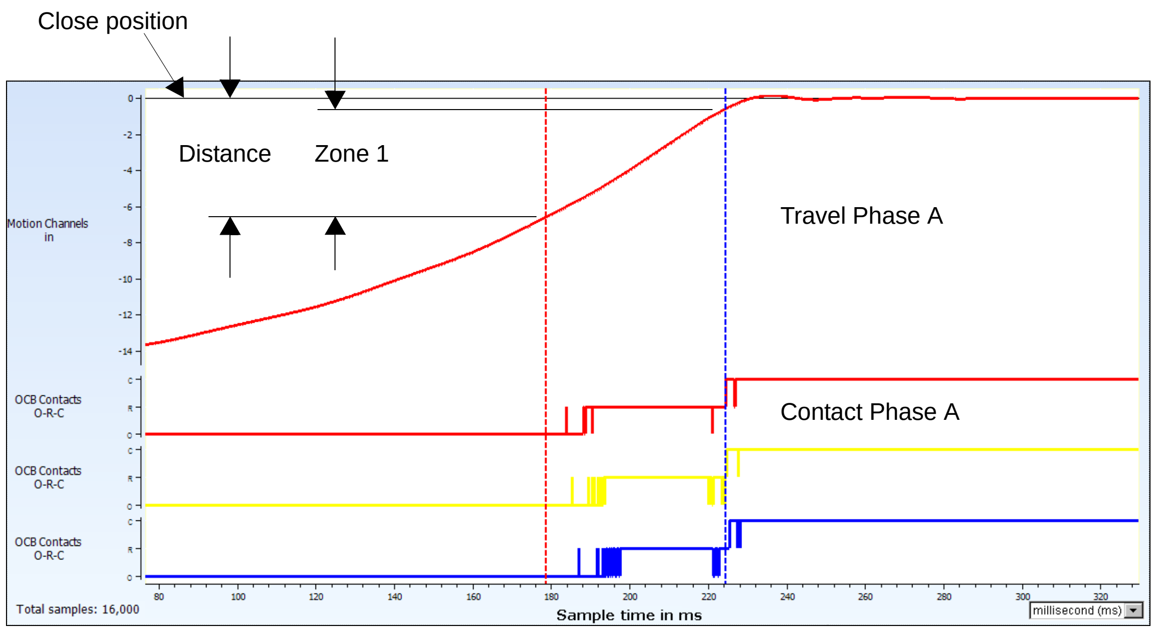


Figure 4.54 Average Velocity Distance to Contact Close, Motion Channel #1 (Phase A) Active

For the EHV circuit breaker, the instrument uses the data for Main Contact 1 from the phase of the active motion channel (Figure 4.55).

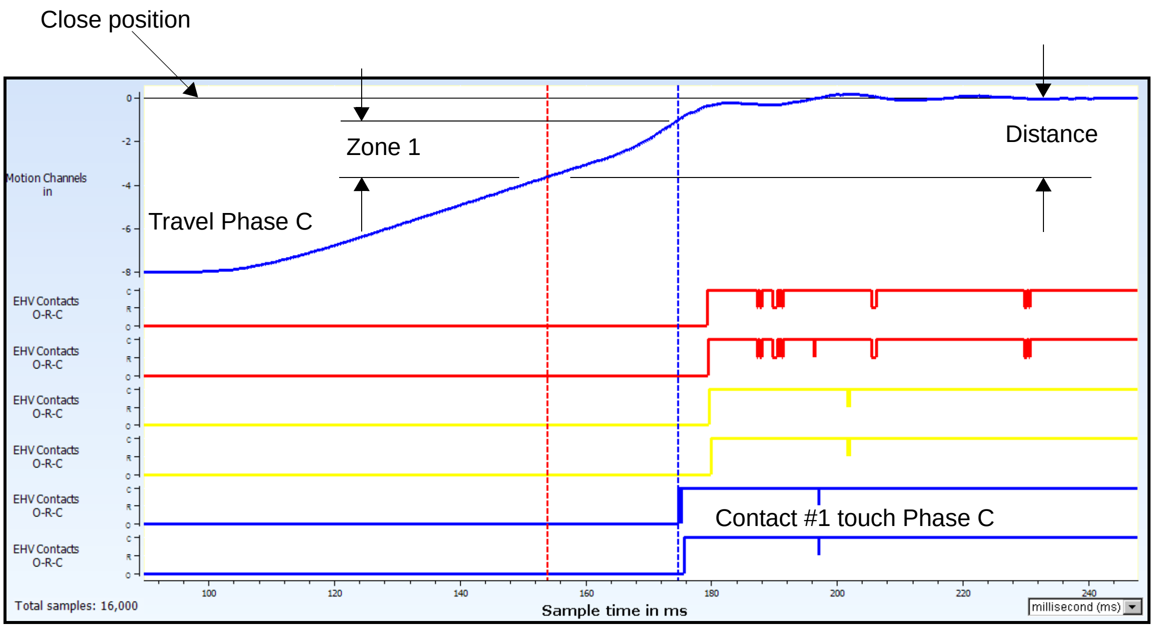


Figure 4.55 Average Velocity Distance to Contact Touch Closing Operation, Motion Channel #3 (Phase C) Active

Zone 2 is similar to Zone 1 and is independent from Zone 1 (Figure 4.56).

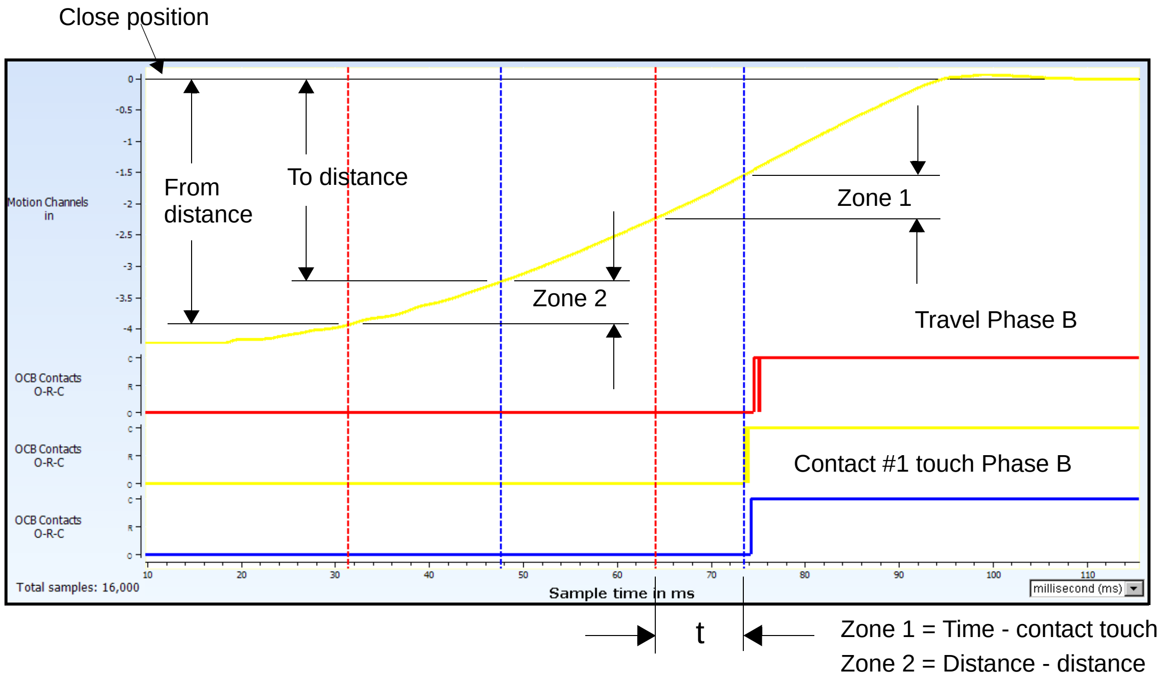


Figure 4.56 Average Velocity Zone 2 Close Operation, Motion Channel #2 (Phase B) Active

- 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 4.57). Unlike distance, travel references the point of contact make and not the fully closed position.

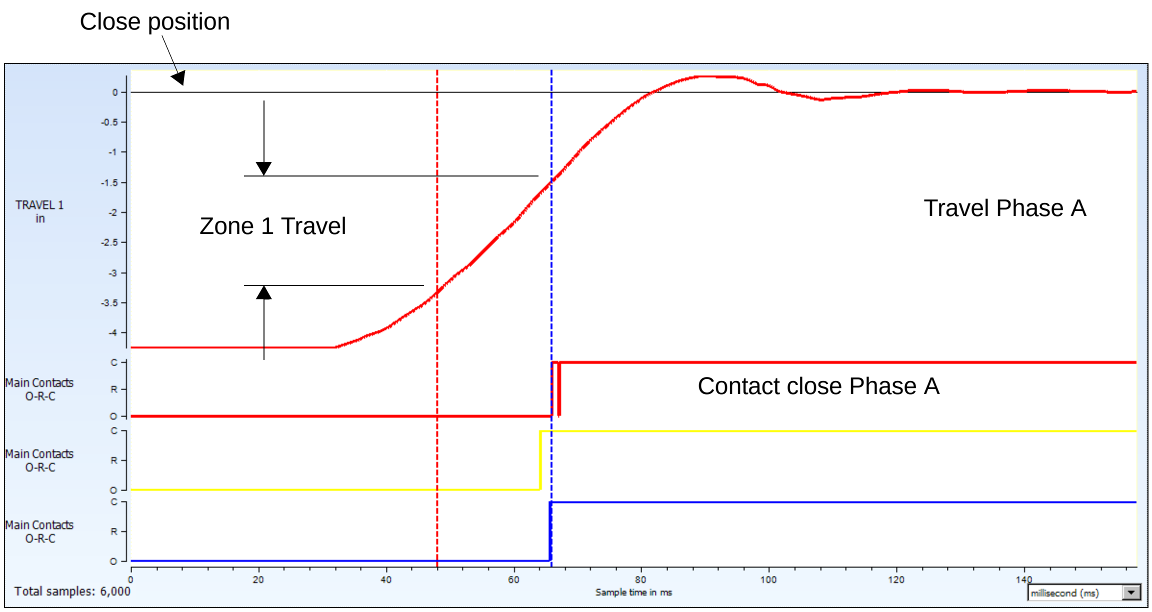


Figure 4.57 Average Velocity Travel to Close Phase A

5. Channel Setup

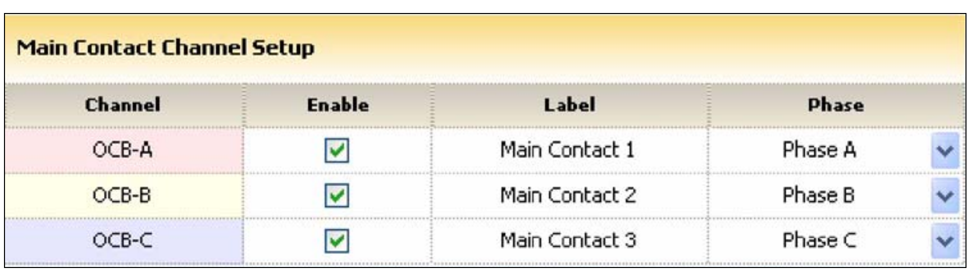
This chapter explains how to set up the main contact, analog, auxiliary, virtual, and motion channels. It contains the following sections:

Main Contact Channels Tab

OCB Channel Setup

This section discusses main contact parameters for an overall circuit breaker test, which consists of 1 measurable break per phase (Figure 5.1). 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 are used to measure the contact timing of any dead tank circuit breaker. 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	☑	Main Contact 1	Phase A
OCB-B	☑	Main Contact 2	Phase B
OCB-C	☑	Main Contact 3	Phase C

Figure 5.1 Dead Tank/OCB – Parameters

EHV Channel Setup

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

Figure 5.2 shows the configuration for a live tank/EHV circuit breaker with multiple breaks.

Main Contact Channel Setup

Channel	Enable	Label	Phase
EHV-A1	☑		Phase A
EHV-A2	☑		
EHV-A3	☑		Phase A
EHV-A4	☐		
EHV-B1	☑		Phase B
EHV-B2	☑		
EHV-B3	☑		Phase B
EHV-B4	☐		
EHV-C1	☑		Phase C
EHV-C2	☑		
EHV-C3	☑		Phase C
EHV-C4	☐		

Figure 5.2 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 5.3).

Motion Channel Setup

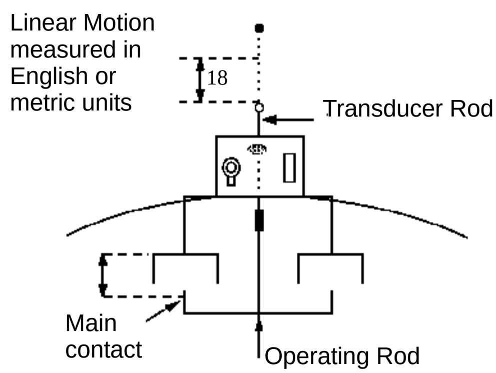
Channel	Enable	Motion Label	Velocity Label	Phase	Transducer Type	Motion Limits	Motion Units	Transducer Scaling	
								Value at Transducer	Value at Contacts
Motion-1	☑	Travel 1	Vel 1	Phase A	Linear	*	Linear	1.000 in	1.000 in
Motion-2	☑	Travel 2	Vel 2	Phase B	Linear	*	Linear	1.000 in	1.000 in
Motion-3	☑	Travel 3	Vel 3	Phase C	Linear	*	Linear	1.000 in	1.000 in
Motion-4	☑	Travel 4	Vel 4	Phase A	Linear	*	Linear	1.000 in	1.000 in
Motion-5	☑	Travel 5	Vel 5	Phase B	Linear	*	Linear	1.000 in	1.000 in
Motion-6	☑	Travel 6	Vel 6	Phase C	Linear	*	Linear	1.000 in	1.000 in

Figure 5.3 Motion Channel Limits

For a transducer type, you can select either linear or rotary.

There is a microswitch in the TR3190 transducer that alerts the instrument 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 TDR instrument does not execute the test and an error message appears.

Figure 5.4 shows the relationships between the test plan and the transducer linear motion characteristics.

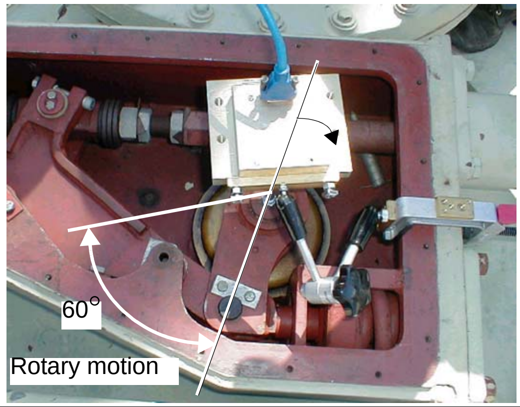


Motion Channel Setup

Channel	Enable	Motion Label	Velocity Label	Phase	Transducer Type	Motion Limits	Motion Units	Transducer Scaling: Value at Transducer	Transducer Scaling: Value at Contacts
Motion-1	✓	Travel 1	Vel 1	Phase A	Linear	*	Linear	1.000 in	1.000 in
Motion-2	✓	Travel 2	Vel 2	Phase B	Linear / Rotary	*	Linear	1.000 in	1.000 in
Motion-3	✓	Travel 3	Vel 3	Phase C	Linear	*	Linear	1.000 in	1.000 in

Figure 5.4 Linear Motion Measured in English or Metric Units

Figure 5.5 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	Transducer Scaling: Value at Contacts
Motion-1	☑	Travel 1	Vel 1	Phase A	Rotary	*	Linear	1.0°	1000.0 mm
Motion-2	☑	Travel 2	Vel 2	Phase B	Linear / Rotary	*	Linear	1.0°	1000.0 mm
Motion-3	☑	Travel 3	Vel 3	Phase C	Rotary	*	Linear	1.0°	1000.0 mm

Figure 5.5 Rotary Motion Measured in Degrees

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

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.

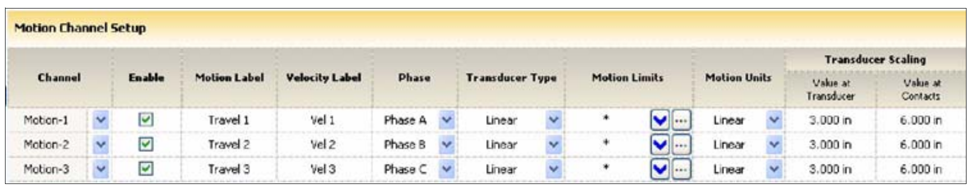
In many circuit breakers, it is not possible to attach a transducer connecting rod to a part of the circuit breaker mechanism that moves directly with the main contacts. However, it should be possible to connect the transducer connecting rod to another location in the mechanism that moves in a secondary 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 5.6 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	Transducer Scaling Value at Contacts
Motion-1	☑	Travel 1	Vel 1	Phase A	Linear	*	Linear	3.000 in	6.000 in
Motion-2	☑	Travel 2	Vel 2	Phase B	Linear	*	Linear	3.000 in	6.000 in
Motion-3	☑	Travel 3	Vel 3	Phase C	Linear	*	Linear	3.000 in	6.000 in

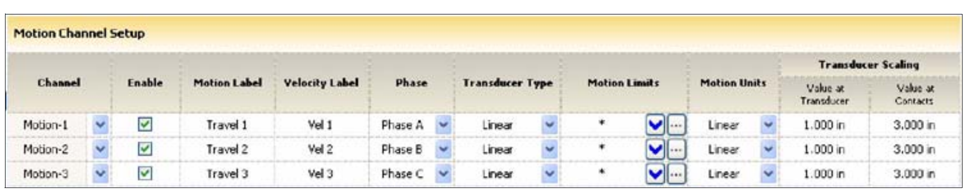
Figure 5.6 Linear-to-Linear Transducer Scaling

In this example, the instrument 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 5.7 shows transducer scaling.


Motion Channel Setup

Channel	Enable	Motion Label	Velocity Label	Phase	Transducer Type	Motion Limits	Motion Units	Transducer Scaling Value at Transducer	Transducer Scaling Value at Contacts
Motion-1	☑	Travel 1	Vel 1	Phase A	Linear	*	Linear	1.000 in	3.000 in
Motion-2	☑	Travel 2	Vel 2	Phase B	Linear	*	Linear	1.000 in	3.000 in
Motion-3	☑	Travel 3	Vel 3	Phase C	Linear	*	Linear	1.000 in	3.000 in

Figure 5.7 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 x 3 = 0.00375".

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

Rotary-to-Linear Transducer Scaling

Figure 5.8 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	Transducer Scaling: Value at Contacts
Motion-1	☑	Travel 1	Vel 1	Phase A	Rotary	*	Linear	50.0°	1.000 in
Motion-2	☑	Travel 2	Vel 2	Phase B	Rotary	*	Linear	50.0°	1.000 in
Motion-3	☑	Travel 3	Vel 3	Phase C	Rotary	*	Linear	50.0°	1.000 in

Figure 5.8 Rotary-To-Linear Transducer Scaling

Rotary-to-linear transducer scaling is used when the manufacturer provides specification for the linear motion of the contacts. However, the only access to the mechanism consists of a rotary motion access point (Figure 5.9). 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

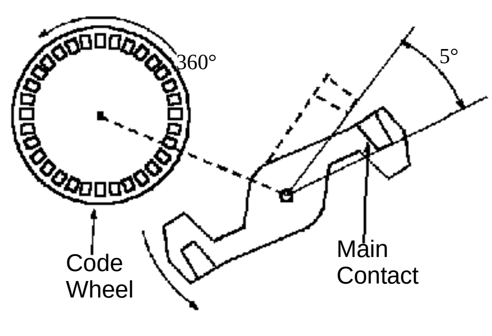
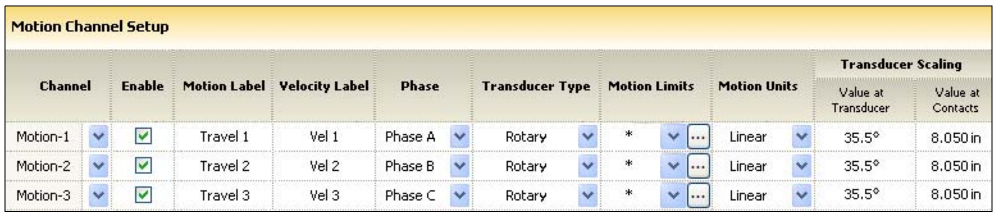


Figure 5.9 Transducer Wheel

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 5.10).


Motion Channel Setup

Channel	Enable	Motion Label	Velocity Label	Phase	Transducer Type	Motion Limits	Motion Units	Transducer Scaling: Value at Transducer	Transducer Scaling: Value at Contacts
Motion-1	☑	Travel 1	Vel 1	Phase A	Rotary	*	Linear	35.5°	8.050 in
Motion-2	☑	Travel 2	Vel 2	Phase B	Rotary	*	Linear	35.5°	8.050 in
Motion-3	☑	Travel 3	Vel 3	Phase C	Rotary	*	Linear	35.5°	8.050 in

Figure 5.10 Rotary-To-Linear Transducer Scaling

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

35.5 °/360 ° x 5" = 0.493".

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" x 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".

Analog, Aux Tab

Analog Channels

Figure 5.11 shows the Analog Channel parameters and specifications.

Analog Channels

Channel	Enable	Label	Phase	Type	Range	Analog Scaling				
						Low Reference		High Reference		
						Sensor	Value	Sensor	Value	Units
Analog-1	☑		Phase A	Voltage	300 V	0.0 V	0.0 V	300.0 V	300.0 V	V
Analog-2	☑		Phase B	Voltage	300 V	0.0 V	0.0 V	300.0 V	300.0 V	V
Analog-3	☑		Phase C	Voltage	300 V	0.0 V	0.0 V	300.0 V	300.0 V	V

Figure 5.11 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 5.11 on page 5-8). 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 Reverence Value—250 (e.g. 25 mbar x 10)
- Unit—mbar

Voltage Range Selection

The following voltages are available:

- .2 V peak
- 2 V peak
- 10 V peak
- 100 V peak
- 200 V peak
- 300 V peak
- 500 V peak (Not supported by the TDR9000)

Current Selection for Probes

You can use an analog channel to measure current probes that provide a voltage output. It is important to select appropriate matching current ranges in T-Doble and on the probe itself. The recommended probes are:

- Autozero probe (Doble P/N 401-0055) clip-on, Hall effect probe with current ranges 20 A and 200 A

  This probe provides 2 V output on both ranges when current is at maximum.
- Fluke Y8-100 clip-on, Hall effect probe with current ranges 20 A and 200 A

  This probe provides 2 V output on both ranges when current is at maximum.
- F. W. Bell CG-100A clip-on, Hall effect probe with current ranges of 10 A and 100 A

  This probe provides 1 V output on both ranges when current is at maximum. It is also capable of 100% overload, bringing output to 2 V.

T-Doble has two current ranges to use with a Doble probe:

- Low – 20 A
- High – 200 A

On the low (20A) range, 6.12 A through the probe produces the following outputs:

- 20 A corresponds to V_{out} = 2 V
- 6.12 A corresponds to V_{out} = 0.612 V

This voltage is interpreted by the TDR instrument on the 20 A scale as:

- 2 V corresponds to 20 A
- 0.612 V corresponds to $I_2 = 6.12$ A

Auxiliary Contact Channels

Figure 5.12 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.

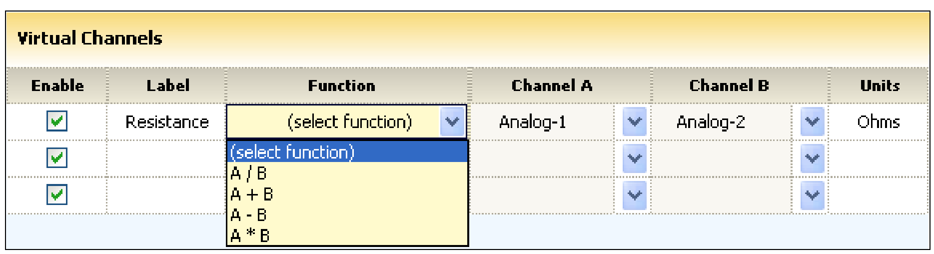
Auxiliary Contact Channels

Channel	Enable	Label
Aux-1	☑	52-a
Aux-2	☑	52-b
Aux-3	☑	

Figure 5.12 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 Analog-1 (DC Voltage) and Analog-2 (DC Current) (Figure 5.13).



Virtual Channels

Enable	Label	Function	Channel A	Channel B	Units
☑	Resistance	(select function)	Analog-1	Analog-2	Ohms
☑					
☑					

Figure 5.13 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 6-31.

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

The Test Setup tab of the Test Plan page provides access to the main test parameters. See Figure 6.1.

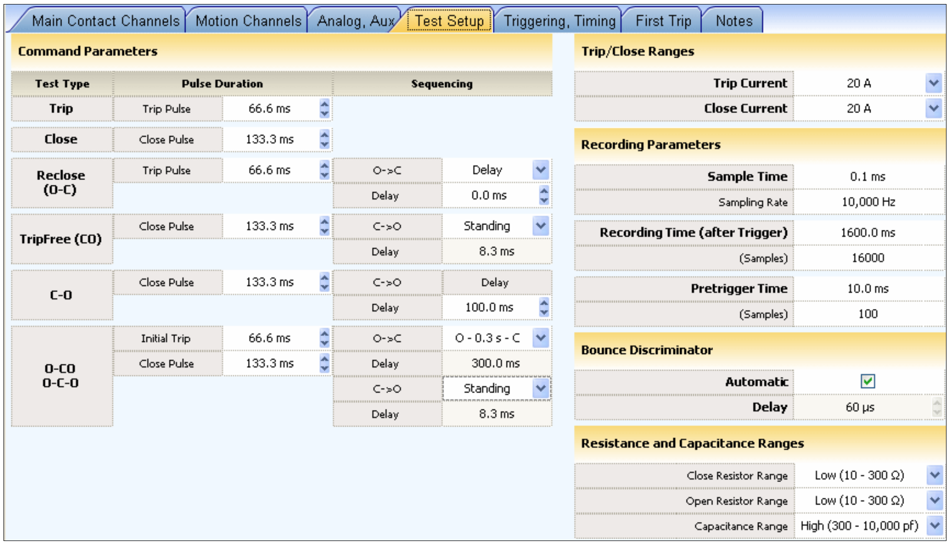


Figure 6.1 Test Setup Tab of Test Plan Page

Command Parameters

The Command Parameters table lists the default Pulse Duration and Sequencing parameters configured for each test. See Figure 6.2.

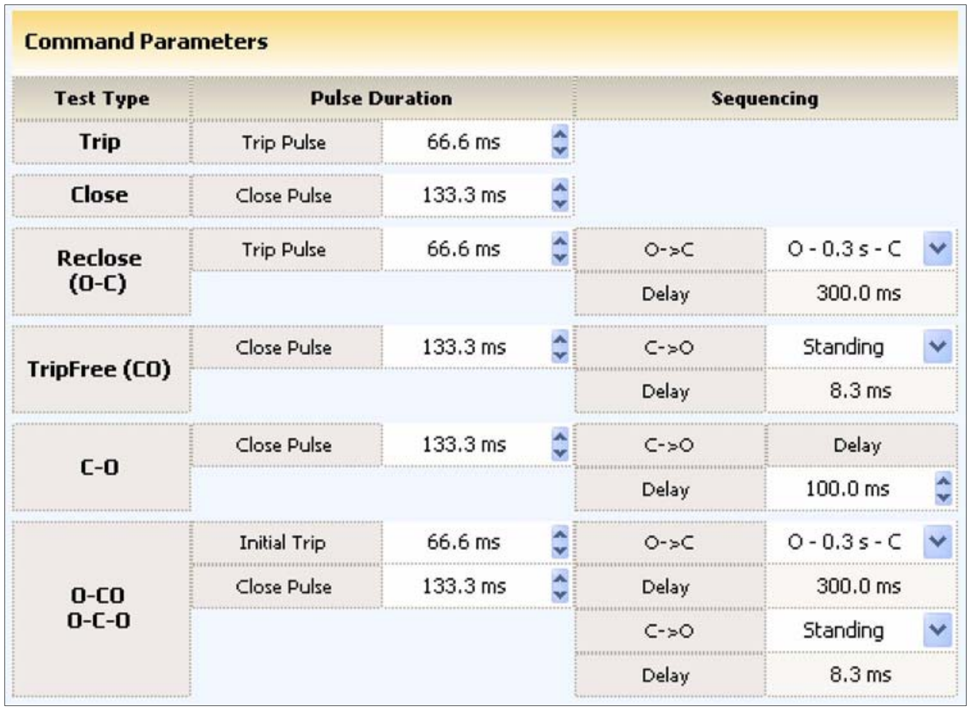


Figure 6.2 Command Parameters

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 6.3 shows a waveform generated by the Trip test.

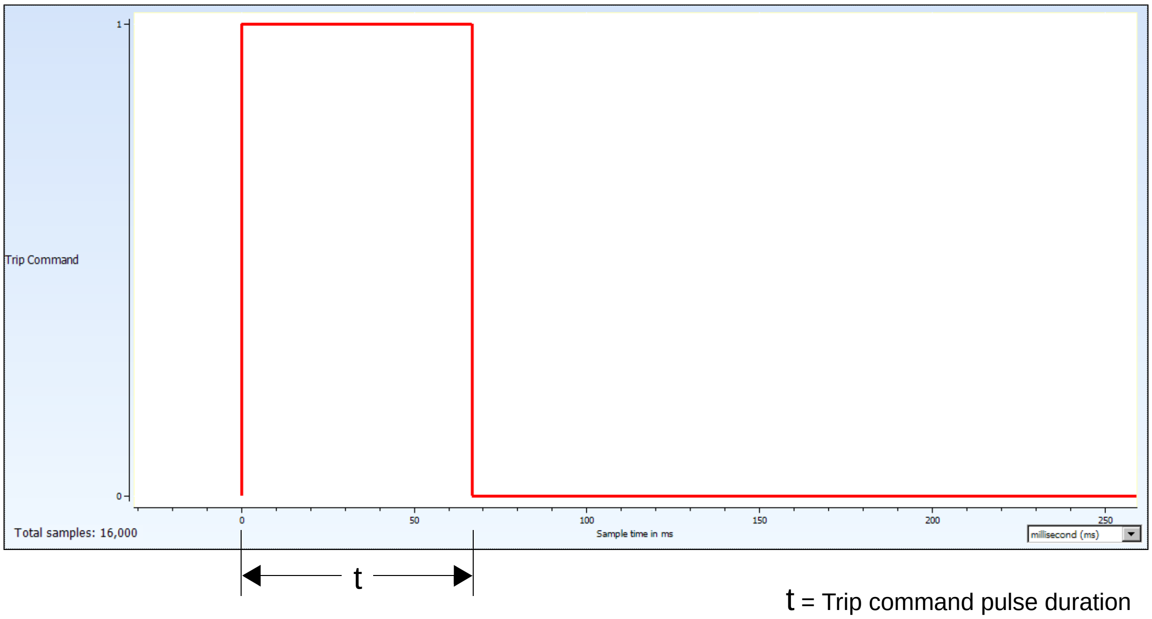


Figure 6.3 Trip Command Pulse

Table 6.1 Trip Test Command Parameters

Command Parameter	Definition
Trip Pulse	Determines the duration of the trip pulse sent to operate the trip circuit of the circuit breaker. Default values are: • 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 6.4 shows a waveform generated by the Close test.

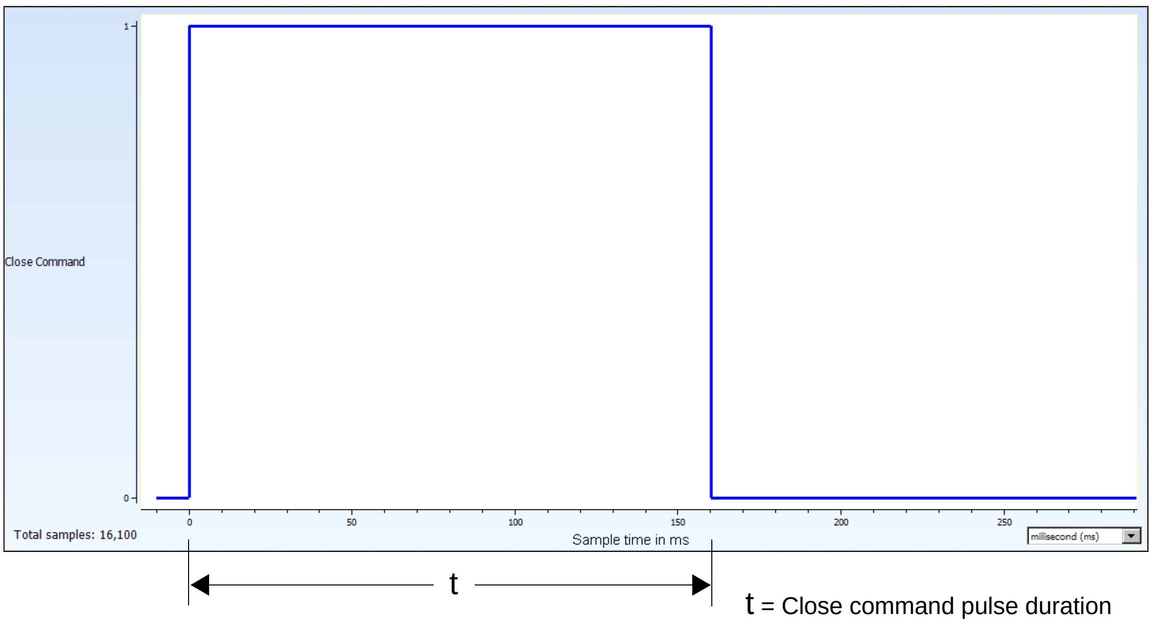


Figure 6.4 Close Command Pulse

Table 6.2 Close Test Command Parameters

Command Parameter	Definition
Close Pulse	Determines the duration of the close pulse sent to operate the close circuit of the circuit breaker. Default values are: • 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 6.5 shows a waveform generated by the TripFree test.

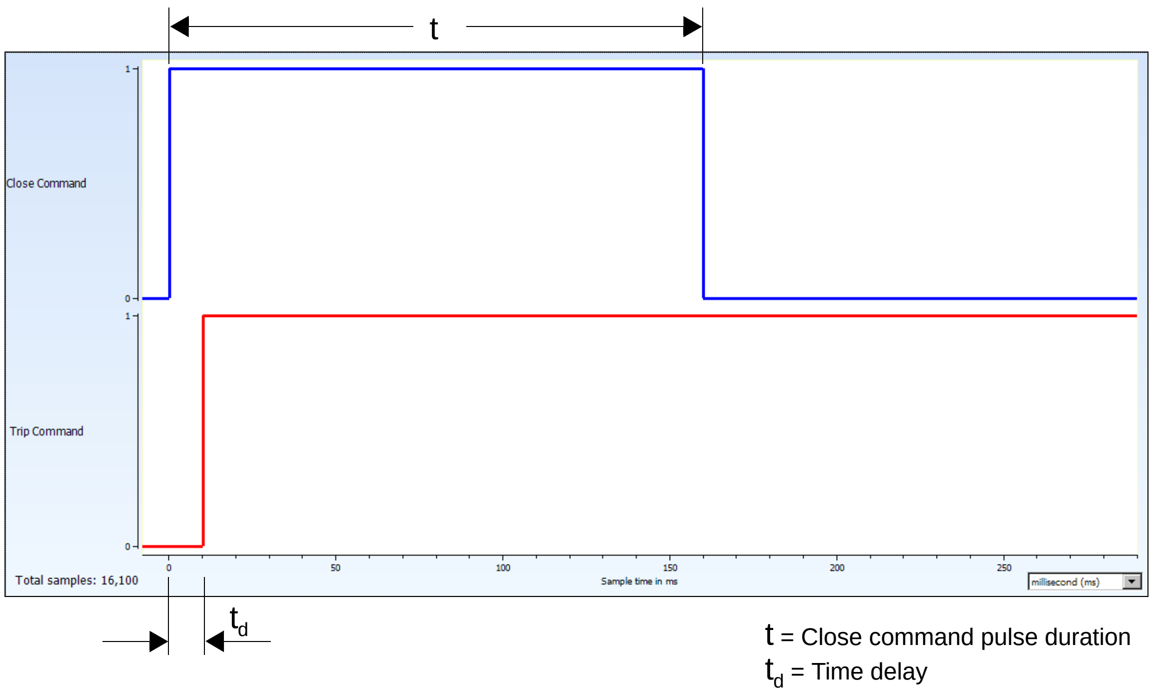


Figure 6.5 TripFree Command Pulse

Table 6.3 TripFree Test Command Parameters

Command Parameter	Definition
Close Pulse	Determines the duration of the close pulse sent to operate the close circuit of the circuit breaker. Default values are: • 133.3 ms for 60 Hz • 160 ms for 50 Hz

Table 6.3 TripFree Test Command Parameters (Continued)

Command Parameter	Definition
C→O	Determines when the trip pulse is initiated. There are three values: • Standing—See "C→O Parameter: Standing Option" on page 6-7 • First Touch—See "C→O Parameter: First Touch Option" on page 6-7 • All Close, Any Phase—See "C→O Parameter: All Close, Any Phase Option" on page 6-8

C→O 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 6.6). When Standing is selected, you cannot edit the Delay value.

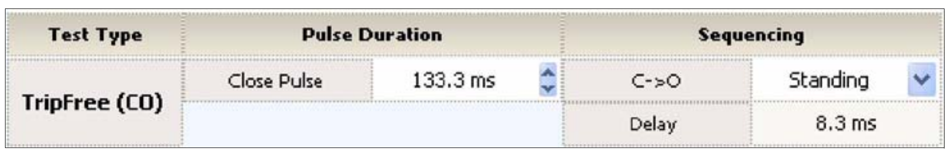


Figure 6.6 TripFree Standing

See Figure 6.5 on page 6-6 for a TripFree command pulse with a delay of 8.3 ms.

C→O 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 6.7).

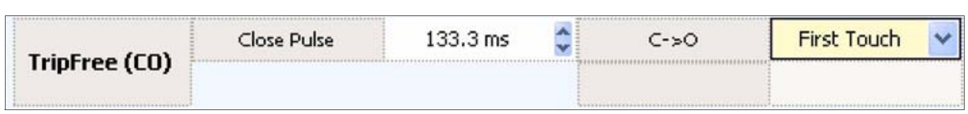


Figure 6.7 TripFree First Touch

Figure 6.8 shows how the Trip command is started when Contact 1in Phase A makes a first touch.

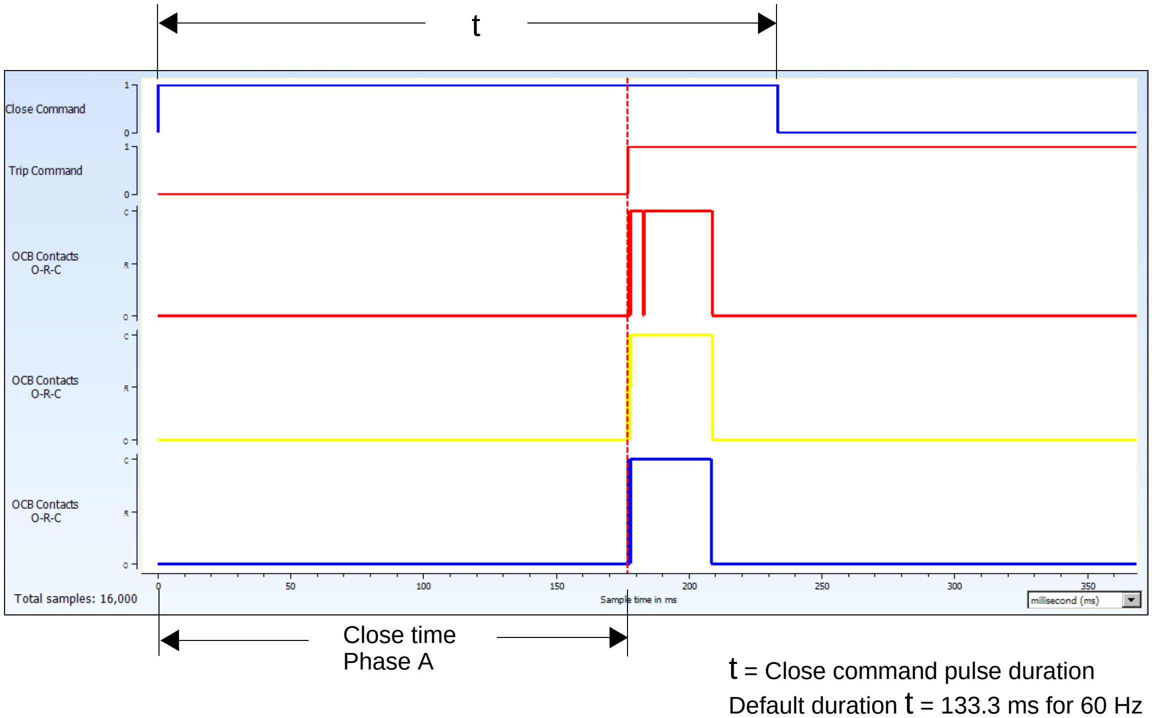


Figure 6.8 TripFree Started by Contact 1 First Touch

C→O 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.

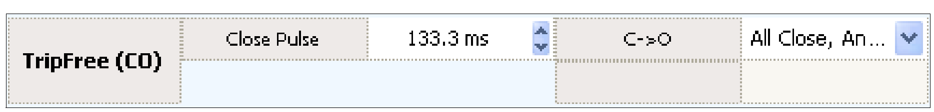


Figure 6.9 TripFree All Close, Any Phase

Reclose (O-C) Test

During the Reclose 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 6.10 shows a waveform generated by the Reclose test.

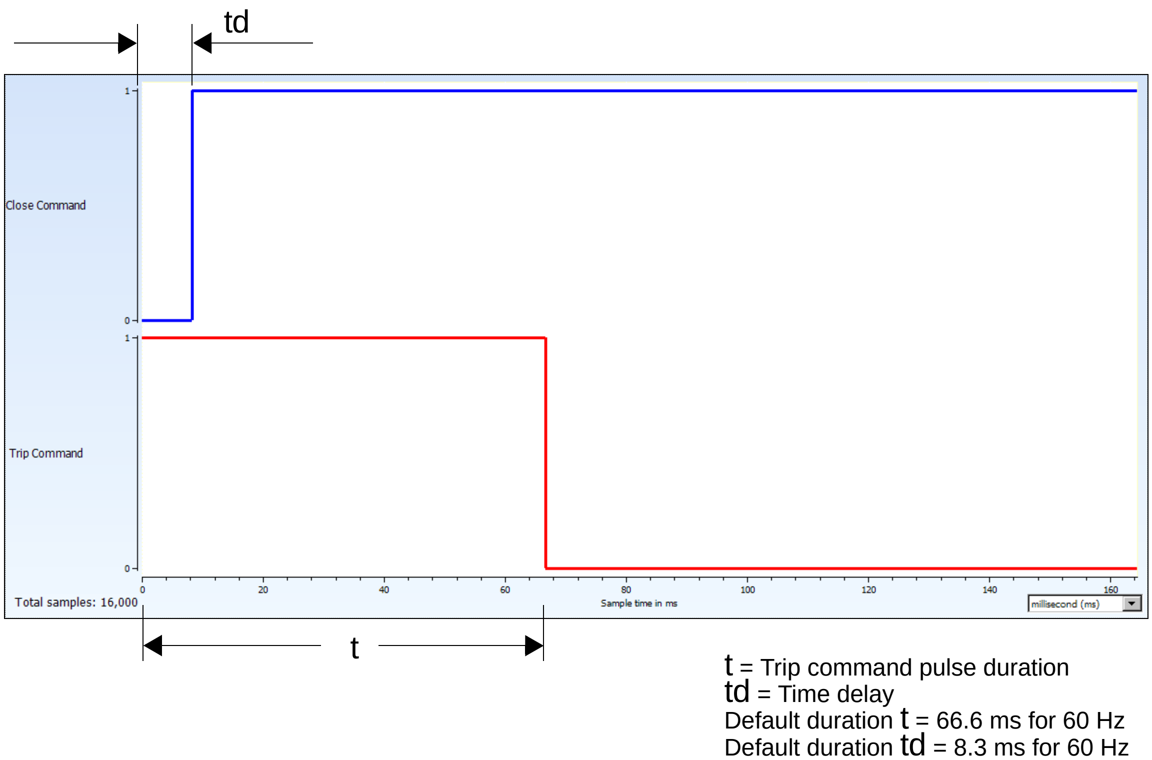


Figure 6.10 Reclose Command Pulse

Table 6.4 Reclose Test Command Parameters

Command Parameter	Definition
Trip Pulse	Determines the duration of the trip pulse sent to operate the trip circuit of the circuit breaker. Default values are: • 66.6 ms for 60 Hz • 80 ms for 50 Hz

Table 6.4 Reclose Test Command Parameters (Continued)

Command Parameter	Definition
O→C	Determines when the close pulse is initiated. There are three values: • O - 0.3 s - C—See "O→C Parameter: O - 0.3 s - C Option" on page 6-10 • Delay—See "O→C Parameter: Delay Option" on page 6-11

O→C Parameter: O - 0.3 s - C Option

The O - 0.3 s - C parameter performs a Reclose test with a 300 ms delay after test initiation. This delay value cannot be edited. (Figure 6.11).

Figure 6.11 Reclose O - 0.3 s - C

Figure 6.12 shows how the O - 0.3 s - C Close command is delayed.

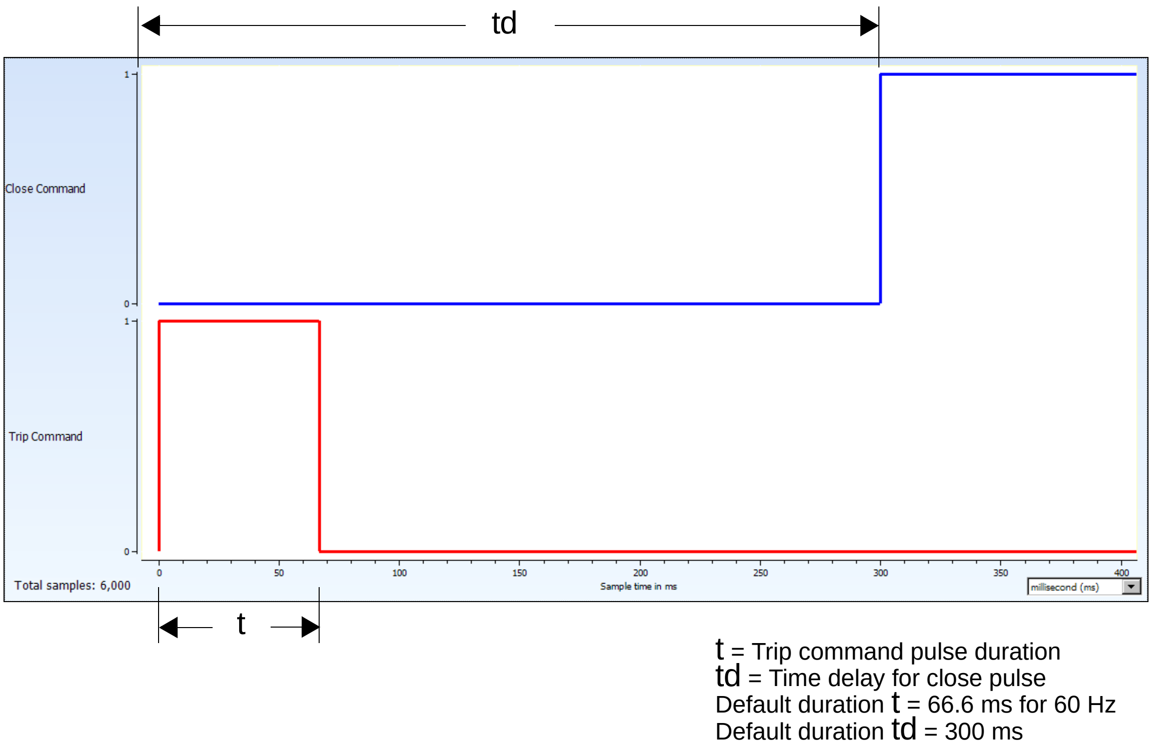


Figure 6.12 Reclose O - 0.3 s - C Operation

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 6.13).

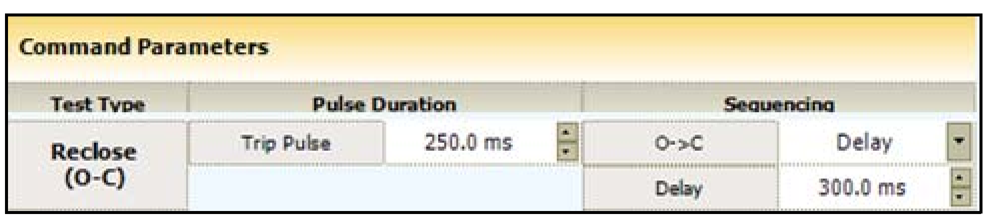


Figure 6.13 Reclose with a User-defined Delay of 300 ms

Figure 6.14 shows a Reclose delay with a default delay length of 300 ms.

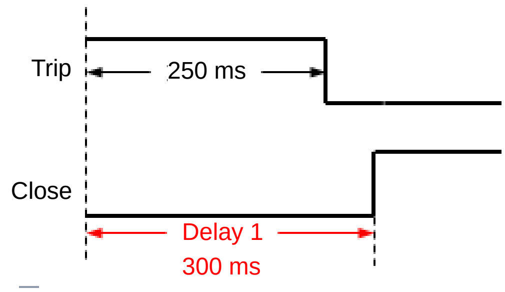


Figure 6.14 Reclose Delay Operation

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 6.15 shows a waveform generated by the C-O test.

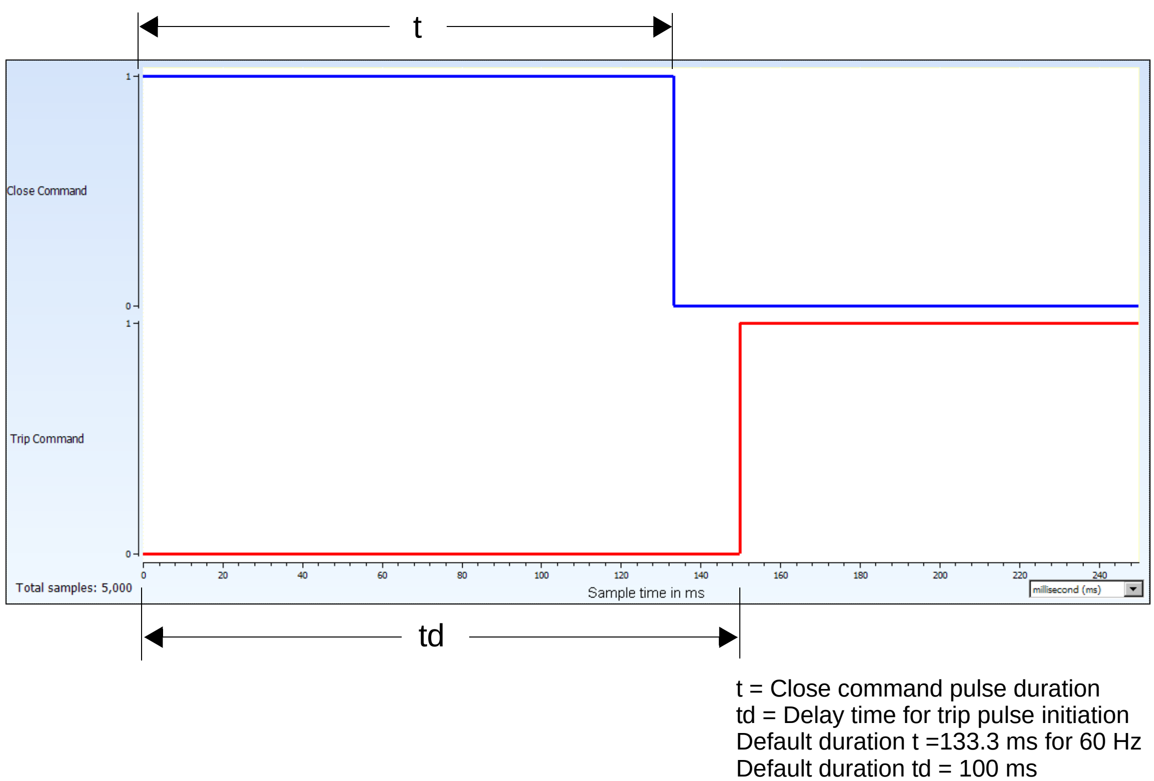


Figure 6.15 C-O Command Pulse

Table 6.5 C-O Test Command Parameters

Command Parameter	Definition
Close Pulse	Determines the duration of the close pulse sent to operate the close circuit of the circuit breaker. Requires a delay value (0.0 to 1600 ms; default is 100 ms).

After test initiation, the close pulse is applied after the specified time delay (0.0 to 1600 ms) and continues for the duration of the test (Figure 6.16).

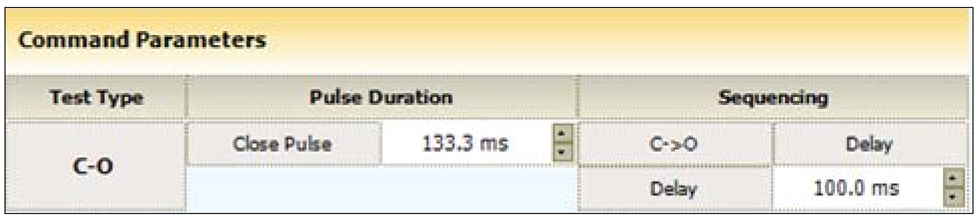


Figure 6.16 C-O Delay of 100 ms

The delay length default value is 100 ms.

Figure 6.17 shows how the C-O command is delayed.

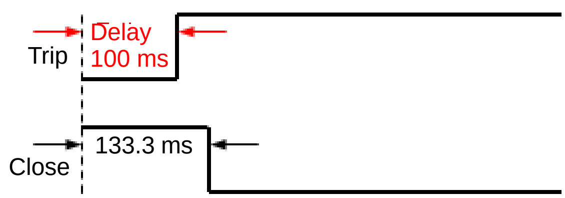


Figure 6.17 C-O Delay Operation

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 requirement is based on the pickup and dropout time of the TR3000's relay, which allows the SCR inside the instrument to initiate the command pulse. To maintain plan compatibility, these limits are maintained for the TDR900 and TDR9000.

Figure 6.18 shows a waveform generated by the O-CO and O-C-O tests.

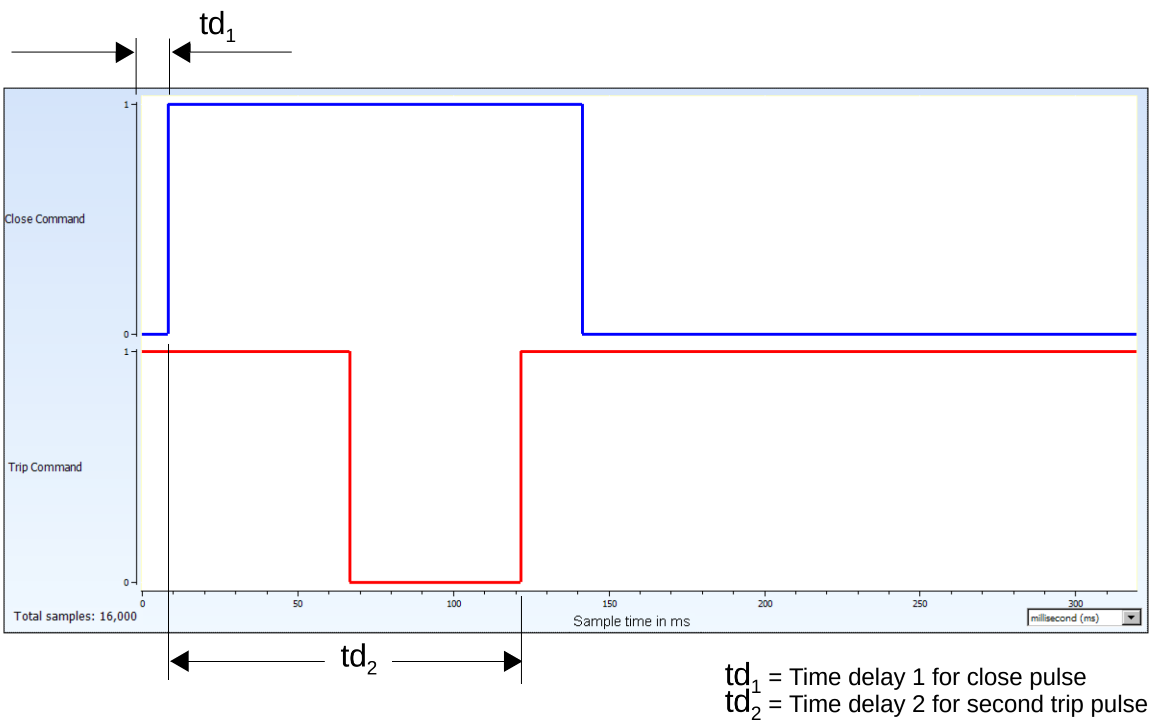


Figure 6.18 O-C-O Command Pulse

Table 6.6 O-CO and O-C-O Test Command Parameters

Command Parameter	Definition
Trip Pulse	Determines the duration of the trip pulse sent to operate the trip circuit of the circuit breaker.
Initial Trip	Determines the duration of the first trip pulse sent to operate the trip circuit of the circuit breaker. Default values are: • 66.6 ms for 60 Hz • 80 ms for 50 Hz
Close Pulse	Determines the duration of the close pulse sent to operate the close circuit of the circuit breaker.
O→C	Determines when the close pulse is initiated: • 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.
C→O	Determines when the open pulse is initiated. There are four values: • Standing—See “C→O Parameter: Standing Option” on page 6-16 • First Touch—See “C→O Parameter: First Touch Option” on page 6-17 • All Close, Any Phase—See “C→O Parameter: All Close, Any Phase Option” on page 6-18 • Delay—See “C→O Parameter: Delay Option” on page 6-19

C→O 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 6.19). 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.

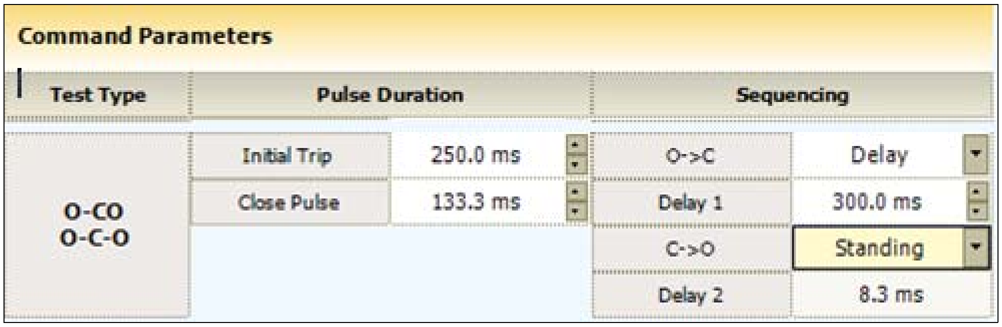


Figure 6.19 O-C-O Standing

The minimum Delay 2 value is calculated as follows:

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

Figure 6.20 shows an O-C-O command pulse with a a Reclose (O→C) Delay 1 of 300 ms and a standing TripFree (C→O) Delay 2 of 8.3 ms.

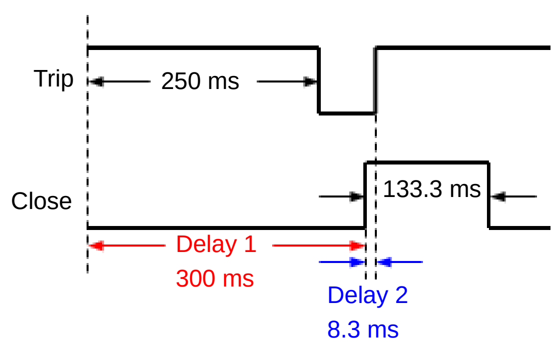


Figure 6.20 O-CO Standing Delay Operation

C→O Parameter: First Touch Option

A trip command of a specified duration is applied to the circuit breaker at time zero (Figure 6.21). 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.

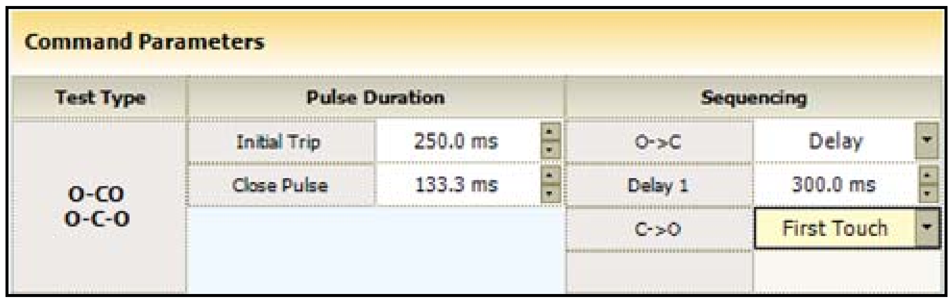


Figure 6.21 O-C-O First Touch

The minimum Delay 1 value can be calculated as follows:

Delay1 ≥ Trip Pulse + 55 ms

Figure 6.22 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.

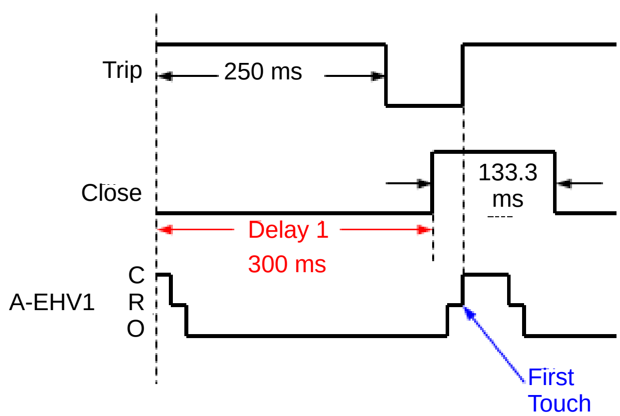


Figure 6.22 O-C-O First Touch Operation

C→O 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.

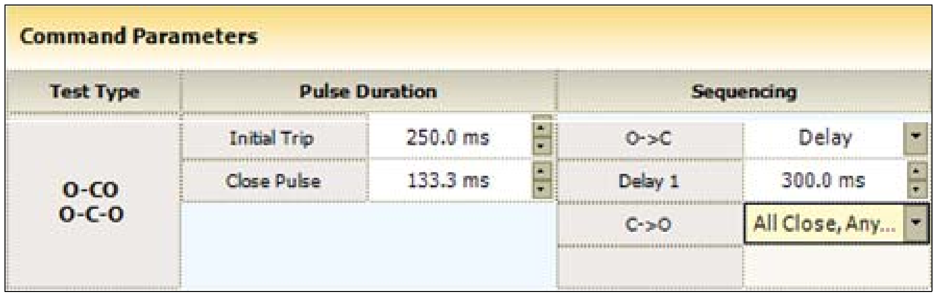


Figure 6.23 TripFree All Close, Any Phase

Figure 6.24 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.

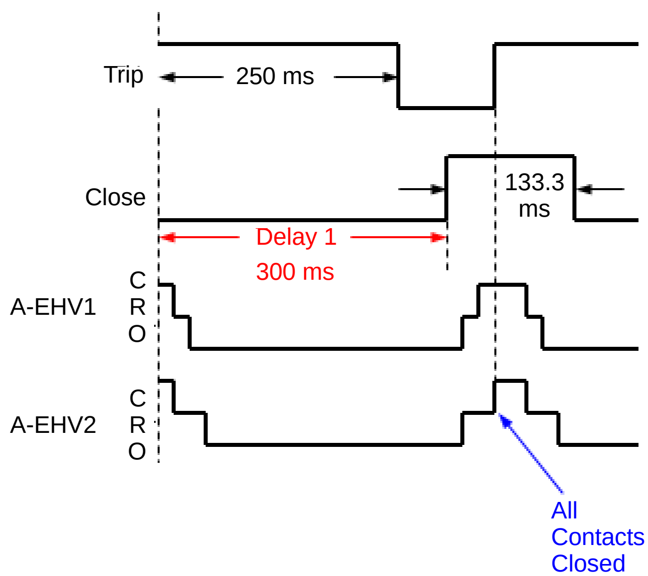


Figure 6.24 O-C-O All Close, Any Phase Operation

C→O 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.

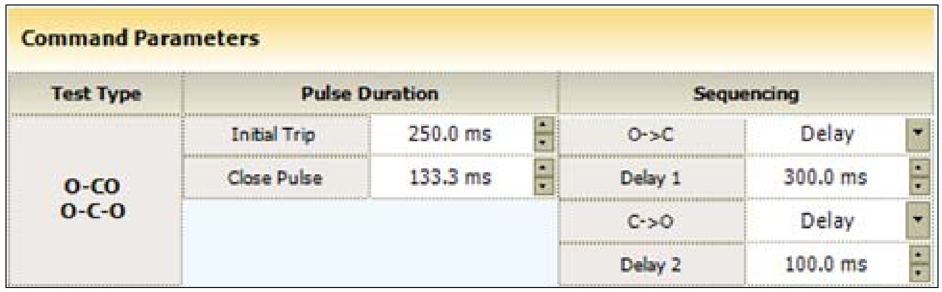


Figure 6.25 TripFree Delay

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

Delay 1 length $\leq$ 55 ms + Trip Pulse

The minimum Delay 2 length can be calculated as follows:

Delay 2 length > 55 ms + (Trip pulse – Delay 1 length)

Figure 6.26 shows how the TripFree delay works.

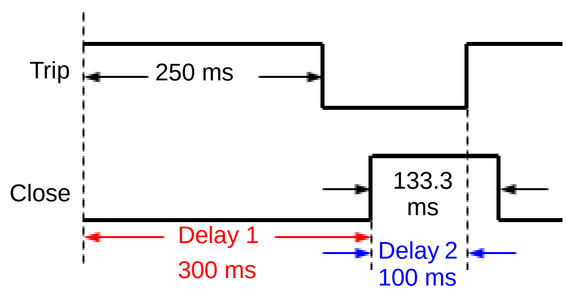


Figure 6.26 TripFree Delay Operation

Record Only Test

The Record Only test is a convenience for users who may wish to record activity on main contacts, resistor switches, analog channels, and so on.

You can configure this test to run a Slow Close test.

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 following ranges are available:

- Trip Current Range: 0-2; 0-5; 0-20; 0-100 A
- Close Current Range: 0-0.2; 0-1; 0-5; 0-20 A

Figure 6.27 Trip/Close Range

NOTE	**TDR9000 only: The Trip/Close module has configuration options only when the Trip/Close Current option is being used. This window configures the current range expected on the Trip or Close control circuit.**

Trip Pulse (Timing)

The trip pulse is adjustable in 1/10 ms increments. Select a pulse length that is long enough to allow the *X* relay to drop out and de-energize the coil or the *A* switch to de-energize the trip coil. The trip pulse default values are:

- 66.6 ms for 60 Hz
- 80 ms for 50 Hz

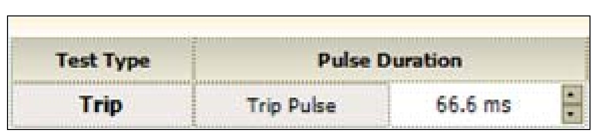


Figure 6.28 Trip Parameters

Close Pulse (Timing)

The close pulse is adjustable in 1/10 ms increments. Select a close pulse duration that is long enough for the circuit breaker mechanism and control circuit to complete the entire close operation. The default close pulse values, which are adequate for most circuit breakers, are as follows:

- 133.3 ms for 60 Hz
- 160 ms for 50 Hz

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

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

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 6.29).

Test Type	Pulse Duration	
Close	Close Pulse	133.3 ms

Figure 6.29 Close Parameters

Figure 6.30 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 switch. The close time is measured from the test initiation. (If the Relative to Test Initiation option is selected in Resistor Switch Timing Specification, see “Resistor Timing – Close” on page 4-22.)

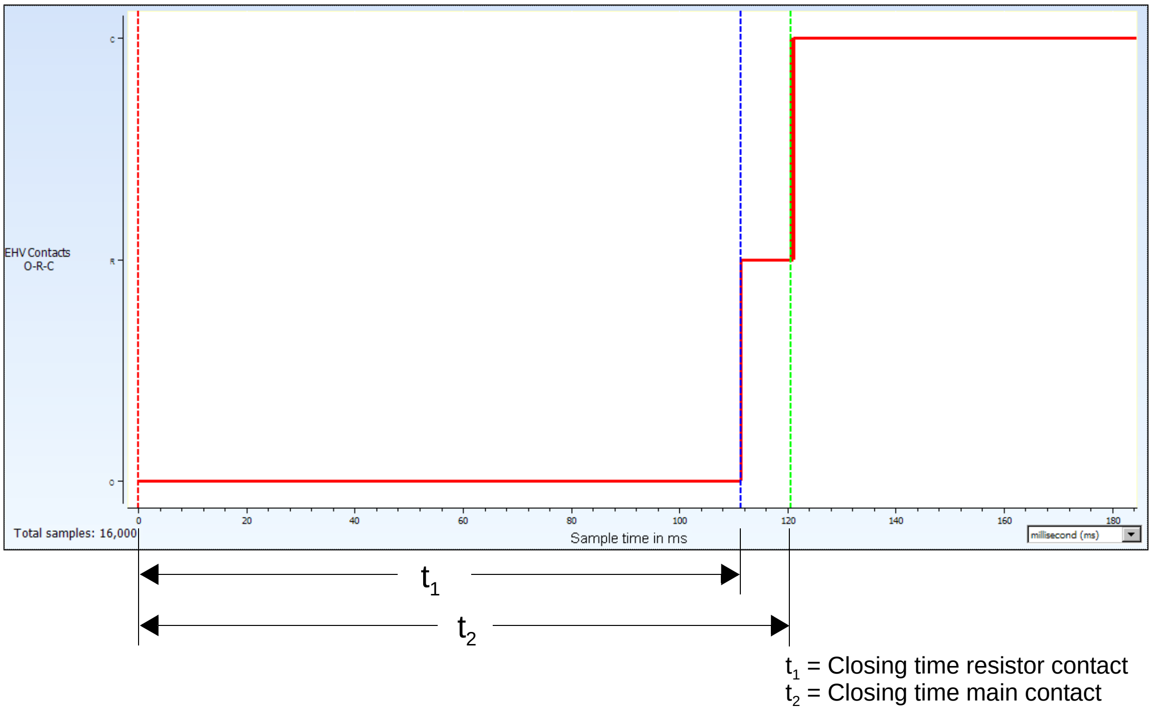


Figure 6.30 Close Time

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 6.31).

Timing Reference Setup

Test Type	Timing Reference	Detail	
Trip	Internal (When Test Starts)		
Close	Close Current	Threshold	1.00 V
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 6.31 Set Close Current and Threshold Value

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

The selection made calculates the timing of the main contact (t_2) and resistor switch (t_1) (Figure 6.32 on page 6-23) 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 4-22.

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

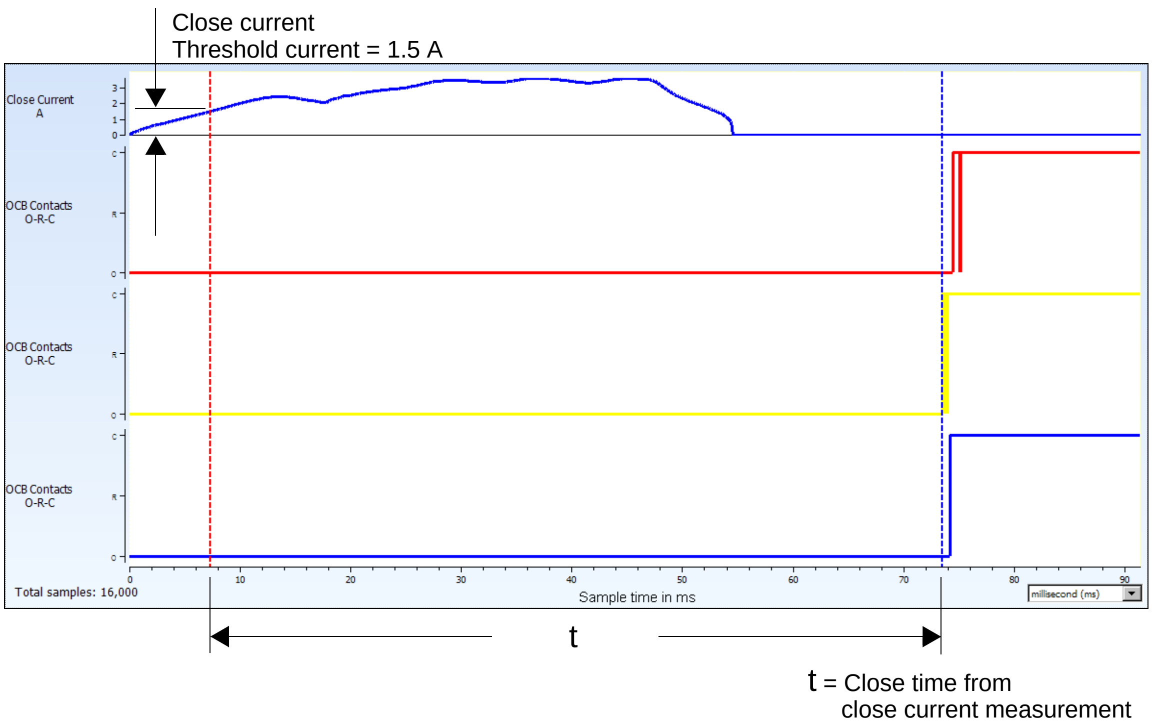


Figure 6.32 Close Timing from Close Current Measurement

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 6.33 on page 6-24).

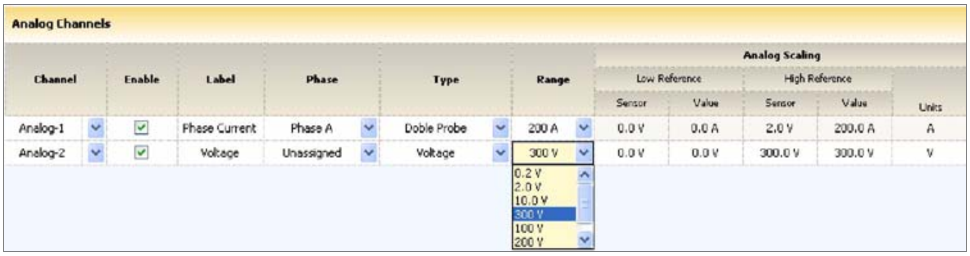


Figure 6.33 Set Magnitude of Analog Measurement

The measurements in Figure 6.34 were calculated using an external current probe with a selected range of 20 A. The timing of the main contact (t2) and resistor switch (t1) is calculated in this way:

1. The T0 option is selected in “Resistor Timing – Close” on page 4-22.
2. The designated channel reaches the threshold current (10 A in this example) of the full scale current selected for that channel (Figure 6.34).
3. The calculation is made.

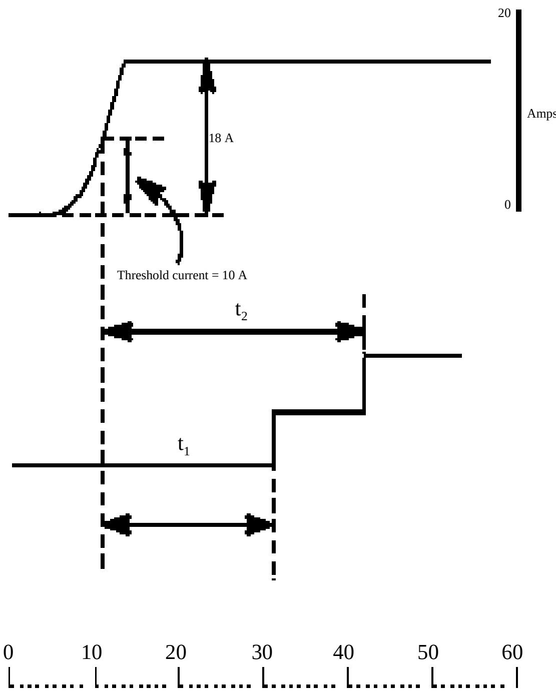


Figure 6.34 Close Timing from Current Measurement

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 6.35 shows an example for voltage. The timing of the main contact (t2) and resistor switch (t1) is calculated in this way:

1. The Relative to Test Initiation option is selected in “Resistor Timing – Close” on page 4-22.
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.

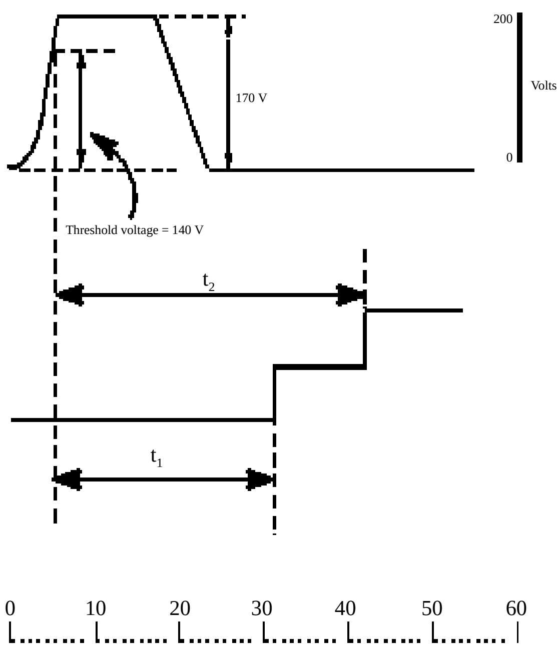


Figure 6.35 Close Timing from Voltage Measurement

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 6.36 shows how to select the channel.

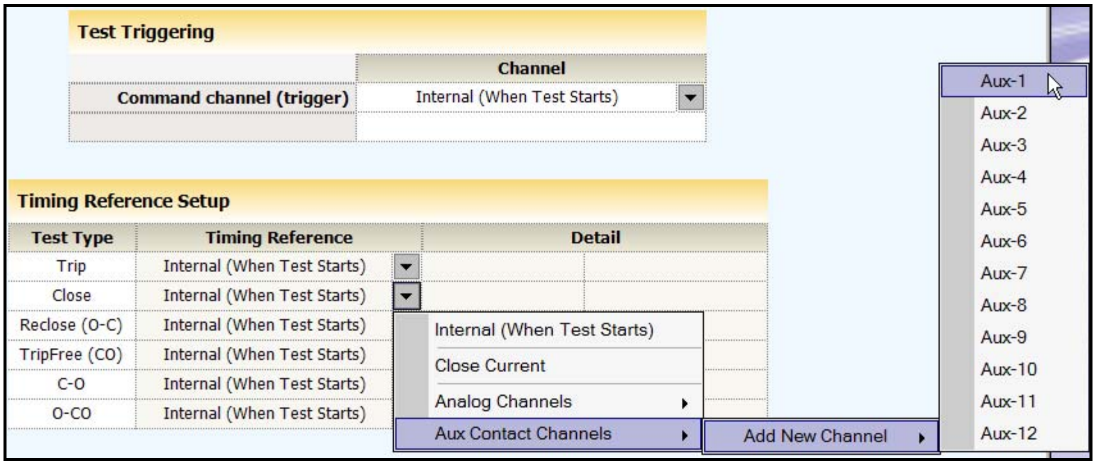


Figure 6.36 Set Contact Channel

To calculate the timing of the main contact (t2) and resistor switch (t1):

1. The T0 option is selected in "Resistor Timing – Close" on page 4-22.

2. The first transition of the selected auxiliary contact occurs.

3. The calculation is made. See Figure 6.37.

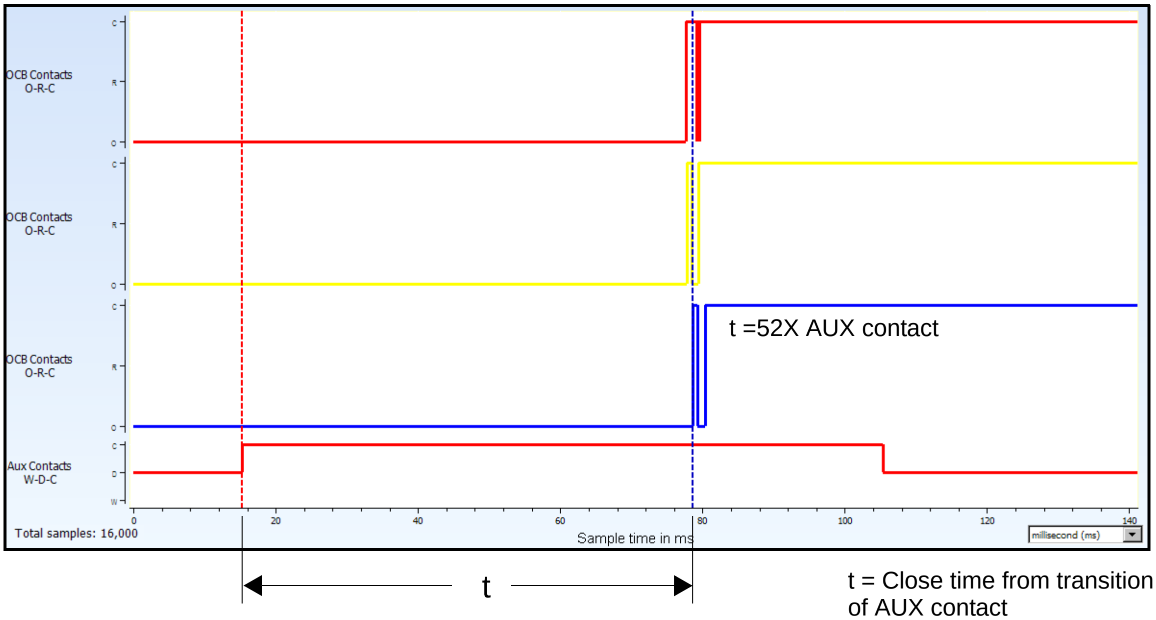


Figure 6.37 Closing Time Measured from Transition of AUX Contact

Recording Parameters

Recording Parameters	
Sample Time	0.1 ms
Sampling Rate	10,000 Hz
Recording Time (after Trigger)	1600.0 ms
(Samples)	16000
Pretrigger Time	10.0 ms
(Samples)	100

Figure 6.38 Recording Parameters

The Sample Time, Recording Time (after Trigger), and Pretrigger Time are configurable. When one of these values is configured, the sample information associated with it adjusts automatically. Table 6.7 lists the recording times and their associated sampling rate.

Table 6.7 Recording Time and Sampling Rate

Recording Time	Sampling Rate
500 ms	10 kHz
1600 ms	10 kHz
10 s	1 kHz (TDR9000)
	10 kHz (TDR900)
20 s (TDR900 only)	10 kHz
30 s (TDR9000 only)	500 Hz
1 min	200 Hz
5 min	50 Hz
20 min	10 Hz

NOTE

TDR9000 only: Recording Time is not used for the Capacitance test.

The Pre-trigger Time field sets a length of time, in ms or cycles, in which data is recorded before a triggering event occurs. Pre-trigger Time can be set for normal test initiation, as well as AUX contact and trigger in signals used as trigger references.

Bounce Discriminator

The Bounce Discriminator is a digital filter that distinguishes between real contact activity and cross-coupled signals with 2 microsecond 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.

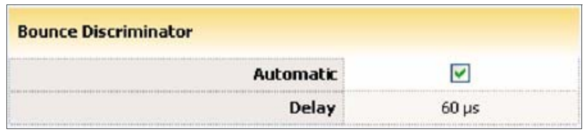


Figure 6.39 Bounce Discriminator

TDR9000 Only: Resistance and Capacitance Ranges

The Capacitance test is used to measure EHV grading capacitors. These capacitors are located in parallel with the main contacts and can be measured through the EHV instrument inputs when the contacts are open. The test measures capacitance, in the range of 75 to 10,000 pF, between each of the two EHV leads and the common lead for each phase and each module. The test measurement accuracy is in the range of ± 5%. Because the circuit breaker is not operated during the test, no waveform is sent through the system.

Figure 6.40 shows the resistance and capacitance range parameters.

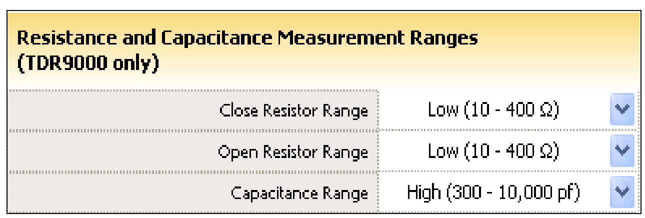


Figure 6.40 Resistance and Capacitance Ranges

Parameters

Parameters include:

- Open and Close Resistor Range—A scrollable list for selecting the resistor configuration. Choices include:
  - 10 - 400 Ω
  - 300 - 7,000 Ω
- Cap. Range—A scrollable list for selecting the capacitor configuration, for EHV contacts only. Choices include:
  - 75 - 2,500 pF
  - 300 - 10,000 pF

OCB Resistor Ranges (TDR9000 Only)

For single-break-per-phase circuit breakers with resistors, set a resistor value range in the test plan for the program to pick up the resistor level for the time during which the resistor is in the circuit during circuit breaker operation, and for correct wipe measurement.

If there is no resistor in parallel with the contact, set the resistor range to **None**. If the value of the resistor overlaps both ranges, either can be selected.

Please note that:

- An incorrect resistor range setting can result in an incorrect wipe calculation. The average velocity values can also be incorrect if Contact Open or Contact Close was used to specify the measurement zone.
- Setting the Open resistor range or Close resistor range on any OCB module sets the range for all OCB modules in that TDR9000.

Table 6.8 lists the voltages used to test main contacts.

Table 6.8 TDR9000 Only: Voltages Used to Test Main Contacts (OCB)

Item Tested	Range	Test Voltage
Resistor, OCB	10 – 400 Ω	7.5 V
Resistor, OCB	300 – 7,000 Ω	48 V
All without resistors	None	15 V

EHV Resistor Ranges (TDR9000 Only)

For multiple-break-per-phase circuit breakers with insertion resistors, select a resistor value range in the test plan that enables the TDR9000 to pick up the resistor level for the:

- Time during which the resistor is in the circuit during circuit breaker operation
- Correct wipe measurement

If no resistor is in parallel with the contact, set the resistor range to NONE. If the value of the resistor overlaps both ranges, either can be selected.

If there is no pre-insertion resistor in parallel with the contact, the select default resistor range **None**. If the value of the resistor overlaps both ranges, either range can be selected.

These values apply to all EHV channels of that module. The Trip and Close resistor ranges always appear, and must be set correctly, even if the resistor value measurement option is not present.

Please note that:

- An incorrect resistor range setting can result in an incorrect Wipe calculation. The average velocity values can also be incorrect if Contact Open or Contact Close was used to specify the measurement zone.
- Setting the Trip resistor range or Close resistor range on any EHV module sets the range for all EHV modules in that TDR9000.

Table 6.9 lists the test voltages used when testing main contacts.

Table 6.9 TDR9000 Only: Voltages Used to Test Main Contacts (EHV)

Item Tested	Range	Test Voltage
Resistor, EHV	10 – 300 Ω	7.5 V
Resistor, EHV	200 – 500 Ω	15 V
All without resistors	None	15 V

First Trip Test

The First Trip test uses the analog and auxiliary channels of the TDR instrument 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 cables, because the main contacts are energized. In consequence, phase current waveforms replace the usual main contact and resistor switch timing measurements.

Breakers Eligible for First Trip Testing

The TDR instrument 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 contact monitor 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 TDR instrument**. 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.

TDR9000 Only: Required Components

The following TDR9000 components are required to perform a First Trip test using an external trigger for the minimum set of channels listed in:

- An Event module (T9433)
- System module with Trigger In/Out (T9003, T9004, T9005)
- Two Doble current probes (P/N 401-055)

The following components are required for the recommended set of channels:

- Two Event modules (T9433)
- System module with Trigger In/Out (T9003, T9004, T9005)
- Five Doble current probes (P/N 401-0055)

Configuring 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 if using an auxiliary contact channel

    Or,

  - External Trigger (TDR9000 only) if the option is available

  Transition

  - Open→Closed
  - Closed→Open
  - Wet→Dry
  - Dry→Wet
  - Any change

The trigger event is the change of state the TDR instrument 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**, **Add New Channel**, and an Aux channel (see Figure 6.41).

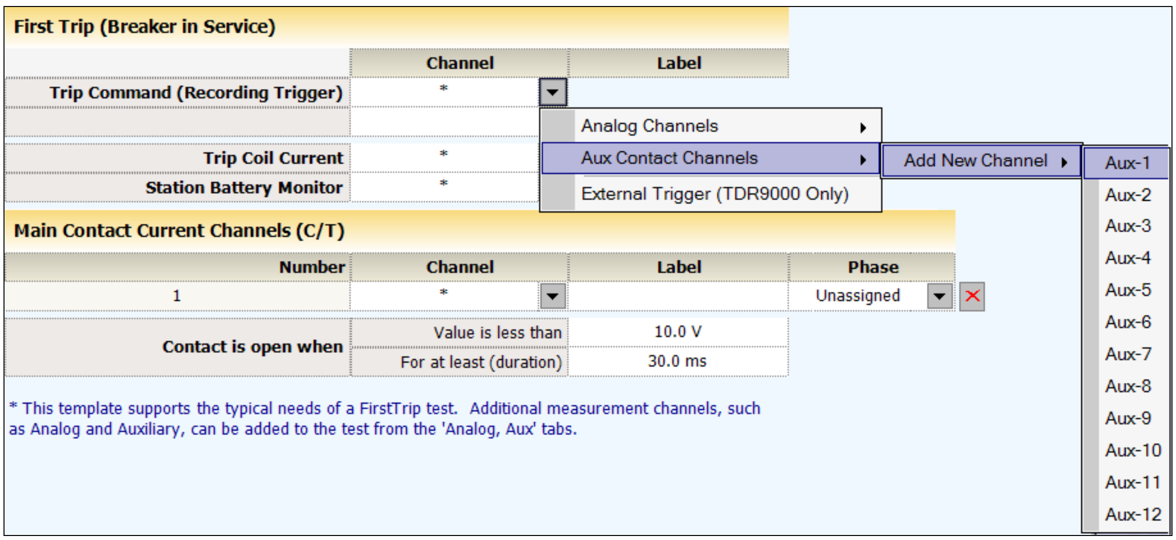


Figure 6.41 First Trip (Breaker in Service)

Select the pre-trigger time or leave it at the default: zero (see page 6-27). However, to capture the entire recording, it is recommended that pre-trigger time be longer than the opening time of the AUX contact.

- If the relay contact state is measured using a Trigger In channel, there is no need to activate an auxiliary contact channel for it. Activate only the channels being used.
- 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 6.42). All analog currents are measured using Doble probes, except for the DC supply voltage. Activate only the channels being used.

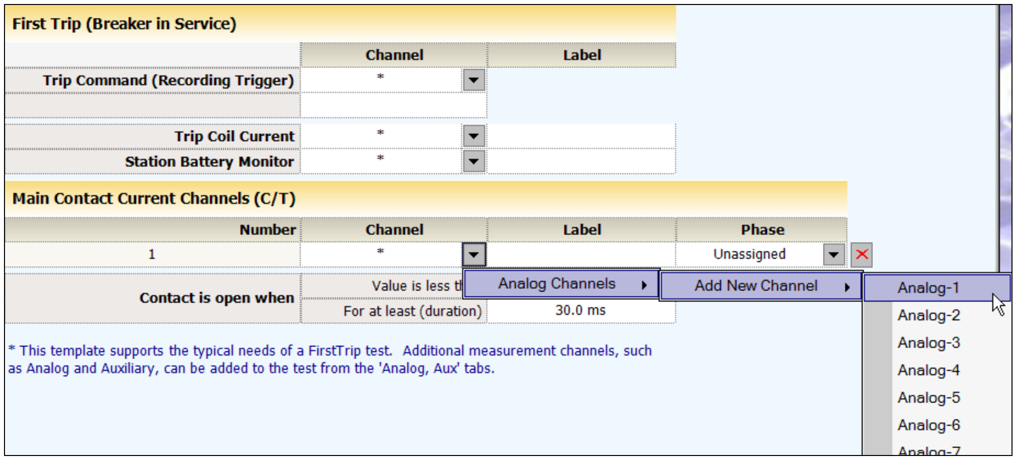


Figure 6.42 Main Contact Current Channels

Instrument Connections for First Trip Tests

Table 6.10 lists the connections to the TDR instrument required for a minimum set of channels. This is an external trigger test, so no control cables are used.

Table 6.10 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	Auxiliary Contact	Event
5	52CS/T contact state (for Trigger In source)	Auxiliary Contact	Event or Trigger In*

*Connect to an event channel if using an Auxiliary Contact trigger source and to the Trigger In jacks if using a Trigger In source.

Table 6.11 lists the connections to the TDR instrument required for a recommended set of channels.

TDR9000s only: This table applies to a TDR9000 with two Event modules.

Table 6.11 Recommended Set of Channels

Item	Signal	Type	Instrument Connection
1	Main Contact Current A (from CT secondary)	Analog	Event
2	Main Contact Current B (from CT secondary)	Analog	Event
3	Main Contact Current C (from CT secondary)	Analog	Event
4	Trip relay coil current	Analog	Event
5	DC Supply Voltage	Analog	Event
6	52X or 52Y relay coil current	Analog	Event
7	52A contact state	Auxiliary Contact	Event
8	52B contact state	Auxiliary Contact	Event
9	52X contact state	Auxiliary Contact	Event
10	52Y contact state	Auxiliary Contact	Event
11	52CS/T contact state (for Trigger In source)	Auxiliary Contact	Event or Trigger In*

* Connect to an event channel if using an auxiliary contact trigger source and to the Trigger In jacks if using a trigger in source.

Making Circuit Breaker Connections

Leads for measuring the main contact current are connected via a clip-on probe to the current transformer secondary of 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 TDR instrument so that cable lengths suffice to make the connection. The connections to the breaker are as follows:

1. Connect the test set ground connection to the circuit breaker ground.
2. Connect a Doble current probe (Doble P/N 401-0055) to a CT secondary for each phase being measured to record the Main Contact currents and then connect the current probe leads to the analog channels on the instrument.
3. Connect the current probes (Doble P/N 401-0055) to selected trip coil circuits and then connect the leads to Doble probes and into the analog channels, as required. Zero the probes.

   This records the selected trip coil currents.
4. Connect a set of analog cables across the DC supply switch and into the instrument analog connector.

   This records the DC supply voltage.
5. Connect auxiliary contact cables across the selected contacts and into the instrument Auxiliary connector.

   This records the selected contact states.
6. Make one of these two connections:
   - If you are using the TDR9000 with a trigger option and if Trigger In is set as the trigger source in the test plan—Connect the Trigger In cables across the 52CS/T contacts.
   - For all other configurations—Connect Auxiliary Contact cables across the 52CS/T contacts, ensuring that Aux Contact is set as the trigger source in the test plan.

   When the Trigger In or Connect Auxiliary Contact cable is used as an external trigger signal, it records the 52CS/T contact state.

Disconnecting After a First Trip Test

To disconnect after a First Trip test:

1. On the TDR900 or TDR9000, turn the power switch to **OFF**.
2. Disconnect the cables from the circuit breaker. **Always disconnect these cables before disconnecting any other cables!**
3. Disconnect the Doble current probe from the CT secondary phases.
4. Disconnect Doble current probes from the selected relay coil circuits.
5. Disconnect the analog cable across the DC supply switch.
6. Disconnect the auxiliary contact cables from the selected contacts.
7. Disconnect:
   - Trigger In cables across the 52CS/T contacts

     or
   - Auxiliary contact cables across the 52CS/T contacts
8. Unplug the breaker control cable from the instrument.
9. Unplug the AC power cord from the power receptacle.
10. Unplug the AC power cord from the instrument.
11. Remove the safety switch cable from the SAFETY receptacle on the instrument.
12. Disconnect the instrument ground connection to circuit breaker ground.
13. Remove the ground cable from the connection to the ground grid.

7. Triggering and Timing Setup

This chapter describes the triggering and timing parameters. It contains the following sections:

Test Triggering Limits

The Test Triggering feature enables the user to operate a circuit breaker using an external trigger, such as a command from a remote control room, instead of the Run Test button.

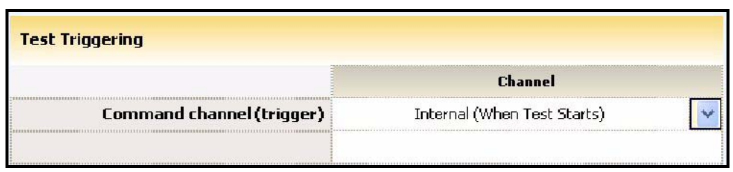


Figure 7.1 Test Triggering

There are four trigger channels:

- Internal—Test recording is triggered internally and accepts no external trigger inputs. The instrument controls the circuit breaker using the Trip/Close module.
- Analog—Any analog channel can be selected and used to trigger and initiate a test. (Figure 7.2) To do this, configure a threshold setting that references a specific analog channel. The trigger activates if the measurement exceeds the threshold.

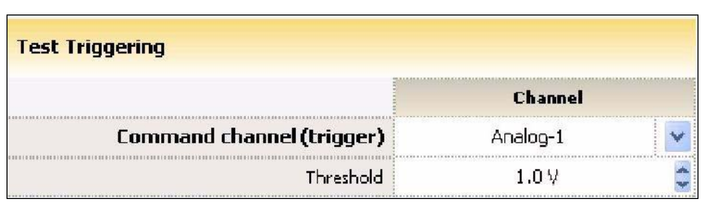


Figure 7.2 Analog Contact Trigger Limits

- AUX Contact—An input that comes in through an auxiliary contact triggers the test and is assigned to be recorded on a designated channel of the Event module (Figure 7.3). The Trip/Close module is not used for this test. The trigger can be one of five types:
  - Open to Close
  - Close to Open
  - Wet to Dry
  - Dry to Wet
  - Any Change

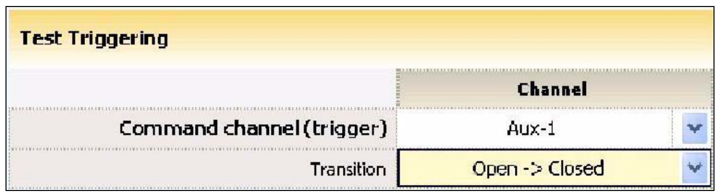


Figure 7.3 AUX Contact Trigger Limits

NOTE

The AUX Contact Trigger In channel is designed to work in a substation using station battery voltages as follows:

- **TDR9000—48 V DC or higher. Voltages less than 48 V DC may not meet the threshold requirements of the Volts On state.**
- **TDR900—38 V DC or higher. Voltages less than 38 V DC may not meet the threshold requirements of the Volts On state.**

To set up the trigger, select the auxiliary channel and select the transition type for the trigger. To record the timing of the channel receiving the trigger, activate this chosen channel. For more information, see "Auxiliary Contact Channels" on page 5-10.

The note on page 6-28 describes the pre-trigger data functionality available for this test.

- External Trigger (TDR9000 only)—A System Trigger In (Figure 7.4) functions somewhat differently from an AUX Contact Trigger In. An input that comes in through the External Trigger connection of the System module, is conditioned by a delay time, and starts the TDR9000 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.

Although the System module Trigger In channel is a tri-state channel like the Aux Contact channel, it is not a measurement channel. For each of the two settings, it detects the state change, but only the fact that a trigger event has occurred is sent to the firmware.

Trigger In detects two different sets of either/or conditions:

- Open to Closed or On to Off—Detects a transition from Open to Close or from Volts On to Volts Off
- Closed to Open or Off to On—Detects a transition from Close to Open or from Volts Off to Volts On

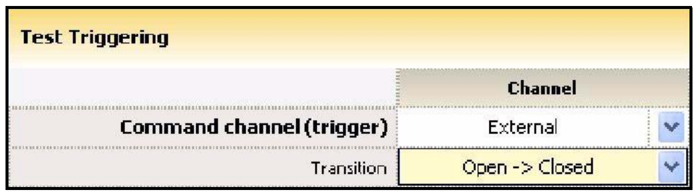


Figure 7.4 External Trigger Limits (TDR9000 only)

NOTE

Only the Trigger In channel on the System module is rated for 600 V peak operation.

The System Trigger In channel is designed to work in a substation using station battery voltages of 48 V DC or higher. Voltages less than 48 V DC may not meet the threshold requirements of the Volts On state.

The System Trigger In channel cannot be in the active state when the test is started. The active state is the second state of the trigger event transition. In an Open to Close transition, closed is the active state. Therefore, if *Open to Close* or *On to Off* is selected, and *Continue* is clicked while the Trigger In channel is connected across a closed switch, the test is aborted because the trigger input is already in the active state.

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 works. For more information, see page 6-28.

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 7.5.

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 7.5 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

Trigger Out Limits (TDR9000 Only)

By connecting a circuit breaker to the TDR9000 through the Trigger Out connector, you can operate the circuit breaker by using an input generated by the TDR9000. You can set both pulse width and trigger delay. Trigger Out limits pertain to only one thing: the Trigger Out channel. Trigger Out is essentially a solid state switch output (dry contact) that can be used to control an accessory or trigger another TDR9000. The trigger can operate in circuits up to 300 V peak, 0.5 A maximum.

When Enabled is selected, the fields shown in Figure 7.6 are activated.

Trigger Out (TDR9000 Only)

Enable	Pulse Width	Polarity	Delay
✓	66.6 ms	Active Closed	0.0 ms

Figure 7.6 Trigger Out Limits

The Trigger Out fields are used as follows:

- Pulse Width—The length of signal transmission in ms sent to the circuit breaker that determines the length of time that Trigger Out remains in the active condition.
- Trigger Delay—The length of time between the inception of the test and when the trigger is set.

  This defines the timing relationship between the trigger input and the trigger output. The Trigger Out channel can be used with internal triggering when controlling the test initiation with the Trip/Close control or with an external System trigger input. Trigger Out cannot be used with Event triggers like Aux. Contact Trigger input.

  When used with internal triggering (Trip/Close control), the delay can be either positive or negative:

  - A positive delay causes the Trigger Out channel to transition to the active state after the recording has begun (delayed by Trigger Delay value).
  - A negative delay causes the Trigger Out channel to transition to the active state immediately after the safety switch is activated, with the Trip/Close commands and recording delayed by the Trigger Delay value.

  When used with external triggering, only positive delay values are valid. The Trigger Out channel transitions to the active state after the external trigger in event occurs, which is delayed by the Trigger Delay value.

- Polarity—Active Closed or Active Open options are available.

8. 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

Once a test is run, the Results and Plots pages become active (Figure 8.1).

- 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.

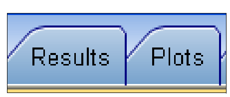


Figure 8.1 Navigation Tabs Available After a Test

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

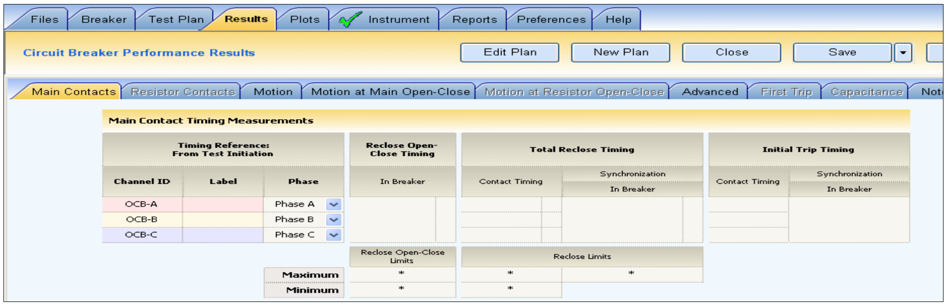


Figure 8.2 Results Page

Figure 8.3 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 Fail ⚠ 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 ✓	0.04 cy ✓
OCB-B	CONTACT2	Phase B	4.99 cy ✓	
OCB-C	CONTACT3	Phase C	4.96 cy ✓	
			Close Limits	
		Maximum	6.00 cy	0.20 cy
		Minimum	0.00 cy	

Figure 8.3 Sample Main Contacts Data

Figure 8.4 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 Velocities		Travel			
			Close					
			Close Zone 1	Close Zone 2	Total Travel	Overtravel	Rebound	Contact Wipe
Motion-1 (TRAVEL 2) Phase B	Zone Type		Dist; Dist	Dist; Dist				
	Measured		4.057 m/s ✓	*	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 8.4 Sample Motion Measurements Data

Figure 8.5 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 8.5 Sample Motion at Main Open/Close Data

Viewing Graphical Results

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

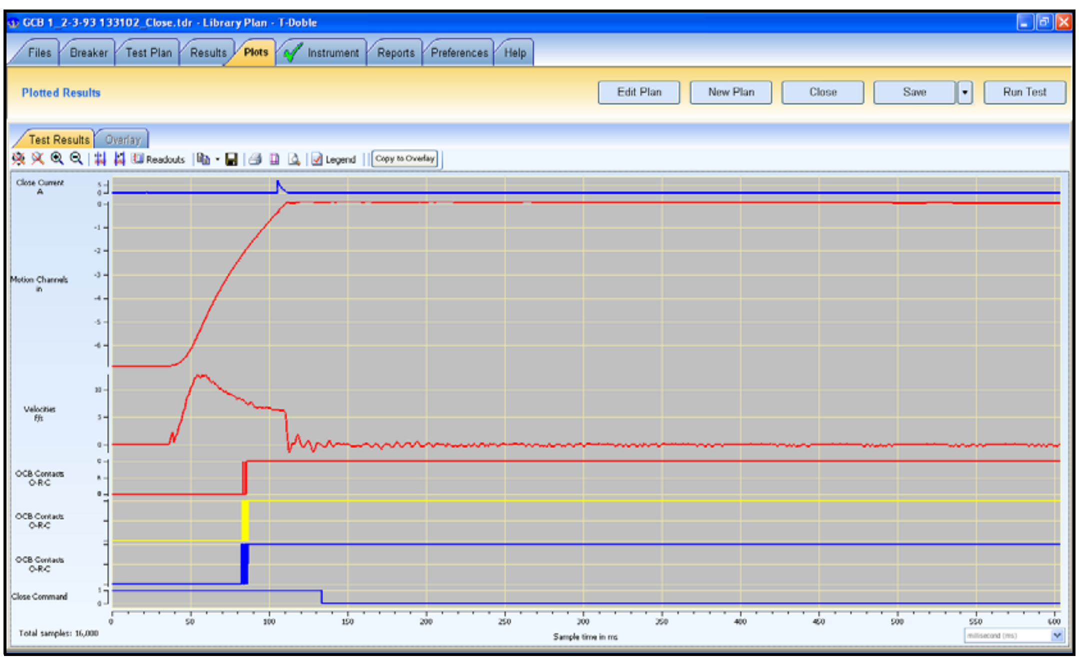


Figure 8.6 Results Tab of Plots Page

Setting Plotting Preferences

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

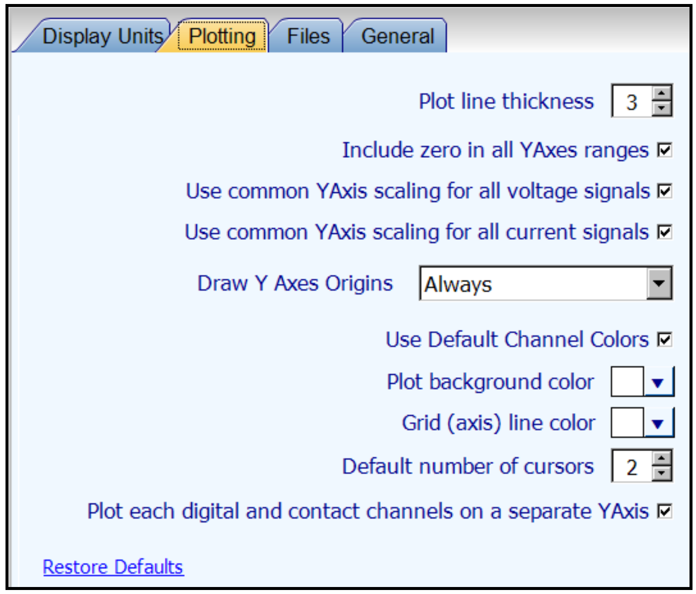


Figure 8.7 Plotting Tab of Preferences Page

Table 8.1 describes the plotting values you can set.

Table 8.1 Plotting Preferences

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

Table 8.1 Plotting Preferences (Continued)

Setting	Description
Use Default Channel Colors	Select or deselect. Sets channel colors as follows: • Phase A—Red • Phase B—Yellow • Phase C—Blue
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.
Restore Defaults link	Click to restore system default plotting values.

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.

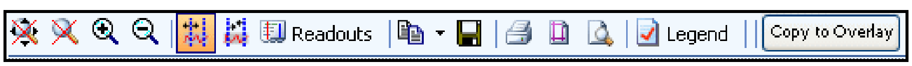


Figure 8.8 Toolbar on Plots Page

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.

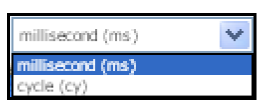
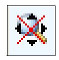
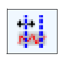
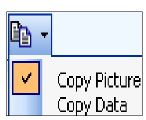
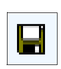
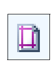
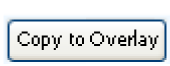


Figure 8.9 Selection Box for Unit of Measurement

Table 8.2 explains the purpose of each icon.

Table 8.2 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.
	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.

Figure 8.10 shows cursors positioned on precise sampling points.

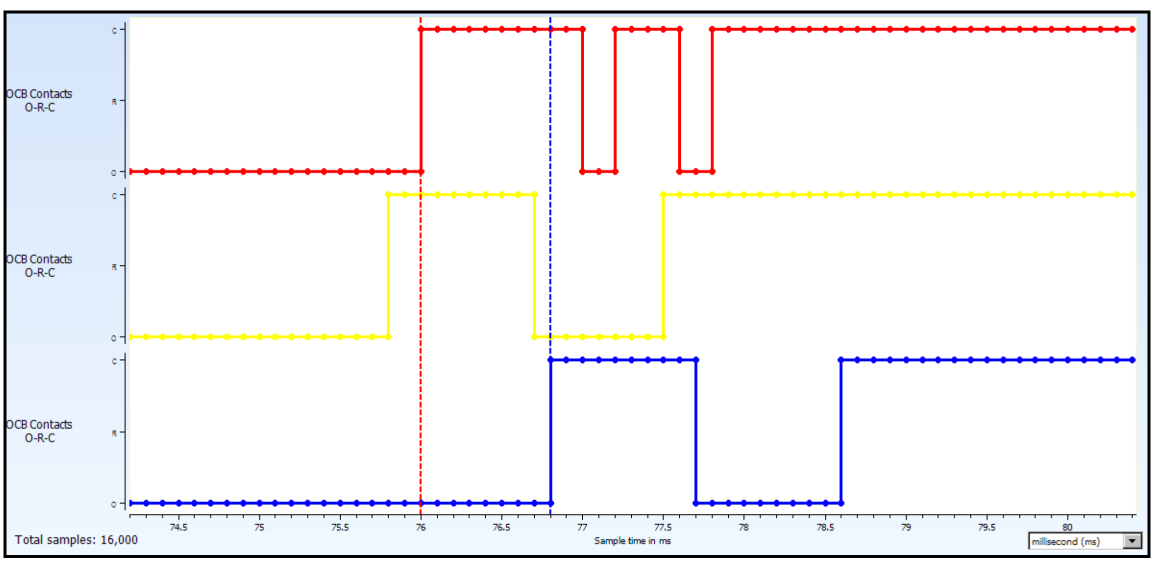
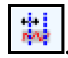


Figure 8.10 Cursors Positioned on Sampling Points

To activate the cursors:

1. Click the **Show Data Cursors** button .

   Two cursors appear in the window and the Cursor Values table appears. It displays time and trace values.

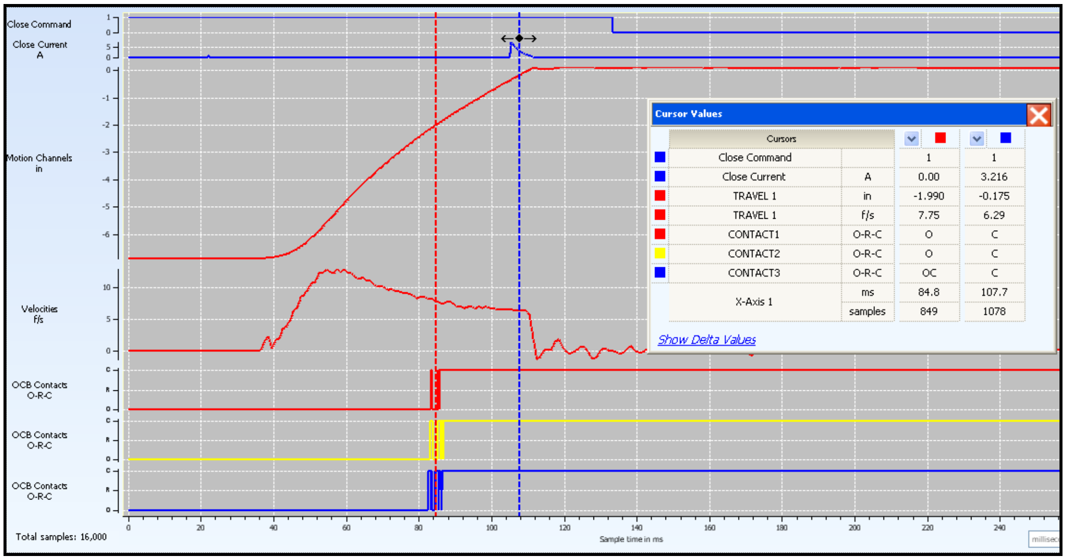


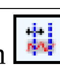
Figure 8.11 Two Cursors and Cursor Values Table

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 cursors are active, a Delta values column appears in the table.
4. Reposition a cursor by dragging it with the mouse or by using the keyboard arrow keys to make precision moves. (See Table 8.3.)

Table 8.3 Precision Cursor Movement

Key	Cursor Direction
Left arrow	Moves 0.1 ms (1 sample) left.
Right arrow	Moves 0.1 ms right.

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

Reading the Cursor Values Table

The Cursor Values table provides readouts for all active cursors.

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.

Viewing Trace Information

Basic trace display properties are set in the Preferences page. (See “Setting Plotting Preferences” on page 8-5.) To view trace information:

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

The Plot Legend window appears.

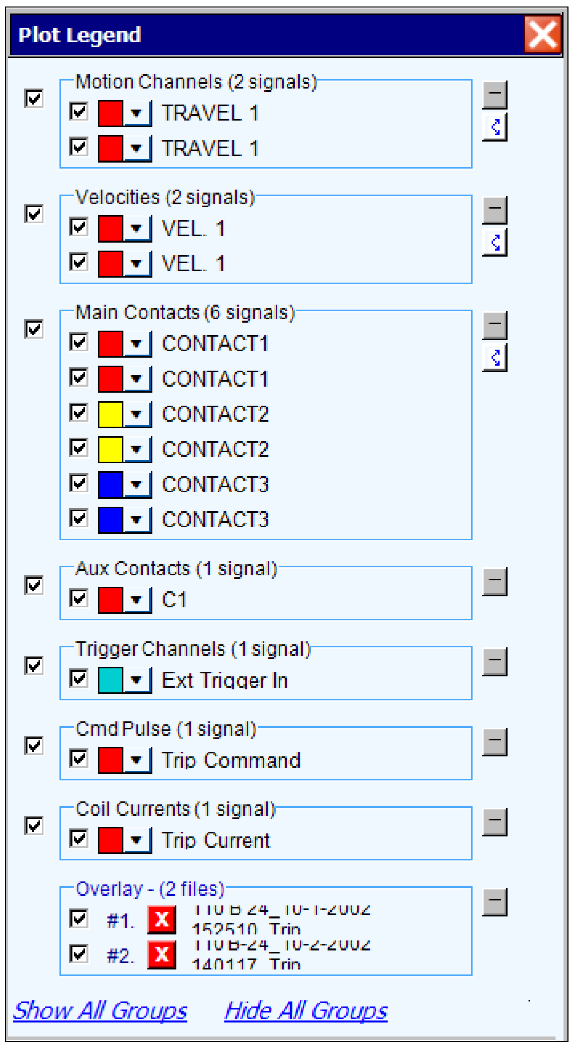


Figure 8.12 Plot Legend Window for Two Overlaid Signals

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 remove an overlaid set of traces—Deselect the check mark to the left of the trace in the Overlay section of the Plot Legend window. See Figure 8.12.
- 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 Moves All 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.

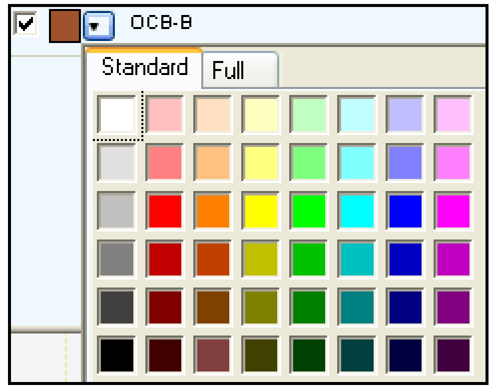


Figure 8.13 Selecting a Trace Color

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 8.14 shows an example. You can add more overlays by following the same steps.

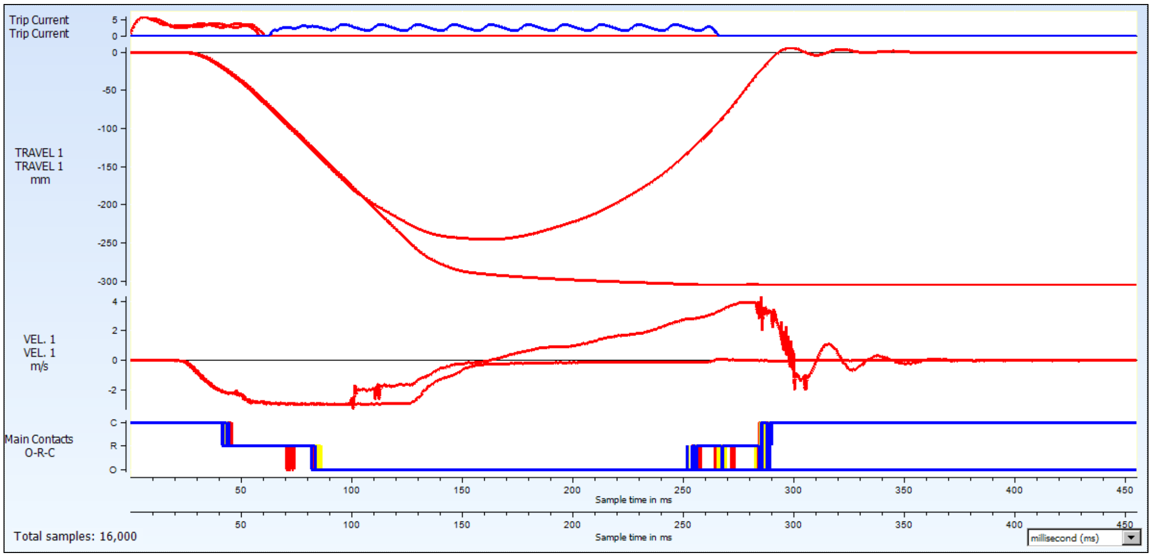


Figure 8.14 Overlaid Test Results

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 Fail 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.

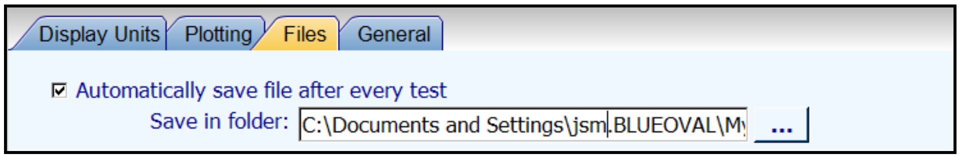
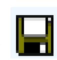


Figure 8.15 Automatically Saving Test Results

  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. It provides a screen shot of the Nameplate as a convenience.

Nameplate Data

Location: Nameplate tab of Breaker page

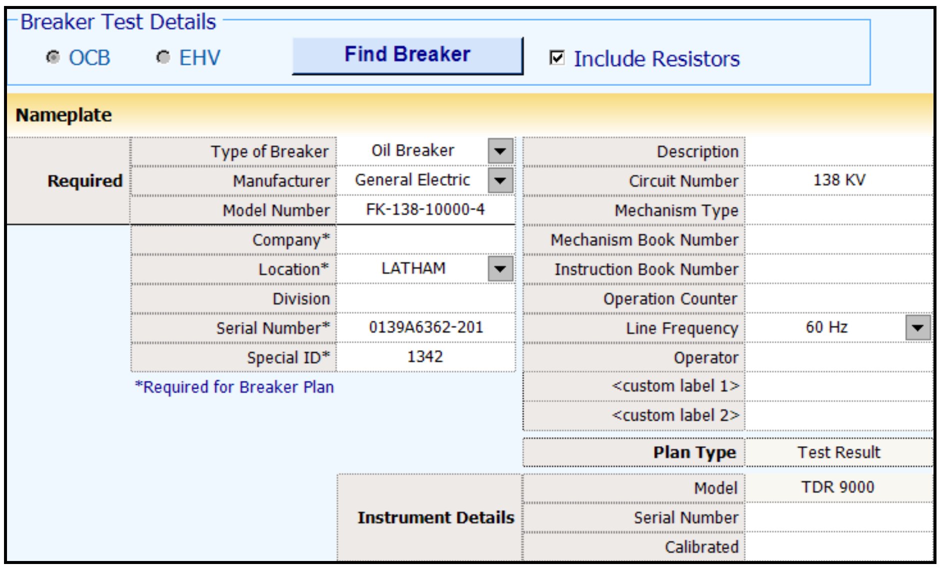


Figure 8.16 Sample Nameplate for Trip Test

Plotted Results

Location: Test Results tab of Plots page

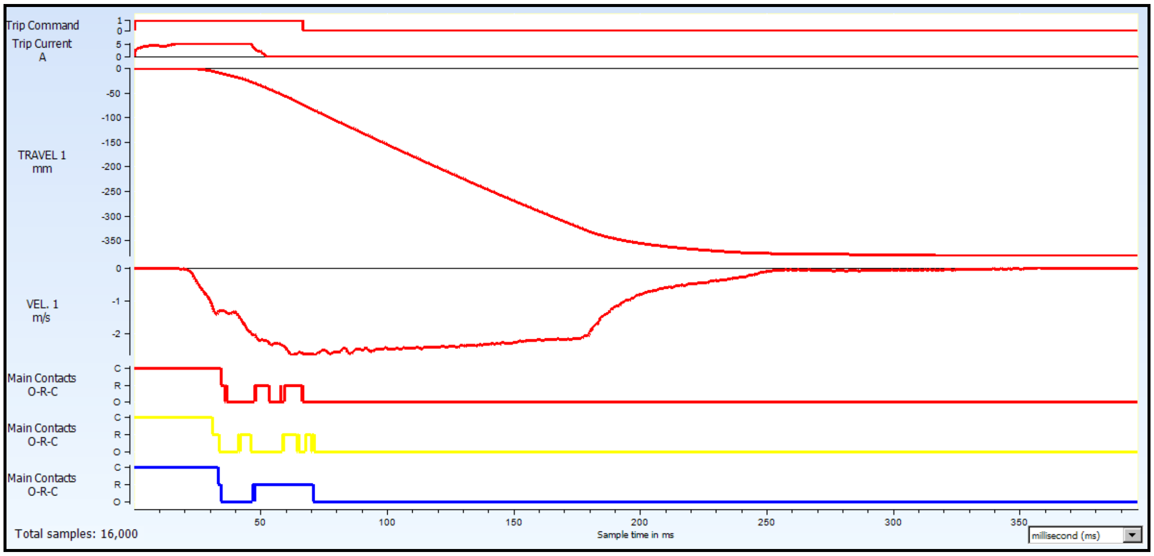


Figure 8.17 Plotted Results of Trip Test

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 Fail 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 8.18 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 Fail status

Resistor Contact Timing Measurements

				Resistor Close Timing From Test Initiation		Resistor Close Timing Relative to Main Contact			
Channel ID	Label	Phase	Resistance	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		11.9 ms	✓		
OCB-C	CONTACT3	Phase C	441.0 Ω	54.7 ms		11.7 ms	✓		
				Close Limits		Close Limits			
		Maximum	*	*	*	15.0 ms		5.0 ms	
		Minimum	*	*		8.0 ms			

Figure 8.19 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 Fail ⚠ status

Motion Measurements

Channel and Phase			Zone Velocities – Open – Open Zone 1	Zone Velocities – Open – Open Zone 2	Travel – Total Travel	Travel – Overtravel	Travel – Rebound	Travel – Damping
Motion-1 (TRAVEL 1) Phase A		Zone Type	Dist; Dist	Dist; Dist				
		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	
		Min	11.00 f/s	*	14.500 in	0.000 in	0.000 in	

Figure 8.20 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 – Travel from Start Position (Contact Wipe)	At Main Contact Open – Average Velocity*	At Main Contact Open – Time from Initiation**	Motion Reference Channel
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 8.21 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 8.22 Resistor Contact Open/Close Data for Trip Test

Close Test Results

This section provides a complete set of sample results for a Close test. It provides a screen shot of the Nameplate as a convenience.

Nameplate Data

Location: Nameplate tab of Breaker page

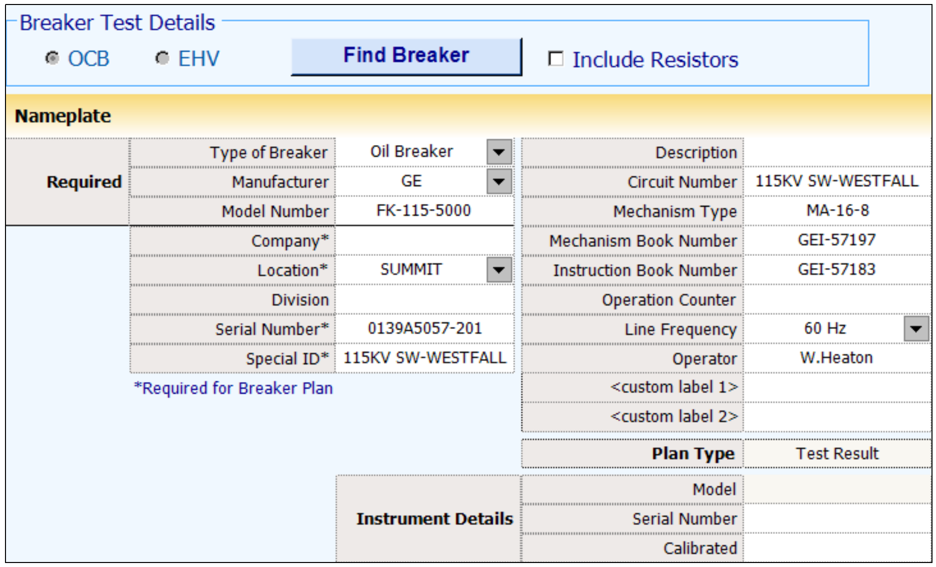


Figure 8.23 Sample Nameplate for Close Test

Plotted Results

Location: Test Results tab of Plots page

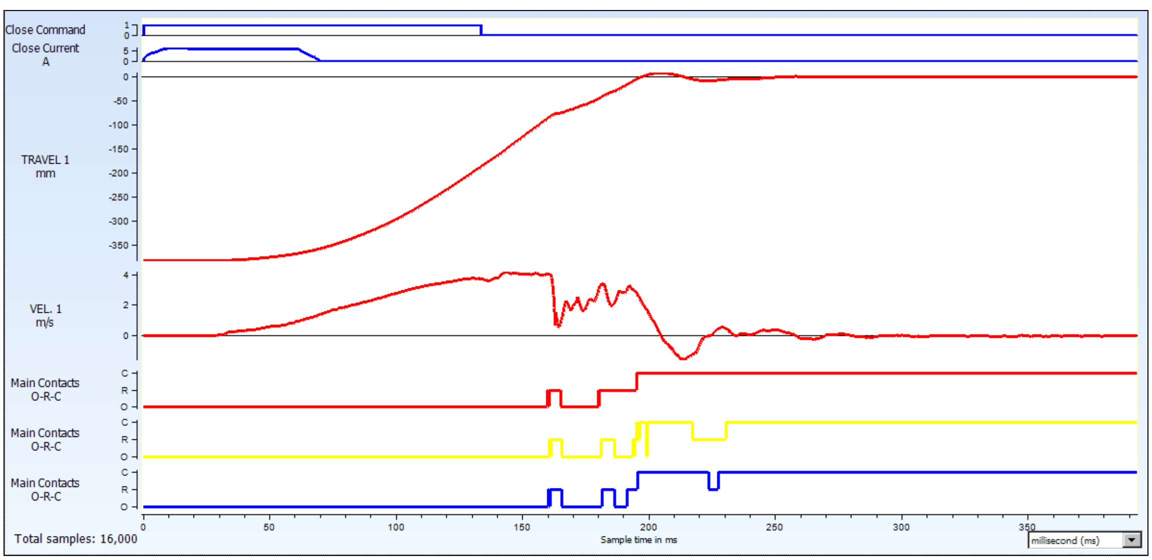


Figure 8.24 Plotted Results of Close Test

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 Fail 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 8.25 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 Fail status

Resistor Contact Timing Measurements

				Resistor Close Timing From Test Initiation		Resistor Close Timing Relative to Main Contact	
Channel ID	Label	Phase	Resistance	Contact Timing	Synchronization In Breaker	Contact Timing	Synchronization 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		45.6 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 8.26 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 Fail ⚠ status

Motion Measurements

Channel and Phase			Zone Velocities – Close – Close Zone 1	Zone Velocities – Close – Close Zone 2	Travel – Total Travel	Travel – Overtravel	Travel – Rebound	Travel – Contact Wipe
Motion-1 (TRAVEL 2) Phase B		Zone Type	Dist; Dist	Dist; Dist				
		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	*	*	*
		Min	3.700 m/s	*	160.0 mm	*	*	*

Figure 8.27 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 – Travel from Start Position	At Main Contact Close – Average Velocity*	At Main Contact Close – Time from Initiation**	Motion Reference Channel
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 8.28   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 8.29 Resistor Contact Open/Close Data for Close Test

Reclose Test Results

This section provides a complete set of sample results for a Reclose test. It provides a screen shot of the Nameplate as a convenience.

Nameplate Data

Location: Nameplate tab of Breaker page

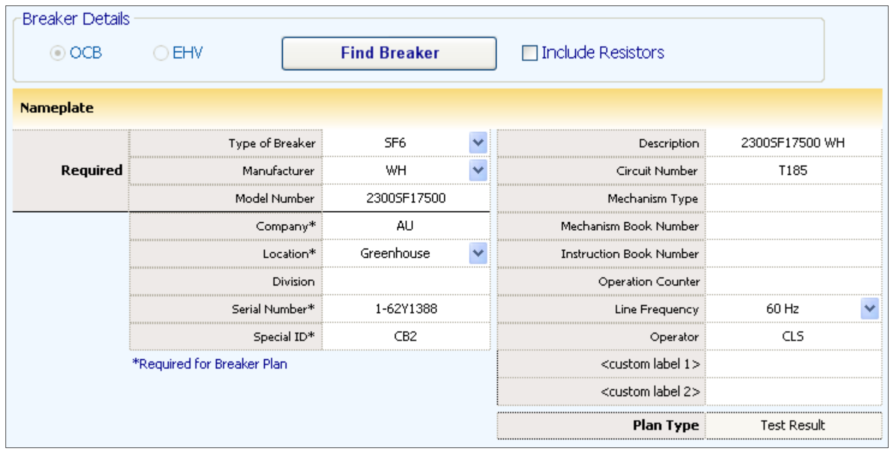


Figure 8.30 Sample Nameplate for Reclose Test

Plotted Results

Location: Test Results tab of Plots page

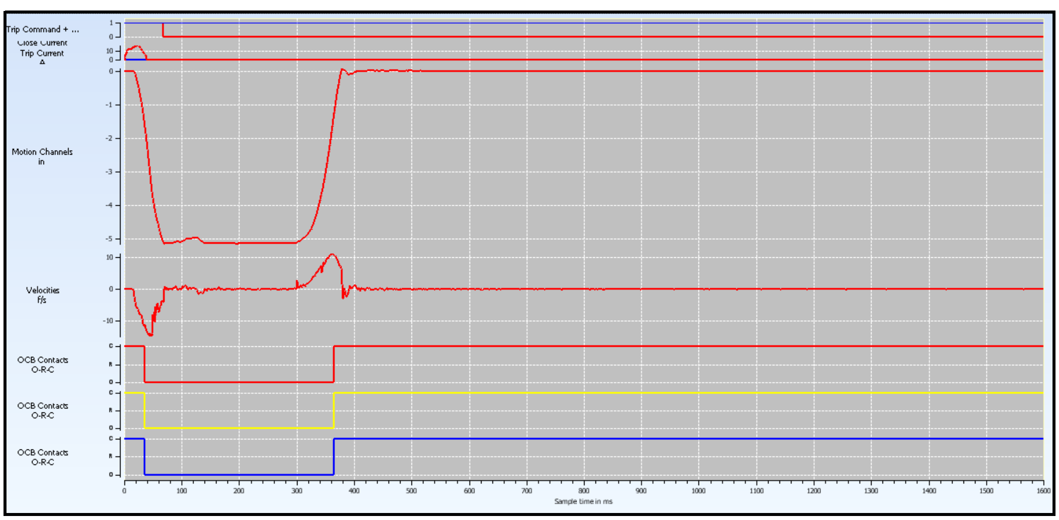


Figure 8.31 Plotted Results of Reclose Test

Main Contact Data

Location: Main Contacts tab of Results page

The Main Contact Timing Measurements table presents the following data:

- Measured values:
  - Main Contact Reclose Open-Close Timing
  - Total Reclose Timing
  - Reclose Synchronization
  - Initial Trip Timing
  - Initial Trip Synchronization
- Manufacturer's limits:
  - Main Contact Reclose Open-Close Timing
  - Total Reclose Timing
  - Reclose Synchronization
- Pass or Fail 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 In Breaker	Contact Timing	Synchronization In Breaker
OCB-A	CONTACT1	Phase A		364.5 ms		34.8 ms	
OCB-B	CONTACT2	Phase B	328.8 ms	365.1 ms	0.6 ms	35.3 ms	0.9 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 8.32 Main Contact Timing Data of Reclose Test

Motion Data

Location: Motion tab of Results page

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

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

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

Motion Measurements

Channel and Phase			Zone Velocities – Open – Open Zone 1	Zone Velocities – Open – Open Zone 2	Travel – Total Travel
Motion-1 (TRAVEL 1) Phase A	Zone Type		Dist; Dist	Dist; Dist	
	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 8.33 Motion Data for Reclose 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 Reclose 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 Reclose test on the Motion at Main Open/Close tab.

Motion Measurements, Main Contacts Open/Close

Channel	Label	Phase	At Main Contact Open – Travel from Start Position	At Main Contact Open – Average Velocity*	At Main Contact Open – Time from Initiation**	Motion Reference Channel
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 8.34   Motion at Main Open/Close for Reclose Test

TripFree Test Results

This section provides a complete set of sample results for a TripFree test. It provides a screen shot of the Nameplate as a convenience.

Nameplate Data

Location: Nameplate tab of Breaker page

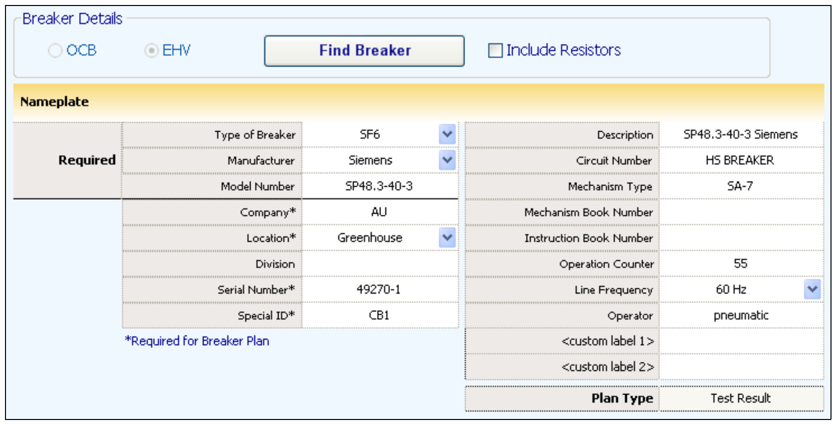


Figure 8.35 Sample Nameplate for TripFree Test

Plotted Results

Location: Test Results tab of Plots page

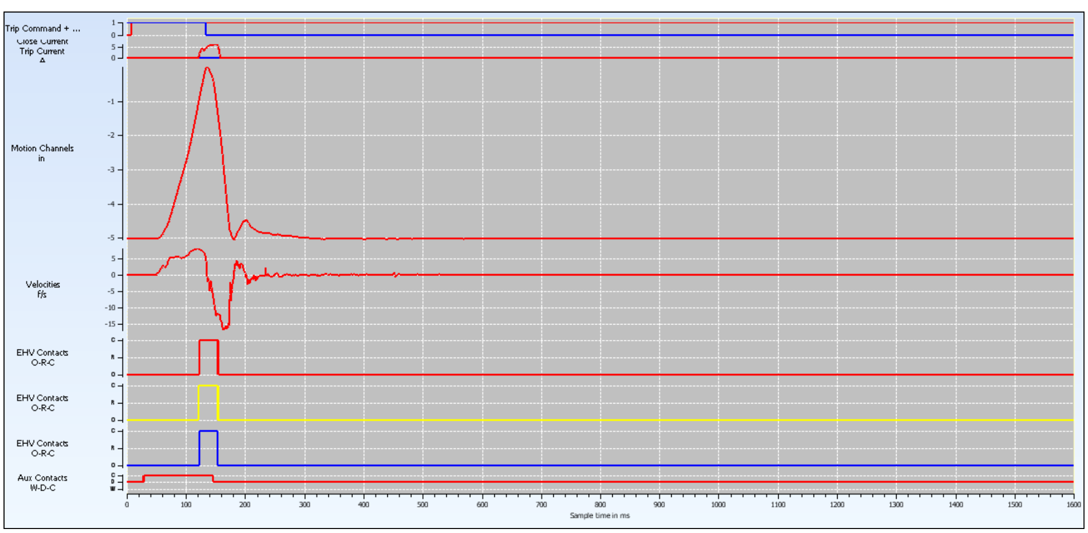


Figure 8.36 Plotted Results of TripFree Test

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 Fail status

Figure 8.37 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 Fail 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) Phase A	Zone Type		Dist; Dist	Dist; Dist	
	Measured		See note	See note	106.8 mm ✓
	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 8.38 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 8.39 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. It provides a screen shot of the Nameplate as a convenience.

Nameplate Data

Location: Nameplate tab of Breaker page

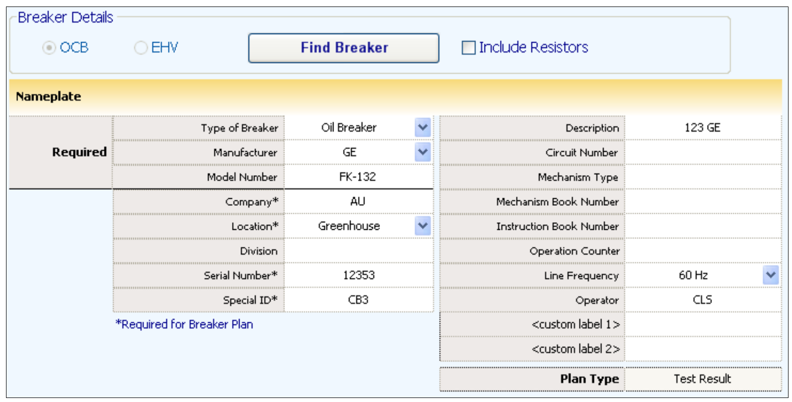


Figure 8.40 Sample Nameplate for O-C-O Test

Plotted Results

Location: Test Results tab of Plots page

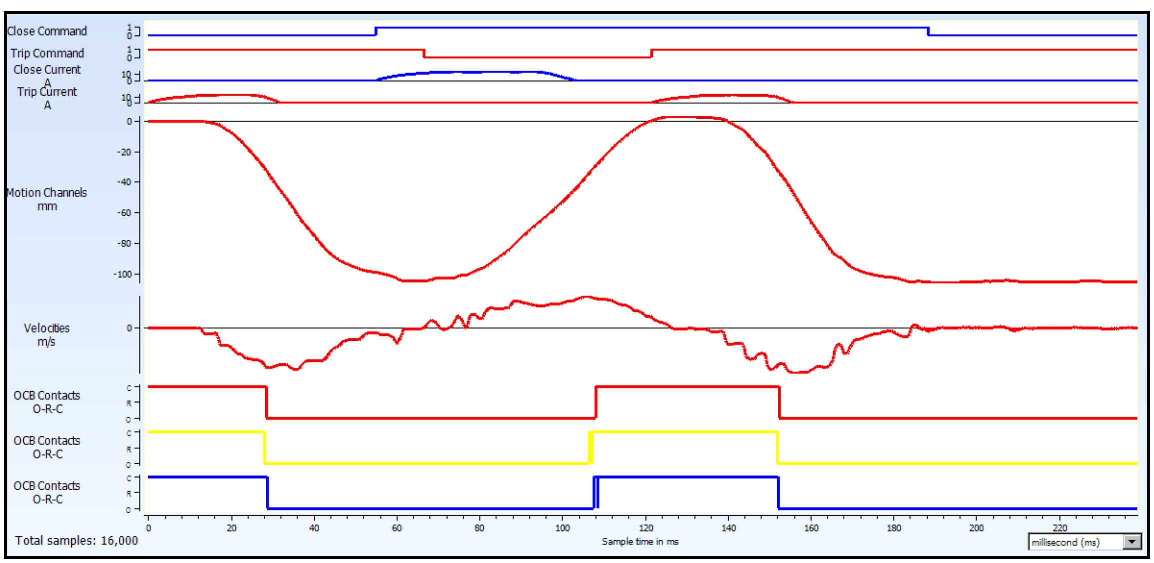


Figure 8.41 Plotted Results of O-C-O Test

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	Contact Timing	Synchronization In Breaker	Contact Timing	Synchronization In Breaker	Contact Timing	Synchronization In Breaker
OCB-A	CONTACT1	Phase A	429.9 ms	0.6 ms	12.4 ms	0.5 ms	104.8 ms	0.1 ms
OCB-B	CONTACT2	Phase B	429.3 ms		11.9 ms		104.7 ms	
OCB-C	CONTACT3	Phase C	429.7 ms		12.2 ms		104.8 ms	

Figure 8.42 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 Fail 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) Phase A		Zone Type	
		Measured	71.5° ⚠
	Limits	Max	47.0°
		Min	43.0°

Figure 8.43 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 8.44 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 Design page opens (see Figure 8.45).

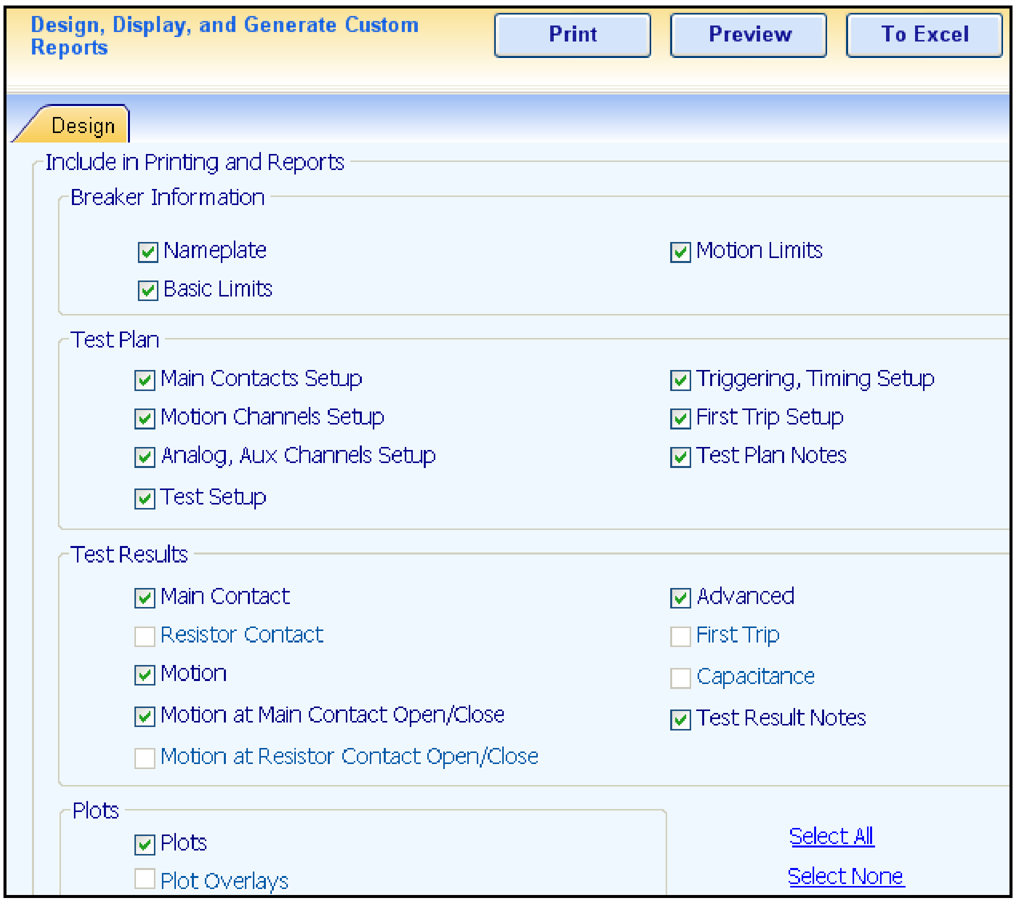


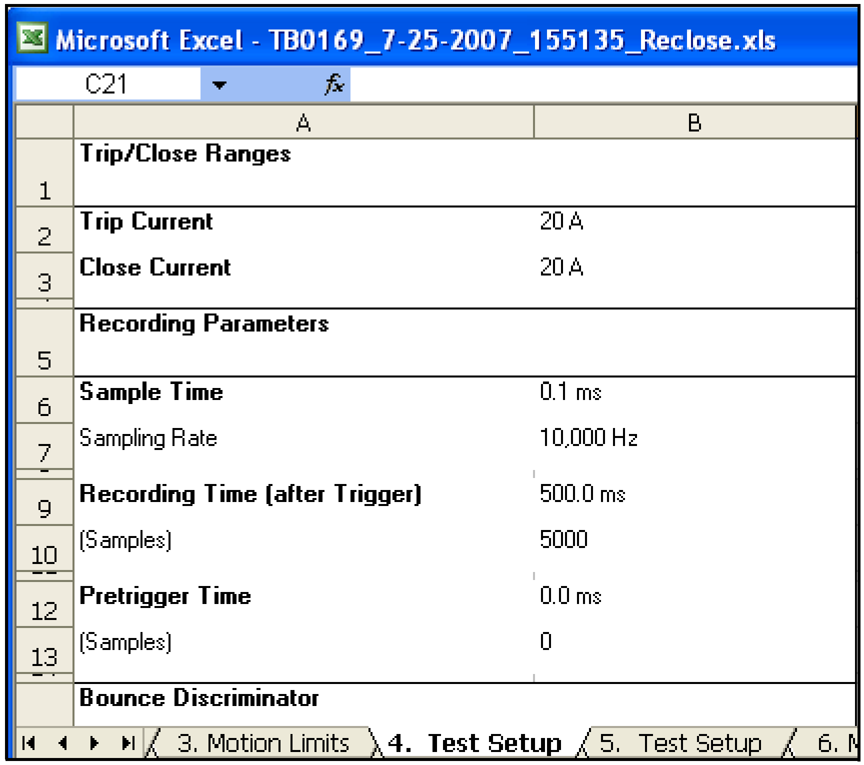
Figure 8.45 Design Page of Reports Tab

2. From the Breaker Information, Test Plan, Test Results, and Plots sections, select the elements you wish to include in the report.

3. 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 8.46 shows a sample Excel spreadsheet containing report data.The sample here contains 18 tabs; the Test Setup tab is displayed.



Microsoft Excel - TB0169_7-25-2007_155135_Reclose.xls

C21

	A	B
1	**Trip/Close Ranges**	
2	**Trip Current**	20 A
3	**Close Current**	20 A
5	**Recording Parameters**	
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	

3. Motion Limits / **4. Test Setup** / 5. Test Setup / 6. M

Figure 8.46 Sample Excel Spreadsheet

9. TDR900 Hardware and Supported Tests

This chapter describes the TDR900 hardware and optional accessories, and provides a brief overview of the tests supported by the TDR900. This chapter contains the following sections:

Introduction

The TDR900 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 9.1 TDR900 Circuit Breaker Test System

Figure 9.2 shows the TDR900 and optional accessories.

Figure 9.2 TDR900 and Optional Accessories

Optional Accessories

The following optional accessories can be ordered with the TDR900:

- Optional 90 ft (27 m) test cable (OCB or EHV)
- Safety flag plug
- Doble motion transducers
- Mechanical adapter clamp set. (Kit includes three (3) C-clamps and six (6) Vise-Grip C-clamps)
- Doble current probe (20/200 A)
- 3 A fast blow fuses
- Printer model P1 external USB thermal printer
- Additional T-Doble software licenses

Front Panel Characteristics

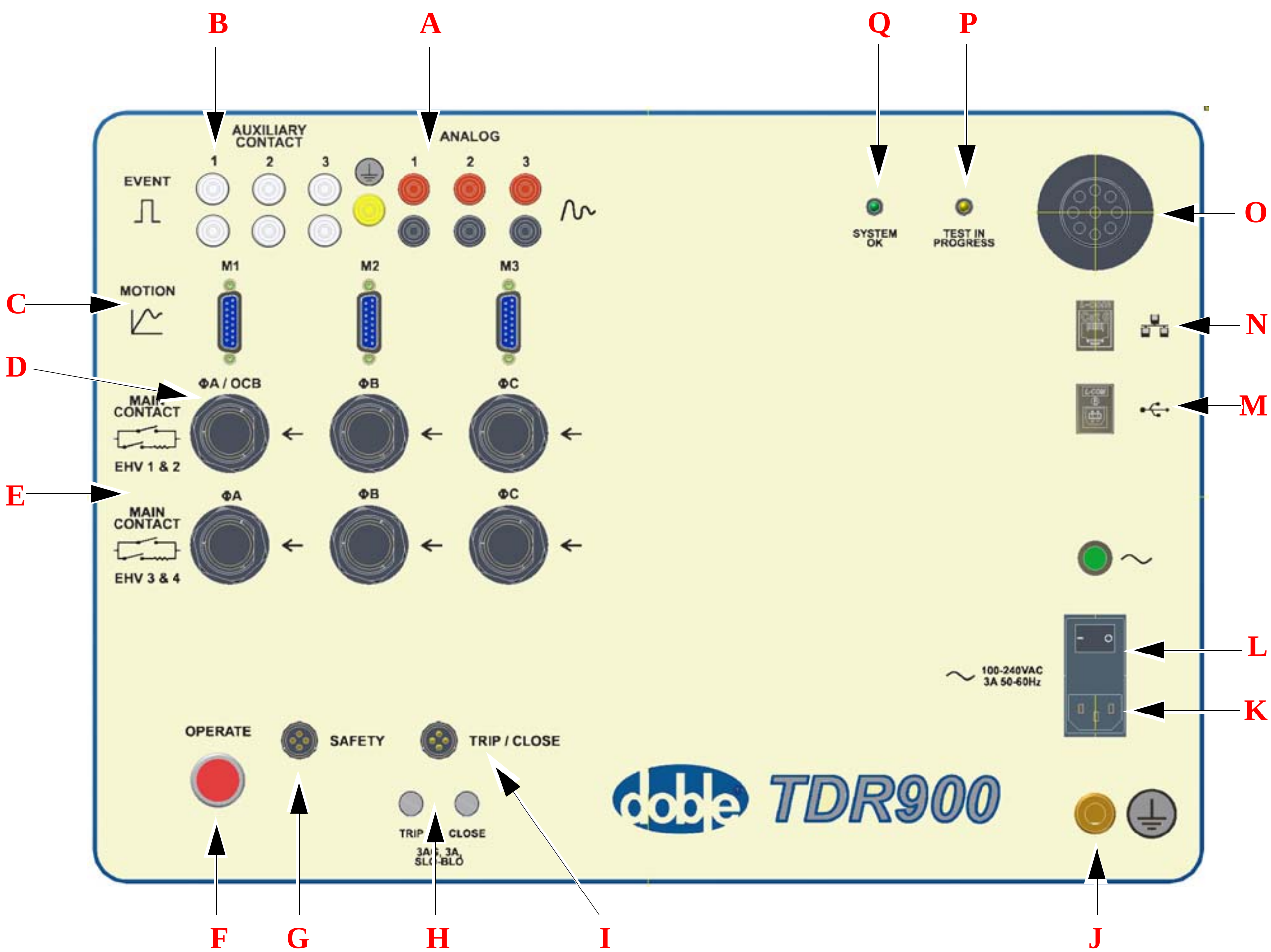


Figure 9.3 TDR900 Front Panel

Table 9.1 describes the connections and controls present on the TDR900 Front Panel. See Appendix F, “TDR900 Circuit Breaker Test System Specifications,” for technical details.

Table 9.1 TDR900 Front Panel Connections and Switches

Item	Description
A	General-purpose analog measurement connectors (shrouded banana jack) for voltage, current shunt, and current probe inputs
B	Auxiliary contact timing measurement connectors (shrouded banana jack)
C	Motion transducer cable connectors, 15-pin female
D	OCB cable connector (upper left main contact connector only)
E	EHV contact monitor cable connectors, circular 12-pin male
F	Manual Operate button
G	Safety switch cable or safety bypass flag connector, 4-pin male
H	Trip and Close fuses
I	Trip/Close control connector, 5-pin male
J	System safety ground Twist-Lock connector used with the ground cable
K	Power ON/OFF switch
L	IEC standard power cord connector, 3-pronged male
M	USB over serial port
N	Ethernet port
O	Speaker
P	LED indicating that a test is in progress
Q	DC power sources valid operation LED

System Topography

Figure 9.4 shows the topology of the TDR900 in the test environment.

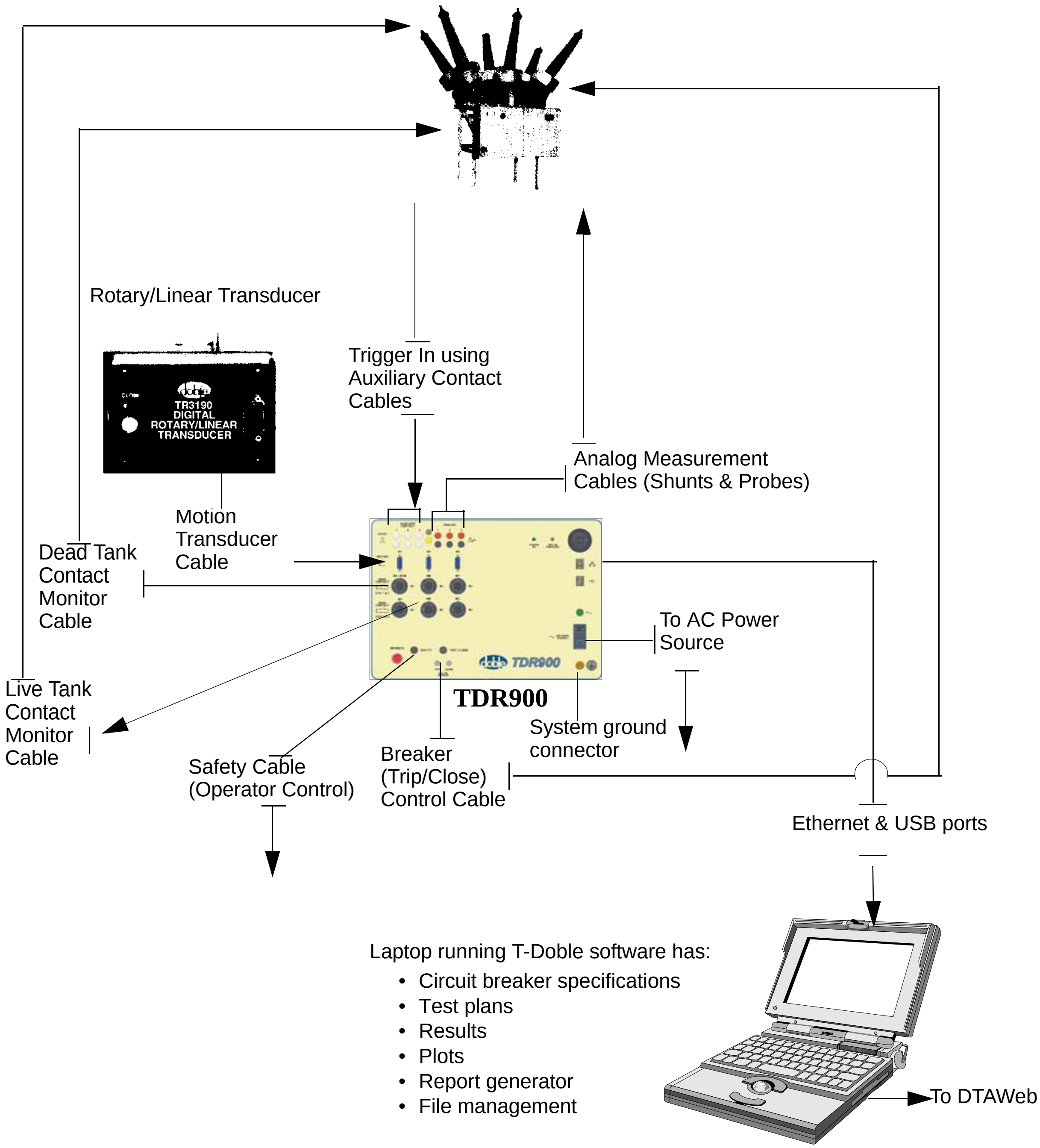


Figure 9.4 TDR900 System Topology

TDR900 Measurement Channels

The TDR900 provides four types of measurement channels:

- OCB (Main contact and resistor switch)
- EHV (Main contact and resistor switch)
- Motion (Digital)
- Event (Analog and Auxiliary)

Event Channels (Analog and Auxiliary)

Event channels are split into two groups:

- Analog channels
- Auxiliary contact channels

A combination of these channels is used to monitor the characteristics of the circuit breaker's operating 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. (See Chapter 7: "Triggering and Timing Setup" for more information.)

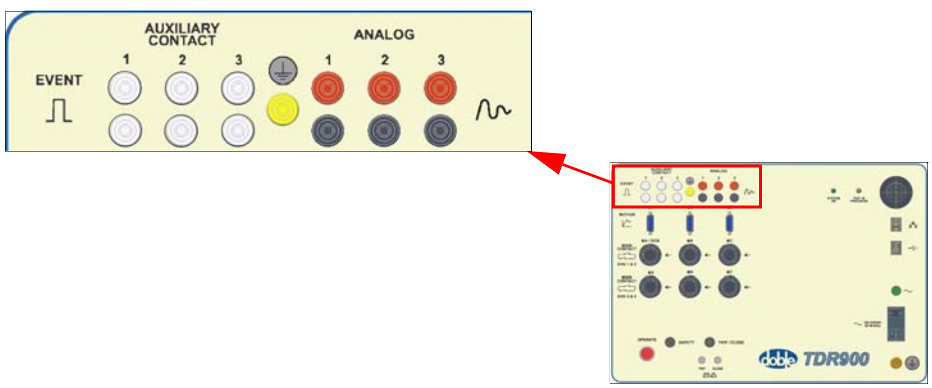


Figure 9.5 TDR900 Event Connectors

Analog Channels

Three 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 instrument 10 kHz sample rate.

NOTE

For applications using a current probe, you must zero the probe. See "Doble Probe" on page 12-8.

Auxiliary Contact Channels

The auxiliary contact channels monitor the state of up to three sets 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

The TDR900 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 Analog, Aux tab of the Test Plan page (see page 5-8 for configuration).

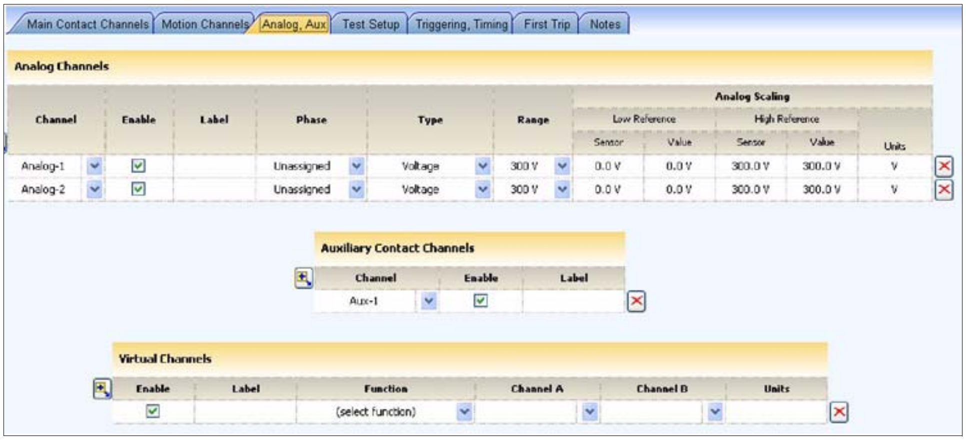


Figure 9.6 Analog and Auxiliary Settings on the Analog, Aux Tab

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's operating mechanism.

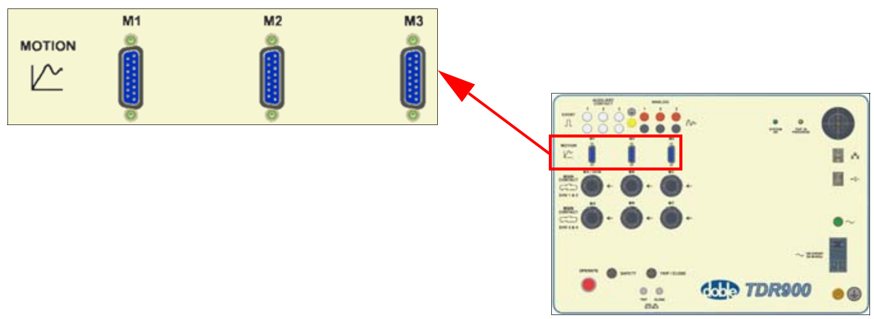


Figure 9.7 TDR900 Motion Connectors

Setting the Motion Parameters

Motion parameters are set in two locations:

- Motion Channels tab of the Test Plan page (see Figure 9.8). See page 5-2 for configuration.
- Motion Limits tab of the Breaker page (see Figure 9.9). See page 4-30 for configuration.

Motion Channel Setup

Channel	Enable	Motion Label	Velocity Label	Phase	Transducer Type	Motion Limits	Motion Units	Transducer Scaling: Value at Transducer	Transducer Scaling: Value at Contacts
Motion-1	☑	LINKAGE		Phase A	Linear	Limits #1	Linear	1.0 mm	1.0 mm
Motion-2	☑	MECHANISM		Phase B	Linear	Limits #2	Linear	80.0 mm	120.0 mm
Motion-3	☐	Motion-3		Phase C	Linear	*	Linear	1000.0 mm	1000.0 mm

Figure 9.8 Motion Settings on the Motion Channels Tab

Travel Limits

	Travel Type	Label			Total Travel	Overtravel Open	Overtravel Close	Rebound Open	Rebound Close	Contact Wipe
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: Zone Type	From	To	Velocity: 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 9.9 Motion Settings on the Motion Limits Tab

OCB Channel

The OCB channel measures main contact and resistor switch 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.

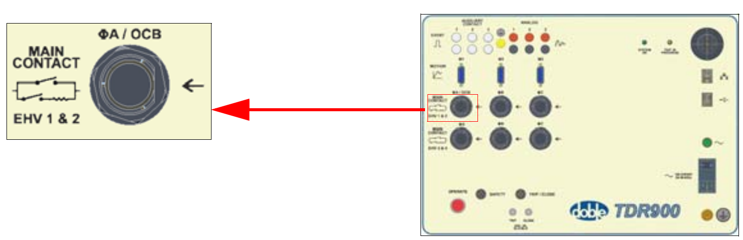


Figure 9.10 TDR900 OCB Connector

Setting the OCB Parameters

OCB parameters are set in two locations:

- Main Contact Channels tab of the Test Plan page (Figure 9.11). See page 4-9 for configuration.
- Basic Limits tab of the Breaker page (Figure 9.12). See page 5-1 for configuration.

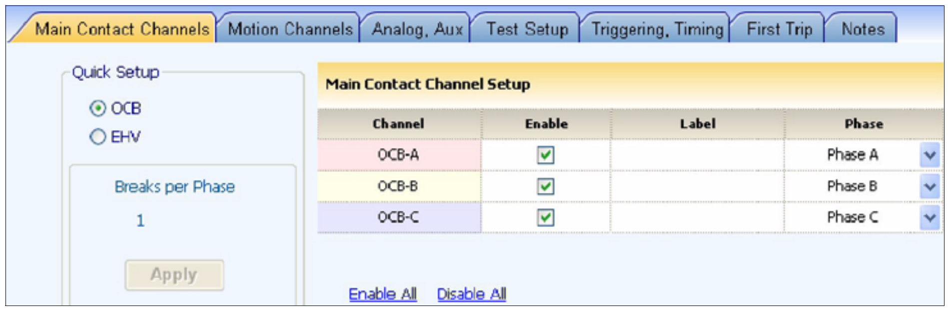


Figure 9.11 OCB Parameters on the Main Contact Channels Tab

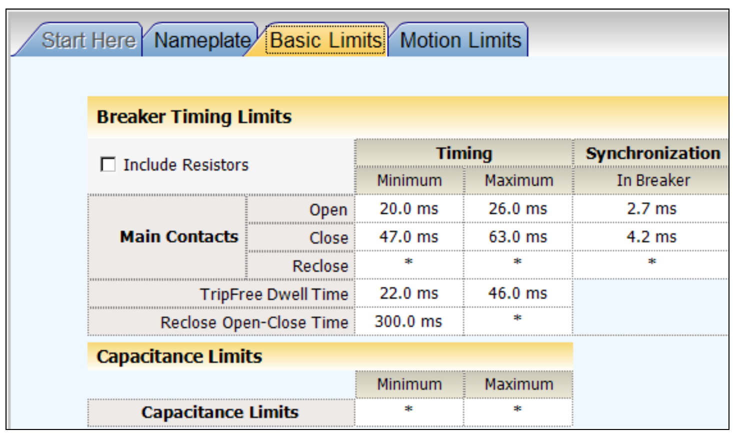


Figure 9.12 OCB Parameters on the Basic Limits Tab

EHV (Live tank)

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

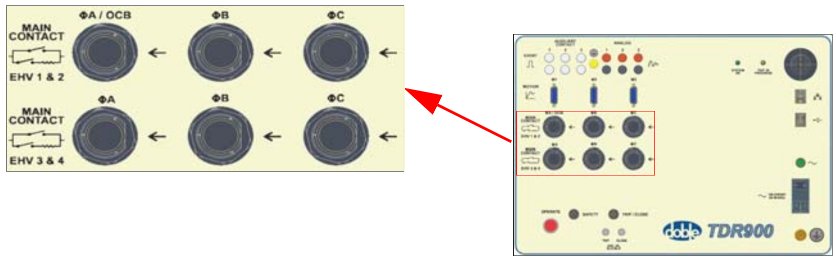


Figure 9.13 TDR900 EHV Connectors

Setting the EHV Parameters

EHV parameters are set in two locations:

- Main Contact Channels tab of the Test Plan page (Figure 9.14). See page 4-9 for configuration.
- Basic Limits tab of the Breaker page (Figure 9.15). See page 5-1 for configuration.

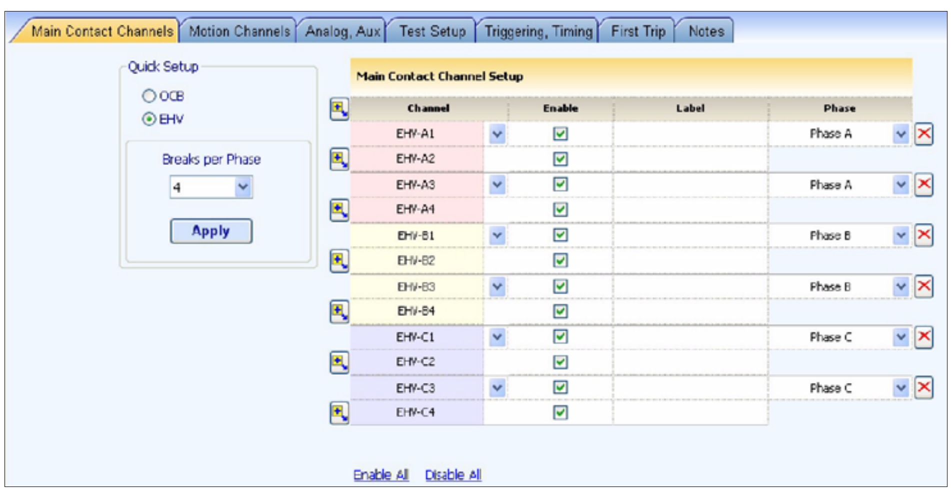
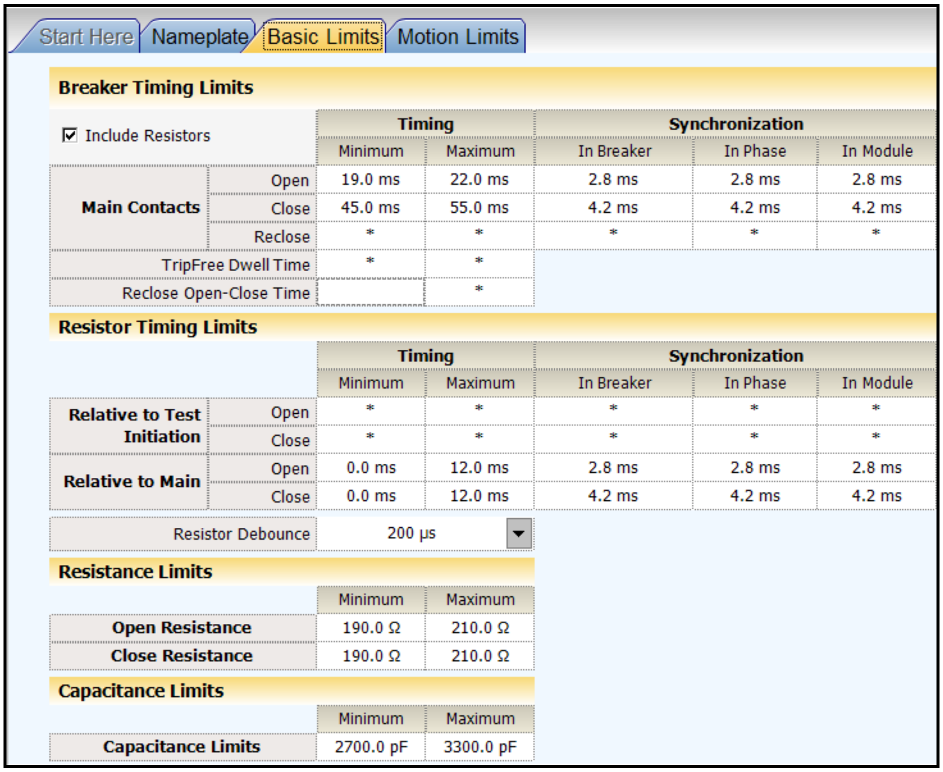


Figure 9.14 EHV Settings on the Main Contact Channels Tab



Start Here | Nameplate | Basic Limits | Motion Limits

Breaker Timing Limits

☑ Include Resistors

		Timing		Synchronization		
		Minimum	Maximum	In Breaker	In Phase	In Module
Main Contacts	Open	19.0 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 µs

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 9.15 EHV Settings on the Basic Limits Tab

Command Functions

The TDR900 provides the following command functions:

- Test instrument initiation—Operate button, Safety Switch, or Safety Flag.
- Circuit breaker Trip and Close control—The instrument 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 switches) during the test.

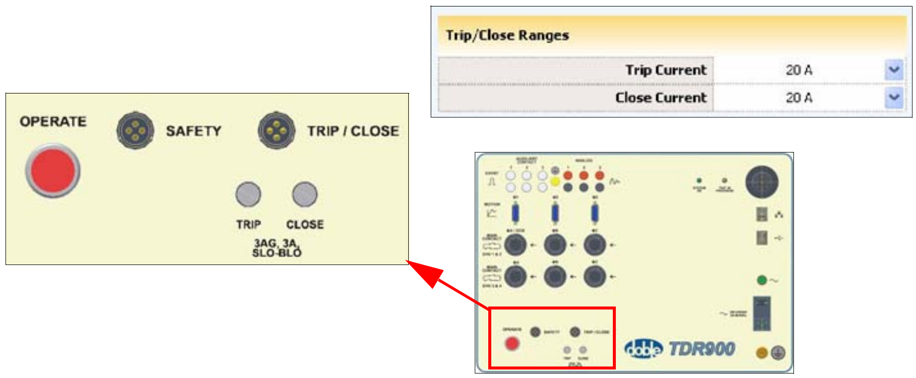


Figure 9.16 Command Functions and Trip/Close Parameters

Operate Button

The Operate button initiates the test and starts the control-and-record process.

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 Flag into this connector and initiate the tests from the laptop, without using the Operate button or 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 TDR900 to control these tests:

- Trip (O)
- Close (C)
- TripFree (CO)
- Reclose (O-C and O-0.3 s-C)
- C-O
- 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 9.17.

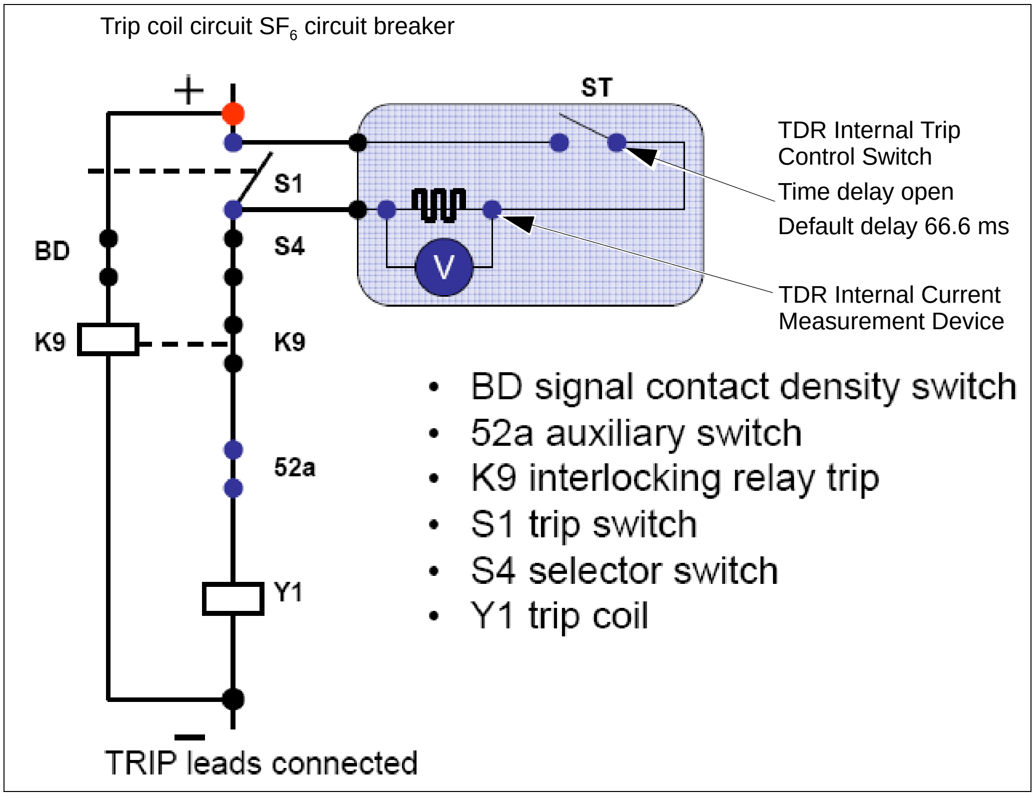


Figure 9.17 Trip/Close Command Application

Trip/Close Current

The Trip/Close command function includes an internal current measurement for the Trip and Close circuits. This Trip and Close circuit current is measured during a Trip/Close test by:

- Passing the Trip and Close currents through current meters
- Displaying the result as a current waveform and as a peak current value

NOTE

If the correct Close command currents do not appear, refer to the Doble Application Note: "AN7: Monitoring Closing Coil Current with the Current Shunt in the Close Circuit" on page H-23 of this guide.

Triggers

The TDR900 provides a Trigger Input capability.

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 TDR900 provides the following communications options:

- Ethernet port
- USB over serial port

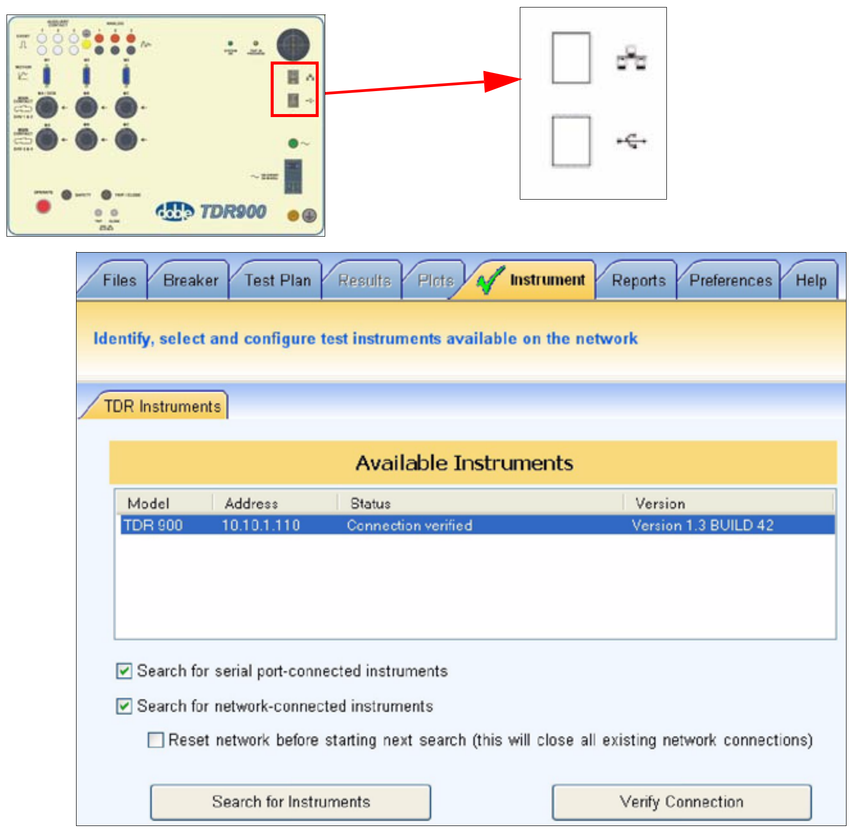


Figure 9.18 Ethernet and USB Ports and the Instrument Page

Supported Tests

Table 9.2 lists the nine circuit breaker tests that the TDR900 performs and gives a state description of the sequencing that comprises the test. When a test is run, the instrument stores and plots the data. The data can be printed to the optional printer in the field or to an office printer.

Trigger Input is available for all tests.

NOTE **For the First Trip test, if the Trigger Input parameter is set to None (Internal), a dialog box states that only AUX Contact and Trigger In are valid trigger types.**

Table 9.2 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
Reclose (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	—	—	—	—

Trip Test

During the Trip test, a single user-specified command is issued to open the circuit breaker. For a description of the test command parameter, see “Trip Test” on page 6-4.

Figure 9.19 shows a Trip Command pulse plot generated by the Trip test.

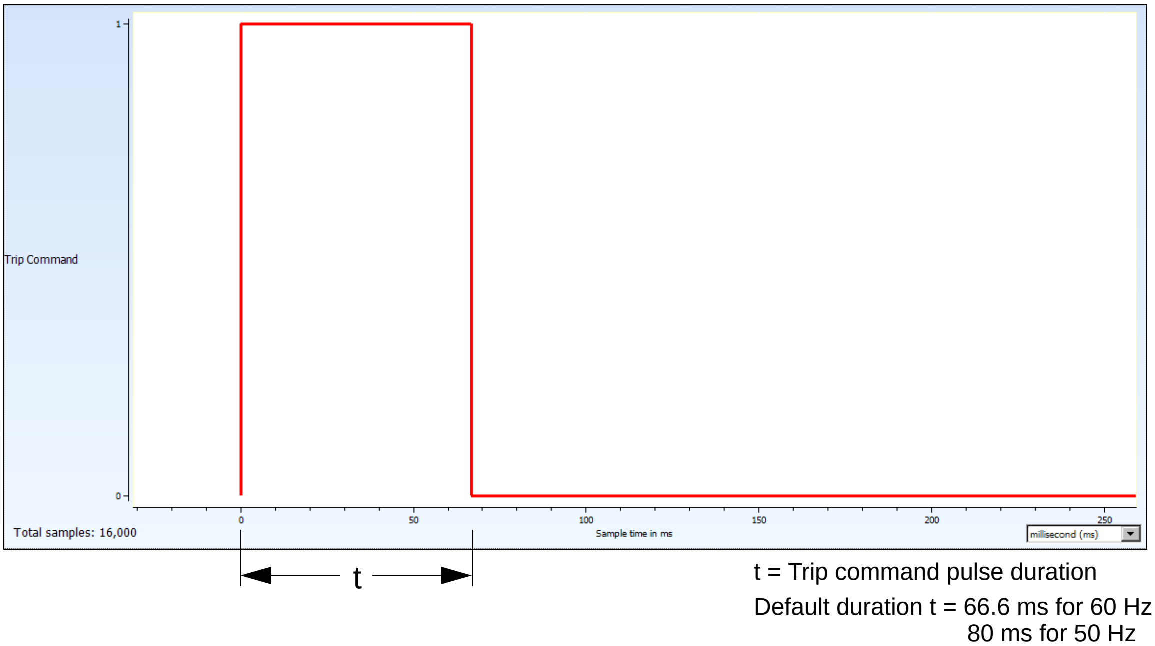


Figure 9.19 Trip Command Pulse

Close Test

During the Close test, a single, user-specified command is issued to close the circuit breaker. For a description of the test command parameter, see “Close Test” on page 6-5.

Figure 9.20 shows a Close Command pulse plot generated by the Close test.

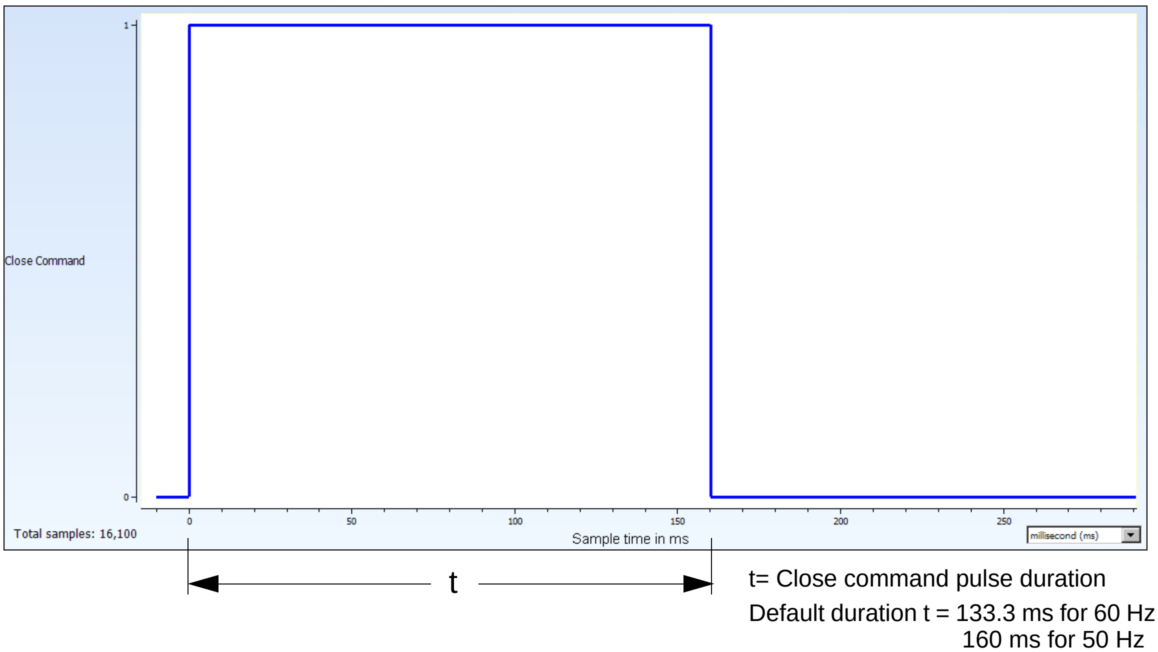


Figure 9.20 Close Command Pulse

TripFree (CO) Test

During the TripFree test, dual, user-specified commands are issued to close the circuit breaker and open it shortly after. For a description of the test command parameters, see "TripFree (CO) Test" on page 6-6.

Figure 9.21 shows the Close and Trip Command Pulse plots generated by the TripFree test.

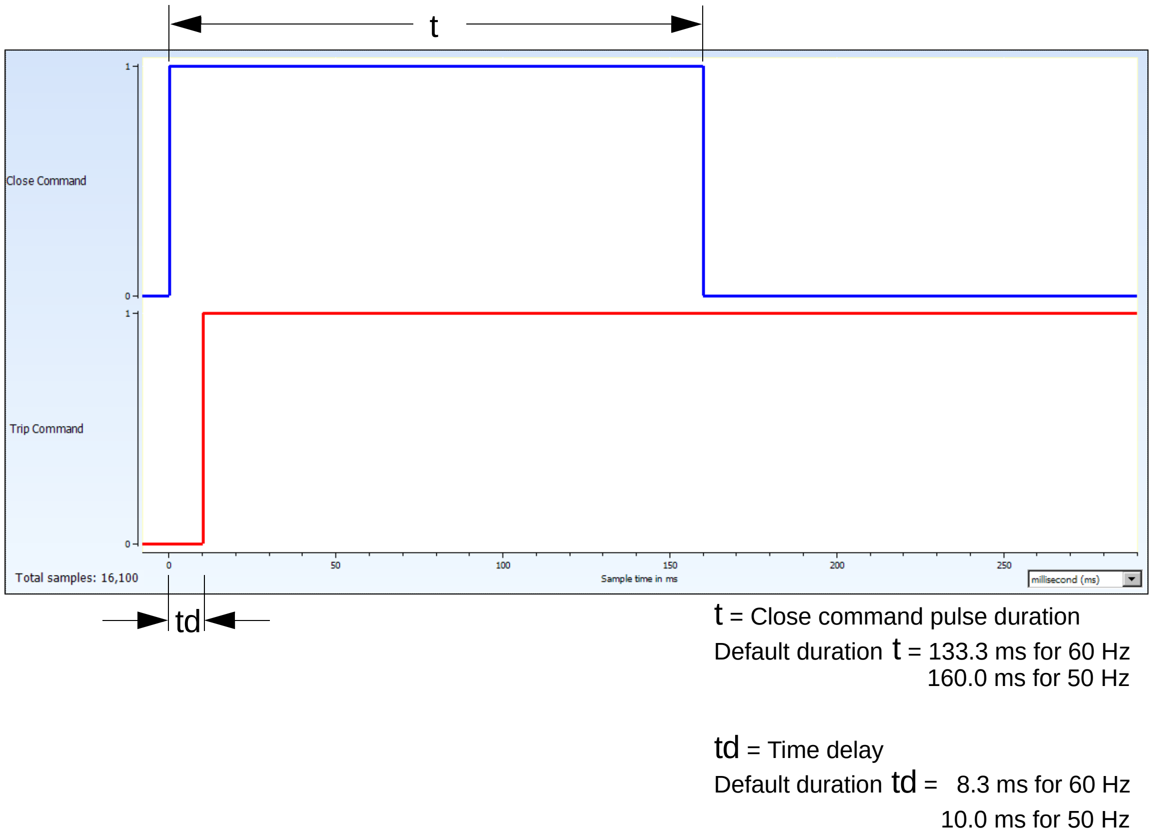


Figure 9.21 TripFree Command Pulse

Reclose (O-C) Test

During the Reclose test, dual, user-specified commands are issued to open the circuit breaker and then close it shortly after. A delay maybe specified to time both operations. For a description of the test command parameters, see “Reclose (O-C) Test” on page 6-9.

Figure 9.22 shows the Trip and Close Command Pulse plots generated by the Reclose test.

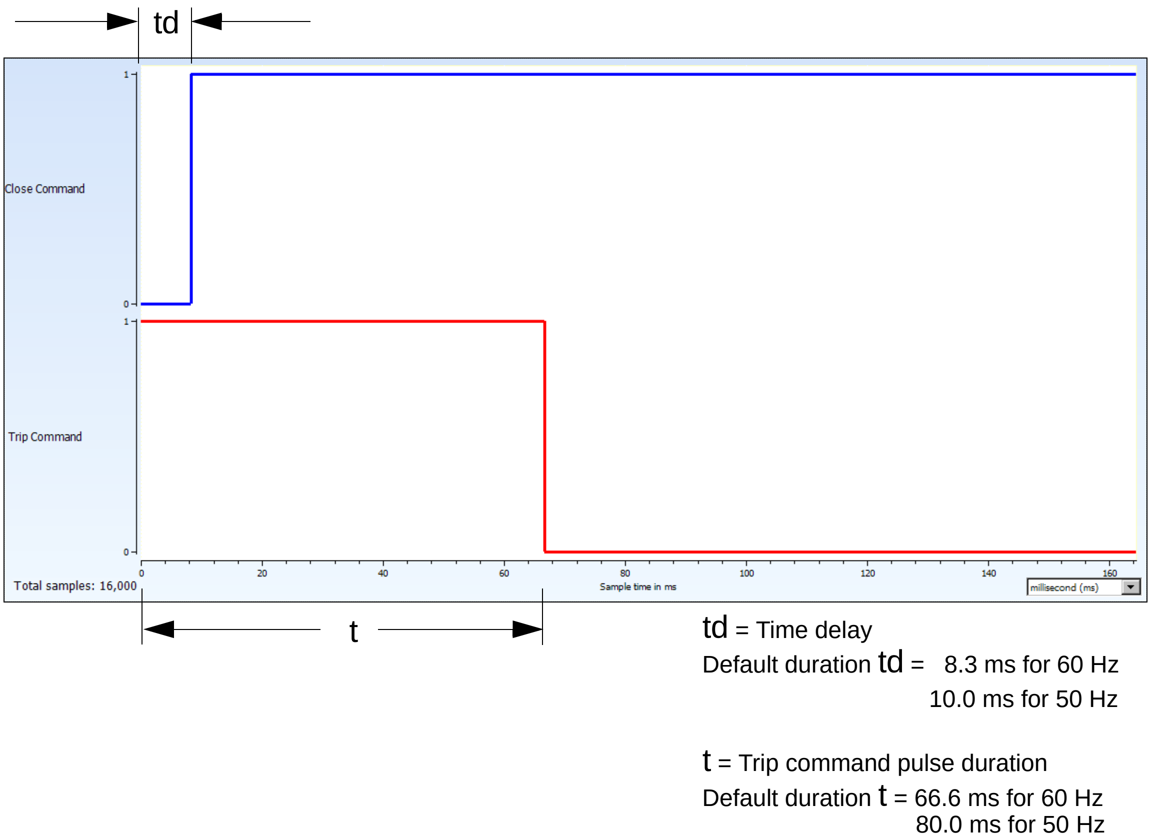


Figure 9.22 Reclose Command Pulse

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 the delay between closing and opening. For a description of the test command parameters, see "C-O Test" on page 6-12.

Figure 9.23 shows the Close and Trip Command Pulse plots generated by the C-O test.

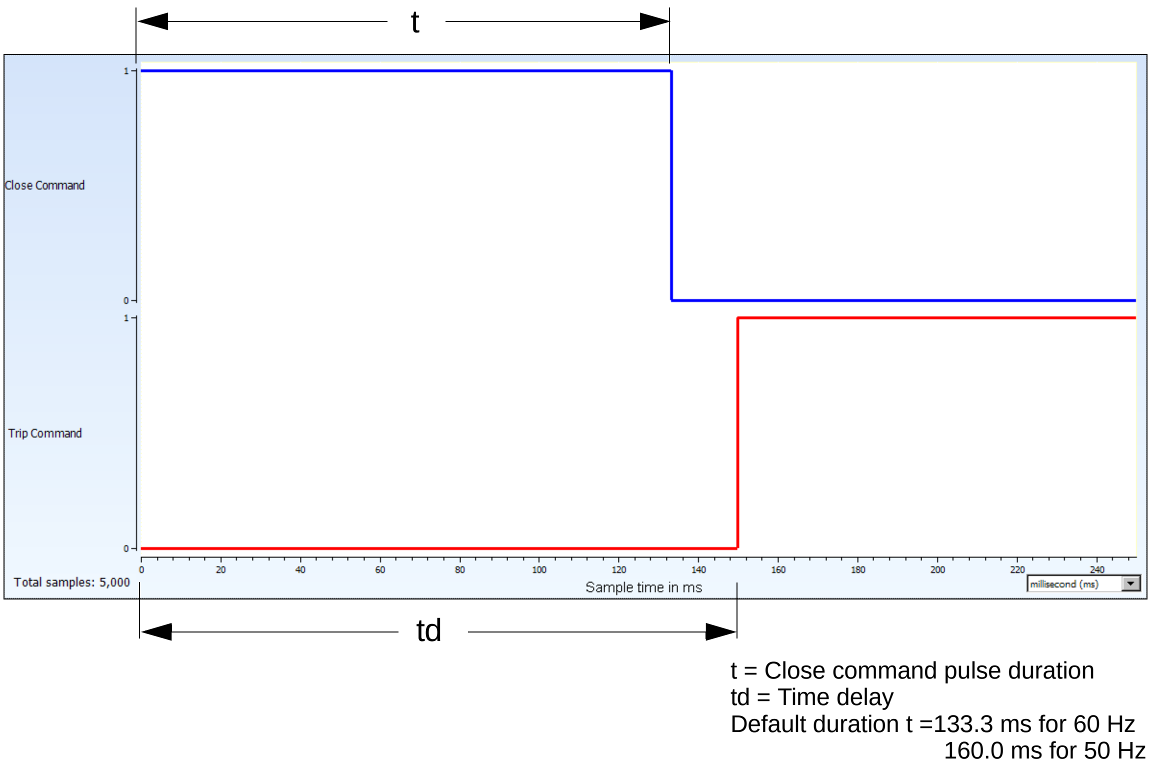
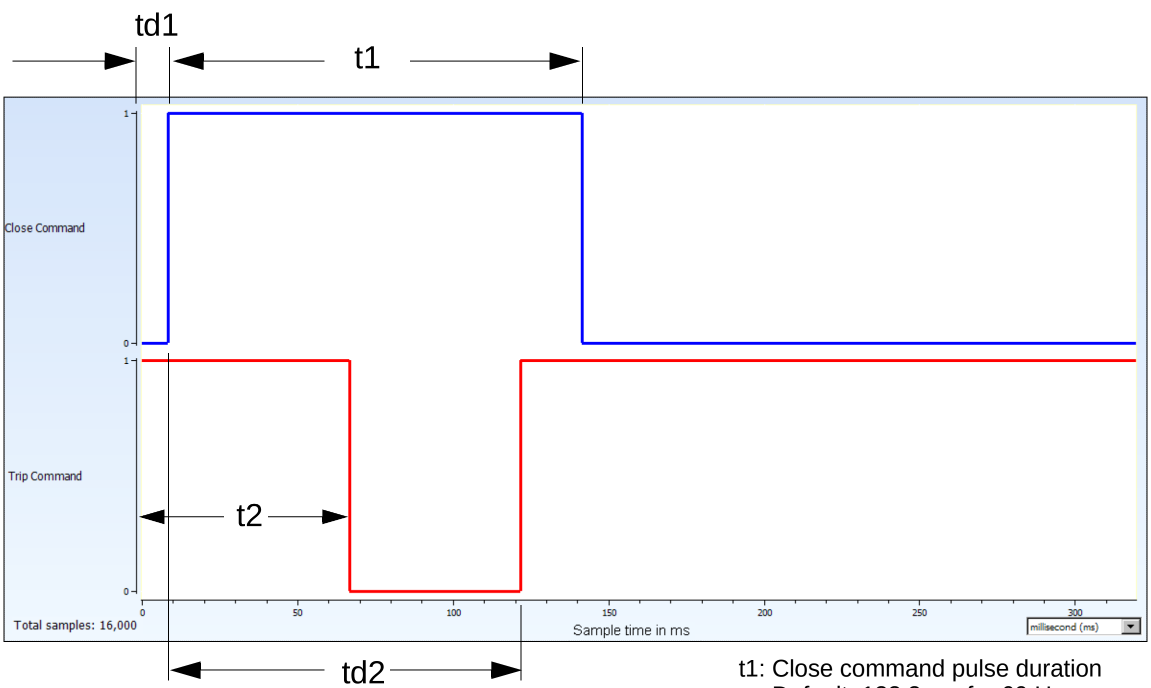


Figure 9.23 C-O Command Pulse

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. For a description of the tests, see “O-CO and O-C-O Tests” on page 6-14.

Figure 9.24 shows the Trip and Close Command Pulse plots generated by the O-CO and O-C-O tests.



t1: Close command pulse duration
Default: 133.3 ms for 60 Hz

t2: Initial Trip command pulse duration
Default: 66.6 ms for 60 Hz

td1: Time delay 1

td2: Time delay 2

Figure 9.24 O-C-O Command Pulse

First Trip Test

The First Trip test uses the analog and auxiliary channels of the TDR instrument 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.

For a complete discussion of the First Trip test, see "First Trip Test" on page 6-31.

Record Only Test

The Record Only test is a convenience for users who may wish to record a customized setup that is not included in the standard test operation types.

10. TDR900: Running a Test

This chapter provides the minimum information required to make connections between a circuit breaker and the TDR900 Circuit Breaker Test System, run a test, and save the test results. It contains the following sections:

Front Panel Reference

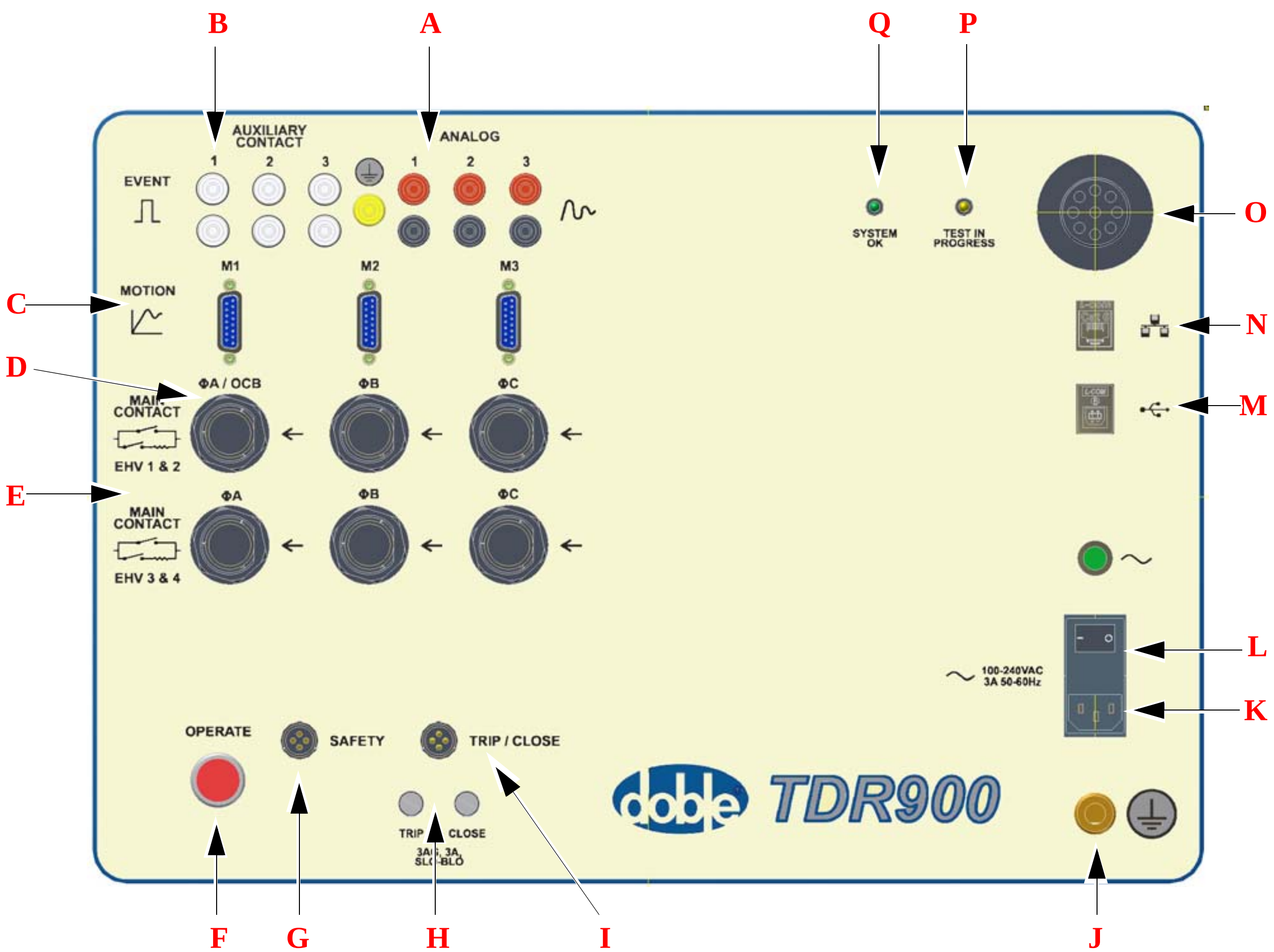


Figure 10.1 TDR900 Front Panel

Table 10.1 describes the connections and controls present on the TDR900 Front Panel. See Appendix F, "TDR900 Circuit Breaker Test System Specifications," for technical details.

Table 10.1 TDR900 Front Panel Connections and Switches

Item	Description
A	General-purpose analog measurement connectors (shrouded banana jack) for voltage, current shunt, and current probe inputs
B	Auxiliary contact timing measurement connectors (shrouded banana jack)
C	Motion transducer cable connectors, 15-pin female
D	OCB cable connector (upper left main contact connector only)
E	EHV contact monitor cable connectors, circular 12-pin male
F	Manual Operate button
G	Safety switch cable or safety bypass flag connector, 4-pin male
H	Trip and Close fuses
I	Trip/Close control connector, 5-pin male
J	Power ON/OFF switch
K	System safety ground Twist-Lock connector used with the ground cable
L	IEC standard power cord connector, 3-pronged male
M	USB port
N	Ethernet port
O	Speaker
P	LED indicating that a test is in progress
Q	DC power sources valid operation LED

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 10-4.
2. Make connections to the TDR900. See page 10-5.
3. Make connections to the circuit breaker. See page 10-11.
4. Remove safety grounds. See page 10-29.

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 TDR900 is designed to test circuit breakers with one side of the circuit breaker at ground potential at all times.
- The contact monitor cables act as antennae for electrostatic pickup, electromagnetic pickup, or both. In order to minimize this exposure, the TDR900 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 TDR900 Connections

WARNING!	**To reduce problems associated with electrostatic discharge, always confirm that appropriate service disconnects are secured. Then, connect cables to the TDR900 in this order:** **1. Safety ground cable** **2. Power supply cable** **3. Communication cable** **4. Other cables required for the test to be performed** **Only after all connections are made to the TDR900 can you make connections to the testing breaker.** **Follow all safety procedures.**

Grounding the TDR900

To ground the TDR900 and attach the power cable:

1. Plug the ground cable into the System ground receptacle. (See **J** in Figure 10.1 on page 10-2.) Ground the other end.
2. Plug the safety switch cable into the SAFETY receptacle. (See **G** in Figure 10.1 on page 10-2.) If you plan to use an external trigger, plug in the Safety Bypass flag.
3. Ensure that the power supply voltage is correct (100 - 240 V AC, 50 or 60 cycles).
4. Attach the power cord. (See **L** in Figure 10.1 on page 10-2.)

Connecting the Instrument to the Laptop

To connect the TDR900 to the laptop:

1. If you are not using battery power, connect the power cable to the laptop power connector.
2. Connect the laptop to the TDR900 using one of the following cables:
   - Ethernet
   - USB
   - USB/Ethernet (First-generation TDR900 only)

   (See **M** and **N** in Figure 10.1 on page 10-2.)

3. Turn the laptop power switch **ON**.
4. Double-click the **T-Doble** icon shown below or select **Start**/**All Programs**/**Doble Engineering**/**T-Doble**.

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 contact monitor cable to OCB connector and then to appropriate circuit breaker terminals.

  See **D** in Figure 10.1 on page 10-2. Connect alligator clip leads as labeled: A,B,C Common or 1,2,3 Common.
- EHV contact monitor cables to EHV connectors and then to appropriate circuit breaker terminals.

  See **E** in Figure 10.1 on page 10-2. Connect alligator clip leads as labeled: PH A, Contact 1,2, Common, etc.

Event Connections: Auxiliary Contact Channels

The TDR900 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 Analog, Aux tab of the Test Plan page. For more information, see "Auxiliary Contact Channels" on page 5-10.

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 **B** on Figure 10.1 on page 10-2.)
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 TDR900 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 (mV 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 Analog, Aux tab. For more information, see “Analog Channels” on page 5-8.

To connect a voltage input:

1. Attach the instrument end of the Doble-supplied analog cable to a pair of Analog Channel banana jacks. (See **A** on Figure 10.1 on page 10-2.)

   The instrument 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 **E** on Figure 10.1 on page 10-2.)

   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 inputs can be configured for 20 A or 200 A. To configure them, open the Test Plan page and select the Analog, Aux tab. See Figure 10.2.

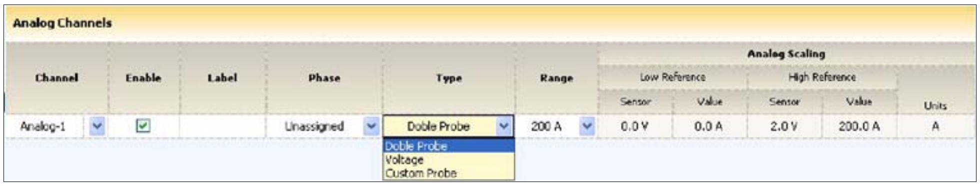


Figure 10.2 Configuring a Doble Probe

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 instrument end of the analog cable into the desired Analog Channel connector. (See **A** on Figure 10.1 on page 10-2.)

   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 **J** on Figure 10.1 on page 10-2.) 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 by setting 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

To set up a current shunt:

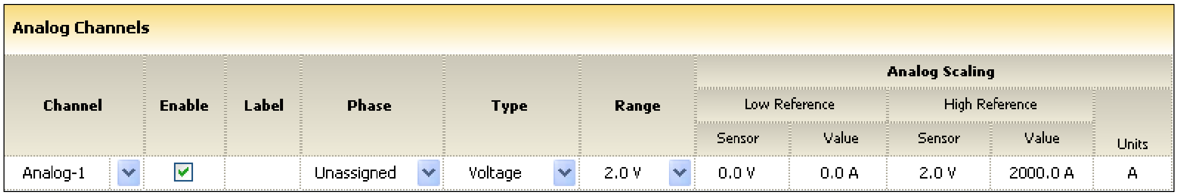
1. Connect the instrument end of the Doble-supplied analog cable to a pair of Analog Channel banana jacks. (See **A** on Figure 10.1 on page 10-2.)

   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 **J** on Figure 10.1 on page 10-2.)

   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 **Analog, Aux** tab.

5. In the Type column, select **Voltage**.
6. Make all other appropriate settings.

   Figure 10.3 shows the settings for a current shunt with 200 mV for 100 A.



Analog Channels										
						Analog Scaling				
						Low Reference		High Reference		
Channel	Enable	Label	Phase	Type	Range	Sensor	Value	Sensor	Value	Units
Analog-1	☑		Unassigned	Voltage	2.0 V	0.0 V	0.0 A	2.0 V	2000.0 A	A

Figure 10.3 Current Shunt Setting in Analog Channels Table

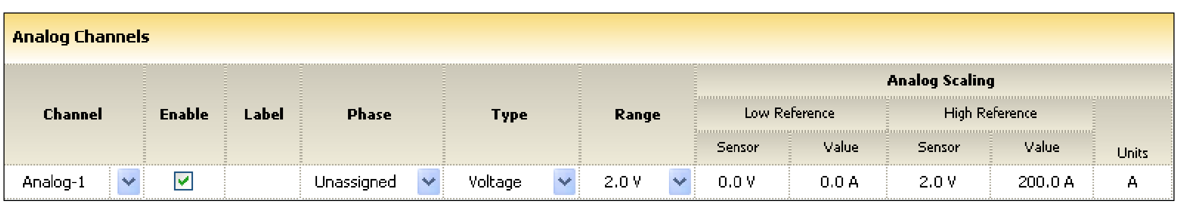
Current Probe

To set up a current probe:

1. Connect the instrument end of the Doble-supplied analog cable to a pair of Analog Channel banana jacks. (See **A** on Figure 10.1 on page 10-2.)

   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 **J** on Figure 10.1 on page 10-2.)

   Multiple shields can be stacked.
3. Attach the other end of the cable to the current probe.
4. To configure the current probe, open the Test Plan page of T-Doble and select the **Analog, Aux** tab.
5. In the Type column, select **Voltage**.



Analog Channels										
						Analog Scaling				
						Low Reference		High Reference		
Channel	Enable	Label	Phase	Type	Range	Sensor	Value	Sensor	Value	Units
Analog-1	☑		Unassigned	Voltage	2.0 V	0.0 V	0.0 A	2.0 V	200.0 A	A

Figure 10.4 Current Probe Setting in Analog Channels Table

6. Make all other appropriate settings.

   Figure 10.4 shows the settings for a current probe with 2 V corresponding to 200 A.

Trip/Close Connections

To make Trip/Close connections to the TDR900:

1. Connect the instrument end of the breaker control cable to the TRIP/CLOSE connector on the TDR900. (See **I** in Figure 10.1 on page 10-2.) 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 TDR900 to act as a series switch that applies +DC voltage to the appropriate coil for operation.

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 **C** in Figure 10.1 on page 10-2.)

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 breaker control cable to the control circuit of the circuit breaker.
2. Make one of the following two possible sets of connections:

   Option 1:

   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

   Option 2:

   a. Two trip leads between the +DC voltage and the trip coil
   b. Two close leads between the +DC voltage and the close coil

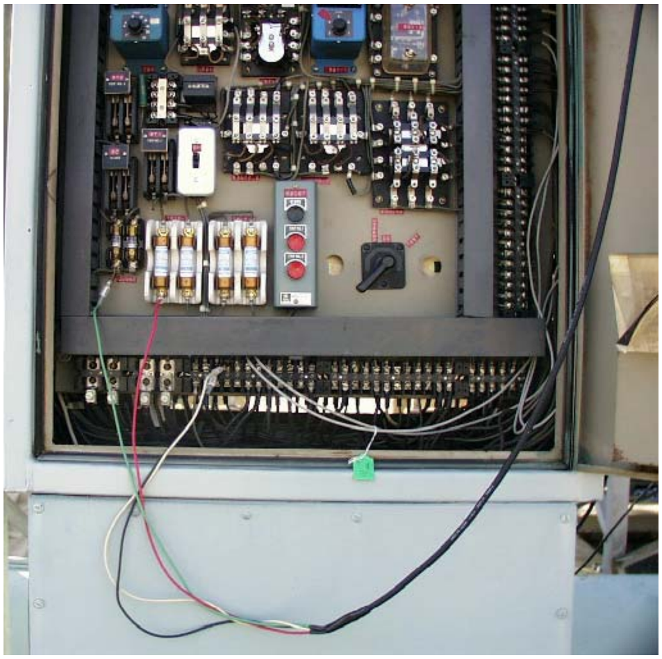


Figure 10.5 Step 1: Circuit Breaker Control Cabinet Preparation

Main Contact Connections

OCB Overall Timing Test Circuit Breaker

To make OCB connections:

1. Connect an OCB contact monitor cable to the appropriate circuit breaker terminals as listed in Table 10.2. Because test voltages are below 48 V, it is important to provide good connections between the contact monitoring cables and the terminals.

Table 10.2 OCB Dead Tank Connections

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

Because test voltages are below 48 V, it is important to double-check 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.

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

   Doble does not supply grounding jumpers for this step.

3. 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 10.6 shows a typical mounting of the rotary/linear transducer.

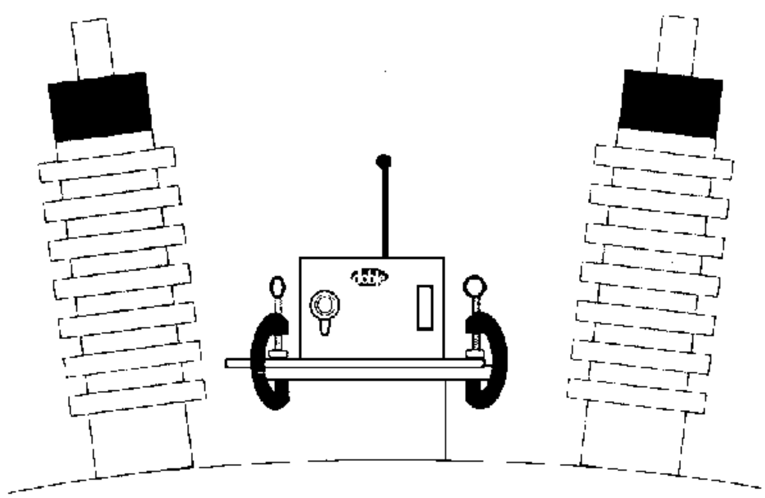


Figure 10.6 Rotary/Linear Transducer

4. Install a mounting platform for the transducer.

   Mounting clamps and platforms are not supplied as standard equipment with the TDR900. Optional mounting kits are available for specific circuit breaker models. A general-purpose mounting adapter is available from Doble (P/N TR3177). It facilitates 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 linear transducer. Other thread sizes are available as optional equipment from Doble.

WARNING!

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. (See Figure H.18 on page H-19.)

   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 10.7 shows the cable connections for the dead tank test.

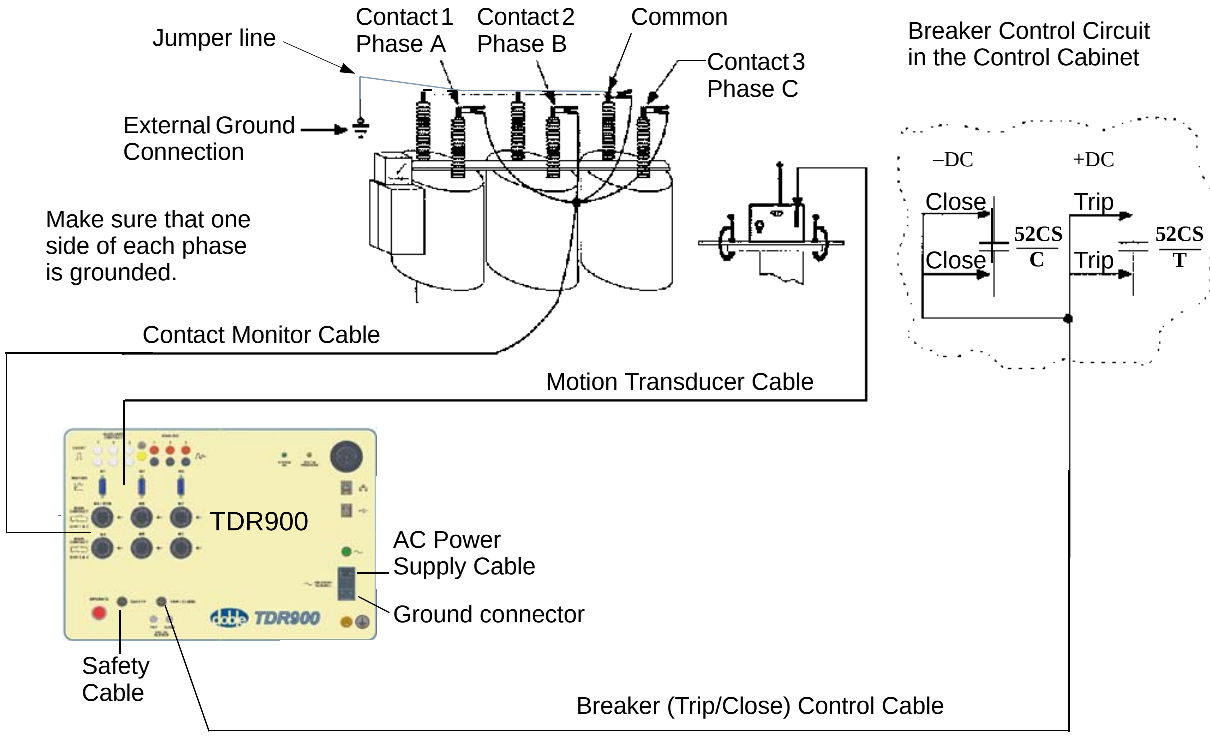


Figure 10.7 TDR900 Cable Diagram – Dead Tank

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 contact monitor cables to the appropriate circuit breaker terminals as listed in Table 10.3 on page 10-16.

NOTE

Because the test voltage for the main contacts is between 7.5 V and 15 V, 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 10.3 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 5-4.
- Transducer configuration—See "Configuring the TR3190 Digital Rotary/Linear Transducer" on page 10-21.

Table 10.4 lists available circuit breaker adapters.

Table 10.4 Circuit Breaker Adapters

Doble Adapter	Circuit Breaker Manufacturer	Circuit Breaker Type
TR3172	Westinghouse	SFA
TR3173	GE	GE Metalclad Air Magnetic circuit breakers (specify 13.8 or 4 kV)
TR3174	GE	GE Metalclad Air Magnetic circuit breakers (above 2000 A)
TR3175	Hitachi	Independent Pole Operation (IPO)
TR3176	Hitachi	HVB, Ganged operating mechanism
TR3177	N/A	General Purpose Tank Adapter
TR3178	Hitachi	HVB-IPO Spacer
TR3179	GE	Metalclad VB-1 Vacuum circuit breakers
TR3180	ABB	HPL Insulator Column
TR3181	ABB	HPL Mechanism Cabinet
TR3182	GEC	Alsthom HFG SF6

Table 10.4 Circuit Breaker Adapters (Continued)

Doble Adapter	Circuit Breaker Manufacturer	Circuit Breaker Type
TR3183	ABB	Coupling 8mmINT x 0.38 lg.
TR3184	Westinghouse	SF Mechanical Interface
TR3185	N/A	Universal Mechanical Transducer Mounting

Figure 10.8 shows the cable interconnections for the live tank test.

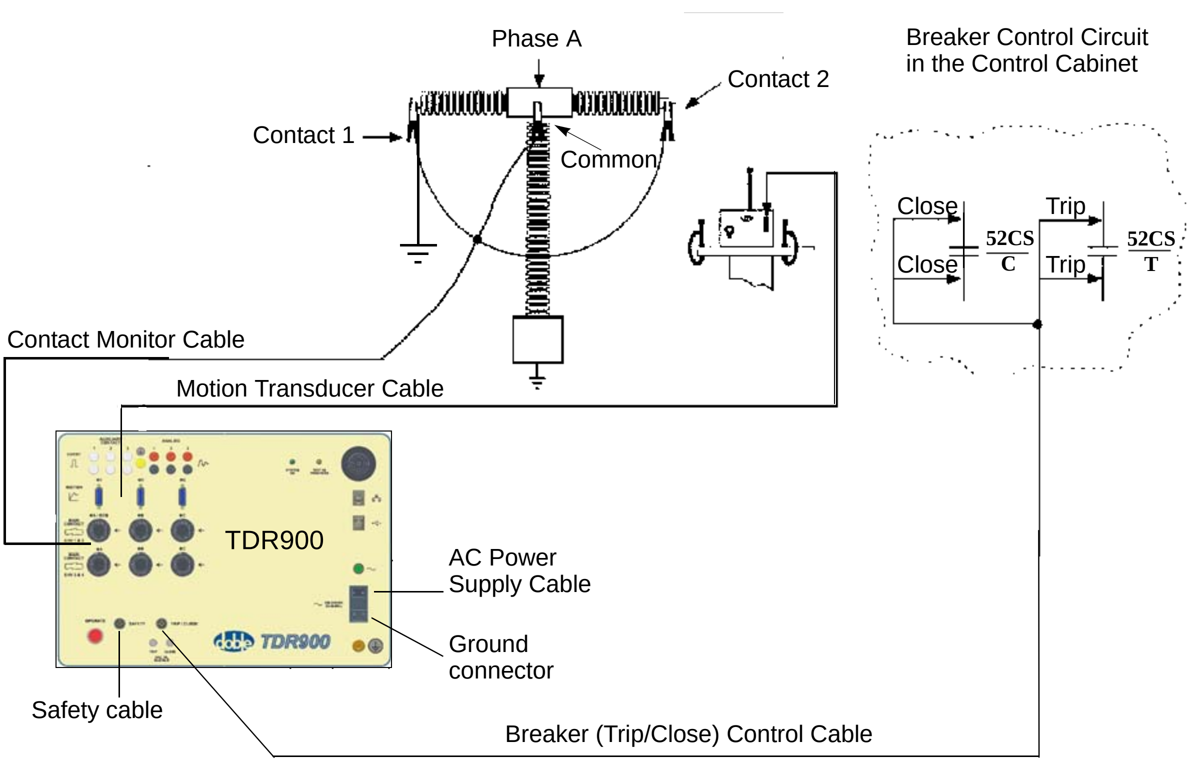
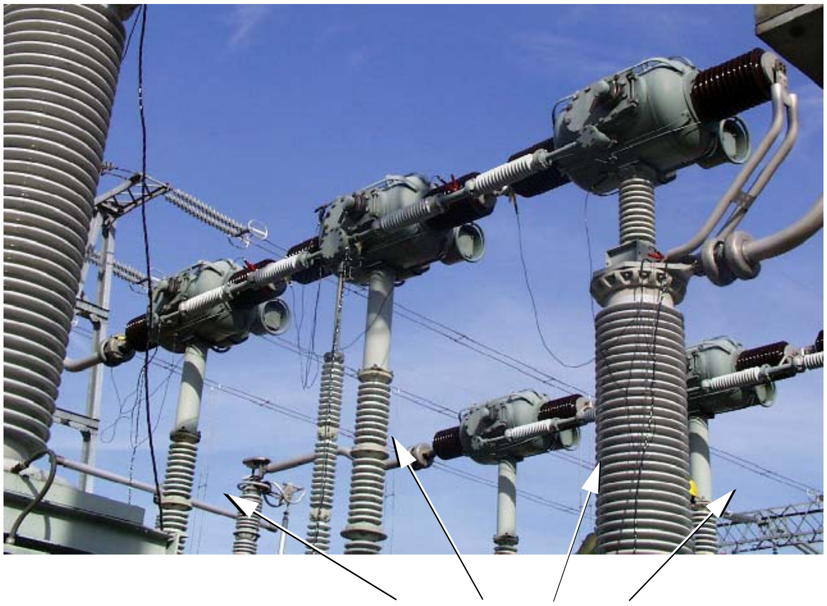


Figure 10.8 TDR900 Cable Diagram – Live Tank

Figure 10.9 shows an installation with live tank circuit breaker contact monitor cabling in place.



EHV Contact Monitor Cabling

Figure 10.9 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 TDR900.

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 TDR900:

- Trigger In
- Trip/Close

Trigger In Setup

To make Trigger In 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 TDR900:

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

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 *away from*, not toward, the person performing the installation. This is usually the closed position.**

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 10.10 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.

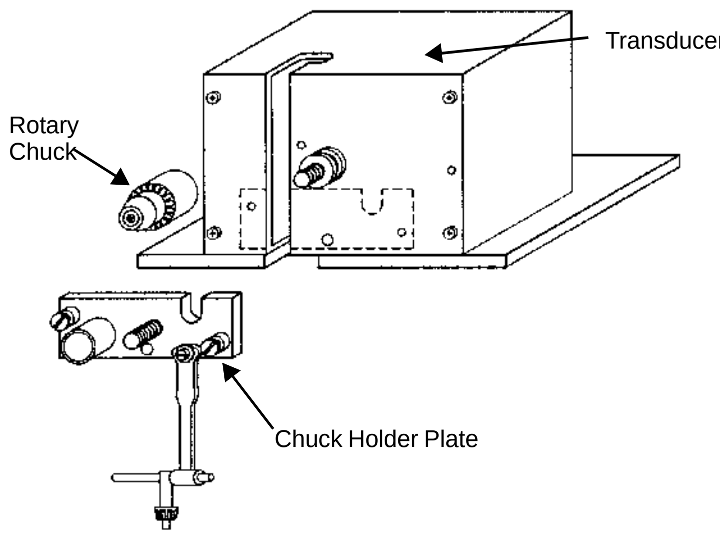


Figure 10.10 TR3190 (TR3160LR) Transducer Components

The chuck holder plate is shipped in two different configurations, as shown in Figure 10.11 on page 10-22. This plate provides four different functions:

- When mounted in the ROTARY position:
  - It depresses a micro-switch that indicates to the TDR900 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.

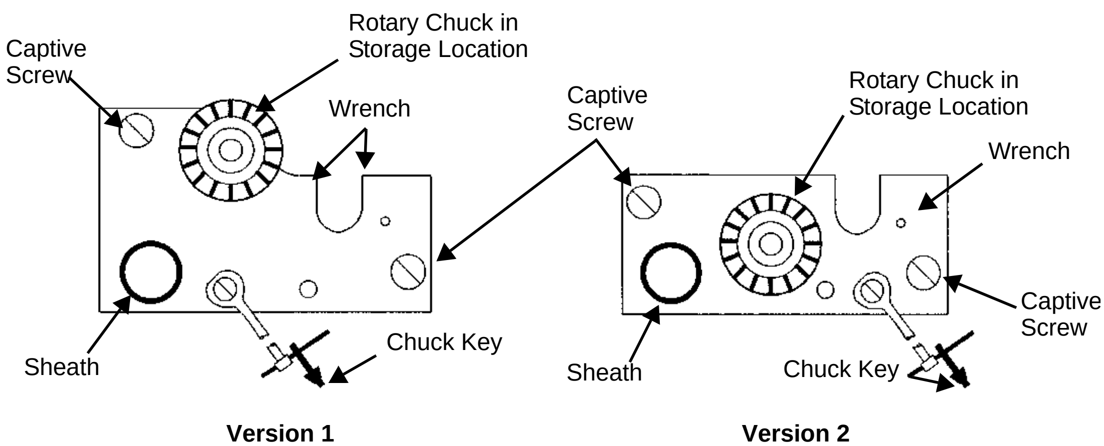


Figure 10.11 Chuck Holder Plate Configuration

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 10.12.)

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.

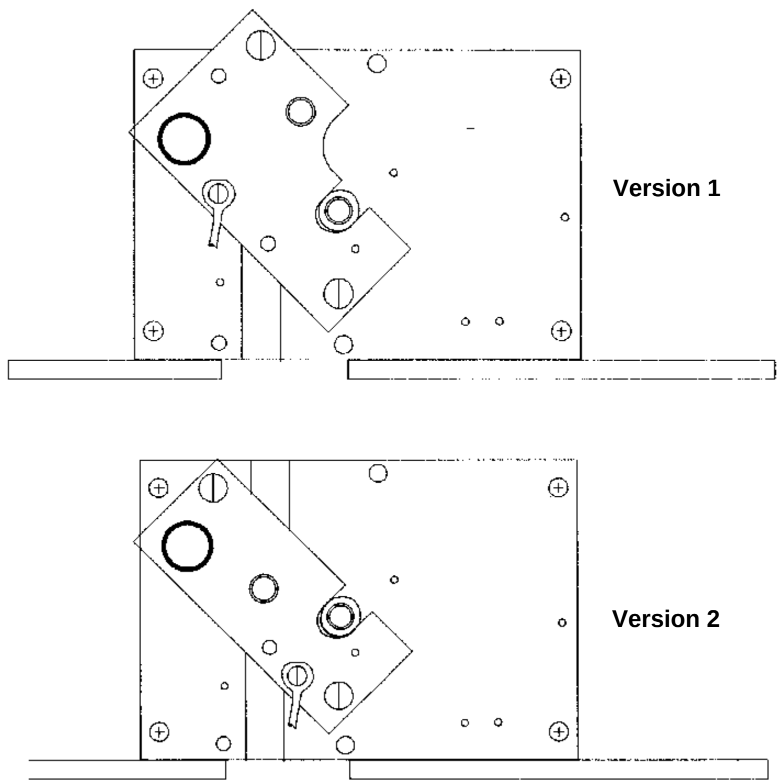


Figure 10.12 Chuck Holder Plate Mounting to Tighten Rotary Chuck

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 10.13 on page 10-24.)

Configuration is complete.

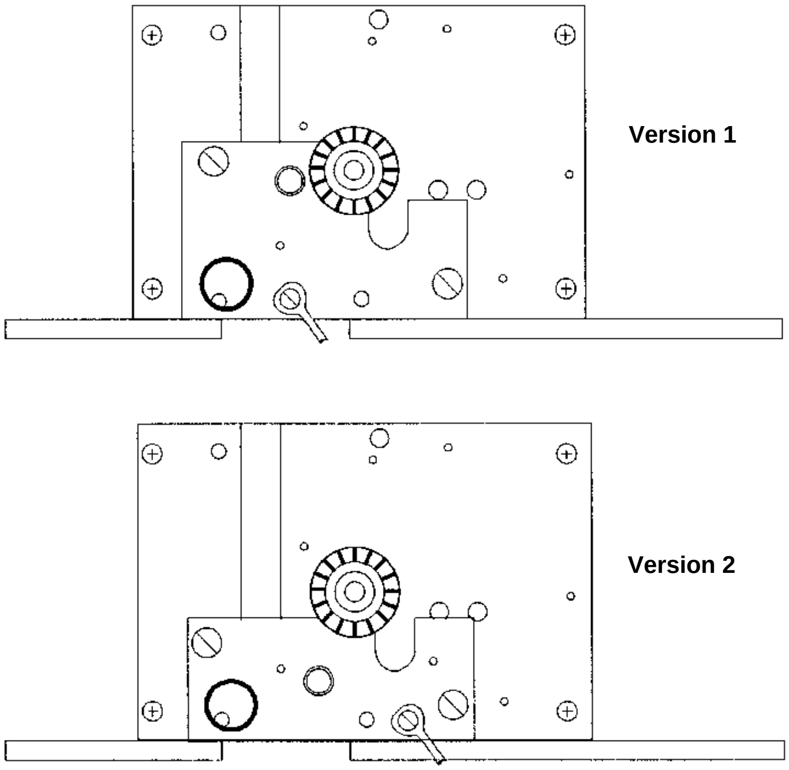


Figure 10.13 Chuck Holder Plate mounted in ROTARY position

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 10.14 on page 10-25.)
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 page 10-23.

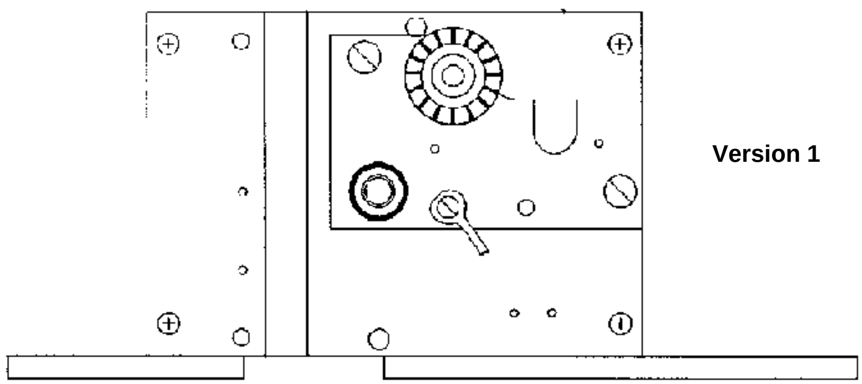
5. Store the rotary chuck on the chuck holder plate as shown in Figure 10.11 on page 10-22.

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 10.14.

Configuration is complete.



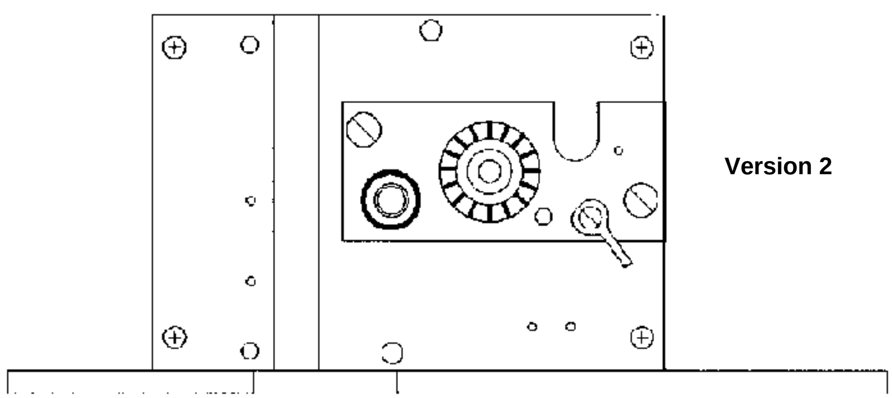


Figure 10.14 Chuck Holder Plate Mounted in LINEAR Position

Configuring the TR3160™ Motion Transducer

The TR3160 Motion Transducer is used to measure linear or, with the optional TR3165 rotary adapter, rotary motion. The setup for both is described below.

There are two configurations of the TR3160, which differ only in the design of the rotary adapter mechanism:

- The TR3160 model has a rotary adapter (see Figure 10.15).
- The TR3160LR has the chuck holder plate described in "Configuring the TR3190 Digital Rotary/Linear Transducer" on page 10-21. Use the procedures given in this section to configure the TR3160LR.

  The TR3160LR configuration is also indicated in the serial number on the side of the transducer.

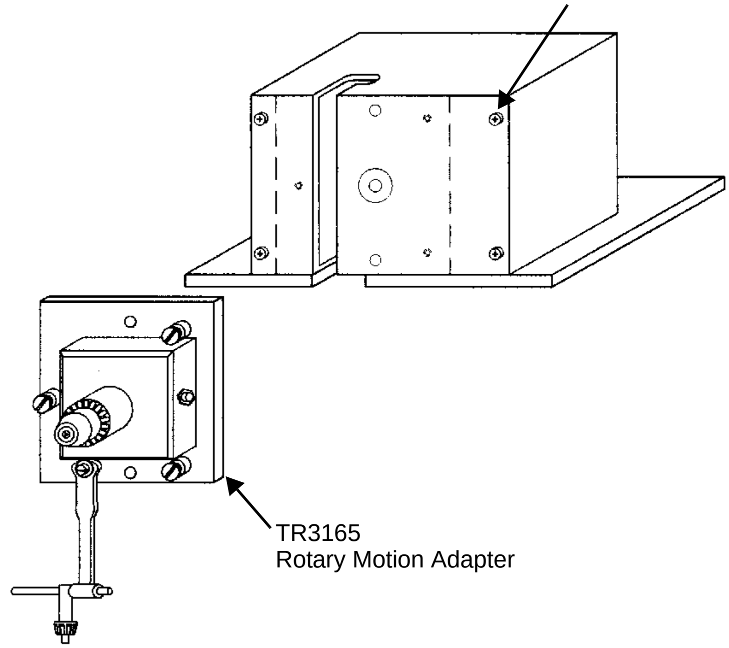


Figure 10.15 TR3160 Transducer Components

The rotary adapter, shown in Figure 10.16, provides two different functions:

- When mounted in the ROTARY position, the adapter toggles a micro-switch that indicates to the instrument that a rotary measurement is being performed.
- When mounted in the ROTARY position, it covers the gate area, which serves as a reminder that it must be removed prior to inserting the travel rod to perform a linear measurement.

NOTE

If the rotary chuck requires tightening, tighten while using the locking pin to hold the rotary shaft in place.

To tighten the rotary chuck:

1. Press on the locking pin while rotating the rotary chuck. The locking pin drops into a slot in the rotary shaft and holds the rotary shaft in place.
2. Insert the chuck key into the rotary chuck and tap it with a light object until the rotary chuck rotates clockwise.

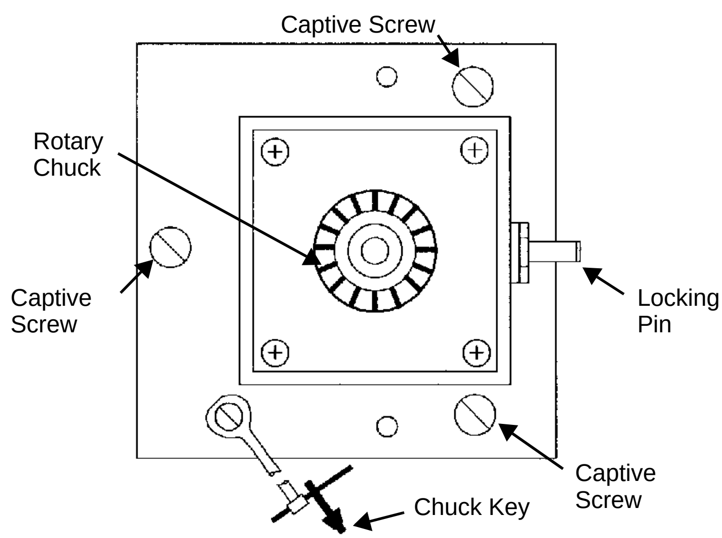


Figure 10.16 Rotary Adapter

Rotary Motion

To configure for rotary motion:

1. Mount the rotary adapter onto the transducer by inserting the hex shaft that extends from the back of the rotary chuck into the hexagonal opening in the face of the transducer and align the three captive screws. (See Figure 10.17.)
2. Tighten the captive screws.

   Configuration is complete.

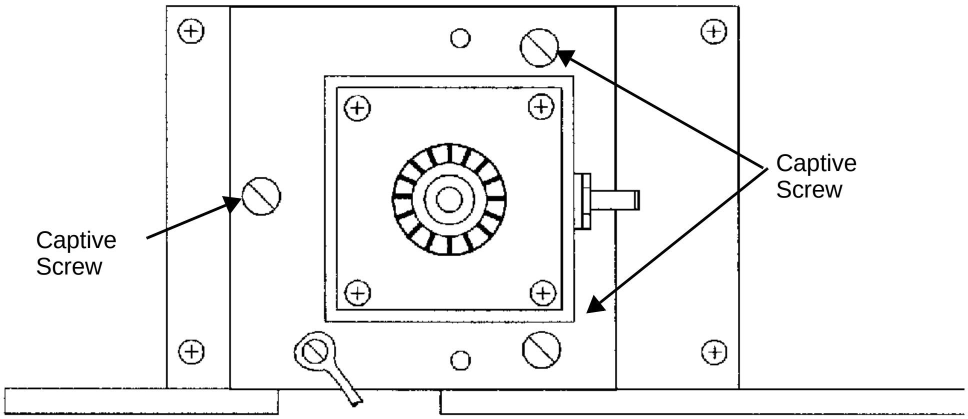


Figure 10.17 Rotary Adapter Mounted on Transducer

Linear Motion

To configure for linear motion:

1. Remove the rotary adapter from the transducer by loosening the three captive screws.
2. Store the rotary adapter in the cable bag to avoid damage.

Configuration is complete.

Step 4: Creating a Test Plan

Go to Chapter 6, "Setting Up Tests," for instructions. Then go to "Step 5: Removing Safety Grounds" on page 10-29 to continue.

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
- High voltages

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.

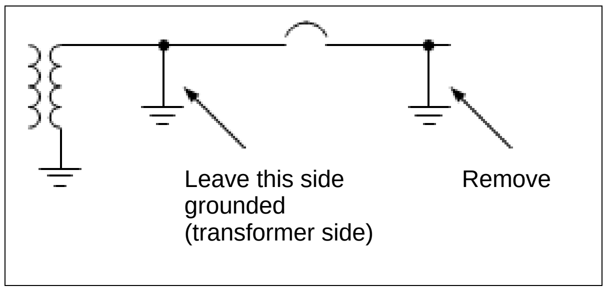


Figure 10.18 Neutral-Grounded Transformer and Ground Connections

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

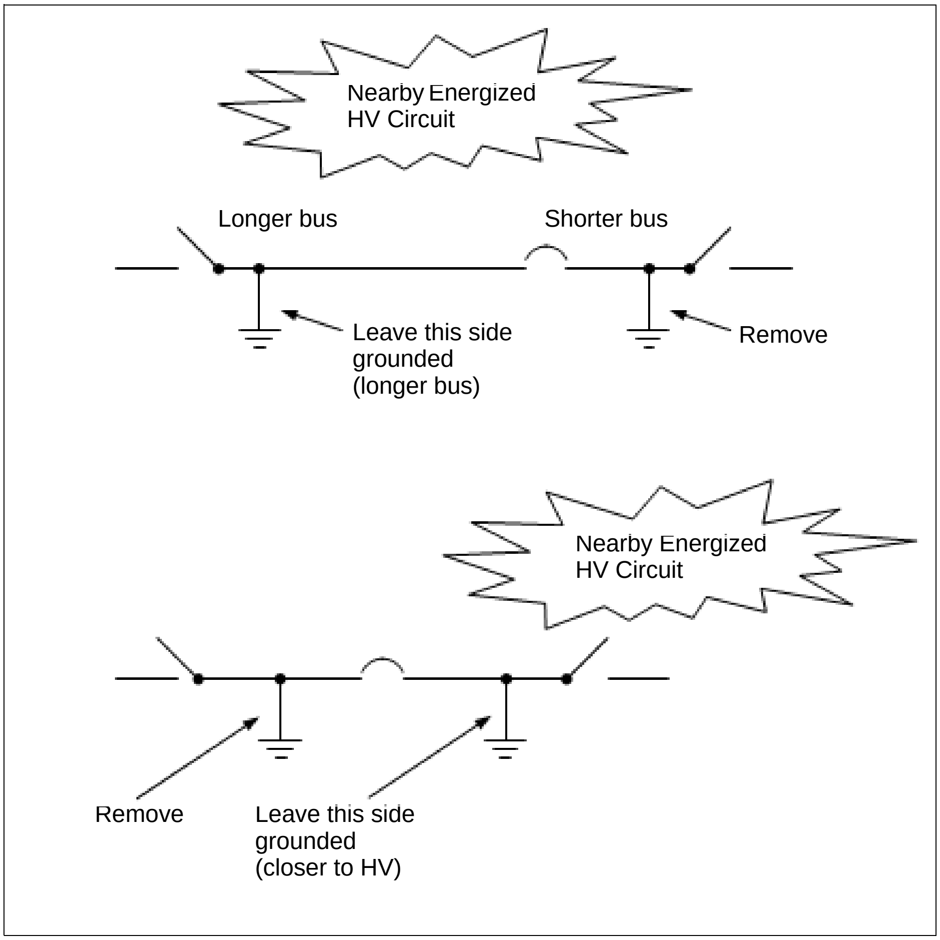


Figure 10.19 High Voltages and Ground Connections

Step 6: Using the Pretest Checklist

Use the checklist given in Table 10.5 to ensure that the system is safely configured for testing.

Table 10.5 Pretest Checklist

Item	
Circuit breaker under test is removed from service according to government and company safety rules. (Not applicable to First Trip tests.)	☐
The TDR900 is properly grounded with a safety ground cable.	☐
Proper AC power is available.	☐
All cables are connected to the TDR900.	☐
Transducer connecting rod is coupled to the circuit breaker rod. (Not applicable to First Trip tests.)	☐
Rotary Attachment is installed. (Optional. Not applicable to First Trip tests.)	☐
All Motion Transducer cables are connected to the corresponding transducer. (Not applicable to First Trip tests.)	☐
All contact monitor cables are connected to the circuit breaker. terminals (Not applicable to First Trip tests.)	☐
After OCB or EHV connections are made, some grounds are removed for purposes of test. (Not applicable to First Trip tests.)	☐
The test plan has been configured.	☐
All the current probes are zeroed (if used).	☐

Step 7: 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 instrument.

Step 8: Running the Test

Safely Activating a Test

The TDR900 provides three 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.
- Operate button—Press the **Operate** button on the face of the instrument to activate the test.
- T-Doble—With the Safety Flag Plug 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.

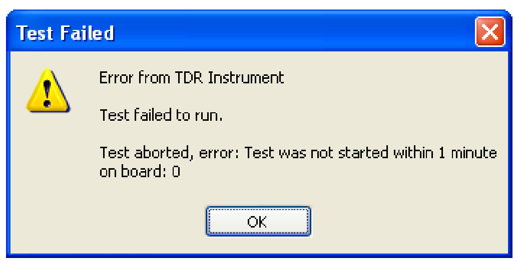


Figure 10.20 Test Aborted—Slow Switch Release

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

Figure 10.21 Test Aborted—Premature Switch Release

Procedure

To run a test:

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

The Select Test window appears.

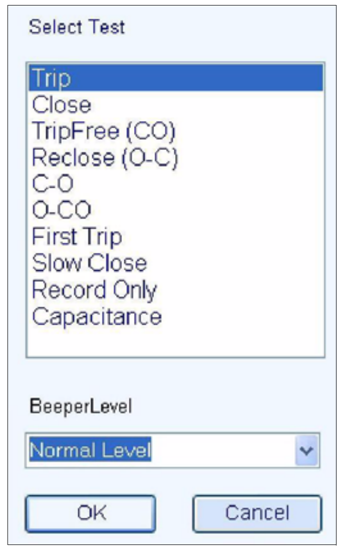


Figure 10.22 Select Test Window

2. Select the test of interest.

The instrument 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 10.23 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 in the Plots window. See Chapter 8, "Displaying and Interpreting Test Results," for information.

Step 9: Disconnecting After the Test

1. Turn the power switch of the TDR900 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 TDR900 second.**

4. Remove the contact monitor cables from the circuit breaker.

   Do not pull the cables. Remove the cables at the connection.
5. Unplug the following cables from the instrument:
   a. Contact Monitor
   b. Motion Transducer
   c. Breaker Control
6. Unplug the AC power cord from the power receptacle.
7. Unplug the AC power cord from the instrument.
8. Remove the safety switch cable from the **SAFETY** receptacle on the instrument.
9. Remove the safety ground from the TDR900.
10. Remove safety grounds from the circuit breaker.
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.

11. TDR9000 Hardware and Supported Tests

This chapter describes the TDR9000 hardware and optional accessories, and provides a brief overview of the tests supported by the TDR9000. This chapter contains the following sections:

Introduction

The TDR9000 Circuit Breaker Testing System is a configurable, modular instrument with flexibility for a wide array of configuration possibilities. The instrument measures, analyzes, and records the electrical and mechanical performance of circuit breakers in the field.

The T-Doble software can configure the instrument to perform both on-line and off-line circuit breaker tests, as well as read inputs from a varying set of external data collection devices connected through the Event module channels.

Figure 11.1 shows the TDR9000 in one of its more comprehensive configurations, which is used for live tank and dead tank circuit breaker testing. It contains:

- One OCB/Motion module with three motion channels
- Two EHV modules
- Two Event modules with three analog and three auxiliary contact channels each
- A System module (required) that includes the optional Trip/Close Current and Trigger In/Out functions

Front Panel Characteristics

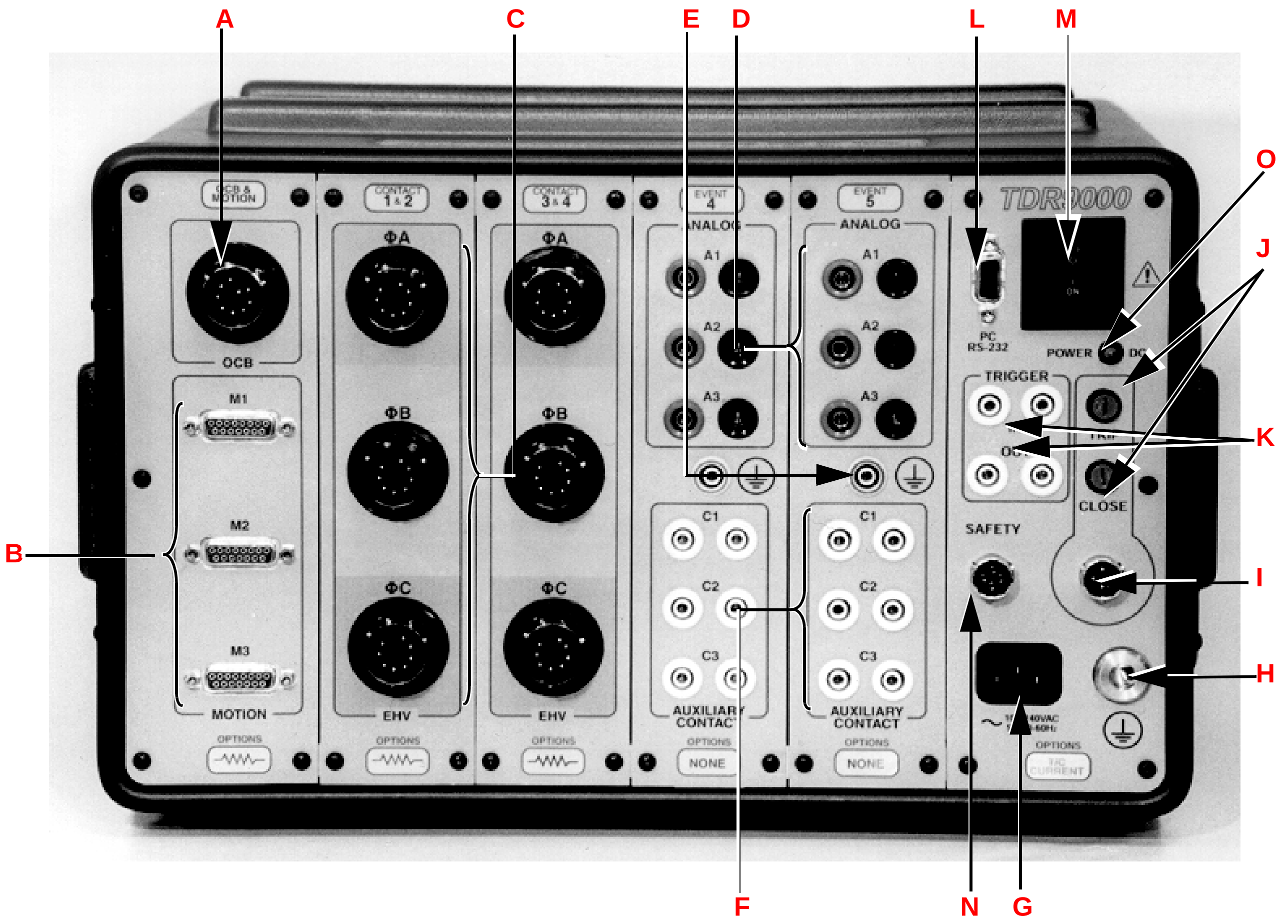


Figure 11.1 TDR9000 Configured for Live and Dead Tank Testing

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Table 11.1 TDR9000 Front Panel Connections and Switches

Item	Description
A	OCB contact monitor cable connector, circular 12-pin male
B	Motion transducer cable connectors, 15-pin female
C	EHV contact monitor cable connectors, circular 12-pin male
D	General-purpose analog measurement connectors (shrouded banana jack) for voltage, current shunt, and current probe inputs
E	Shrouded banana jack connector for connecting the shield lead of analog test cables to the chassis ground
F	Auxiliary contact timing measurement connectors (shrouded banana jack)
G	IEC standard power cord connector, 3-pronged male
H	System safety ground Twist-Lock connector used with the ground cable
I	Trip/Close control connector, 5-pin male
J	Trip and Close fuses
K	Trigger In and Trigger Out connectors (shrouded banana jack)
L	RS-232 connector, 9-pin female for the Doble-supplied serial communications cable
M	Power ON/OFF switch
N	Safety switch cable or safety bypass flag connector, 4-pin male
O	DC power sources valid operation LED

Optional Accessories

The following optional accessories can be ordered with the TDR9000:

- Optional 90 ft (27 m) test cable (OCB or EHV)
- Safety flag plug
- Doble motion transducers
- Mechanical adapter clamp set. (Kit includes three (3) C-clamps and six (6) Vise-Grip C-clamps)
- Doble current probes (20 A/200 A ranges)
- 3 A fast blow fuses
- Printer model P1 external USB thermal printer
- Additional T-Doble software licenses

System Topography

Figure 11.2 on page 11-5 shows the topology of the TDR9000 in the test environment.

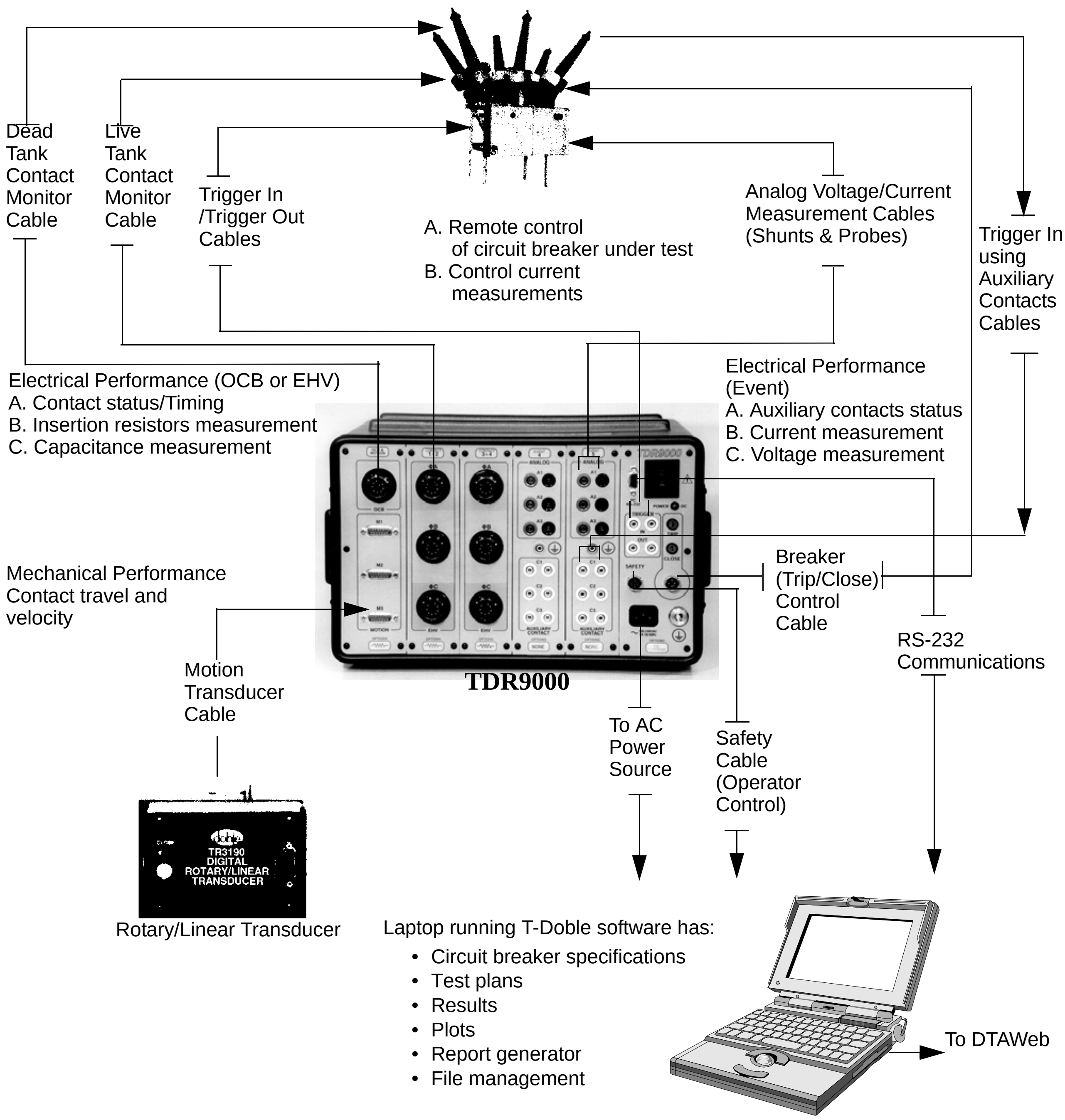


Figure 11.2 TDR9000 System Topology

Modules and Backplane Slots

Figure 11.3 shows the numbering that identifies the boards that populate the TDR9000 backplane.

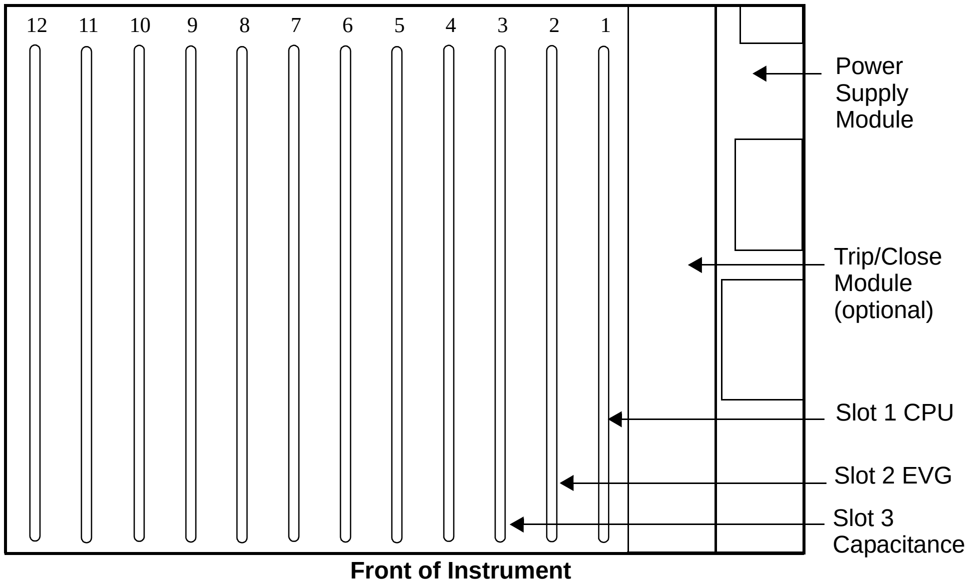


Figure 11.3 TDR9000 Backplane Slots - Top View

Modules can be installed in various combinations by Doble when the system is ordered. Some modules have two boards (a master and a slave) and require two backplane slots in order to operate. As a result, once a location is configured for a one-board module, a two-board module cannot be placed there later.

When it is possible to change module types, you must also change the backplane card or cards. *Always follow the instructions provided by Doble.*

OCB/Motion Module

OCB and Motion are independent functions that are packaged together for convenience. You can order a module that includes OCB functions only, Motion functions only, or a combination of the two. Figure 11.4 shows the available configurations.

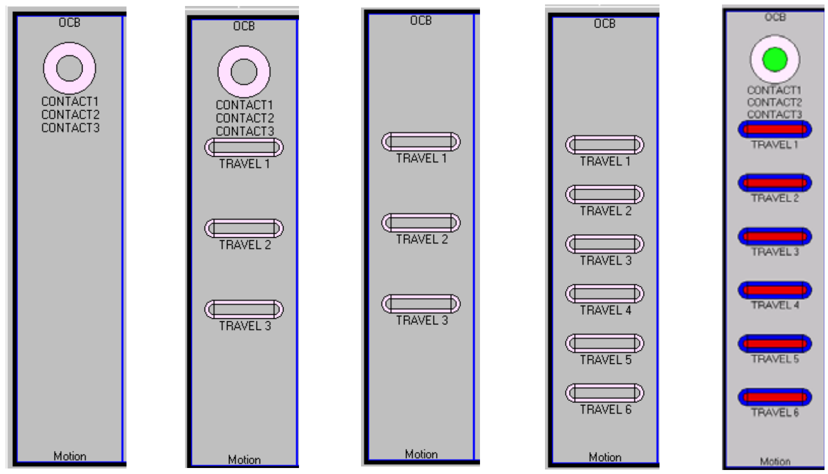


Figure 11.4 OCB/Motion Module Configurations

OCB Function

The OCB channel measures main contact and resistor switch timing for circuit breakers that allow access to only a single measurable break per phase. The OCB function measures main and resistor switch contact timing for single-break-per-phase circuit breakers. Close pre-insertion and grading resistor value ranges are configurable; this configuration applies to all three contacts of the OCB connector.

Status information is available for each contact. In addition, the Doble T9120 option measures the resistance of close pre-insertion and grading resistors.

Using the motion channels, T-Doble can set two user-defined zones for the measurement of average velocities and a range of expected speeds that should occur in those zones. Additionally, to accommodate the need for indirect measurements on some transducers, T-Doble includes 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.

Setting the OCB Parameters

OCB parameters are set in two locations:

- Basic Limits tab of the Breaker page (see page 4-9 for configuration)
- Main Contact Channels tab of the Test Plan (see page 5-1 for configuration)

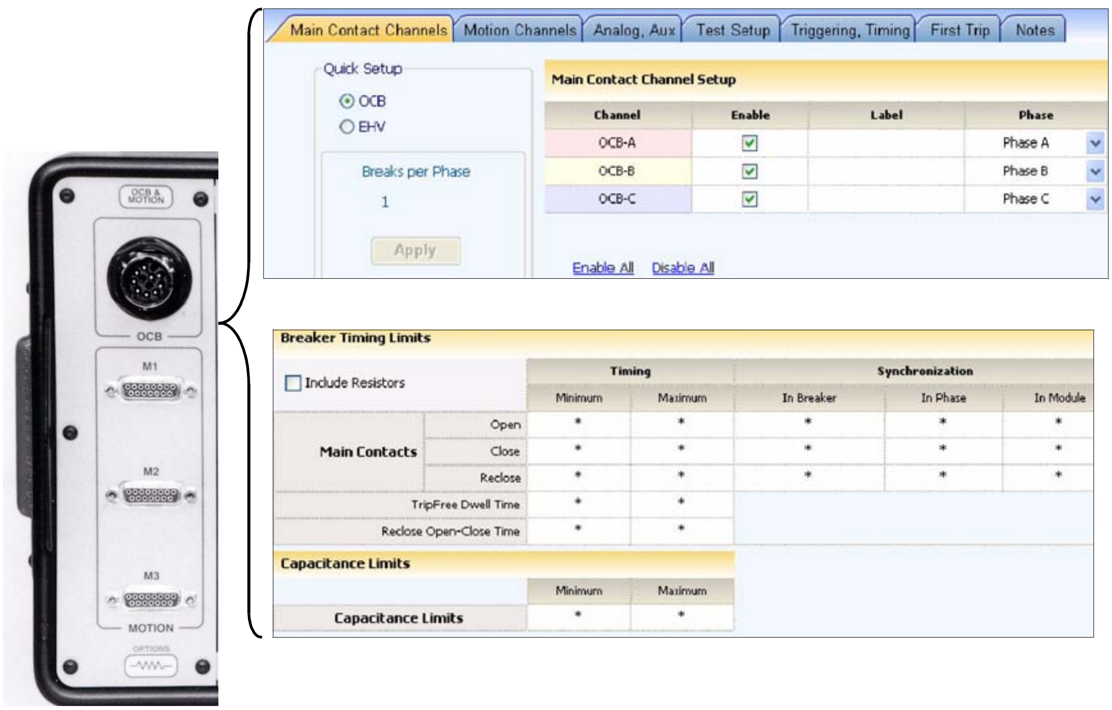


Figure 11.5 OCB Connector and Parameters

Motion Functions

The Motion function records the motion of the circuit breaker contacts through a digital rotary or linear transducer attached to the operating mechanism. Possible configurations include three or six motion channels. The software accommodates:

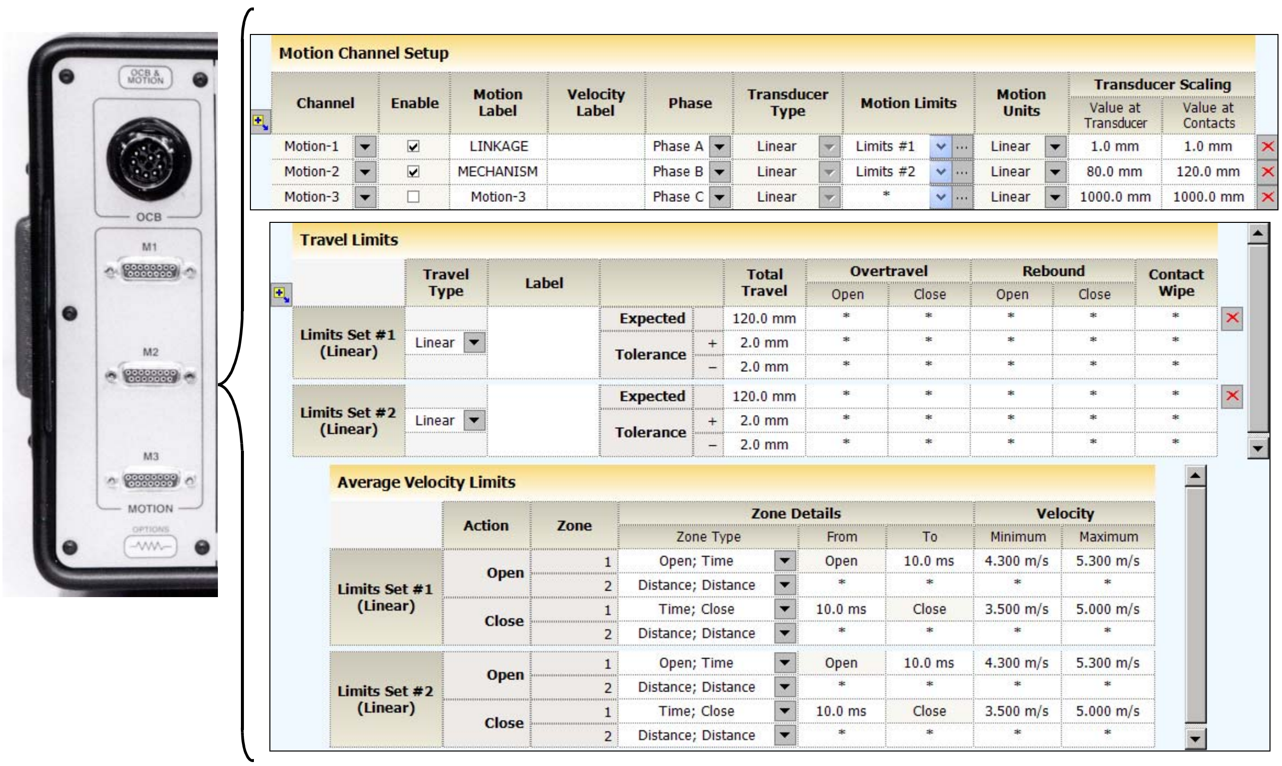
- User-defined zones of measurement for calculating average velocities
- Indirect motion measurements via transducers and transducer scaling as specified by user-defined inputs

T-Doble enables you to set two user-defined zones for the measurement of average velocities and to set a range of expected velocities that should occur in those zones. Additionally, T-Doble includes transducer scaling to accommodate the need for indirect measurements on some circuit breaker mechanisms. Transducer scaling uses two user-entered values to perform a scaling calculation that correlates a measurement taken at a transducer to the motion of the contacts.

Setting the Motion Parameters

Motion parameters are set in two locations:

- Motion Channels tab of the Test Plan page (see page 5-2 for configuration)
- Motion Limits tab of the Breaker page (see page 4-30 for configuration)



Motion Channel Setup

Channel	Enable	Motion Label	Velocity Label	Phase	Transducer Type	Motion Limits	Motion Units	Transducer Scaling: Value at Transducer	Transducer Scaling: Value at Contacts
Motion-1	☑	LINKAGE		Phase A	Linear	Limits #1	Linear	1.0 mm	1.0 mm
Motion-2	☑	MECHANISM		Phase B	Linear	Limits #2	Linear	80.0 mm	120.0 mm
Motion-3	☐	Motion-3		Phase C	Linear	*	Linear	1000.0 mm	1000.0 mm

Travel Limits

	Travel Type	Label			Total Travel	Overtravel Open	Overtravel Close	Rebound Open	Rebound Close	Contact Wipe
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: Zone Type	Zone Details: From	Zone Details: To	Velocity: Minimum	Velocity: 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 11.6 Motion Connectors and Parameters

EHV Module

The EHV module measures the main contact and resistor contact timing for circuit breakers (usually live tank circuit breakers) having two or more measurable breaks per phase. The EHV module can reside in Locations 2 through 5. Each EHV module measures two breaks per phase on all three phases.

Options are available to measure (1) the ohmic value of the close pre-insertion and grading resistor, and, (2) the capacitance of grading capacitor assemblies installed in parallel with the circuit breaker contacts.

Figure 11.7 on page 11-11 gives the available configurations for the EHV module.

Setting the EHV Parameters

EHV parameters are set in two locations:

- Main Contact Channels tab of the Test Plan page (see page 5-1 for configuration)
- Basic Limits tab of the Breaker page (see page 4-9 for configuration)

Breaker Timing Limits

☑ Include Resistors		Timing		Synchronization		
		Minimum	Maximum	In Breaker	In Phase	In Module
Main Contacts	Open	19.0 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 µs				

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 11.7 EHV Configuration and Parameters

Event Module

This module consists of two sets of channels:

- Analog channels
- Auxiliary contact channels

A combination of these channels is used to monitor the characteristics of the circuit breaker's operating mechanism. 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. (See Chapter 7, "Triggering and Timing Setup," for more information.)

NOTE	**The Event modules are numbered from left to right. Be sure that the connections you make on the Front Panel reflect this numbering order. This module can be used in Locations 1 through 5.**

Analog Channels

T-Doble can configure the three general-purpose analog inputs to read voltages directly or to read currents from Doble probes (P/N 401-0055) and custom current probes. Analog inputs are converted by a high speed, 12-bit analog-to- digital converter and then recorded at the instrument 10 kHz sample rate.

NOTE	**For applications using a current probe, you must zero the probe. See "Doble Probe" on page 12-8.**

Auxiliary Contact Channels

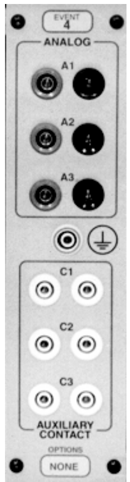
The auxiliary contact channels monitor the state of up to three sets of auxiliary contacts, ascertaining whether a contact is:

- Closed
- Open Dry: No voltage detected on the open contact
- Open Wet: Voltage detected on the open contact

The TDR9000 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 contact channels are set on the Analog, Aux tab of the Test Plan page (see page 5-8 for configuration).



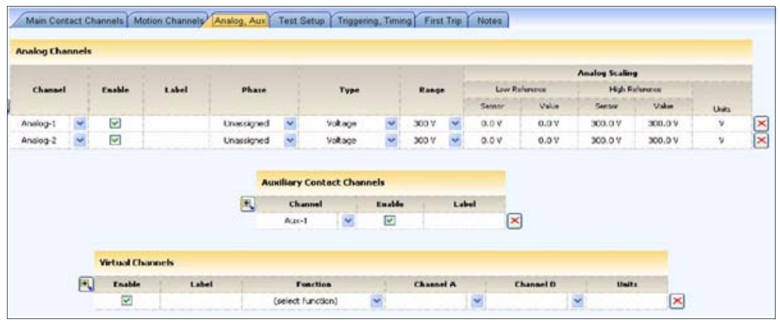


Figure 11.8 Event Module Configuration and Parameters

System Module

The System module is mandatory and must be installed in Location 6. It provides basic functions such as communications, power, and test control. The module is minimally comprised of:

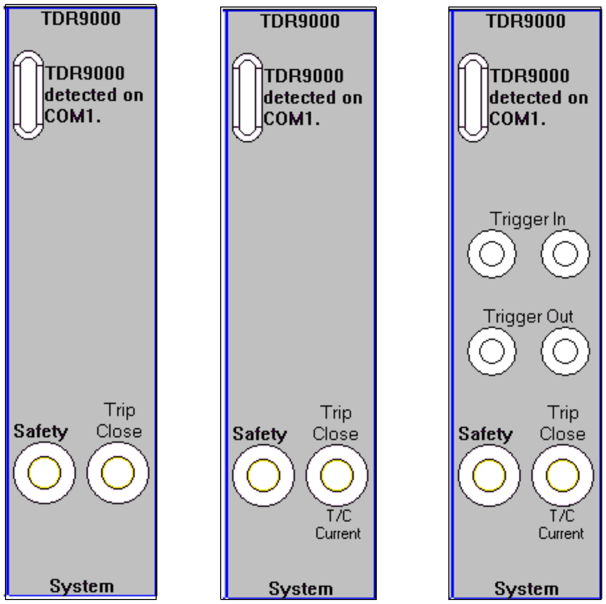
- Power switch
- RS-232 communications connector (to the laptop)
- Safety switch cable input connector
- AC power supply receptacle
- System ground connector
- Trip/Close basic function

Two optional functions are available for the System module:

- Trip/Close Current—Internally measures the Trip and Close currents
- Trigger In/Trigger Out—Triggers input during First Trip tests or when TDR9000 is in recording mode.
    - Trigger In—Monitors an external trigger (such as an auxiliary contact) to initiate a test.

- Trigger Out—Operates a circuit breaker or other device using an input generated by the TDR9000. Trigger Out pulse width and delay are configurable.

Figure 11.9 shows the available configurations for the System module.



Basic Trip/Close Function | Trip/Close and Current Option | Trip/Close, Current, and Triggers

Figure 11.9 System Module Configurations

Trip/Close Function

Trip/Close operates the circuit breaker under test through the action of solid-state switches. Because Trip/Close is polarity-insensitive, the user need not know lead polarity.

The Trip/Close control function consists of hardware inside the TDR9000, and connectors, fuses, and protection circuits. Trip/Close enables the TDR9000 to control the following tests:

- Trip (O)
- Close (C)
- TripFree (CO)
- C-Delay-O
- Reclose (O-C)
- O-CO, O-0.3 s-C), and O-Delay-C-Delay-O

Trip/Close normally connects across the circuit breaker manual Trip or Close switch, as shown in Figure 11.10.

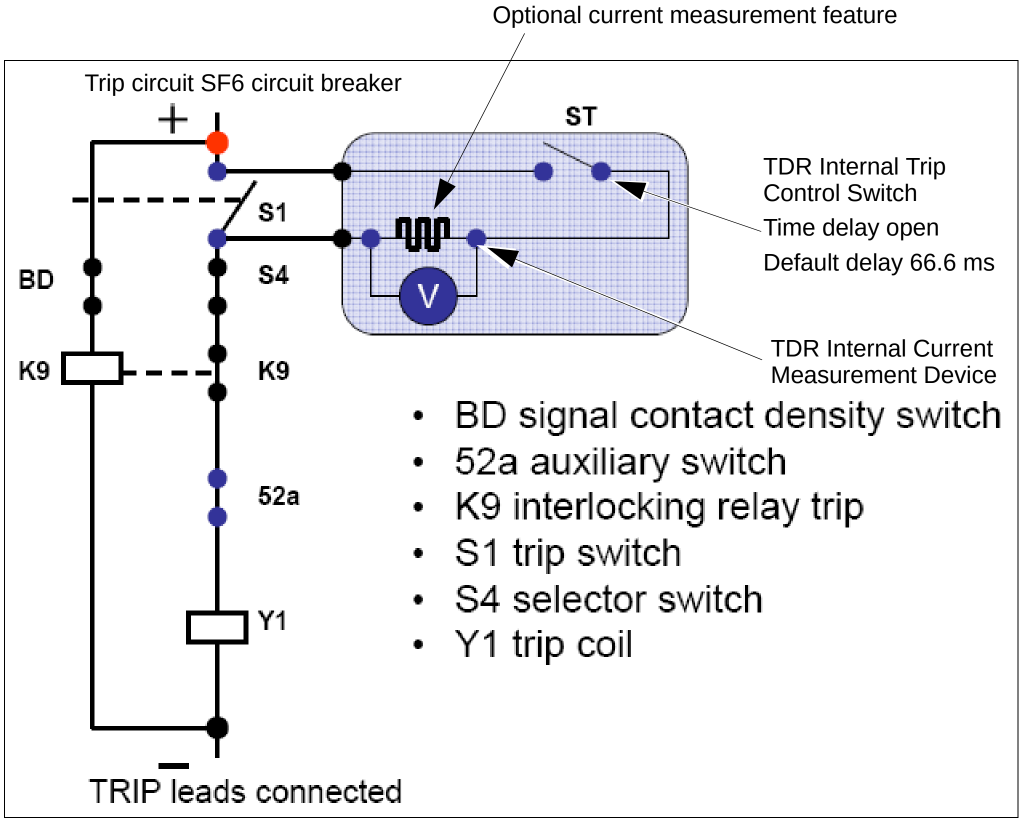


Figure 11.10 Trip/Close Module Application

Setting the Trip/Close Parameters

The Trip/Close parameters are set in the Test Setup tab of the Test Plan page (see page 6-20 for configuration).

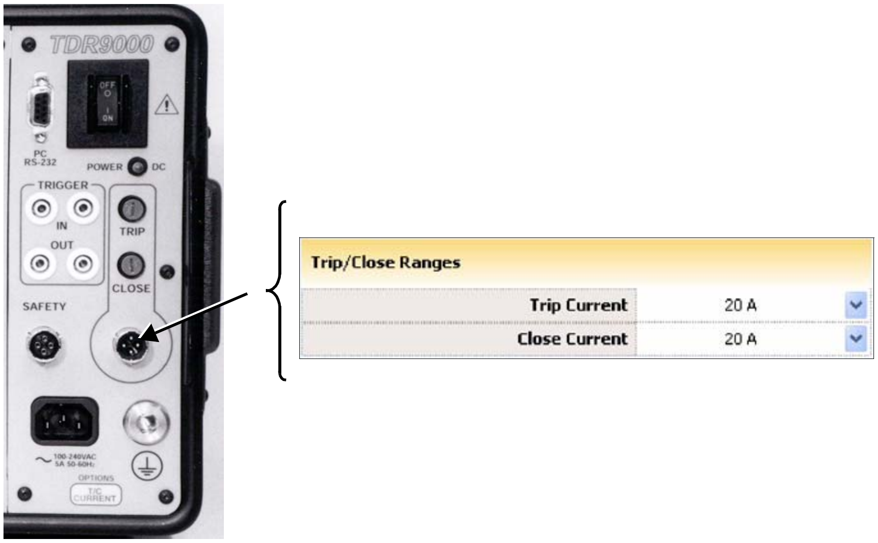


Figure 11.11 Trip/Close Function of System Module

Optional Current Measurement Feature

The Trip/Close function can be outfitted with an optional feature that measures the internal Trip and Close circuit current during a Trip/Close test by:

- Passing Trip and Close currents through current:mV shunts in the Trip/Close module
- Converting the measured voltage to a digital reading
- Displaying the result as a current waveform or as a peak current value

Optional Trigger Functions

The TDR9000 comes with Trigger Input and Trigger Output capabilities.

Setting the Trigger Parameters

The Trigger parameters are set in the Triggering, Timing tab of the Test Plan page. (See Chapter 7, "Triggering and Timing Setup," for more information.)

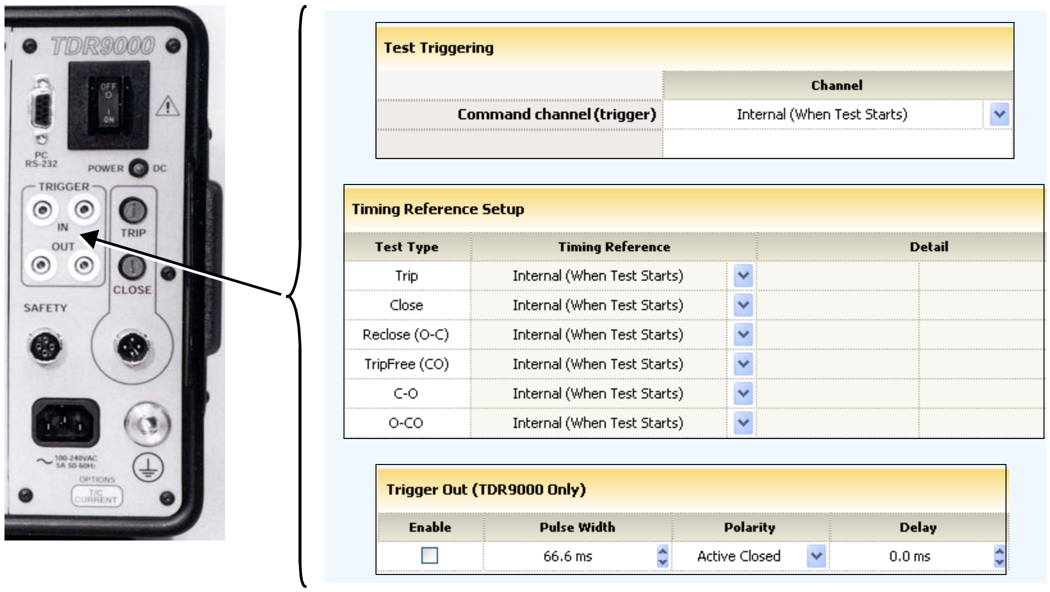


Figure 11.12 Trigger In and Trigger Out Functions of System Module

Other Front Panel Functions

Serial Interface Connector

Serial communication is via the electrically-isolated PC RS-232 connection. The baud rate of this connection is set at 38.4 kbits/s. Doble supplies a 25 ft (7.6 m) double-shielded cable for connecting this interface.

Printer Port

The TDR9000 can be ordered with a Pentax® PocketJet II™ thermal printer. The printer provides print outs of test plans, tabular results and graphical results in the field. For easy storage and transport, the printer is mounted in the instrument cover. When in use, the printer is connected to the PC's parallel port.

TDR9000 Front Panel Configurations

Table 11.2 lists the possible Front Panel configurations. Some configurations require that different boards be used in the backplane slots.

Table 11.2 Front Panel Configurations

Location 1	Location 2	Location 3	Location 4	Location 5	Location 6
Motion/OCB or Empty	Empty	Empty	Empty	Empty	System
Motion/OCB or Empty	EHV 1-2	Empty	Empty	Empty	System
Motion/OCB or Empty	EHV 1-2	EHV 3-4	Empty	Empty	System
Motion/OCB or Empty	EHV 1-2	EHV 3-4	EHV 5-6	Empty	System
Motion/OCB or Empty	EHV 1-2	EHV 3-4	EHV 5-6	EHV 7-8	System
Motion/OCB or Empty	Empty	Empty	Empty	Event 5	System
Motion/OCB or Empty	Empty	Empty	Event 4	Event 5	System
Motion/OCB or Empty	Empty	Event 3	Event 4	Event 5	System
Motion/OCB or Empty	Event 2	Event 3	Event 4	Event 5	System
Motion/OCB or Empty	EHV 1-2	Empty	Empty	Event 5	System
Motion/OCB or Empty	EHV 1-2	EHV 3-4	Empty	Event 5	System
Motion/OCB or Empty	EHV 1-2	EHV 3-4	EHV 5-6	Event 5	System
Motion/OCB or Empty	EHV 1-2	Empty	Event 4	Event 5	System
Motion/OCB or Empty	EHV 1-2	EHV 3-4	Event 4	Event 5	System
Motion/OCB or Empty	EHV 1-2	Event 3	Event 4	Event 5	System

Supported Tests

Table 11.3 lists the ten circuit breaker tests that the TDR9000 performs and gives a state description of the sequencing that comprises the test. When a test is run, the instrument stores and plots the data. The data can be printed to the optional printer in the field or to an office printer.

Trigger Input and Trigger Output are available for all tests.

NOTE

For the First Trip test, if the Trigger Input parameter is set to None (Internal), a dialog box appears stating that only AUX Contact and Trigger In are valid trigger types.

Table 11.3 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
Reclose (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	—	—	—	—
Capacitance: For EHV contacts only. This test checks the capacitance characteristics of the grading capacitors connected across the main contact of a circuit breaker. The circuit breaker must be open, but is not operated during the test.				

Trip Test

During the Trip test, a single user-specified command is issued to open the circuit breaker. For a description of the test command parameter, see "Trip Test" on page 6-4.

Figure 11.13 shows a Trip Command pulse plot generated by the Trip test.

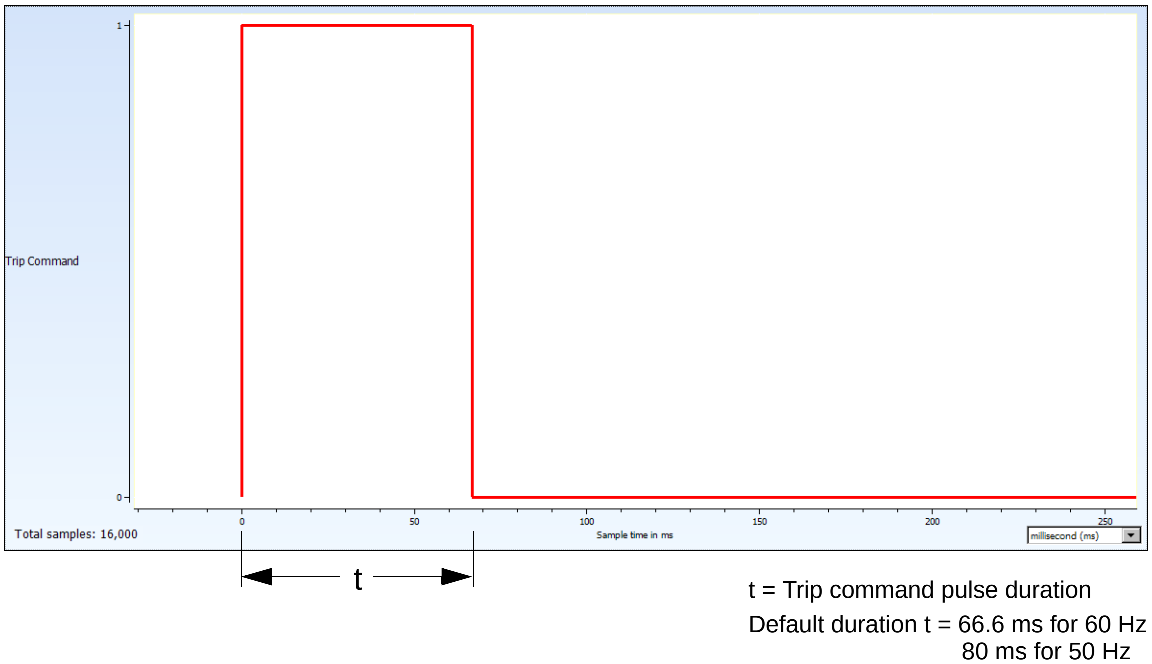


Figure 11.13 Trip Command Pulse

Close Test

During the Close test, a single, user-specified command is issued to close the circuit breaker. For a description of the test command parameter, see “Close Test” on page 6-5.

Figure 11.14 shows a Close Command pulse plot generated by the Close test.

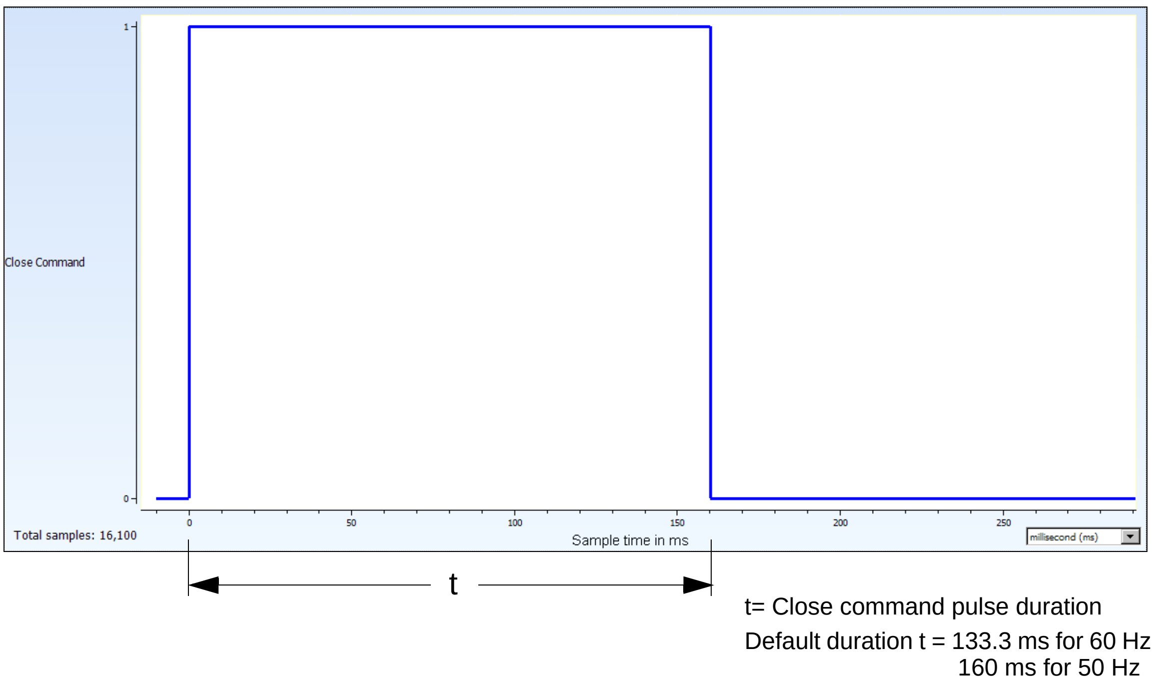
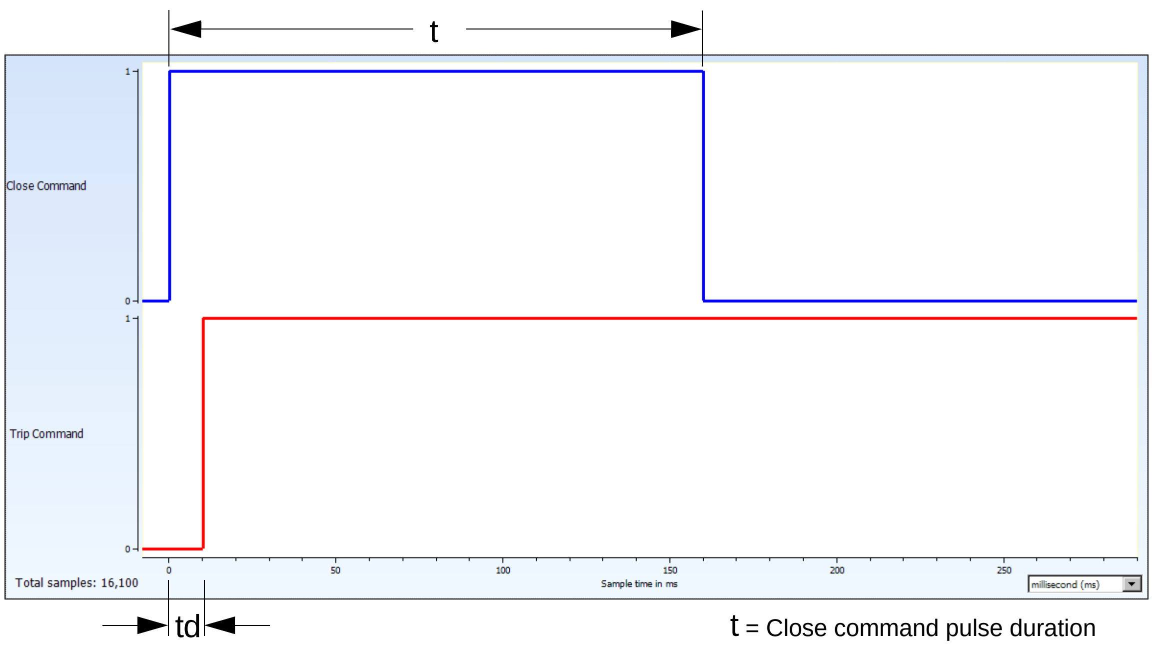


Figure 11.14 Close Command Pulse

TripFree (CO) Test

During the TripFree test, dual, user-specified commands are issued to close the circuit breaker and open it shortly after. For a description of the test command parameters, see “TripFree (CO) Test” on page 6-6.

Figure 11.15 shows the Close and Trip Command Pulse plots generated by the TripFree test.



t = Close command pulse duration
Default duration t = 133.3 ms for 60 Hz
160.0 ms for 50 Hz

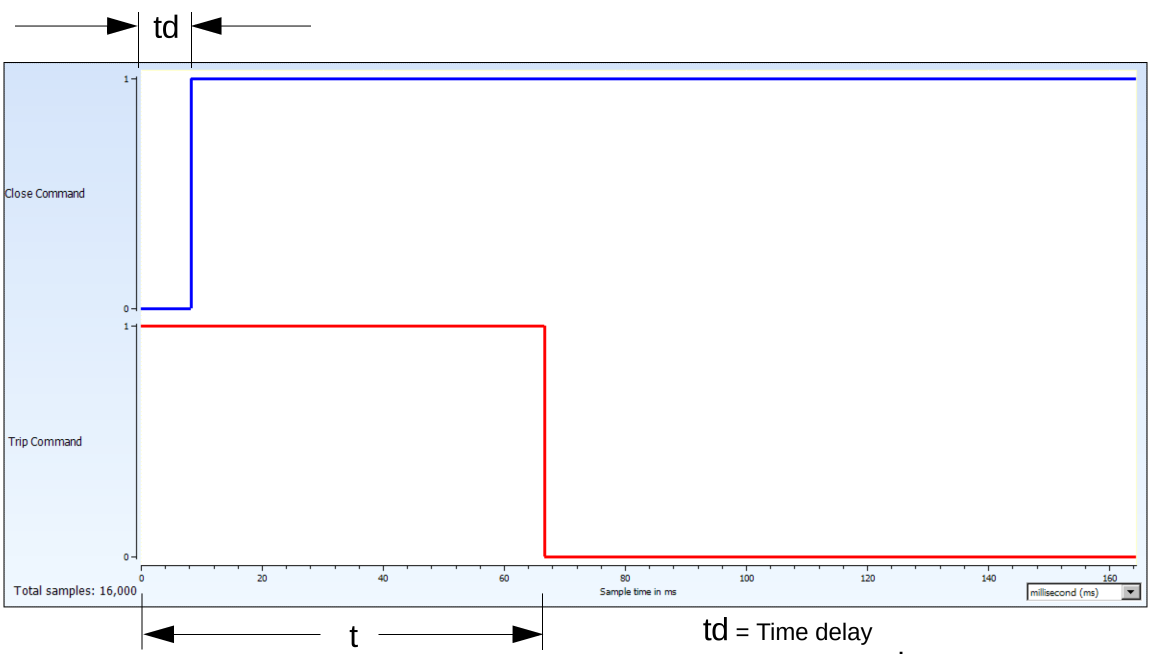
td = Time delay
Default duration td = 8.3 ms for 60 Hz
10.0 ms for 50 Hz

Figure 11.15 TripFree Command Pulse

Reclose (O-C) Test

During the Reclose test, dual, user-specified commands are issued to open the circuit breaker and then close it shortly after. A delay maybe specified to time both operations. For a description of the test command parameters, see "Reclose (O-C) Test" on page 6-9.

Figure 11.16 shows the Trip and Close Command Pulse plots generated by the Reclose test.



td = Time delay
Default duration td = 8.3 ms for 60 Hz
10.0 ms for 50 Hz

t = Trip command pulse duration
Default duration t = 66.6 ms for 60 Hz
80.0 ms for 50 Hz

Figure 11.16 Reclose Command Pulse

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 the delay between closing and opening. For a description of the test command parameters, see "C-O Test" on page 6-12.

Figure 11.17 shows the Close and Trip Command Pulse plots generated by the C-O test.

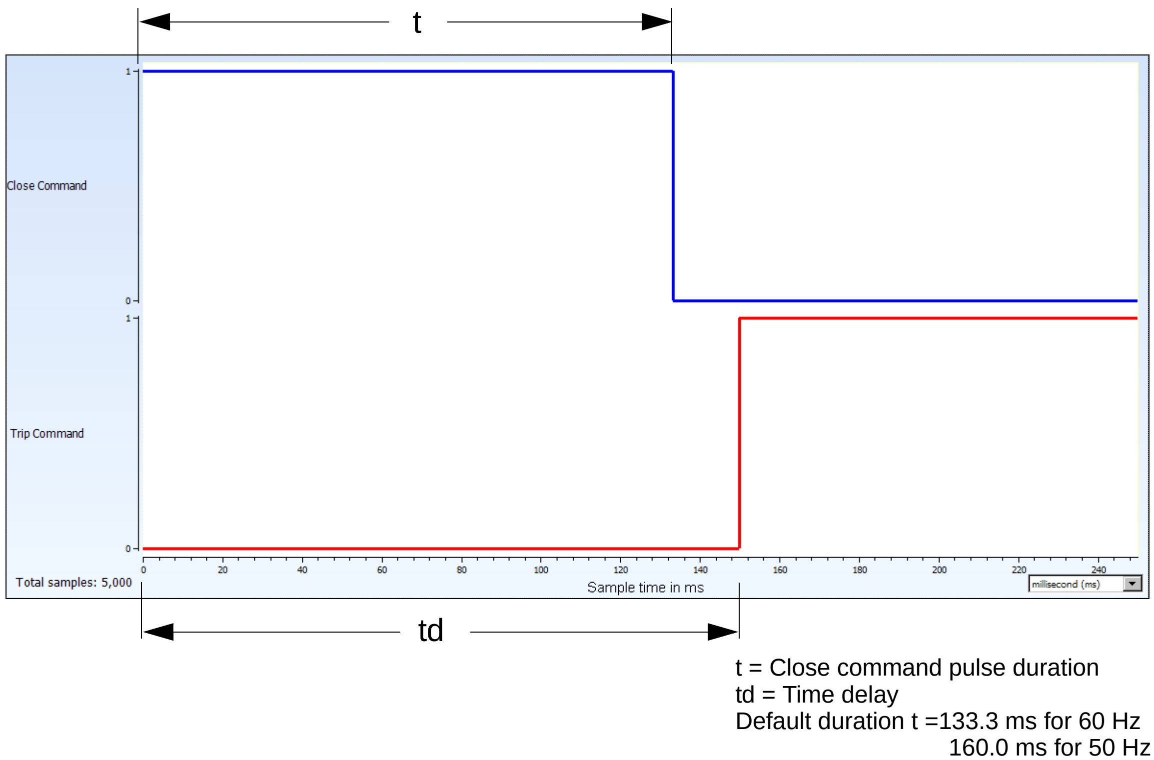


Figure 11.17 C-O Command Pulse

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. For a detailed description of the test, see “O-CO and O-C-O Tests” on page 6-14.

Figure 11.18 shows the Trip and Close Command Pulse plots generated by the O-CO and O-C-O tests.

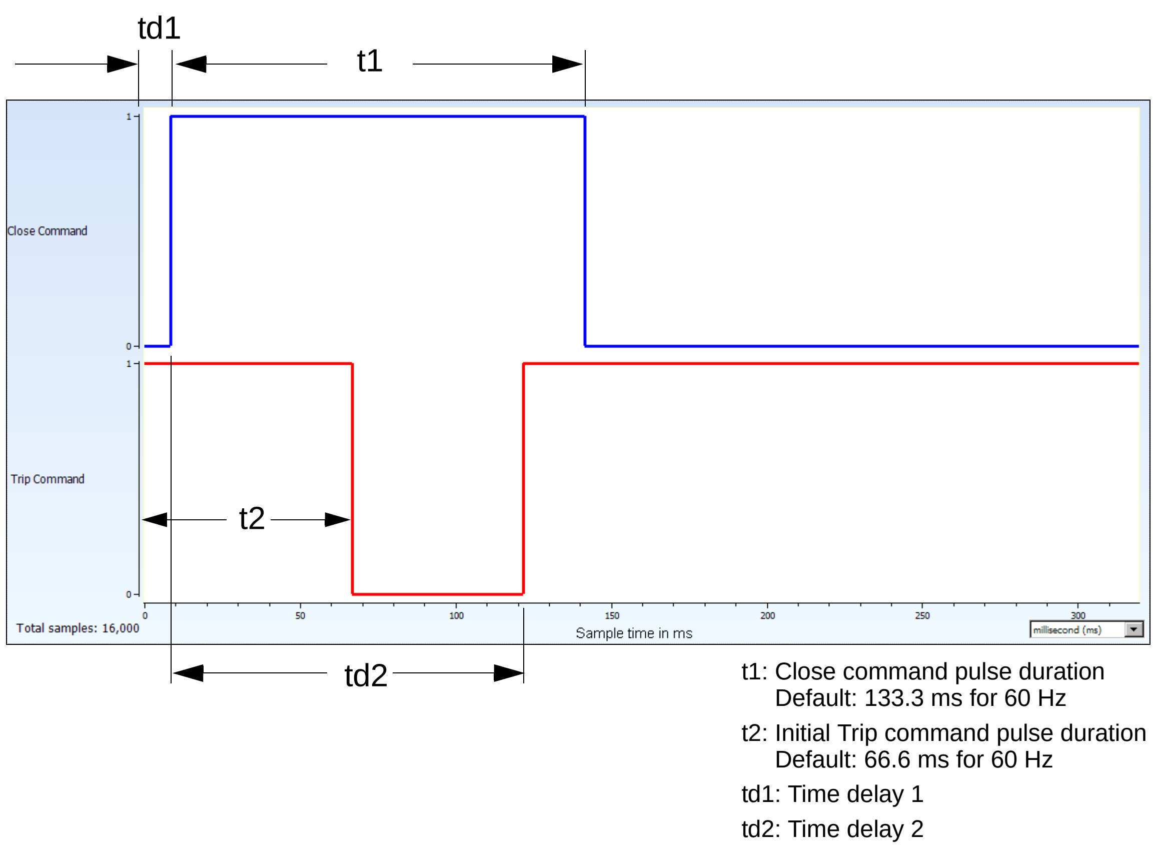


Figure 11.18 O-C-O Command Pulse

First Trip Test

The First Trip test uses the analog and auxiliary channels of the TDR instrument 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.

For a complete discussion of the First Trip test, see "First Trip Test" on page 6-31.

Record Only Test

The Record Only test is a convenience for users who may wish to record a customized setup that is not included in the standard test operation types.

Capacitance Test

The Capacitance Measurement test is used to measure EHV grading capacitors. These capacitors are located in parallel with the main contacts and can be measured through the EHV instrument inputs when the contacts are open. The test consists of measuring capacitance, in the range of 75 to 10,000 pF, between each of the two EHV leads and the common lead for each phase and each module. The test measurement accuracy is in the range of ± 5%. Because the circuit breaker is not operated during the test, no waveform is sent through the system.

12. TDR9000 Setting Up and Running Tests

This chapter provides the minimum information required to make connections between a circuit breaker and the Doble TDR9000 Circuit Breaker Test System, run a test, and save the test results. It contains the following sections:

Front Panel Reference

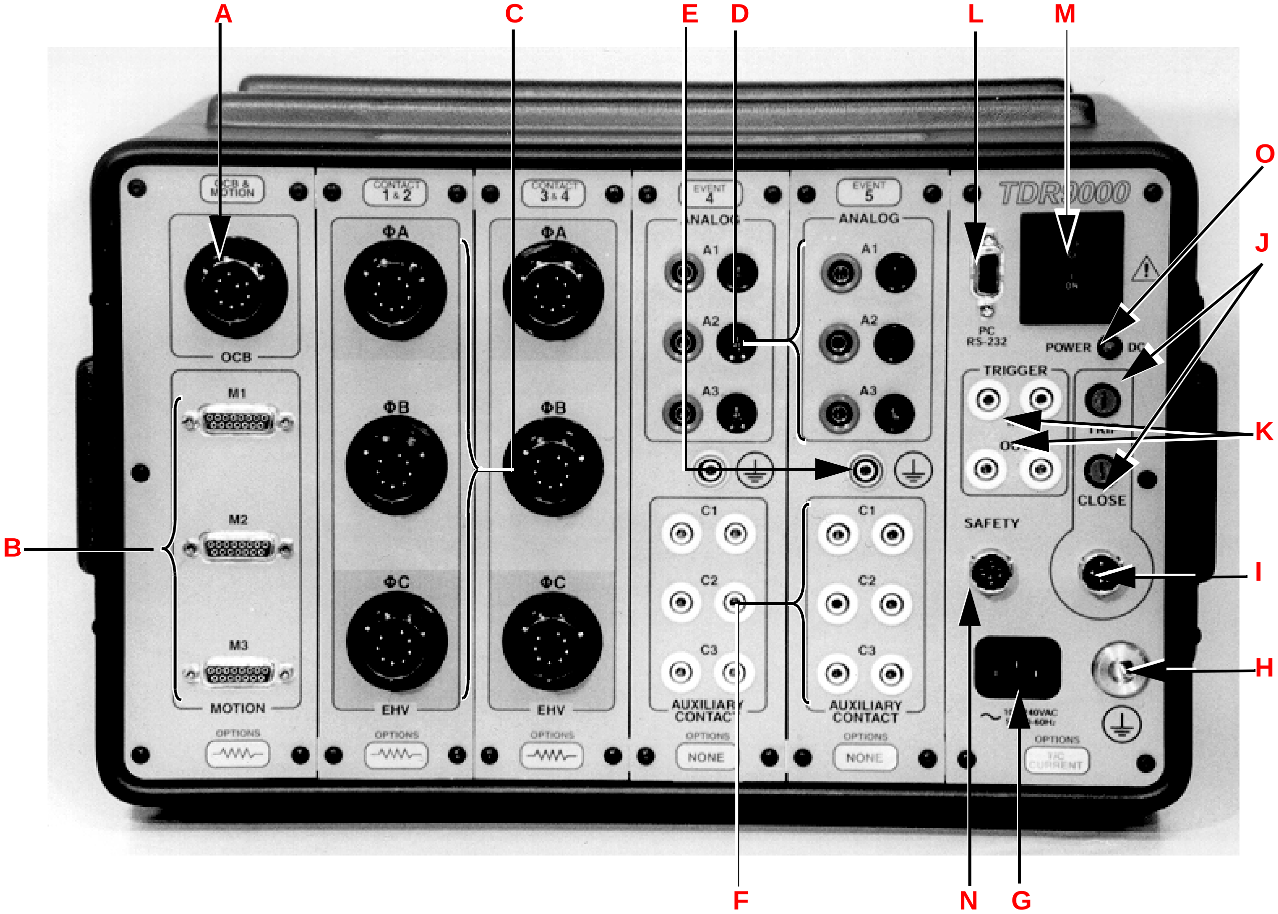


Figure 12.1 TDR9000 Front Panel Connections

Table 12.1 TDR9000 Front Panel Connections and Switches

Item	Description
A	OCB contact monitor cable connector, circular 12-pin male
B	Motion transducer cable connectors, 15-pin female
C	EHV contact monitor cable connectors, circular 12-pin male
D	General-purpose analog measurement connectors (shrouded banana jack) for voltage, current shunt, and current probe inputs
E	Shrouded banana jack connector for connecting the shield lead of analog test cables to the chassis ground
F	Auxiliary contact timing measurement connectors (shrouded banana jack)
G	IEC standard power cord connector, 3-pronged male
H	System safety ground Twist-Lock connector used with the ground cable
I	Trip/Close control connector, 5-pin male
J	Trip and Close fuses
K	Trigger In and Trigger Out connectors (shrouded banana jack)
L	RS-232 connector, 9-pin female for the Doble-supplied serial communications cable
M	Power ON/OFF switch
N	Safety switch cable or safety bypass flag connector, 4-pin male
O	DC power sources valid operation LED

Follow These Steps in 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 12-4).
2. Make connections to the TDR9000 (see page 12-5).
3. Make connections to the circuit breaker (see page 12-12).
4. Remove safety grounds (see page 12-29).

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 TDR9000 is designed to test circuit breakers with one side of the circuit breaker at ground potential at all times.
- The contact monitor cables act as antennae for electrostatic pickup, electromagnetic pickup, or both. In order to minimize this exposure, the TDR9000 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 TDR9000 Connections

> **WARNING!**
>
> **To reduce problems associated with electrostatic discharge, always follow this procedure to connect cables to the TDR9000.**
>
> **Follow all safety procedures.**

1. Confirm that appropriate service disconnects are secured.
2. Connect the safety ground cable.
3. Connect the power supply cable.
4. Connect the communication cable.
5. Connect the remaining cables required for the test to be performed.
6. Make connections to the testing breaker.

Grounding the TDR9000

To ground the TDR9000 and attach the power cable:

1. Remove the front protective cover and store it in a safe place for reuse.

   If a printer is in use, put the cover and printer assembly near the laptop.
2. Plug the ground cable into the System ground receptacle (H in Figure 12.1 on page 12-2). Ground the other end.
3. Plug the safety switch cable into the SAFETY receptacle of the System module (N in Figure 12.1 on page 12-2). If you plan to use an external trigger, plug in the Safety Bypass flag.
4. Ensure that the power supply voltage is correct (100 - 240 V AC, 50 or 60 cycles).
5. Attach the power cord (G in Figure 12.1 on page 12-2).

Connecting the Instrument to the Laptop and Printer

Printer Driver and Power

If the printer driver is not already installed on the laptop, see “Loading the Printer Driver (TDR9000 only)” on page B-4.

Two power sources are provided with the printer:

- Rechargeable battery (Instructions for recharging the battery are given in the *Pentax® PocketJet II™ Printer User's Guide*)
- AC adapter with a standard U.S. cable

NOTE **The AC input range of the printer power supply is narrower than that of the TDR9000. If the available power does not meet printer specifications, use the internal battery. For more information, see the printer user guide.**

To connect the TDR9000 to the laptop and printer:

1. Connect the power cable to the laptop power connector.

2. Connect the RS-232 cable to a laptop COM port and the RS-232 9-Pin D connector on the TDR9000 (**L** in Figure 12.1 on page 12-2). A USB-to-serial dongle may be required for newer laptops.

3. Connect the printer parallel interface or USB cable to the TDR9000 interface connector on the printer. Secure the parallel interface catches.

Figure 12.2 Printer Serial Cable Connector

4. Connect the other side of the printer parallel interface cable to the LPT1 port or USB connector on the laptop.

5. Connect the printer to the power source.

6. Turn the laptop power switch **ON**.

7. Double-click the **T-Doble** icon shown below or select **Start/All Programs/Doble Engineering/T-Doble**.

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 contact monitor cable to OCB connector on the TDR9000 OCB/Motion module and then to the appropriate circuit breaker terminals.

  See **A** in Figure 12.1 on page 12-2. Connect alligator clip leads as labeled: A,B,C Common or 1,2,3 Common.

- EHV contact monitor cables to EHV connectors on the TDR9000 EHV module and then to the appropriate circuit breaker terminals.

  See **C** in Figure 12.1 on page 12-2. Connect alligator clip leads as labeled: PH A, Contact 1,2, Common, etc.

Event Module Connections

Setup for the Event module includes:

- Auxiliary Contact Channels
- Analog Channels: Voltage, Doble Probes, and Custom Probes

Auxiliary Contact Channels

The TDR9000 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 Analog, Aux tab of the Test Plan page (see “Auxiliary Contact Channels” on page 5-10).

NOTE

- **It is possible to factory order an Event module configured for use with 24 V station batteries.**
- **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 (**F** on Figure 12.1 on page 12-2).
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.

Analog Channels: Current and Voltage

The TDR9000 monitors both current and voltage using the Analog Channel connectors of the Event module. The Event module analog channels accept:

- Voltage input (up to 300 V peak)
- Doble probe input (mV 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 Analog, Aux tab. See "Analog Channels" on page 5-8 for more information.

To connect a voltage input:

1. Attach the instrument end of the Doble-supplied analog cable to a pair of Analog Channel banana jacks (**D** on Figure 12.1 on page 12-2).

   The instrument 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 on the Event module (**E** on Figure 12.1 on page 12-2).

   Multiple shields can be stacked (see Figure 12.1 on page 12-2).
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 inputs can be configured for 20 A or 200 A. To configure them, open the Test Plan page and select the Analog, Aux tab. See Figure 12.3.

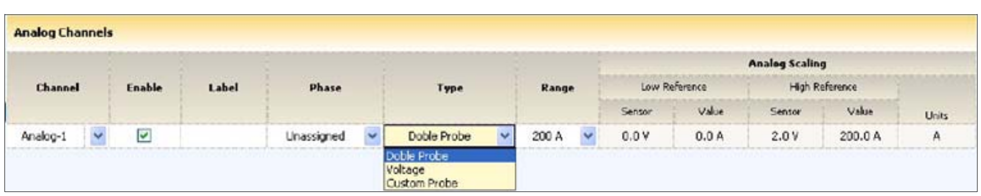


Figure 12.3 Configuring a Doble Probe

You must zero the Doble MR 20 A/200 A/2 V Autozero probe whenever a new test plan is loaded or a channel is activated.

NOTE

To conserve battery power, Doble's MR 20 A/200 A/2 V Autozero 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.

Be 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 instrument end of the probe cable into the desired Analog Channel connector (**D** on Figure 12.1 on page 12-2).

   The Analog Channel inputs are polarity sensitive.
2. Be sure to attach the shield (green and yellow) banana plug to the chassis ground (green and yellow) banana jack on the Event module (**E** on Figure 12.1 on page 12-2). The banana jacks for multiple shields can be stacked.
3. Plug the free end of the analog cable into the current probe.
4. Turn the probe on by setting the selector switch to the desired range.
5. Press the **Zero** button on the probe.
6. Repeat this procedure for any additional probes.
7. Leave the probe on and securely clamp the probe around the wire that carries the current to be monitored.

Custom Current Probe

To set up a custom probe:

1. Connect the instrument end of the Doble-supplied analog cable to a pair of Analog Channel banana jacks (**D** on Figure 12.1 on page 12-2).

   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 on the Event module (**E** on Figure 12.1 on page 12-2).

   Multiple shields can be stacked (see Figure 12.1 on page 12-2).

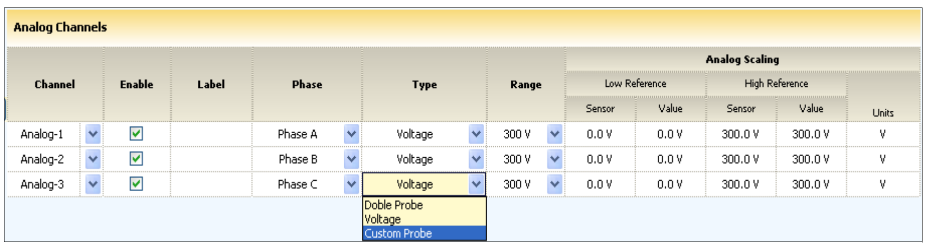
2. Use the attachment accessories provided to attach the other end of the cable across the device to be monitored, either directly across the device or at the terminal block.

For best results, install the custom current probe on the low or neutral side of the circuit through which the test current flows.

3. To configure the custom current probe, open the Test Plan page of T-Doble and select the **Analog, Aux** tab.

4. In the Type column, select **Custom Current Probe**.

When a shunt is used as a custom probe, voltage drop is measured across the shunt. Depending on the configuration, the shunt can provide either voltage or current if the proper scaling is used.


Analog Channels

Channel	Enable	Label	Phase	Type	Range	Analog Scaling: Low Reference Sensor	Low Reference Value	High Reference Sensor	High Reference Value	Units
Analog-1	☑		Phase A	Voltage	300 V	0.0 V	0.0 V	300.0 V	300.0 V	V
Analog-2	☑		Phase B	Voltage	300 V	0.0 V	0.0 V	300.0 V	300.0 V	V
Analog-3	☑		Phase C	Voltage	300 V	0.0 V	0.0 V	300.0 V	300.0 V	V

Figure 12.4 Custom Probe Setting in Analog Channels Table

5. Make all other appropriate settings.

System Control Connections

Two kinds of connections are made on the System module:

- Trip/Close
- Trigger In and Trigger Out

Trip/Close Connections

To make Trip/Close connections to the TDR9000:

1. Connect the instrument end of the breaker control cable to the TRIP/CLOSE connector on the TDR9000 (**I** in Figure 12.1). 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 TDR9000 to act as a series switch that applies +DC voltage to the appropriate coil for operation.

Trigger In/Out Connections

WARNING!

The Trigger In channel of the System module is the only TDR9000 channel rated to 600 V peak. When connecting this channel, use appropriately rated test leads.

To make Trigger In and Trigger Out connections on the System module:

1. Attach one end of the Doble-supplied auxiliary contact cable to a pair of Trigger In or Trigger Out channel banana jacks (**K** on Figure 12.1 on page 12-2).

2. Taking appropriate safety precautions, 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. Please note that Trigger Out performs no monitoring on the device.

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 on the TDR9000 OCB/Motion module (or one of the six, if six channels are available). See **B** in Figure 12.1.
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 breaker control cable to the control circuit of the circuit breaker.
2. Make one of the following two possible sets of connections:

   Option 1

   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

   Option 2

   a. Two trip leads between the +DC voltage and the trip coil
   b. Two close leads between the +DC voltage and the close coil

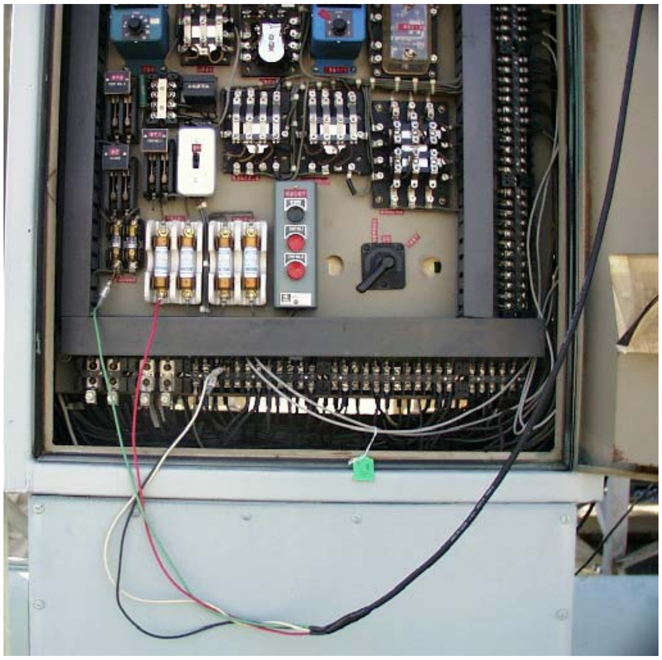


Figure 12.5 Step 1: Circuit Breaker Control Cabinet Preparation

Main Contact Connections

OCB Overall Timing Test Circuit Breaker

To make OCB connections:

1. Connect an OCB contact monitor cable to the appropriate circuit breaker terminals as listed in Table 12.2.

Table 12.2 OCB Dead Tank Connections

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

Because test voltages are below 48 V, it is important to double-check 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.

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

Doble does not supply grounding jumpers for this step.

3. 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 12.6 shows a typical mounting of the rotary/linear transducer.

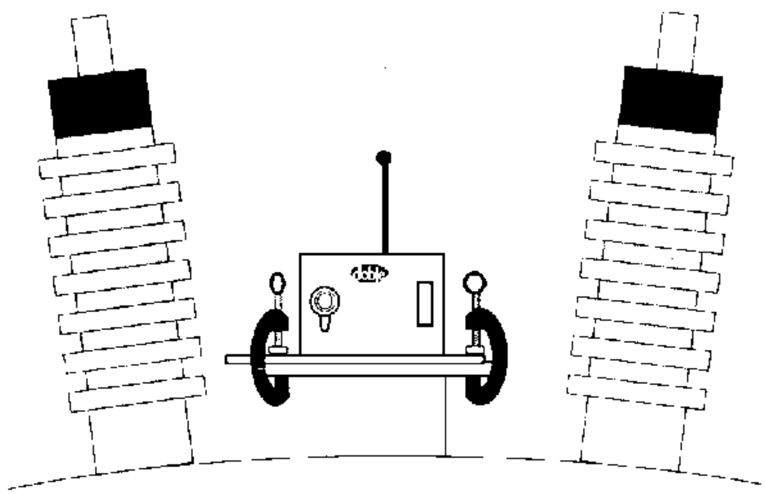


Figure 12.6 Rotary/Linear Transducer

4. Install a mounting platform for the transducer.

   Mounting clamps and platforms are not supplied as standard equipment with the TDR9000. Optional mounting kits are available for specific circuit breaker models. A general-purpose mounting adapter is available from Doble (P/N TR3177). It facilitates transducer mounting for a wide variety of circuit breaker models.

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 linear transducer. Other thread sizes are available as optional equipment from Doble.

WARNING!

Install and remove the transducer rod while the mechanism is up. In this way, 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. (See Figure H.18 on page H-19.)

   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 12.7 shows the cable connections for the dead tank test.

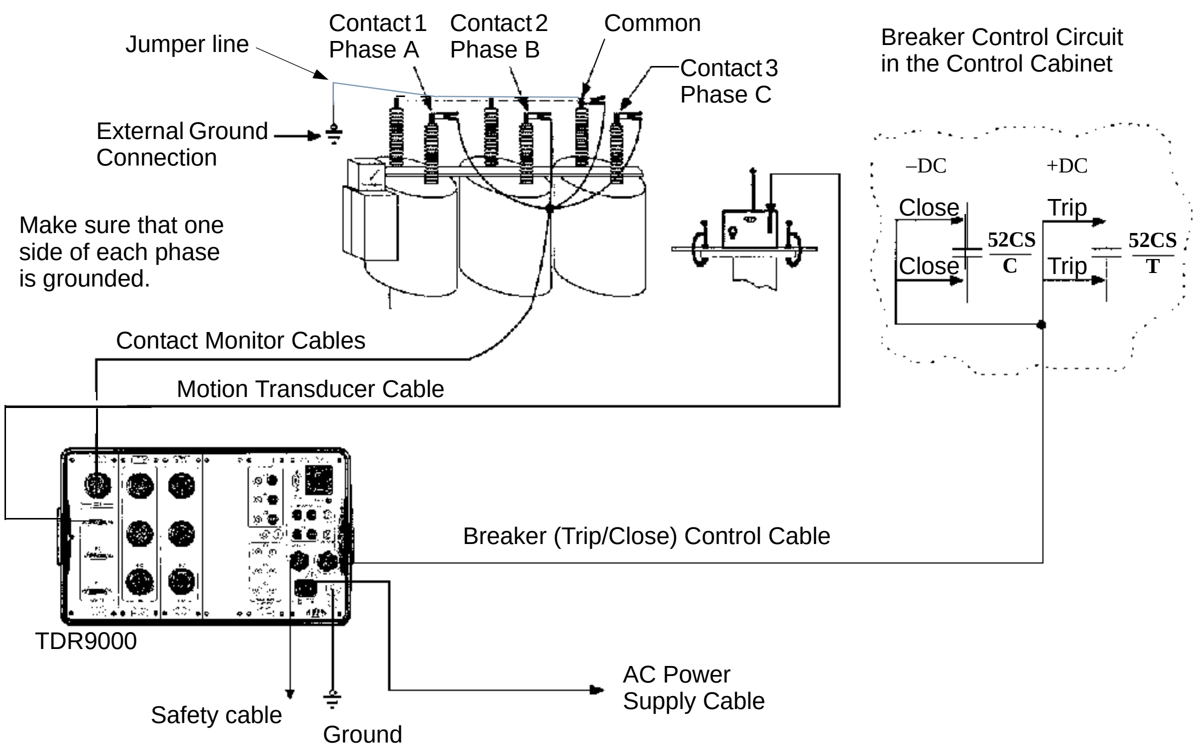


Figure 12.7 Cable Interconnection Diagram – Dead Tank

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 contact monitor cables to the appropriate circuit breaker terminals as listed in Table 12.3.

NOTE

Because the test voltage for the main contacts is between 7.5 V and 15 V, 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 12.3 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 the transducer's transducer scaling, see "Transducer Scaling" on page 5-4. Configuration of transducers is discussed in "Configuring the TR3190™ Digital Rotary/Linear Transducer" on page 12-21 and "Configuring the TR3160™Motion Transducer" on page 12-27.

Table 12.4 lists the circuit breaker adapters available.

Table 12.4 Circuit Breaker Adapters

Doble Adapter	Circuit Breaker Manufacturer	Circuit Breaker Type
TR3172	Westinghouse	SFA
TR3173	GE	GE Metalclad Air Magnetic circuit breakers (specify 13.8 or 4 kV)
TR3174	GE	GE Metalclad Air Magnetic circuit breakers (above 2000 A)
TR3175	Hitachi	Independent Pole Operation (IPO)
TR3176	Hitachi	HVB, Ganged operating mechanism
TR3177	N/A	General Purpose Tank Adapter
TR3178	Hitachi	HVB-IPO Spacer
TR3179	GE	Metalclad VB-1 Vacuum circuit breakers
TR3180	ABB	HPL Insulator Column
TR3181	ABB	HPL Mechanism Cabinet
TR3182	GEC	Alsthom HFG SF6
TR3183	ABB	Coupling 8mmINT x 0.38 lg.
TR3184	Westinghouse	SF Mechanical Interface

Table 12.4 Circuit Breaker Adapters (Continued)

Doble Adapter	Circuit Breaker Manufacturer	Circuit Breaker Type
TR3185	N/A	Universal Mechanical Transducer Mounting

Figure 12.8 shows the cable interconnections for the live tank test.

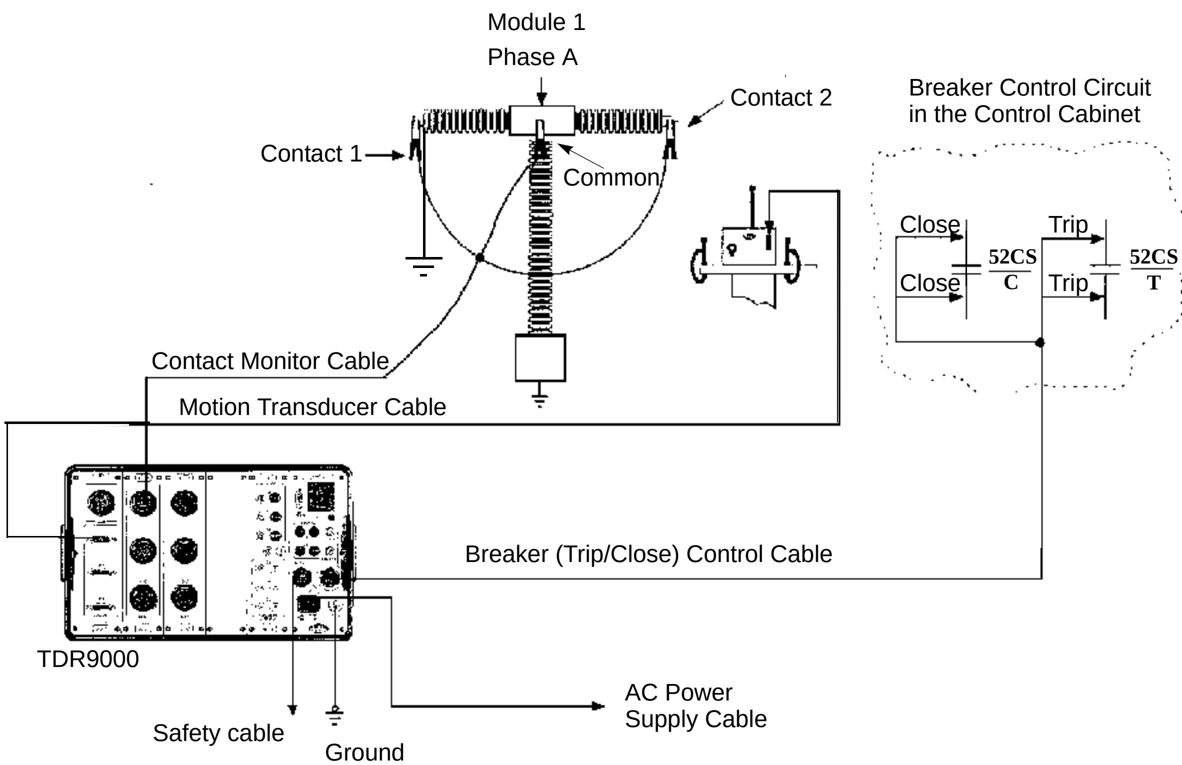


Figure 12.8 Cable Interconnection Diagram – Live Tank

Figure 12.9 shows an installation with live tank circuit breaker contact monitor cabling in place.

Figure 12.9 Installation with Circuit Breaker Contact Monitor Cabling

Event Module Connections

To make connections from the analog or auxiliary contact channels of the TDR9000, see the instructions in the following two subsections.

Analog

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

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 TDR9000:

- Trigger In/Out
- Trip/Close

Trigger In/Out Setup

To make Trigger In or Trigger Out 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 TDR9000:

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

WARNING!	**When using a linear rod, put the circuit breaker in a safe position before beginning transducer installation. A position is safe when an accidental circuit breaker operation draws the rod *away from*, not toward, the person performing the installation. This is usually the closed position.**

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 12.10 shows the three components of the TR3190 (TR3160LR™), which 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.

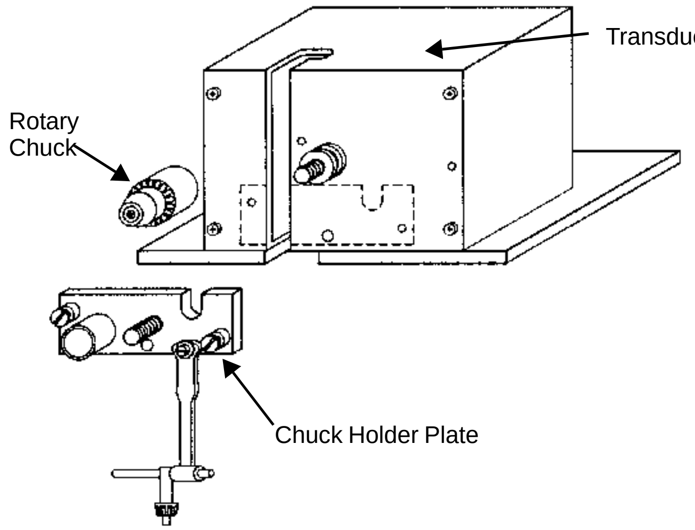


Figure 12.10 TR3190 (TR3160LR) Transducer Components

The chuck holder plate is shipped in two different configurations, as shown in Figure 12.11. This plate provides four different functions:

- When mounted in the ROTARY position
    - It depresses a micro-switch that indicates to the TDR9000 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.

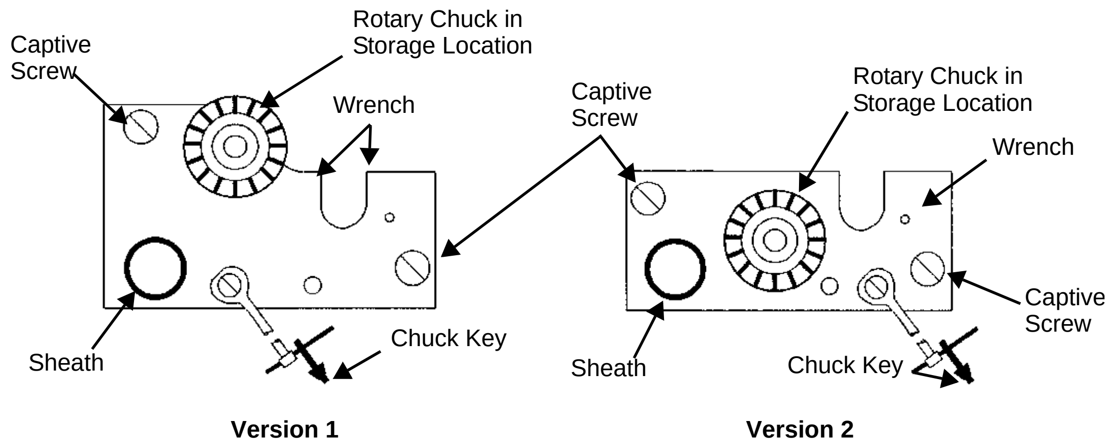


Figure 12.11 Chuck Holder Plate Configuration

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.

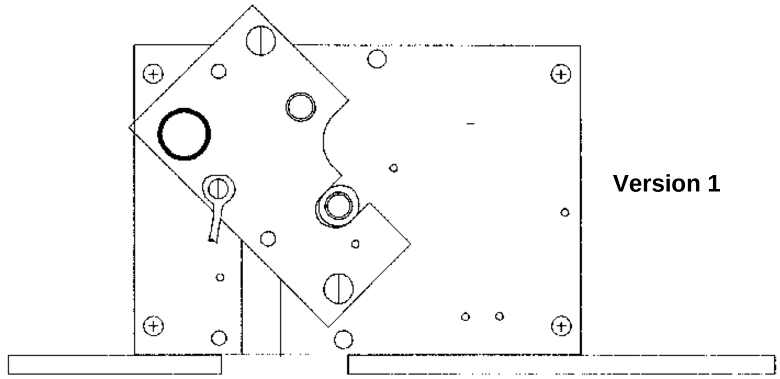
3. Position the wrench portion of the chuck holder plate on the rotary shaft (see Figure 12.12).

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.



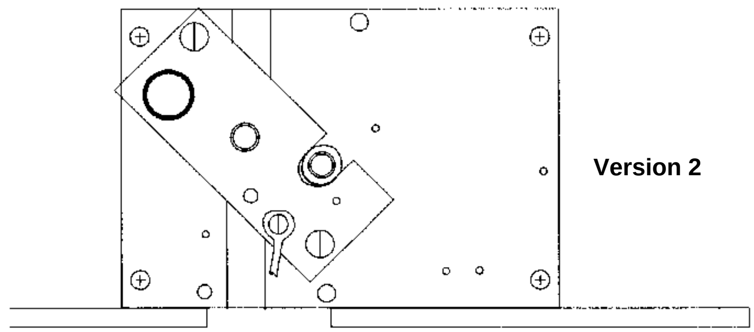


Figure 12.12 Chuck Holder Plate Mounting to Tighten Rotary Chuck

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 12.13).

Configuration is complete.

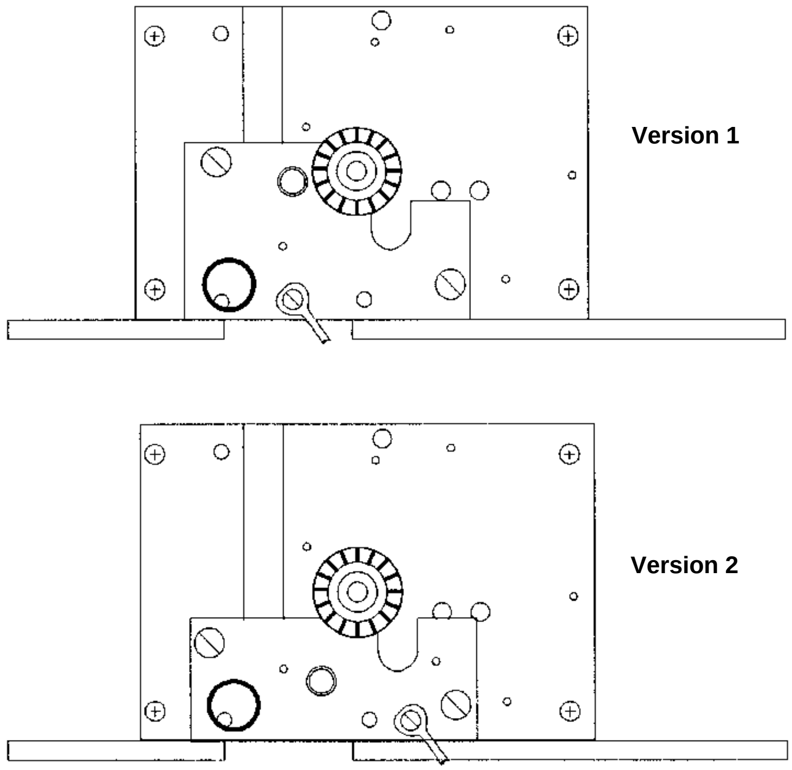


Figure 12.13 Chuck Holder Plate mounted in ROTARY position

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 12.12 on page 12-24).
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 page 12-23.

5. Store the rotary chuck on the chuck holder plate as shown in Figure 12.11 on page 12-23.

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 (Figure 12.14) using the two captive screws to secure it.

Configuration is complete.

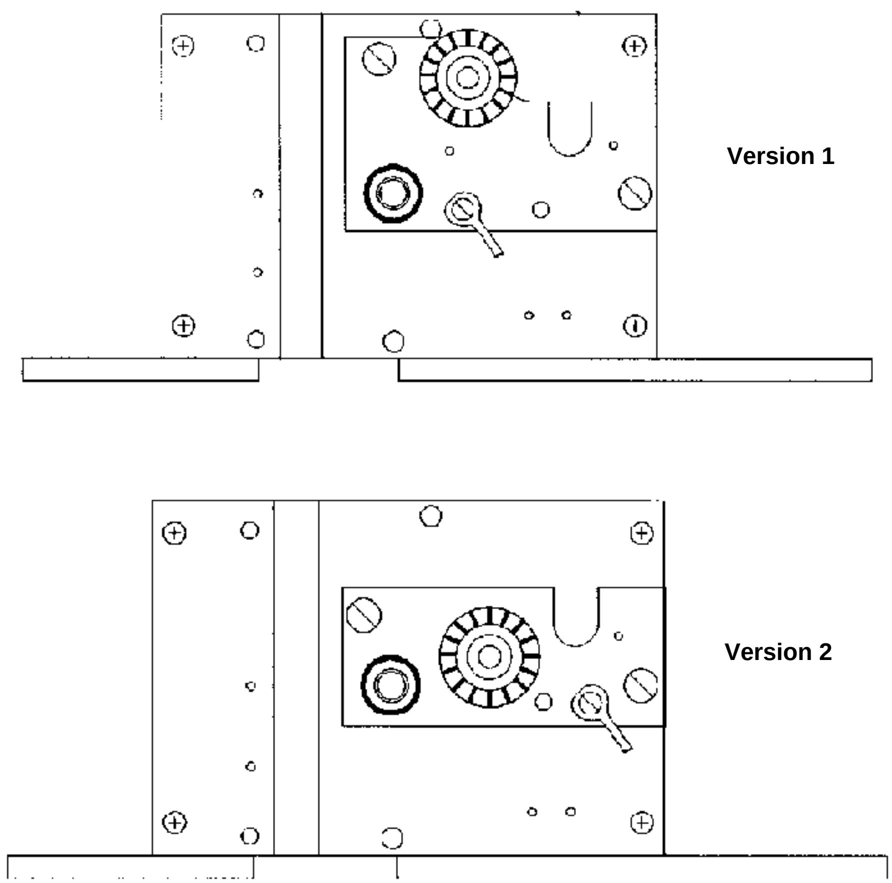


Figure 12.14 Chuck Holder Plate Mounted in LINEAR Position

Configuring the TR3160™ Motion Transducer

The TR3160 Motion Transducer is used to measure linear or, with the optional TR3165 rotary adapter, rotary motion. The setup for both is described below.

Two configurations of the TR3160 differ only in the design of the rotary adapter mechanism:

- The TR3160 model has the rotary adapter shown in Figure 12.15 and is configured using the following procedures.
- The TR3160LR has the chuck holder plate described in "Configuring the TR3190™ Digital Rotary/Linear Transducer" on page 12-21 and is configured using TR3190 procedures.

  The TR3160LR configuration is also indicated in the serial number on the side of the transducer.

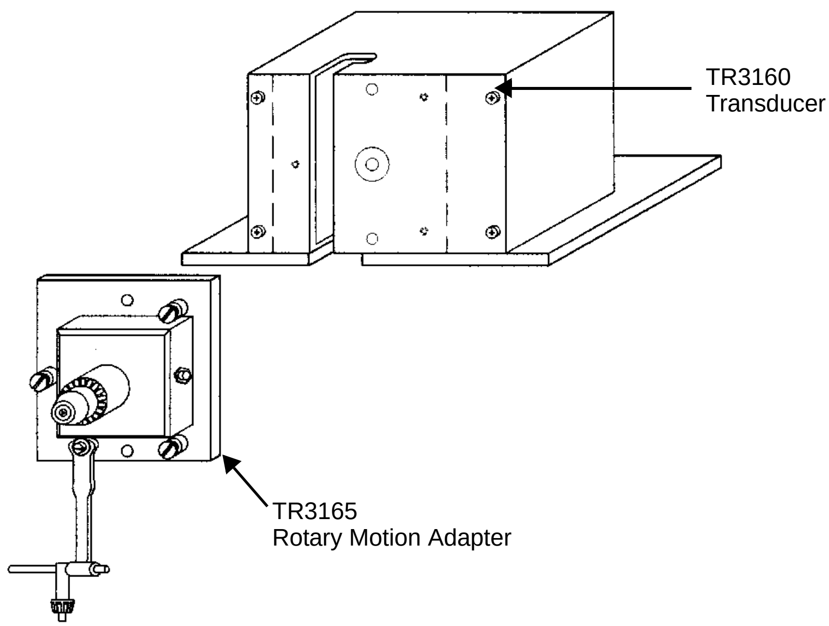


Figure 12.15 TR3160 Transducer Components

The rotary adapter, shown in Figure 12.16, provides two different functions:

- When mounted in the ROTARY position, the adapter toggles a micro-switch that indicates to the instrument that a rotary measurement is being performed.

- When mounted in the ROTARY position, it covers the gate area, which serves as a reminder that it must be removed prior to inserting the travel rod to perform a linear measurement.

NOTE **If the rotary chuck requires tightening, tighten while using the locking pin to hold the rotary shaft in place.**

To tighten the rotary chuck:

1. Press on the locking pin while rotating the rotary chuck. The locking pin drops into a slot in the rotary shaft and holds the rotary shaft in place.
2. Insert the chuck key into the rotary chuck and tap it with a light object until the rotary chuck rotates clockwise.

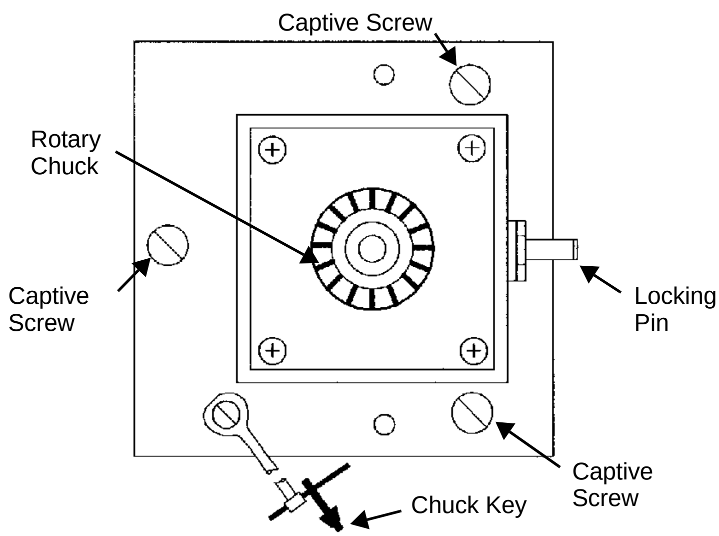


Figure 12.16 Rotary Adapter

Rotary Motion

To configure for rotary motion:

1. Mount the rotary adapter onto the transducer by inserting the hex shaft that extends from the back of the rotary chuck into the hexagonal opening in the face of the transducer and align the three captive screws (refer to Figure 12.17 on page 12-29).
2. Tighten the captive screws.

Configuration is complete.

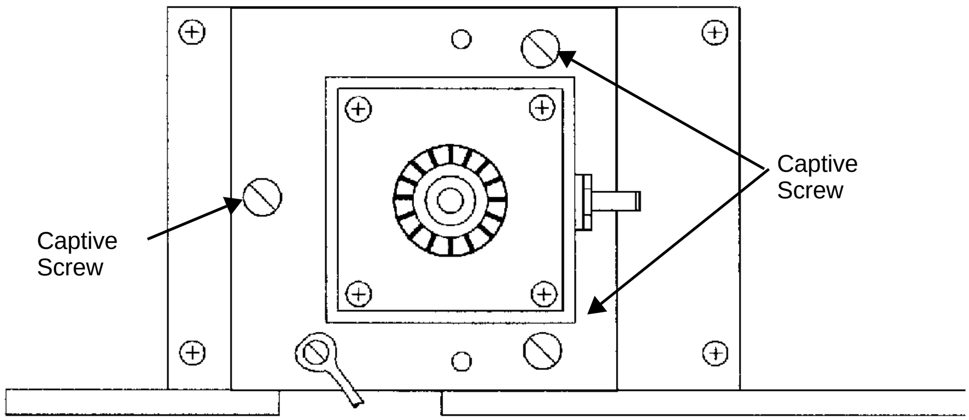


Figure 12.17 Rotary Adapter Mounted on Transducer

Linear Motion

To configure for linear motion:

1. Remove the rotary adapter from the transducer by loosening the three captive screws.
2. Store the rotary adapter in the cable bag to avoid damage.

Configuration is complete.

Step 4: Creating a Test Plan

Go to Chapter 5, "Channel Setup" for instructions. Then go to “Step 5: Removing Safety Grounds” on page 12-29 to continue.

Step 5: Removing Safety Grounds

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

- Neutral-grounded transformers
- High voltages

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 (see Figure 12.18).
- Leave in place the ground connections between the transformer and the circuit breaker (see Figure 12.18).

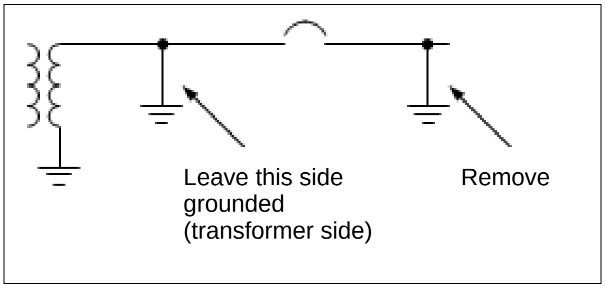


Figure 12.18 Neutral-Grounded Transformer and Ground Connections

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 12.19).

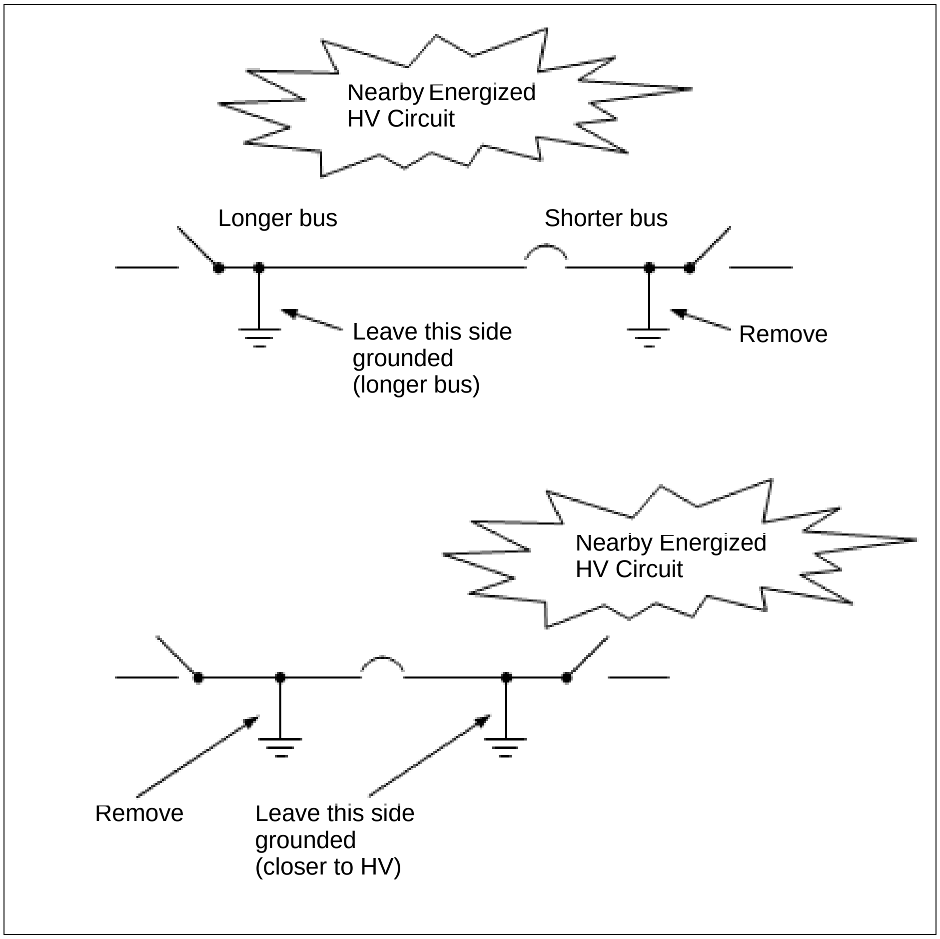


Figure 12.19 High Voltages and Ground Connections

Step 6: Using the Pretest Checklist

Use the checklist given in Table 12.5 to ensure that the system is safely configured for testing.

Table 12.5 Pretest Checklist

Item	
Circuit breaker under test is removed from service according to government and company safety rules. (Not applicable to First Trip tests.)	☐
The TDR900 is properly grounded with a safety ground cable.	☐
Proper AC power is available.	☐
All cables are connected to the TDR9000.	☐
Transducer connecting rod is coupled to the circuit breaker rod. (Not applicable to First Trip tests.)	☐
Rotary attachment is installed. (Optional. Not applicable to First Trip tests.)	☐
All Motion Transducer cables are connected to the corresponding transducer. (Not applicable to First Trip tests.)	☐
All contact monitor cables are connected to the circuit breaker terminals. (Not applicable to First Trip tests.)	☐
After OCB or EHV connections are made, some grounds are removed for purposes of test. (Not applicable to First Trip tests.)	☐
The test plan has been configured.	☐
All the current probes are zeroed (if used).	☐

Step 7: 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 instrument.

Step 8: Running the Test

Safely Activating a Test

The TDR9000 provides two ways of activating a test: from the safety switch cable and from the T-Doble software.

- 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 Flag Plug 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 window shown in Figure 12.20 appears.

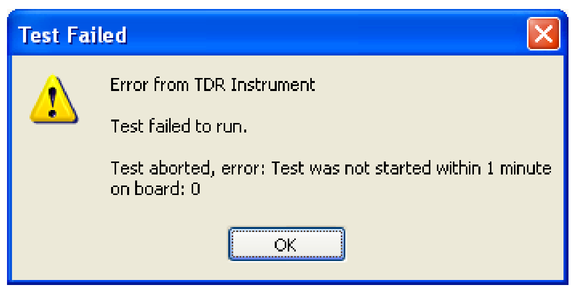


Figure 12.20 Test Aborted—Slow Switch Release

If the Safety Switch is released before the alarm ceases, the test is aborted and the window shown in Figure 12.21 appears.

Figure 12.21 Test Aborted—Premature Switch Release

Procedure

To run a test:

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

   The Select Test window appears.

Figure 12.22 Select Test Window

2. Choose a beeper sound level of **Normal**, **Attenuated**, or **Silent**.
3. Select the test of interest.

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

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

4. Activate the test.

   The test begins and the Test Progress window appears.

Figure 12.23 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 in the Plots window. See Chapter 8, "Displaying and Interpreting Test Results" for information.

Special Considerations for Capacitance Tests

Long Loading Times

For a Capacitance test, making sure all safety issues comply is a lengthy process. The Loading Test status bar cycles a minimum of six times and a maximum of eight times.

Capacitance Test Errors

During a Capacitance test, a Capacitance Error dialog box may appear (Figure 12.24).

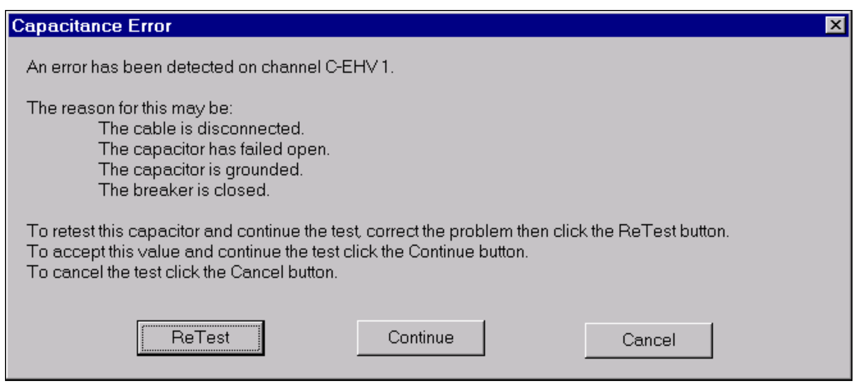


Figure 12.24 Capacitance Testing Error

If this occurs, click one of the buttons:

- **ReTest** to start the test over after fixing the problem
- **Continue** to accept a potentially incorrect value and move to testing the next contact
- **Cancel** to abort the test

Step 9: Disconnecting After the Test

1. Turn the power switch of the TDR9000 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.**
- **Be sure that appropriate service disconnects are secured.**
- **Follow all safety procedures.**
- **Disconnect the cables from the circuit breaker first and the TDR9000 second.**

4. Remove the contact monitor cables from the circuit breaker.

   Do not pull the cables. Remove the cables at the connection.
5. Unplug the following cables from the instrument:
   a. Contact Monitor
   b. Motion Transducer
   c. Breaker Control
6. Unplug the AC power cord from the power receptacle.
7. Unplug the AC power cord from the instrument.
8. Remove the safety switch cable from the SAFETY receptacle on the instrument.
9. Remove the safety ground from the TDR9000.
10. Remove safety grounds from the circuit breaker.
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.

A. Troubleshooting and Replacing Parts

The TDR900 is a self-contained unit. If it requires repair, ship it to Doble. See *"Packing the TDR Instrument for Shipment" on page A-17* *for more information.*

This appendix provides troubleshooting procedures for the TDR9000 and procedures for replacing parts. It contains the following sections:

TDR9000 Module and LED Locations

This section provides the locations of modules, circuit boards, and LEDs in the TDR9000. It also explains the information provided by the LEDs.

Figure A.1 and Figure A.2 show two common configurations of the TDR9000.

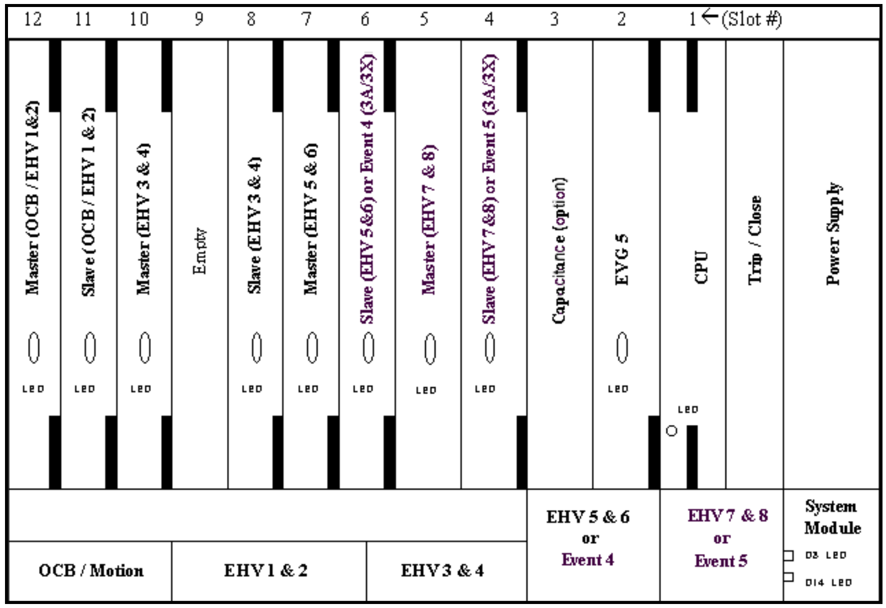


Figure A.1 Schematic of TDR9000 (OCB/Motion Module Installed)

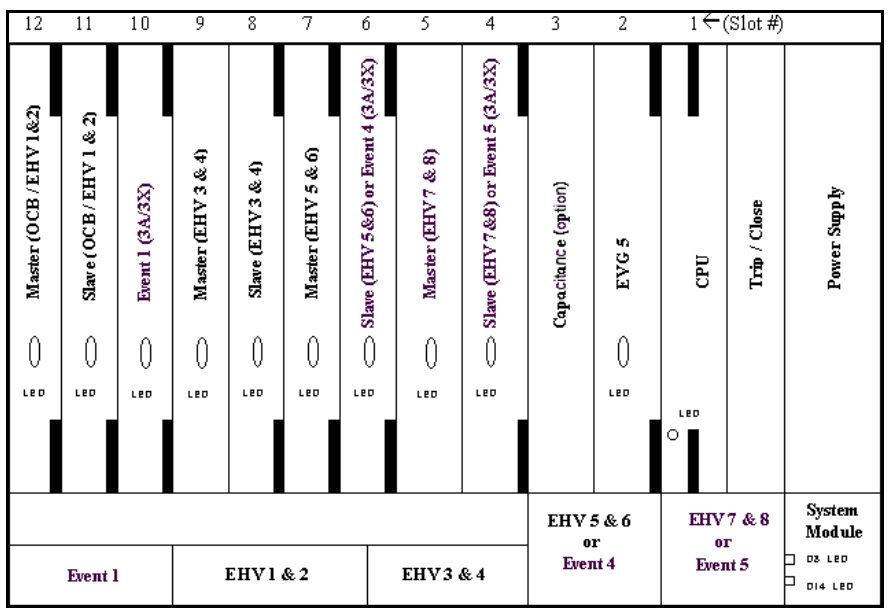


Figure A.2 Schematic of TDR9000 (Event 1 Module Installed)

Circuit Board LEDs

Each TDR instrument circuit board, excluding the Power Supply circuit board and the Trip/Close module, has an LED which is visible through an oval cut into the top of the circuit board housing. (On the TDR900, you must remove the upper cover to see the LEDs.) These LEDs indicate circuit board operation as follows:

- **During startup**—All circuit board LEDs change from red to green.
- **After startup**—All circuit board LEDs should be a steady green, indicating that the set is operating correctly. If any circuit board LED is off, or red, after the startup sequence has finished, that circuit board has experienced a startup problem.

Power Supply LED

Externally, the instrument comes equipped with an LED on the System module front panel that indicates proper operation of the power supply, as shown in Figure A.3.

Figure A.3 Location of DC Power Supply LED

Backplane Board Registration Errors

A backplane board (VME Bus, slots 1 through 12) in the TDR9000 can fail in such a way that the board is not recognized by the instrument. This can happen because connectors are damaged, the board is seated poorly in the backplane, or the board's electronics have a problem.

If the board is not recognized by the TDR9000, there is no failure indication at power-up.

To detect the failed backplane:

1. Power down the instrument.
2. Open the instrument casing. See page A-7 for instructions.
3. Referring to the diagram shown in Figure A.2 on page A-2, look for any LED that is not green.
4. Check the integrity of the connectors. If the connectors appear to be OK, reseat the board, power up the instrument, and check the LED.

Additional Problems and Solutions

Table A.1 lists some additional problems and associated solutions.

Table A.1 Problems and Solutions

Problem Indication	Solutions
Unrecognizable data displayed on the screen or plotted	Check: • Mounting of motion transducer • Line frequency settings • Connections to the breaker contacts or control circuits
Instrument dropped or physically damaged	Return to Doble for repair.
Spilled liquid penetrates the instrument case	Return to Doble for repair.

Table A.1 Problems and Solutions (Continued)

Problem Indication	Solutions
• Breaker does not operate. or • A test is run but the breaker does not respond.	Check the: • Pulse duration setting of the command signal pulse. If the command pulse is too short, the breaker may not respond. • Control cable. Verify that the control cable is properly plugged in to the instrument. Verify that the trip/close connections are made to appropriate locations within the circuit breaker's control circuit. Typically, the Trip connectors of the control cable are connected across the trip contact (52CS/T) and the Close connectors are connected across the close contact (52CS/C) on the circuit breaker's control switch. • Condition of the Trip/Close fuses using an Ohmmeter. Use only 3 A, 250 V, Slo-Blo fuse types. See "Replacing Trip/Close Fuses" on page A-13. • Perform the Trip/Close Command Function Test. See page A-13.
Printer doesn't work	Check that: • Power is ON. • Printer is not jammed. • Refer to Pentax documentation provided with the printer.

Replacement Procedures

Doble replaces only complete printed circuit boards or other subassemblies. None of the solid-state printed circuit boards need user calibration or adjustment. This section discusses the following replacement procedures:

- Internal circuit boards
- Modules
- Power Supply Circuit Board Fuses
- Power Supply Module

WARNING!

Turn power OFF and disconnect from line power before reaching into the instrument.

Replacing Internal Circuit Boards

Every circuit board is shipped with an identifying label. Each slot in the TDR9000 is also labeled. When replacing a circuit board:

- Remove the assembly carefully to avoid damage to its connectors.
- Be sure to place the replacement circuit board in the same location.

Table A.2 lists the replaceable internal boards and their part numbers.

Table A.2 Replaceable Internal Board Part Numbers

Circuit Board	Part Number
EVG	04S-0691-01
CPU	04D-0603-04
Event (3A/3X)	04S-0694-01
Trip/Close Module	03D-1372-01 (with Trip/Close Current) 03D-1372-02 (without Trip/Close Current)
Main Contact Master	04S-0692-01 (with resistance) 04S-0692-02 (without resistance)
Main Contact Slave	04S-0692-03 (with resistance) 04S-0692-04 (without resistance)
Capacitance Measurement Board	04S-0695-01

NOTE

Wear antistatic wrist straps when working with circuit boards.

To prevent further damage, immediately place each removed circuit board or module into the protective packaging that came with the replacement part.

To replace a circuit board:

1. Turn the power OFF.
2. Disconnect all external cables, except the ground cable, from the instrument.
3. On the rear of the unit, unscrew the two flat head screws that hold the two top rubber feet, as shown in Figure A.4.

Figure A.4 Screws that Hold Top Rubber Feet

4. Lift the cover at the back and slide it backwards.
5. Disconnect any ribbon cable connected to the circuit board to be replaced.

   Table A.3 lists the ribbon cables connected to each circuit board type.

Table A.3 Required Cable Disconnects by Circuit Board

Circuit Board	Cables to Disconnect
EVG	W4 and W3—Use the ejectors.
CPU	• W6—Use the two common screws. • W4 and W3—Use the ejectors to disconnect from EVG.
Trip/Close	• W6—Use the two common screws to disconnect from CPU. • W4 and W3—Use the ejectors to disconnect from EVG.

6. Unscrew the captive screws on the circuit board.
7. Unlock and lift the circuit board ejectors and pull the circuit board up and out. Alternately lifting up on the front and rear ejectors eases circuit board removal.

8. Slide the replacement board into the card guides, align the connectors on the replacement board with the connectors on the backplane, and carefully push down on the card ejectors to seat the circuit board.
9. Ensure the replacement board is fully seated by pressing down on the center of the card bracket.
10. Tighten the captive screws on the circuit board.
11. Reconnect any circuit board ribbon cables.
12. Plug the TDR9000 in and power up the unit.
13. Check to make sure the LED associated with the replacement circuit board is lighted and green. The power up process begins about 1 minute before the LED lights up.
14. Replace the top cover and reinstall the two rubber feet.

Replacing Front Panel Modules

The following front panel modules can be replaced in the field:

- OCB/Motion
- EHV
- Event

Table A.4 lists the replaceable modules and their part numbers.

Table A.4 Module Part Numbers

Module	Part Number
EHV	03D-1381-01
Event (3A/3X)	03D-1383-01
OCB/Motion (3 Motion)	03D-1382-01
OCB/Motion (6 Motion)	03D-1382-02
OCB only	03D-1382-05
3 Motion only	03D-1382-03
6 Motion only	03D-1382-04

NOTE

- **The replacement procedure below describes how to replace a module *with the same kind of module*. Only Doble personnel can change the type of module located in a slot.**
- **The System module is not replaceable in the field. Contact Doble Customer Service to replace a System module.**
- **To remove a module in Location 1, first remove the module in Location 2.**
- **The module in Location 1 has five screws; all others have four.**

To replace a module:

1. Turn the power OFF.
2. Disconnect all external cables, except the ground cable, from the instrument.
3. On the rear of the unit, unscrew the two flat head screws that hold the two top rubber feet, as shown in Figure A.4 on page A-7.
4. Lift the cover at the back and slide it backwards.
5. Remove the four hex head screws in the corners of the module using a 5/64" driver. For the module in Location 1, remove the fifth screw also.
6. Pull the module straight forward and out:
   - OCB/Motion or EHV module—Grab a circular connector. Rock the module side-to-side while extracting.
   - Event module—Insert two banana clip leads into two connectors on the module face. Pull gently while rocking the module side-to-side.
7. Align the connector on the replacement module with the connector on the backplane and carefully seat the module.
8. Replace the hex head screws. For the module in Location 1, place the longer screws on the outer edge of the module.
9. Plug the TDR9000 in and power up the unit. Observe the LEDs before replacing the cover.
10. If all circuit board LEDs light up normally, replace the cover and reinstall the two rubber feet.

Replacing Power Supply Fuses

An LED on the System module front panel indicates proper operation of the power supply, as shown in Figure A.5.

Figure A.5 DC Power Supply LED

If this LED is not lit when the power is applied, then one of the two power supply fuses is blown, the power supply is bad, the internal temperature of the instrument is too high, or the monitoring circuit is bad.

To examine the fuses on the power supply module:

1. Turn the power OFF.
2. Disconnect all external cables, except the ground cable, from the instrument.
3. On the rear of the unit, unscrew the two flat head screws that hold the two top rubber feet, as shown in Figure A.4 on page A-7.
4. Lift the cover at the back and slide it backwards.
5. Measure the resistance across the fuse using a multimeter. The fuses are shown in Figure A.6.

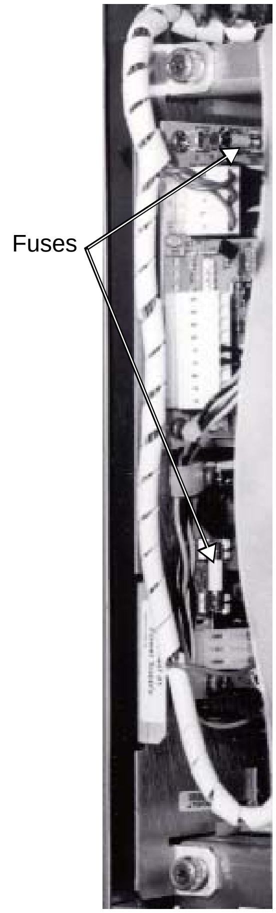


Figure A.6 Power Supply Assembly Fuses

If the meter registers:

- More than 800 kΩ, the fuse is blown. Go to step 4.
- Less than 800 kΩ, the fuse is not blown. Replace the Power Supply circuit board assembly. See page A-12.

6. Pull the blown fuse out and insert a new fuse.

Replacement fuses are 5 x 20 mm and 250 V AC:

- 5 V supply fuse is 3.15 A, Littlefuse #216 3.15 or equivalent
- 24 V supply fuse is 4 A, Littlefuse #216 004 or equivalent

7. Plug the unit in and power up the TDR9000.

8. Check the LED on the System module.

9. Replace the top cover and reinstall the two rubber feet.

Replacing the Power Supply

If the front panel LED does not illuminate and the fuses located on the Power Supply circuit board are not blown, the DC power supply is suspect and should be replaced. The power supply is called out in Figure A.1 on page A-2.

To replace the power supply:

1. Turn the power OFF.
2. Disconnect all external cables, except the ground cable, from the instrument.
3. On the rear of the unit, unscrew the two flat head screws that hold the two top rubber feet, as shown in Figure A.4 on page A-7.
4. Lift the cover at the back and slide it backwards.
5. Unscrew the captive fasteners on the circuit board.
6. Disconnect the two connectors and the green ground connector indicated in Figure A.7.

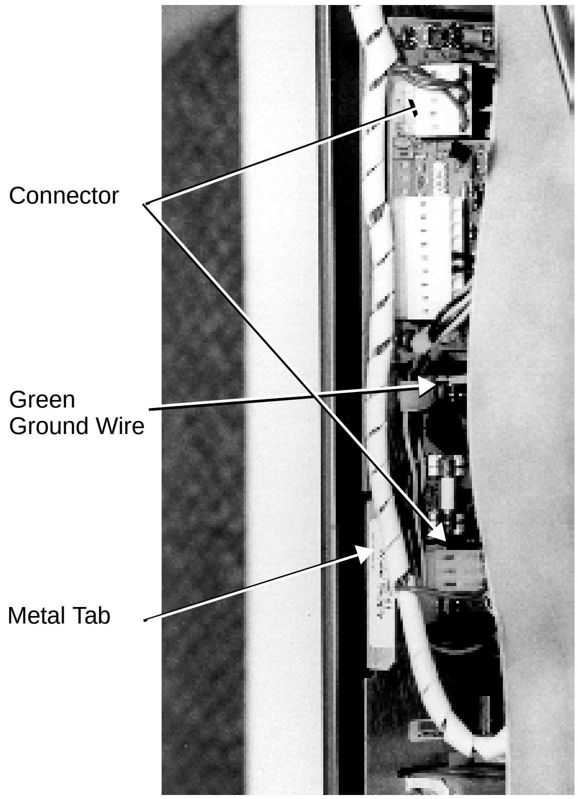


Figure A.7 Power Supply Circuit Board Connectors

7. Pull up gently on the metal tab (Figure A.7) to remove the assembly.

8. Insert the replacement assembly into the guides and gently push it into position.
9. Replace the cables disconnected in step 4.
10. Plug the unit in and power up the TDR9000.
11. Check the LED on the System module front panel.
12. Replace the top cover and reinstall the two rubber feet.

Replacing Trip/Close Fuses

Fuses for the Trip and Close coil currents are located on the TDR9000 front panel, as shown in Figure A.8. The status of a Trip/Close fuse is determined using the procedure for testing the Trip/Close command function given in "Trip/Close Command Function Test" below.

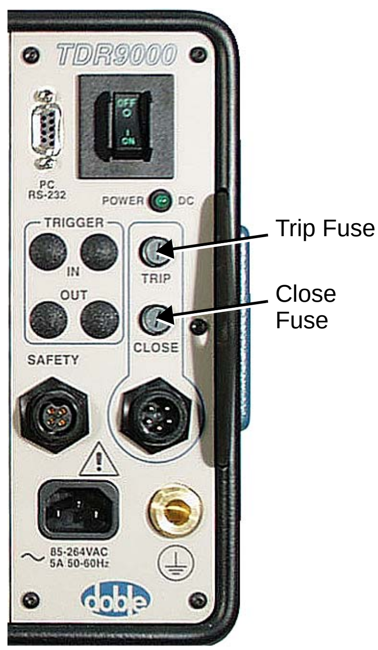


Figure A.8 Trip/Close Fuses

Trip/Close Command Function Test

The TDR9000 Trip/Close module is monitored during every test. If there is an internal electronics problem, a run-time error is reported. These run-time tests cannot test the cables, fuses, or the final high current stage of the module.

If a test is run and no errors are reported, and the circuit breaker does not operate, this procedure isolates the cause of the failure to the Trip/Close fuses or to the breaker control cable responsible for the Trip/Close command function or the Trip/Close module, unless the circuit breaker is defective. Fuses can be checked by inspection. The cable can be checked with a meter, but this is difficult if the pinout pattern is not known. This makes the following procedure the quickest troubleshooting solution.

WARNING!

Before you perform this test, detach from the breaker all cables that are used for this test.

1. Connect the alligator clips of the Breaker (Trip/Close) Control cable across the test clamps of an activated OCB or EHV cable.

   Example

   Connect a Trip clip to a contact clamp, connect a Close clip to another contact clamp, and connect the remaining Trip/Close clips to the common clamp.
2. Run a test sequence that exercises both controls (e.g., TripFree, Reclose, O-C-O).
3. Check for activity on both contact channels.
   - If only one control is misbehaving, the test can be done using only one contact channel and the suspect T/C clip pair. Run a simple test (e.g., Trip, Close).
   - If both the Trip and Close control pulses are seen on the contact channels graphs, the TDR9000 is OK. The problem is outside the instrument.
   - If one or both of the patterns is missing, check the fuses with a meter.
     - If the fuses are OK, then the cable is suspect.
     - If the fuses and cables are OK, then replace the Trip/Close module. Refer to "Replacing Internal Circuit Boards" on page A-6.
     - Otherwise, replace the bad fuse. Refer to "Replacing Trip/Close Fuses".

Replacing Trip/Close Fuses

To replace fuses:

1. Turn the power OFF.
2. Remove and replace the defective fuse using a flat head screwdriver.

WARNING!

Always use a bus type 3 A, 250 V Slo-Blo (Doble Part # 384-0002). Use of any fuse other than the designated type can result in damage to the TDR9000.

3. Restore system connections.
4. Turn the power ON.

Testing and Replacing Cables

TDR9000 cables are listed in Table A.5. If a system failure occurs, and if the failure is traced to a particular cable, ensure that the cable is properly seated and connected before replacing the cable.

Table A.5 Cable Replacement List

Part Number	Description
02C-0019-01	Chassis ground cable (30 ft/9.15 m)
071-0021-01	External cable kit
02B-0050-10	Safety switch cable (25 ft/7.6 m)
181-0095	Power cord (USA standard)
401-0168	RS-232 cable (25 ft/7.6 m)
05B-0620-01	OCB cable (60 ft/18.3 m, standard)
020-0127-01 through 04	EHV cable set (Specify module number)
05B-0621	EHV cable, individual (specify module number and phase)
05B-0634-01 through 03	Analog Channel cable (specify red, yellow or blue)

Table A.5 Cable Replacement List (Continued)

Part Number	Description
05B-0635-01 through 03	Auxiliary contact channel cable (specify red, yellow or blue)
02B-0013-06	Trip/Close Control cable
05C-0648-01	Safety Plug with Flag (used for external trigger test)
181-0107	Motion Transducer cable (40 ft/12.2 m)
03C-1397-01	Battery Clips (black)
03C-1398-01	Battery Clips (red)

Contacting Customer Service

Before calling or sending an e-mail to Customer Service for assistance, please take the following steps:

1. Repeat all the pertinent procedures in this chapter.
2. Check all cable connections.
3. Try the test on another instrument, if available.
4. Make sure the cabling conforms to the requirements of your test plan.
5. Have the following information available:
   - Date of purchase
   - Instrument serial numbers, hardware configuration, and software revision
   - Exact description of the problem, including error messages and the sequence of events before it appeared
   - List of solutions that have been tried
   - Electronics tool kit and digital multimeter, in case Customer Service suggests that a circuit board or subassembly be removed

To contact Doble Engineering Customer Service:

- Telephone—(617) 926-4900
- E-mail—customerservice@doble.com

Packing the TDR Instrument for Shipment

If you need to send the TDR instrument to Doble for servicing, contact Doble Engineering Customer Service at 617-926-4900 or FAX 617-926-0528 for return instructions.

NOTE

Doble Engineering is not responsible for shipping damage. Carefully protect each instrument from shipping and handling hazards. Ensure protective covers are securely in place.

Instruments must be sent to Doble freight pre-paid, unless other arrangements have been authorized in advance by Doble Customer Service.

To prepare an instrument for shipment:

1. Get a Repair Work Order (RWO) number from Doble Customer Service.

   This number is used to track the instrument during shipping.
2. Disconnect and remove all external cables. Do not include manuals, cables, and transducer connecting rods unless recommended by Doble Customer Service.
3. Attach the front cover.
4. Attach the RWO number to the instrument.
5. Reuse the original packing material if it is available. If it is not:
   - Pack the instrument for shipment as normal for fragile electronic equipment. You can use 2-wall minimum corrugated cardboard box with a minimum 2 inch thick poly foam padding, or a wooden crate with minimum of 2 inch thick poly foam padding all around.
   - Order triple-wall shipping containers (Doble Part # 903-0044) from Customer Service.

B. Software Field Upgrades

This appendix gives the procedures for upgrading T-Doble in the field. it contains the following sections:

- “Updating T-Doble” on page B-1
- “Updating the Firmware (TDR900 Only)” on page B-2
- “Loading the Printer Driver (TDR9000 only)” on page B-4

Updating T-Doble

T-Doble software is provided on the CD-ROM that is shipped with the instrument, and on the Doble web site.

To upgrade T-Doble:

1. Navigate to the directory containing the T-Doble software and double-click **setup.exe**.

   The T-Doble 2.0 Setup Wizard window appears.

2. Click **Next**.

   The Select Installation Folder window appears, displaying a default directory for T-Doble: `C:\Program Files\Doble Engineering\T-Doble 2.0\`.

3. Leave the default directory unchanged and click **Next**.

   The Confirm Installation window appears.

4. Click **Next**.

   The Installation Complete window appears.

5. Click **Close**.

Updating the Firmware (TDR900 Only)

NOTE

The firmware of the TDR9000 does not require updating.

A flashloader utility is shipped with the T-Doble software. To load it:

1. Go to the Flashloader folder and double-click **Setup.exe**.
2. Follow the instructions that follow.

Loading the TDR Firmware

To load the TDR firmware:

1. Start up your laptop and the instrument in question.
2. From the Start menu, select **All Programs/Doble Engineering/Flash Loader for M5x00 and TDR900 Instruments**.

   The Language window appears.
3. Select a language.

   The Firmware Upgrade window appears.

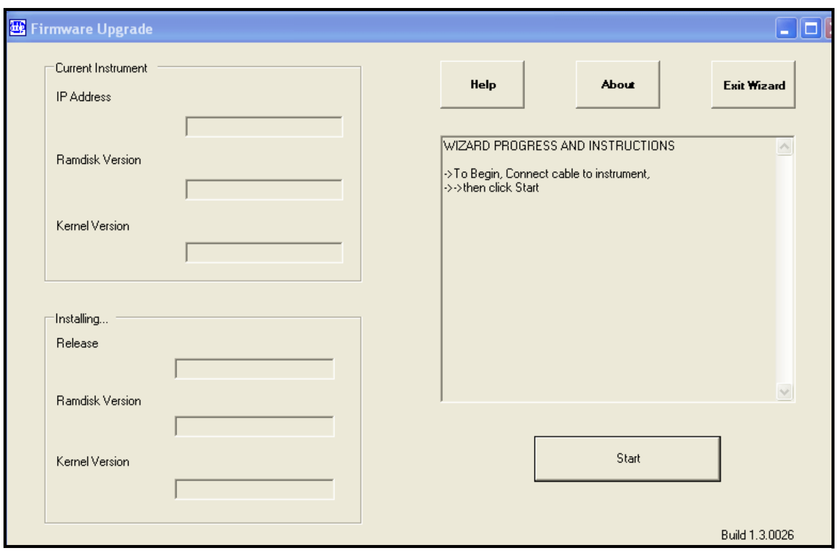


Figure B.1 Firmware Upgrade Window

4. Click **Start**.

   The Select Instrument to Upgrade window appears.

Figure B.2 Select Instrument to Upgrade Window

5. Select **TDR 900 Series** and click **OK**.
6. If the software displays more than one available instrument, select the appropriate one and click **OK**.
7. Click **OK** in the Connection window.

   A window displays the available firmware versions.

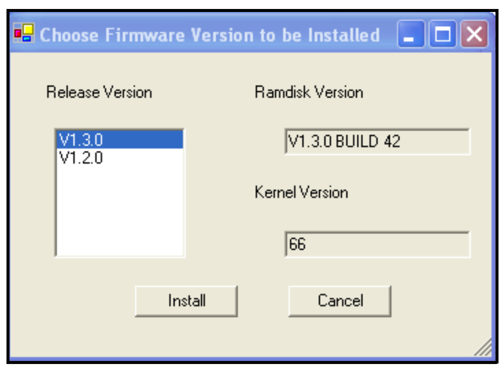


Figure B.3 Choose Firmware Version to Be Installed Window

8. Select the appropriate version and click **Install**.

NOTE

Do not turn off the instrument while the upgrade is in process. Doing so can cause the instrument to become inoperable.

   When the upgrade is complete, a message appears on the Firmware Upgrade window.

9. Close the Flash Loader application and power cycle the instrument.

10. To confirm that the upgrade was successful, launch T-Doble and select **About** from the Help menu to see the version number.

Loading the Printer Driver (TDR9000 only)

In order to print, the Pentax PocketJet II printer requires a driver to be resident on the laptop running the T-Doble program. Printer drivers are available from these locations:

- CD-ROM accompanying the TDR9000
- Doble website

Your software may vary slightly from these directions, depending on the version of Windows operating system you use.

To load the printer driver:

1. Turn on the laptop and wait for Windows to load.

2. Insert the diskette provided into the laptop's floppy drive.

3. Click the **Start** button and select **Printers and Faxes** from the menu.

The Printers and Faxes window appears.

4. Double-click the **Add Printer** icon.

The Add Printer Wizard window appears.

5. Click **Next** and follow the wizard prompts, providing this information:

- Select LPT1 as the port.
- Indicate that you will install the driver from a disk.
- To select a driver, click **OEMSETUP.INF**. From the two versions of the Pentax PocketJet II driver that are then displayed, select **Pentax PocketJet II - Roll Paper**.
- Do not share the printer.
- If a version conflict message appears, keep the newer version.

Pentax PocketJet II Printer Settings

Doble recommends certain modifications to the Pentax PocketJet II printer settings. To make these modifications:

1. Click the **Start** button and select **Printers and Faxes** from the menu.

   The Printers and Faxes window appears.
2. Right-click the **Pentax PocketJet II** icon.

   The Pentax PocketJet II Properties window appears.
3. Click the **Graphics** tab.
4. Click the **Line Art** radio button.
5. Click the **Advanced** tab.
6. Click the **No Feed Mode** radio button.
7. Enter **200** in the “No Feed Mode Extra Feed (# of lines at 300 dpi)” field.
8. Reset the density to **7**.
9. Click **OK** and close the Printers window.

C. Maintenance

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

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 instrument 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 instrument.
- Never insert metal objects, such as screwdrivers or paper clips, inside the instrument while power is ON.
- Unplug the instrument if it is not to be used for an extended period of time. Also unplug it before cleaning it.
- If the instrument is dropped, have it checked by a qualified service technician before placing it back in service. Dropping the instrument can disturb the insulation system.
- Do not place the instrument in excessively warm or humid locations.

Maintenance

The topics that follow discuss the following maintenance related areas:

- Cleaning the TDR instrument
- Replacing the Printer Paper Roll

Cleaning the TDR instrument

Normal care and cleaning of the instrument is comprised of the following areas:

1. Instrument Covers and Panel—Sponge with a mild soap solution. *DO NOT* use household cleaners containing chlorinated or abrasive compounds. *DO NOT* spray liquids directly onto the instrument.
2. Printer—Refer to the printer's service manual for cleaning instructions.

NOTE

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

Replacing the Printer Paper Roll

The optional P1 printer uses the following replacement paper types:

- Cut sheet thermal paper – letter, legal, or A4 sizes
- Rolls of thermal paper – Approximately 100 ft (30.4 m) (Doble P/N 401-0169)

Figure C.1 shows the front panel of the printer.

1	Captive screws
2	Printer control button
3	Paper input slot

Figure C.1 Printer Front Panel

To replace the paper roll:

1. Loosen the two captive screws securing the printer cover and pull the cover up (Figure C.2).

Figure C.2 Printer Cover Lifted Up

2. Rotate the paper roll to remove any remaining paper from the printer's input slot.

3. Push the paper roll to the right and pull it out (Figure C.3).

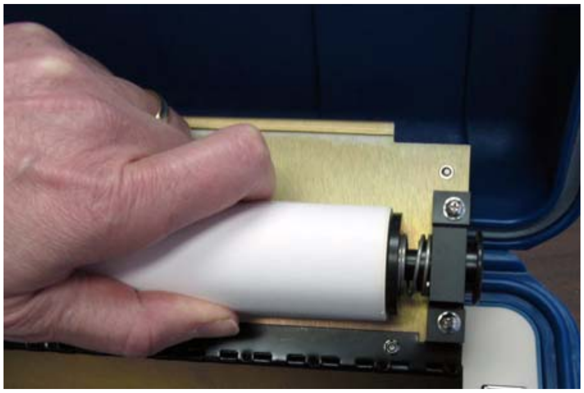


Figure C.3 Removing Paper Roll

4. Insert a new roll so that the paper unrolls from the bottom, not the top, of the roll (Figure C.4).

Figure C.4 Paper Unrolling from Bottom

5. Unroll the first few inches of paper and tear an even edge.

The paper does not feed successfully into the printer if the edge is uneven.

6. Align the bottom edge of the paper roll with the paper input slot. Insert the paper under the paper roller until the roller pulls it into the starting position, then let go.

7. Press the printer control button, (shown in Figure C.1) until the paper feeds through fully aligned (6" -12"). See Figure C.5.

Figure C.5 Paper Correctly Installed

8. Close the printer cover and tighten the two captive screws.

If the paper is skewed after the printer pulls it into the starting position, correct the situation as follows:

- If the printer does not print immediately, open the release cover as far back as it goes. Pull the paper out, reinsert it, and close the cover.
- If the printer does start to print, wait for the page to be printed and then reprint that page if necessary.

The paper can be pulled out of the printer in either direction.

For complete instructions on the operation of the Pentax printer, refer to its user’s manual, which is included with the TDR instrument.

D. 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 D.1.

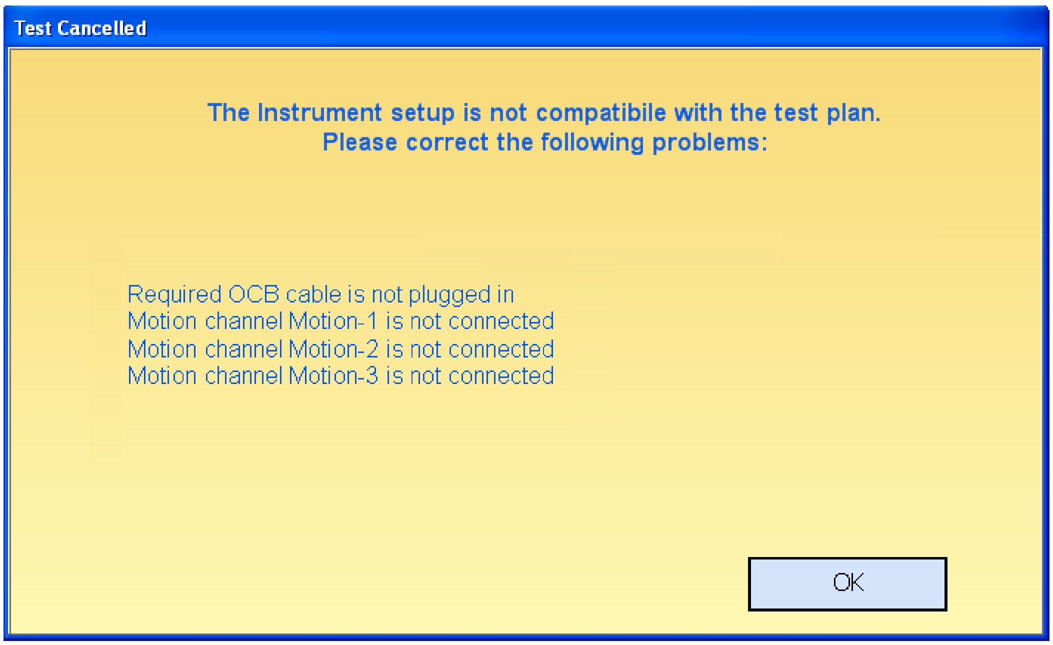


Figure D.1 "Test Cancelled" Error Message

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 D.2 shows an example.

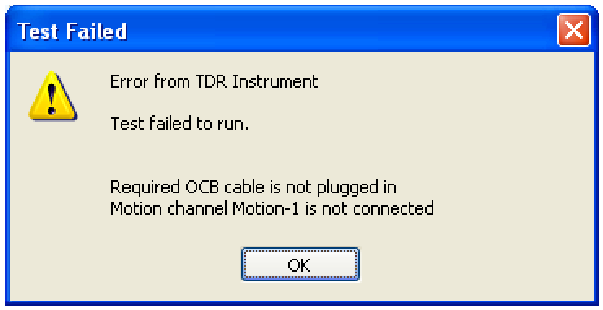


Figure D.2 "Test Failed" Error Message

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

1. Ensure that the equipment under test does not exceed TDR instrument operating limits.

2. Investigate the specific items mentioned in the text of the error message.

3. Call Customer Service.

E. Concepts of Operation

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

- "Channel Types" on page E-1
- "Circuit Breaker Control" on page E-3
- "System Operation" on page E-4

Channel Types

The TDR instruments are multi-purpose data recorders outfitted with various signal sources and receiver channels. The TDR9000 and TDR900 support these channel types:

- Main and contact resistor switch timing
- Pre-Insertion resistor value (TDR9000 only)
- Motion (using a transducer) channels
- Auxiliary contact channels
- Analog channels
- Capacitance channels (TDR9000 only)

Each channel type, except Capacitance, has a different front panel. However, all channels are collected and forwarded to the controller for processing in the same manner. Data processing creates measurements, compares them to specifications (circuit breaker vendor limits or learned results shared between utilities), and produces Pass/Fail 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 TDR instrument. 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 10 kHz 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 µs and is sampled at 2 MHz.

Resistor Switch Timing

Resistor switch 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 *resistance* state.

Resistor Ohmic Value (TDR9000 Only)

The resistor measurement circuit employs the same voltage source and source resistor as the contact timing circuits. The voltage across the contacts is monitored by a voltage-to-frequency converter; this converter's output is optically coupled to a digital counting circuit. Knowing the source voltage, source resistance, and voltage across the pre-insertion resistor contacts allows the actual pre-insertion resistance to be calculated. The output of the digital counting circuit is updated every 800 µs (1.25 kHz).

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 at 10 kHz. 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 10 kHz.

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 10 kHz.

Capacitance Channels (TDR9000 Only)

The Capacitance test is used to measure EHV grading capacitors. These capacitors are located in parallel with the main contacts and can be measured through the EHV instrument inputs when the contacts are open. The test consists of measuring capacitance, in the range of 75 to 10,000 pF, between each of the two EHV leads and the common lead for each phase and each module. The test measurement accuracy is in the range of ± 5%. The circuit breaker is not operated during the test.

Circuit Breaker Control

The system can be configured with 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 the Trip channel and 20 A of current on 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 instrument, 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 instrument and T-Doble, the controller software that runs on a laptop.

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. A main contact measurement could be made up of a channel of contact timing and a channel of pre-insertion resistance value measurement (resistance measurement TDR9000 only). Each 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 38.4 kbps. 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/Fail 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.

F. TDR900 Circuit Breaker Test System Specifications

This appendix provides the specifications for the TDR900 and its operations.

NOTE

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

General Specifications

Table F.1 TDR900 General Specifications

Characteristic	Description
Recordings	• 25 s (all channels at max resolution) • Up to 30 min. (reduced resolution)
Communication	USB or Ethernet
Safety	• Safety Ground • Safety Switch (local and remote) • Audible Indication (test in progress)

Physical Specifications

Table F.2 TDR900 Physical Specifications

Characteristic	Description
Dimensions	• 24.0 X 15.5 X 8.5 in • 60.9 X 39.4 X 21.6 cm
Weight	22 lbs (10 kg)
Power Supply	100 V to 240 V, 50/60 Hz
Temperature	• 0 °C to 50 °C operating • -25 °C to 70 °C storage
Humidity	Up to 95% relative humidity, non-condensing

Main Contact and Resistor Switch Timing

Table F.3 TDR900 Main Contact and Resistor Switch Timing

Characteristic	Description
Number of Phases	3
Breaks Per Phase	4
OCB Configuration	3 contacts
EHV Configuration	[3, 6, 9, 12] contacts
Resolution	100 µs
Resistor Detection Range	10 Ω to 10 kΩ
Voltage Isolation to Chassis	1.0 kV

Trip/Close Initiation Control

Table F.4 TDR900 Trip/Close Initiation Control

Characteristic	Description
Maximum Input Current	± 25 A
Maximum Input Voltage	± 300 V
Voltage Isolation to Chassis	1.0 kV

Motion Channels

Table F.5 TDR900 Motion Channels

Characteristic	Description
Number of Channels	3
Connector	25-pin D
Voltage Isolation to Chassis	1.0 kV

Analog Measurement Channels (3A)

Table F.6 TDR900 Analog Measurement Channels

Characteristic	Description
Number of Channels	3
Maximum Input Voltage	± 300 V
Input Impedance	1 Ω
Resolution	12 Bit
Ranges	± 300 V: ±1.5% Reading, ±2% Full Scale Offset ± 10 V: ±1.5% Reading, ±2% Full Scale Offset ± 2 V: ±1.5% Reading, ±2% Full Scale Offset ± 0.2 V: ±1.5% Reading, ±8% Full Scale Offset
Voltage Isolation to Chassis	1.0 kV

Auxiliary Contact Channels (3X)

Table F.7 TDR900 Auxiliary Contact Channels

Characteristic	Description
Number of Channels	3
Maximum Input Voltage	± 300 V
Open Circuit Voltage	29 V ± 10%
Close Circuit Current	28 mA ± 10%
Voltage Isolation to Chassis	1.0 kV

G. TDR9000 Circuit Breaker Test System Specifications

This appendix provides the specifications for the TDR9000 and its operations.

NOTE

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

OCB/Motion

Table G.1 lists the characteristics of the OCB/Motion module.

Table G.1 OCB/Motion Module Specifications

Characteristic	Description
OCB	
Main Contact Channels	3 channels with 1 break per phase
Contact Sense Voltage for Main Contact Timing	48/15/7.5 V DC (Modified by resistor value)
Contact Sense Voltage for Resistor Switch Timing	48/15/7.5 V DC (Modified by resistor value)
Close and Open Timing Resolution	100 µs
Close and Open Timing Accuracy	± 100 µs
Minimum Contact Bounce Measurement	60 µs
Pre-Insertion Resistor Value Range	10 Ω to 400 Ω, or 300 Ω to 7000 Ω

Table G.1 OCB/Motion Module (Continued)Specifications

Characteristic	Description
Resistor Value Measurement Accuracy	± 10% of resistor value
Motion Transducers	
Linear Transducer	
Range	0.0" to 40.0"
Resolution	0.00125"
Accuracy	± 0.1% of measured value ± 0.1" max error
Display Resolution	0.002"
Maximum Velocity	50 ft/s max
Maximum Acceleration	1200 g for 50 µs max
Rotary Transducer	
Range	0° to 2880°
Resolution	0.09°
Display Resolution	0.1°
Accuracy	± 0.1% of measured value ± 0.1° max error
Velocity	120 rev/s max
Acceleration	30 x 106 deg/s^2 max

EHV Module

Table G.2 lists the characteristics of the EHV module.

Table G.2 EHV Module

Characteristic	Description
Main Contact Channels	6 channels with 2 breaks per phase
Contact Sense Voltage for Main Contact Timing	15 V/7.5 V DC (Modified by pre-insertion resistor value)
Contact Sense Voltage for Resistor Switch Timing	15 V/7.5 V DC (Modified by pre-insertion resistor value)
Close and Open Timing Resolution	100 µs
Close and Open Timing Accuracy	± 100 µs
Minimum Contact Bounce Measurement	60 µs
Pre-Insertion Resistor Value Range	10 Ω to 300 Ω 200 Ω to 500 Ω
Resistor Value Measurement Accuracy	± 10% of resistor value
Capacitance Measurement Range and Accuracy	75 pF to 10,000 pF in the range of ± 5%

Event Module

Table G.3 lists the characteristics of the Event module.

Table G.3 Event Module

Characteristic	Description
Analog Channels	
Number of Channels	3 per module
Sampling Frequency	10 kHz

Table G.3 Event Module (Continued)

Characteristic	Description
Voltage Measurement Range DC or AC peak value	± 300 V
Analog Signal Bandwidth	0 Hz to 5 kHz
Amplitude Accuracy	± 0.5% of full scale, ± 0.5% of reading (± 0.5% of full scale, ± 1.5% of reading for ± 300 V
Current Ranges	0.0 A to 20 A, 0.0 A to 200 A (Probe)
Isolation Voltage to Ground	300 V
Auxiliary Contact Channels	
Number of Auxiliary Contact Channels	3
Sense	Open Wet/Open Dry/Close
Wetting Voltage	28 V
Voltage Input	0.0 V to 300 V

System Module

The System module is comprised of several components whose specifications are given in the following tables.

Table G.4 lists the characteristics of the Trip/Close module.

Table G.4 Trip/Close Module

Characteristic	Description	
	Trip	Close
Peak Voltage	300 V	
Maximum Current Non-Repetitive Pulse	100 A DC	20 A DC
Maximum Turn On/Off Time	10 µs	

Table G.5 list the characteristics of the Trigger In function.

Table G.5 Trigger In

Characteristic	Description
Sense	Open Wet, Open Dry, Close
Wetting Voltage	28 V
Voltage Input	0.0 V to 600 V DC

Table G.6 list the signal characteristics of the System module.

Table G.6 System Module Signal Characteristics

Characteristic	Description
Trip/Close Command	
Pulse Width	8.0 ms to 1600 ms / 0.5 to 96 cycles
Resolution	0.1 ms / 0.1 cycle
Trip Command Current Range	2 A/5 A/20 A/100 A
Close Command Current Range	0.2 A/1 A/5 A/20 A
Delay	
Duration	0 ms to 1600 ms/ 0 to 96 cycles
Resolution	0.1 ms / 0.1 cycle
Recording Time	
Circuit Breaker	Up to 25 s at maximum resolution Up to 30 min at reduced resolution

Physical Specifications

Table G.7 lists TDR9000 physical specifications.

Table G.7 TDR9000 Physical Specifications

Characteristic	Description
Enclosure	High impact, molded, flame retardant ABS. Meets National Safe Transit Association testing specification No. 1A for immunity to severe shock and vibration.
Dimensions	10.0" H x 16.0" W x 15.5" D (25.4cm x 40.6cm x 39.4cm)
Maximum Weight	30 lbs.(13.6 kg): Includes cover, printer and maximum configuration
Supply Voltage	100 V to 240 V AC 50/60 Hz
Electrostatic Discharge Immunity	Meets IEC 1000-4-2 Level 4 (formerly IEC 801-2)
Surge Withstand Capability	Meets ANSI C37.90 1989 ESD

Environmental Specifications

Table G.8 lists TDR9000 environmental specifications.

Table G.8 TDR9000 Environmental Specifications

Characteristic	Description
Storage Temperature Range	–25 °C to 70 °C
Operating Temperature Range	0 °C to 50 °C
Storage Humidity	95%, non-condensing

H. Application Notes

This appendix contains the application notes relevant to operating the TDR instrument and the TR3190.

They include:

AN2: TR3190 Digital, Linear/Rotary Motion Transducer

The TR3190 transducer is used to measure the position and velocity of the operating mechanism of a circuit breaker.

This transducer consists of a reference disk of known diameter, which is directly coupled to an optical shaft encoder. When the breaker operates, it displaces a rod, and the motion of this rod is transmitted through a high pressure friction drive to the circumference of the reference disk. The angular displacement of the disk is proportional to the linear travel of the rod and is encoded by the optical shaft encoder.

With the addition of the rotary adapter, the rotary motion of a shaft in a circuit breaker can be coupled to the transducer and a measurement of angular displacement and angular velocity is obtainable.

The optical encoder translates the rotation of a shaft into interruptions of a light beam. The light source, a light emitting diode, is collimated by a molded lens into a parallel beam of light. The light beam is interrupted by a code wheel comprised of a metal disk with equally positioned apertures around its periphery.

A matching set of apertures is located in a fixed plate. The light beam is transmitted only when the apertures are aligned, which produces a light pulse for each aperture. A molded lens beneath the base plate collects the modulated light and directs it to a detector.

There are two identical channels. Each channel consists of two photodiodes, an amplifier, a comparator, and output buffers. The apertures for the two photodiodes are positioned so that a light period on one detector corresponds to a dark period on the other. The photodiode signals are amplified and fed to the comparator whose output changes state when the difference of the two currents changes sign. The second channel has a similar configuration, but the location of its aperture pair provides an output that is in quadrature to the first channel (phase difference of 90 °). The direction of rotation is determined by observing which of the two channels is the leading wave form. The number of pulses encodes the angular displacement of the disk. This pulse train is converted to a number that is stored in memory at a regular interval. This interval produces a time reference that is used to plot displacement per unit time or instantaneous velocity. The motion plot is produced by plotting the sum of the displacement data vs. time. The delta displacement for each sample interval represents the total displacement that has occurred during the sample interval. Therefore, this data can be translated directly into velocity, which is then plotted for each time interval.

There are a number of different ways the TR3190 Motion Transducer can be interfaced with a breaker. For applications in which part of the accessible breaker mechanism exhibits linear motion, the following method may be employed:

> The transducer is designed to couple to a 1/4" Mild Steel connecting rod, which must be 0.250" ± 0.010" and free from nicks or burrs. Select a point on the breaker mechanism, as close to the contacts as possible, that exhibits linear motion in one plane. The top of the lift rod on most dead tank oil breakers is provided with a #10 x 24 threaded hole for this application. This threaded hole is typically accessible through a small hole located under the cap for the stop adjustment on the center tank. If this attachment point is not provided, it is still possible to attach a rod to other

points on the breaker. For instance, it is often possible to access the lift rod in the cabinet of the breaker. A collar could be fabricated that attaches around the lift rod and provides a place to attach the 1/4" connecting rod. The transducer connecting rod will accommodate 15° of angular displacement. This displacement must be in a plane parallel with the front surface of the transducer. The degree of freedom can be ascertained by placing the rod in the transducer, closing the latch, and then moving the rod back and forth. Observe the motion of the pressure rollers. By using this feature, it is possible to attach the transducer to a point that moves in more than one plane as the breaker operates. In many breaker mechanisms, there are bell cranks that transmit the motion of the prime mover to the contacts. Using a suitable flexible coupling for attaching the connecting rod to a bell crank provides a good representation of contact motion.

Once the attachment point for the connecting rod has been determined, the next step is to provide a suitable mount for the transducer. This mount should be rigid and hold the transducer perpendicular to the line of motion of the connecting rod. In many oil breakers, the cap that covers the access hole is a pipe cap approximately 2" in diameter. Determine the pipe size of the cap. Obtain a pipe coupling, short pipe nipple, and a floor flange to assemble a simple but reliable and rugged circuit breaker mounting adapter. The pipe-coupling, short-nipple, floor-flange assembly is screwed on in place of the cap. After this adapter is screwed on to the breaker, the connecting rod is then installed and the transducer is clamped to the floor flange with *C*-clamps. If this approach is not possible, other fasteners on the breaker can be used, or suitable fixtures can be fabricated that clamp to the structure of the breaker. Remember that the data generated by the transducer is distorted by any motion of the mounting setup during circuit breaker operation.

There are several features of the transducer that are used to alleviate difficult mounting problems. The base plate of the transducer is detached by removing the four flat-head screws visible on the bottom of the device. Other mounting plates can be fabricated to meet special needs, or the transducer can be used without the mounting plate. There are threaded holes on the bottom and front surface of the transducer that are used to secure the transducer to special mounting fixtures. When using this method, take care to ensure the screws that are used are of correct length; screws that are longer than necessary may damage the internal mechanism of the transducer. The transducer can be mounted with either its top or bottom facing the breaker. Avoid applying clamping forces to the housing of the transducer, as it is possible to distort the housing and cause loss of accuracy.

The rotary motion adapter is used to interface to circuit breakers in which the mechanism moves in a rotary manner, or to couple to a part of a breaker mechanism that moves in an arc. If a breaker exhibits rotary motion, observe the mechanism and identify the shaft to be monitored. The rotary motion adapter of the transducer must be attached to the end of this shaft. The adapter is provided with a drill chuck which accommodates up to a 3/8" diameter shaft. The shaft in the breaker can be provided with a threaded hole for a suitable adapter. If this is not the case, an adapter with a 3/8" extension for the chuck collar can be fabricated. This collar slips over the end of the shaft and is retained by a set screw. If this is not possible, the chuck is removed from the rotary motion adapter and other fixtures are installed in its place.

The transducer supports itself on the end of the rotary motion shaft; however, a means of preventing rotation of the transducer during circuit breaker operation must be provided. To do this, a length of 2" x 2" angle is clamped to the transducer and to a suitable part of the circuit breaker structure. Care should be used to minimize the free motion in this setup, as it causes errors in the recorded data. The base plate of the transducer is removed to provide more clearance. When this is done, the angle stock is screwed to the transducer using the base plate mounting holes.

A sensing switch on the transducer determines whether a rotary adapter is in use before the test begins. The software then checks to ensure that the test plan motion channels are properly configured. The actual units in use for the test results are dictated by the entries into the test plan.

If a breaker has no location where there is a rotating shaft, or no point where a linear motion can be monitored, there could be a location where there is a component that moves through an arc. In this case, a small rod (approximately 1/4") is attached to the breaker mechanism with a swivel joint and to a similar length crank arm mounted in the chuck of the Rotary adapter. In this way, the rotation of this shaft is translated and measured.

Some points to consider when designing mounting fixtures for the transducer:

- The fixture should be as rigid as possible, as any motion between the fixture and the breaker appears as an error in the results. This is particularly noticeable if the fixture shakes when the breaker strikes the stop at the end of its travel. This creates the appearance of faulty damping when none exists.
- Be careful in the design of fixtures and devices applied to the moving parts of the breaker mechanism to ensure no interference occurs when the breaker operates.
- Large forces are generated when a breaker is operated; do not stand in line with the motion of the connecting rod or allow loose parts near the transducer.

Specifications

The TR3190 Motion Transducer is designed for interfacing to circuit breakers measuring the motion and velocity of the operating mechanism and particularly the movement of the contacts. Table H.1 lists its specifications. In this table, “g” refers to gravities.

Table H.1 TR3190 Specifications

Specification		Values
Range of measurement	Linear motion	0.0" - 40.0"
	Rotary motion	0.00° - 2880°
Velocity	Linear motion	50.0 ft/s (maximum)
	Rotary motion	120 rev/s (maximum) 43200°/s (maximum)
Acceleration	Linear	100 g 400 g for 50 µs
	Rotary	125,000 rad./s^2 7.162 x 106 °/s^2
Displacement	Accuracy	± 0.1% of measured value or ± 0.1" (whichever is smaller) ± 0.1% of measured value or ± 0.1° (whichever is smaller)
	Resolution/Linear	0.002"
	Resolution/Angular	0.1°

Table H.1 TR3190 Specifications (Continued)

Specification		Values
Environmental	Temperature/Storage	– 55 °C to 70 °C
	Temperature/Operating	– 40 °C to 50 °C
	Acceleration and Vibration/Transporting	ASTM D 999-75 (repetitive shock test)
	Acceleration and Vibration/Operating	Vibration 20 m/s^2, sinusoidal; 5 to 500 Hz Shock 200 m/s^2
	Humidity	95% noncondensing atmosphere
	Contaminates/Transformer Oil	Accuracy is unaffected by oil adhering to the connecting rod
	Contaminates/Soil	Accuracy is unaffected by dirt adhering to the connecting rod
Mechanical	Dimensions	Transducer App. 4.0" x 6.0" x 4.0" See Doble drawing # 76D-0195
	Mounting	Clamping plate 6.0" x 10.0" See Doble drawing # 2FC-1905
	Breaker Interface/Linear	Standard Doble 1/4" Connecting rod: maximum stroke length: 40"
	Breaker Interface/Rotary Adapter	Equipped with 3/8" x 18" threaded shaft, with Jacobs Chuck; other shaft adapters may be fabricated for mounting to the threaded shaft, as required
	Interface to TR3100	Doble P/N 181-0107 (50 ft/15.2 m cable)

Figure H.1 on page H-7 shows the assembly drawing for the TR3190.

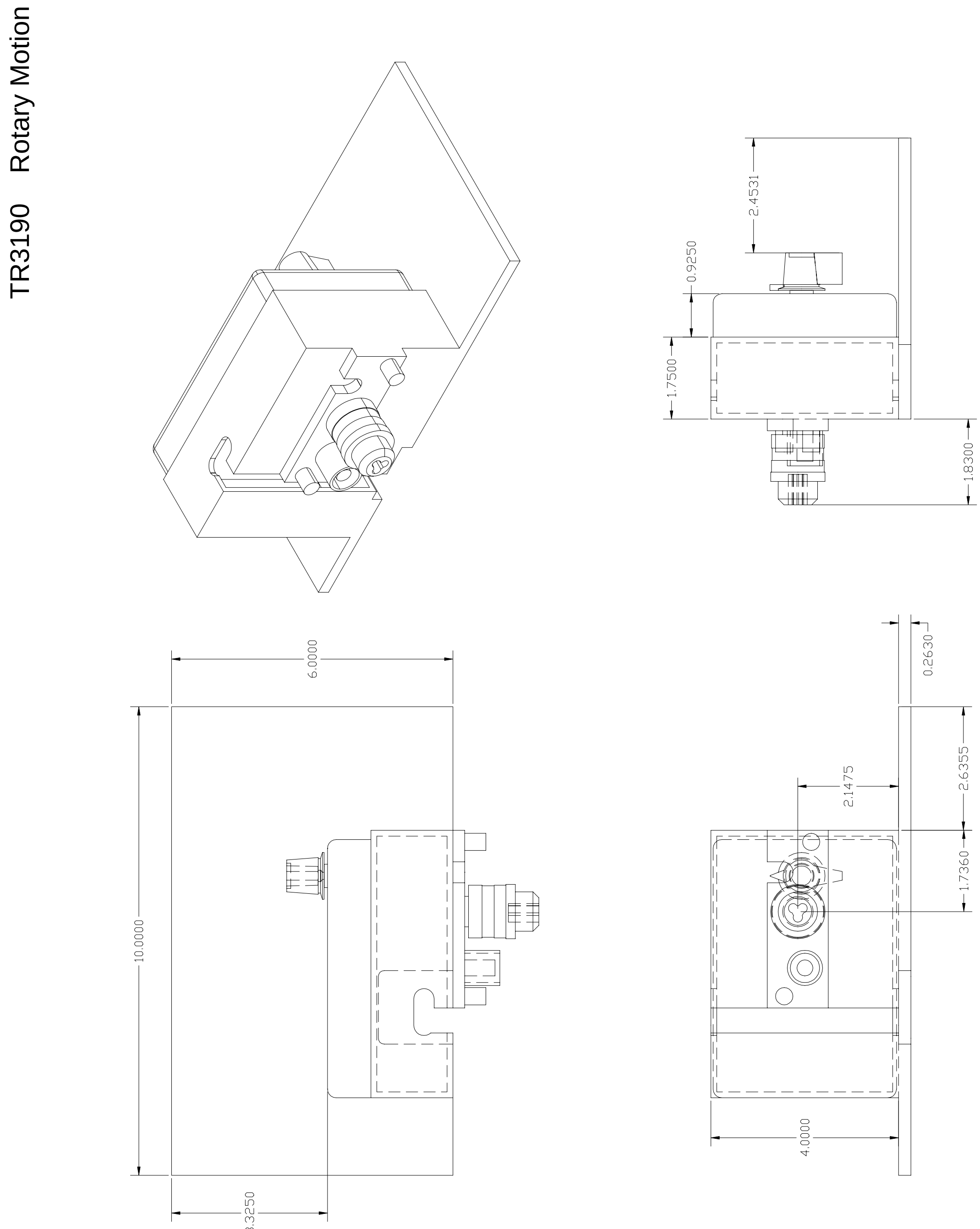


Figure H.1 TR3190 Linear Motion with Rotary Chuck Attached

Also available is the TR3170 Transducer (Figure H.2), a scaled-down version of the TR3190 Transducer, which is designed for linear use only.

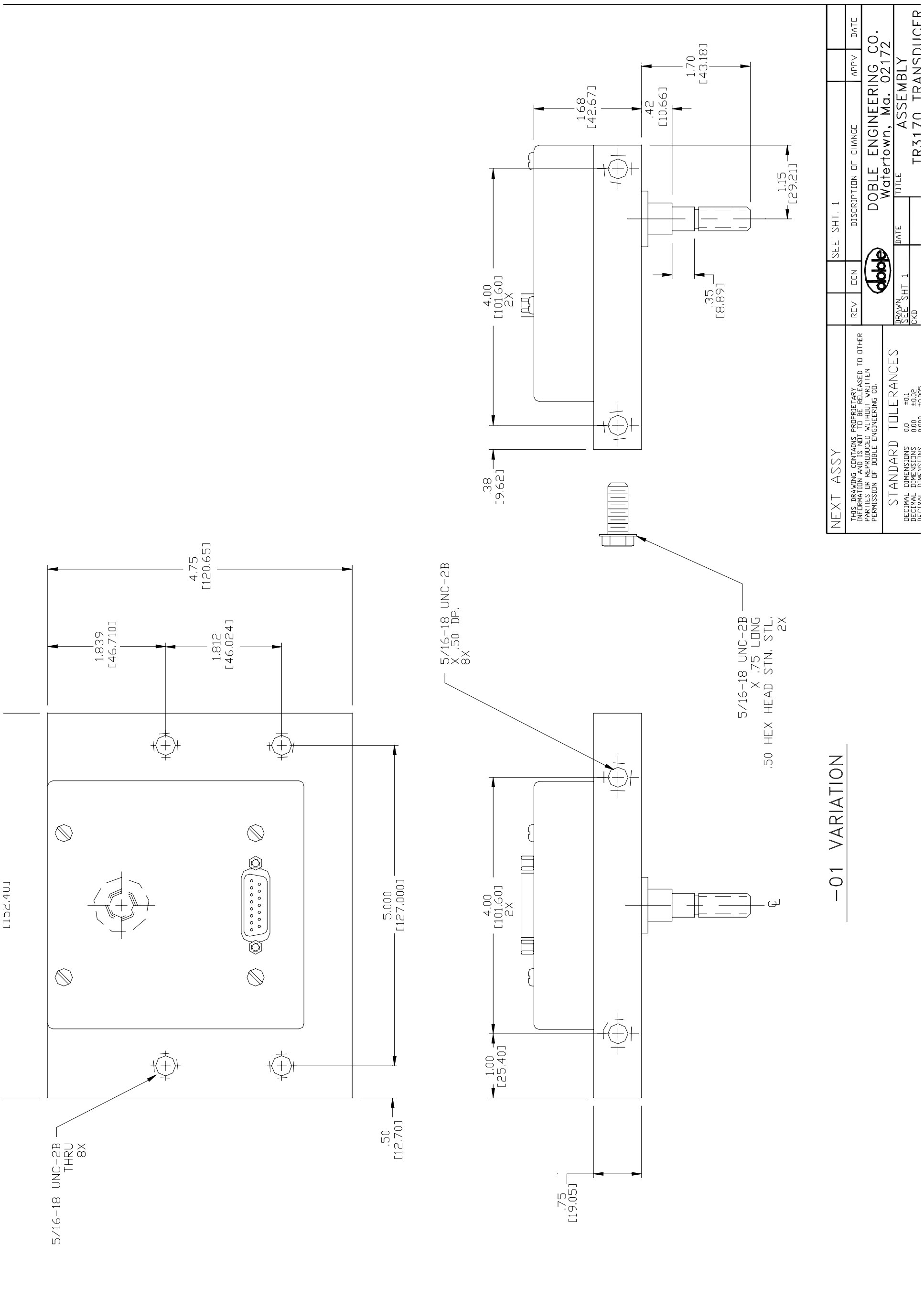


Figure H.2 TR3170 Linear Transducer

AN3: TR3190 Mechanical Interfaces and Other Transducers

Measuring the mechanical displacement and velocity of circuit breaker mechanisms vs. time and contact operation is an important analytical method.

Many utilities use simple, mechanical *Tom Edison Toys* that only measure mechanical displacement vs. time as their primary breaker timing tool. Many years of TR1 and TR2 experience have taught us much about mechanical measurements using the MY transducer, including how to successfully interface the transducer to breaker mechanisms. Although it is straightforward, it is not quite so simple as it appears. High acceleration requires interfaces and transducers with low mass, so as not to affect the measurements. High shock loads at the limits of travel require rugged interfaces so they don't fall apart or impart false movement due to their mechanical instability. High resolution and accuracy are required; none of these characteristics is commercially available, so the TR3190 was born.

"AN2: TR3190 Digital, Linear/Rotary Motion Transducer" on page H-1 describes the design of the TR3190 Digital, Rotary/Linear Transducer in detail and provides insight into the design of adapters and interfaces. It is Doble's policy to develop both rotary and linear motion mechanical interfaces for the TR3190.

Over the years the client users of TR1/TR2 have also developed interfaces and documented many of them. The SFA interface has been developed because the OEM slide wire adapters supplied by Westinghouse to provide electrical measurements of motion are no longer available.

NOTE

The T3 Input Expander was an auxiliary instrument designed to interface between Westinghouse SFA slide wires and TR2/PR2, and to interface to additional MV Transducers for measuring a total of three mechanisms simultaneously.

Photographs of the interface connected to an SFA breaker module, a sketch of the interface form part of this design, will be provided on request.

Other additions include the TR3170 Rotary Transducer and the TR3171 AHMA-4/8 Transducer. The TR3171 Transducer is used on any circuit breaker that uses the AB AHMA-4/8 operator. This includes ABB Type PA circuit breakers, certain ELF circuit breakers, and PM circuit breakers where the voltage class is 345 kV and above.

Adapters and Transducers

Figure H.3 shows the SFA Adapter with the motion lever arms mounted on the TR3170 Transducer, and the hardware supplied with the SFA Adapter.

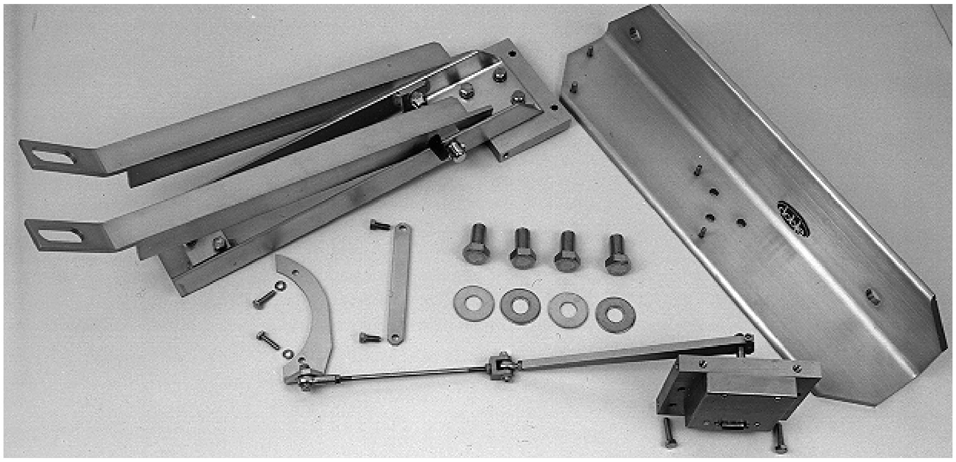


Figure H.3 Westinghouse SFA SF6 Gas Circuit Breaker

Figure H.4 shows the Doble ABB AHMA 4/8 Transducer for use with the ABB SF6 Gas circuit breakers using the AHMA 4 or AHMA 8 operating mechanism. It shown with the drive fork and the gauge block stored on the transducer using the same bolts used during testing.

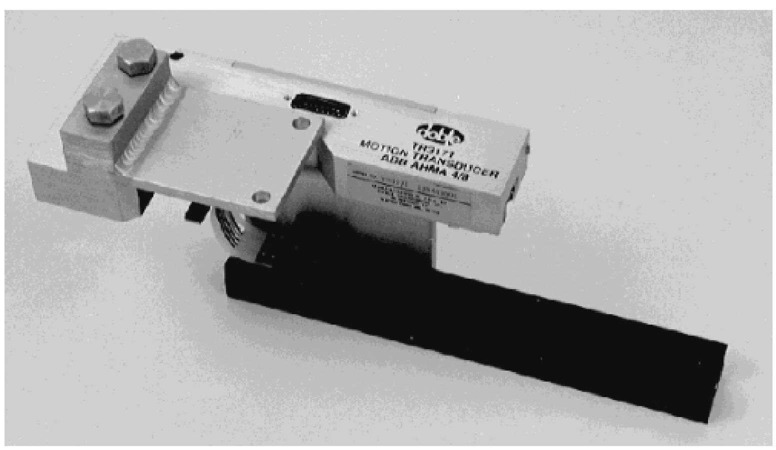


Figure H.4 ABB PA, ELF, and PM (345 kV and above) SF6 Gas Circuit Breakers

Figure H.5 shows the Doble ABB AHMA 4/8 Transducer for use with ABB SF6 Gas circuit breakers using the AHMA 4 or AHMA 8 operating mechanism. It is shown with the drive fork engaging the optical encoder assembly and the gauge block in front of the transducer. The gauge block is used to insure the coupler block is in the same plane as the surface to which the transducer is attached.

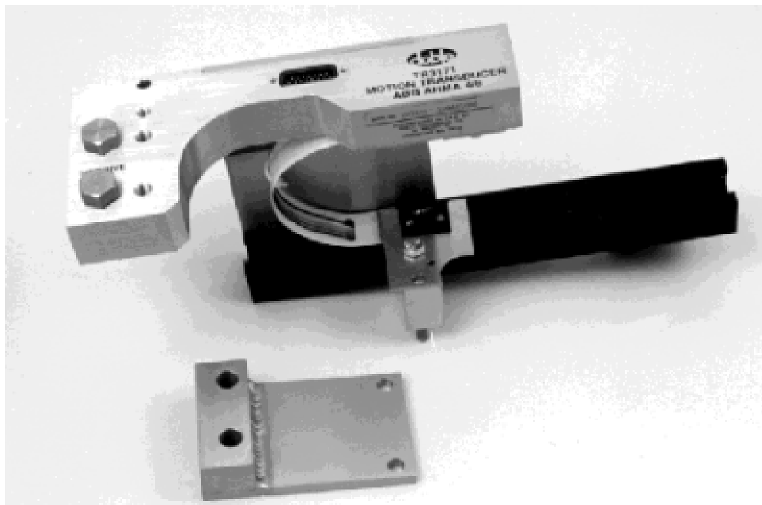


Figure H.5 ABB PA, ELF, and PM (345 kV and above) SF6 Gas Circuit Breakers

Figure H.6 shows an adapter/transducer combination that measures travel at the base of the insulator column. A hex adapter (3/8" - 24 to 12 mm) is mounted on the TR3170 rotary transducer and is attached to the rotating element of the phase.The disc that drives the semaphore remains with the rotary element. The transducer support plate is then attached to the transducer using 5/16" bolts. The transducer or transducer support plate assembly is then bolted to the aluminum casing at the base of the insulator using 8 mm x 25 mm bolts in the tapped holes used for screwing the cover on.

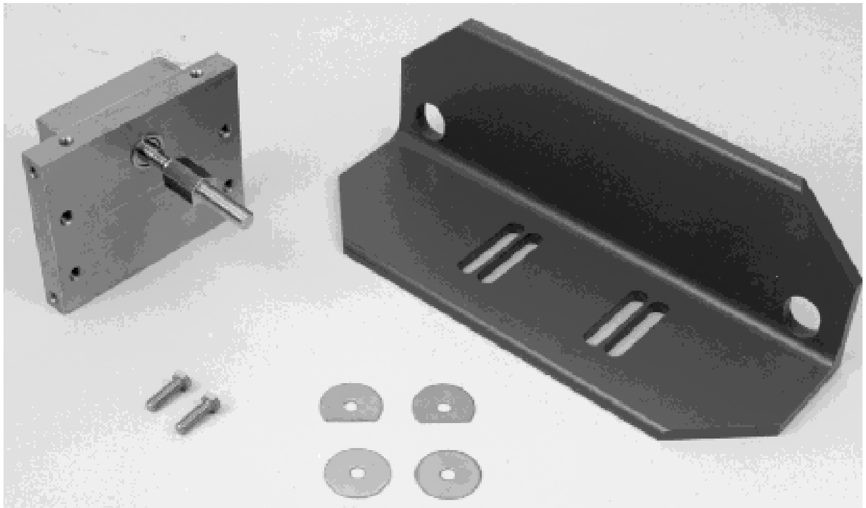


Figure H.6 ABB HPL SF6 Gas Circuit Breaker – Insulator Column

Figure H.7 shows a adapter/transducer combination that measures travel at the chain sprocket in the mechanism cabinet. A hex adapter (3/8" - 24 to 8 mm) is mounted on the TR3170 rotary transducer and is attached to the rotating element in the cabinet. The transducer hex adapter is attached to the rotating mechanism and then to the support plate. The support plate is the clamped to the structural plate in the cabinet using *C*-clamps.

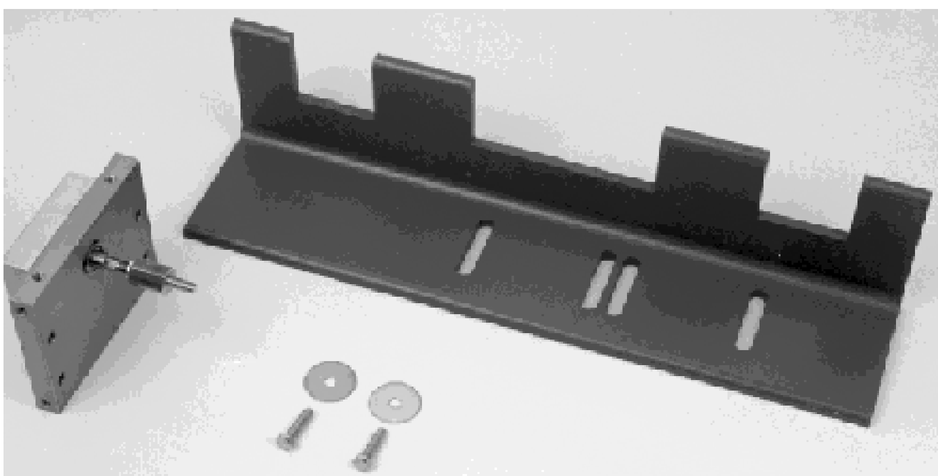


Figure H.7 ABB HPL SF6 Gas Circuit Breaker – Chain Sprocket

Figure H.8 shows an adapter for use with the HVB SF6 Gas circuit breakers that uses a ganged operating mechanism. The adapter has a metric 16 mm thread that treads into a tapped hole on the horizontal operator adjacent to pole 1 and the mechanism cabinet. This is shown with a 24" travel rod.

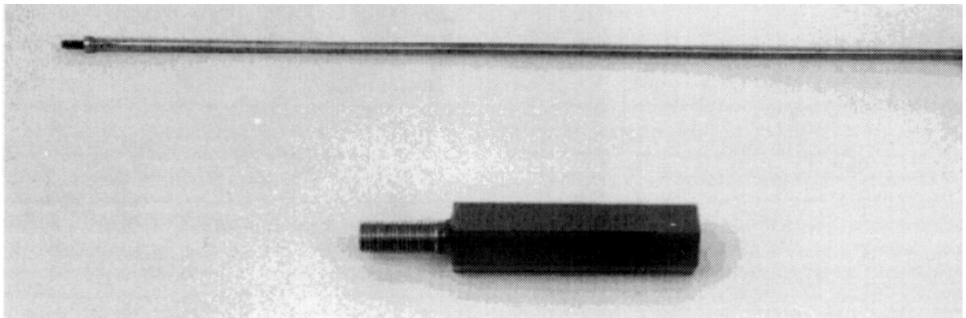


Figure H.8 HVB SF6 Gas Circuit Breakers with Ganged Operating Mechanisms

Figure H.9 shows an adapter for use with HVB SF6 Gas circuit breakers that uses an individual mechanism for each pole. A plate is removed from each pole, the large metric bolt is threaded into the moving element, and the spacer is attached to the point from which the plate was removed using existing hardware. The travel rod is inserted through the large holes in the spacer and is threaded into a tapped hole in the top of the large metric bolt. The transducer is then centered on the travel rod and clamped to the spacer.

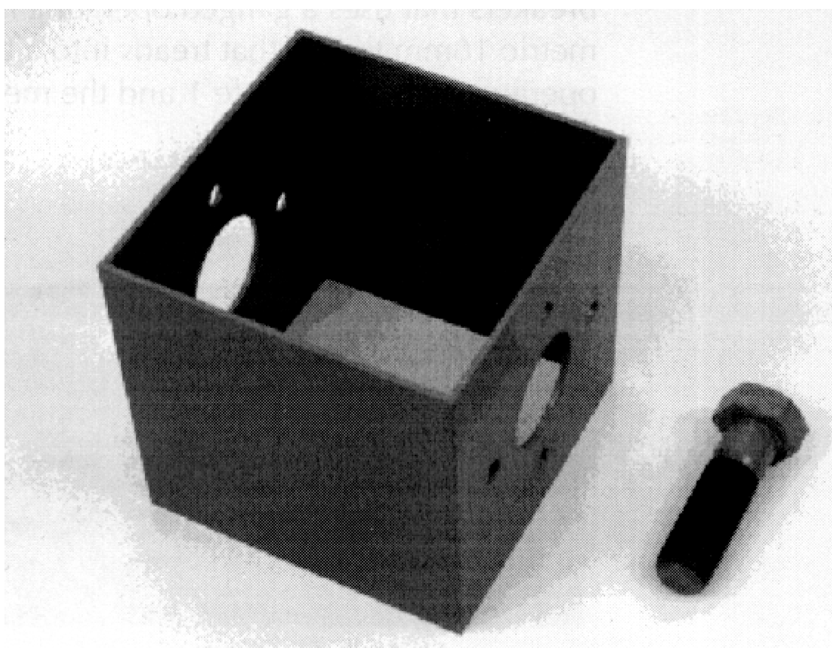


Figure H.9 HVB SF6 ® Circuit Breakers with Independent Pole Operating Mechanisms (IPO)

Figure H.10 on page H-14 shows an adapter that mounts on the moving contact assembly using existing hardware. The plate is clamped to the top of the circuit breaker with the forked arms extending beyond the bushing. The transducer is clamped to the support plate. The plate is bent at the proper angle to ensure the travel rod does not touch the transducer case during circuit breaker operation.

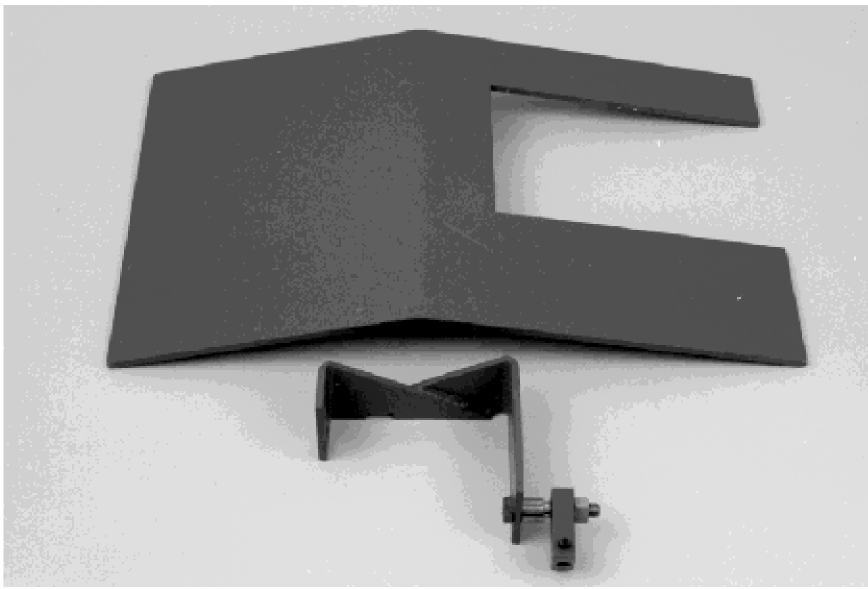


Figure H.10 General Electric Metalclad Air Magnetic Circuit Breakers (600 and 1200)

Figure H.11 on page H-15 shows this adapter for the 2000 A and above range.

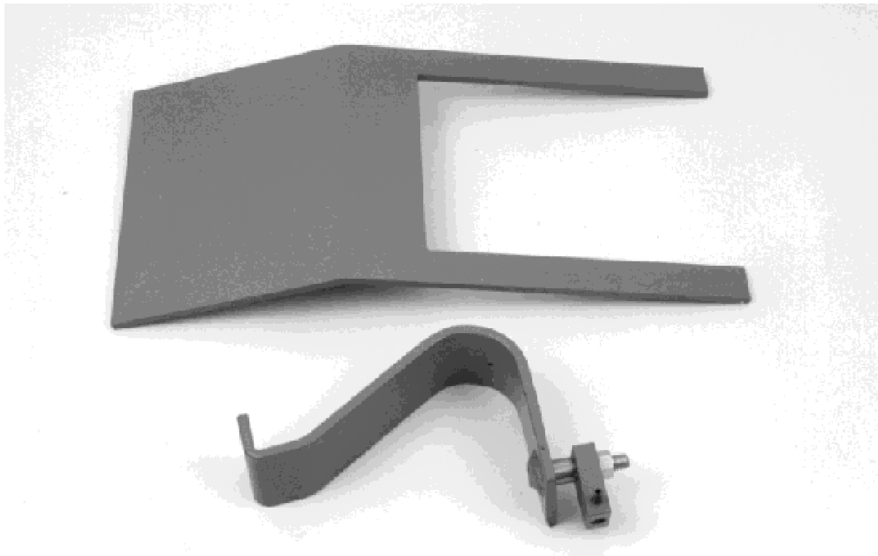


Figure H.11 General Electric Metalclad Air Magnetic Circuit Breakers (2000 A and above)

Figure H.12 shows the adapter for the VBI with the ML-18 operator (left) and the VBl with the ML-17 operator (right). These adapters mount on the vacuum bottle erosion ring and allow travel measurements to be made on the circuit breaker contacts.

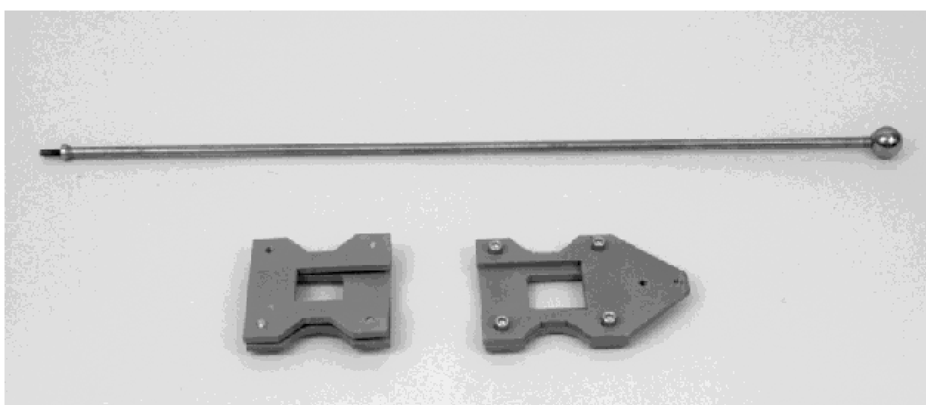


Figure H.12 General Electric Metalclad VBI Vacuum Circuit Breaker

Figure H.13 shows an adapter/transducer combination that measures travel at the bellcrank assembly where operating rod travel perpendicular to contact travel is changed to travel parallel to interrupter travel. A hex adapter (3/8" -24 to 10 mm) is mounted on the TR3170 rotary transducer and is attached to the rotating element of the phase. The transducer is then secured to the cast aluminum casing that surrounds the moving elements with 5/16" bolts and several 5/16" fender washers.

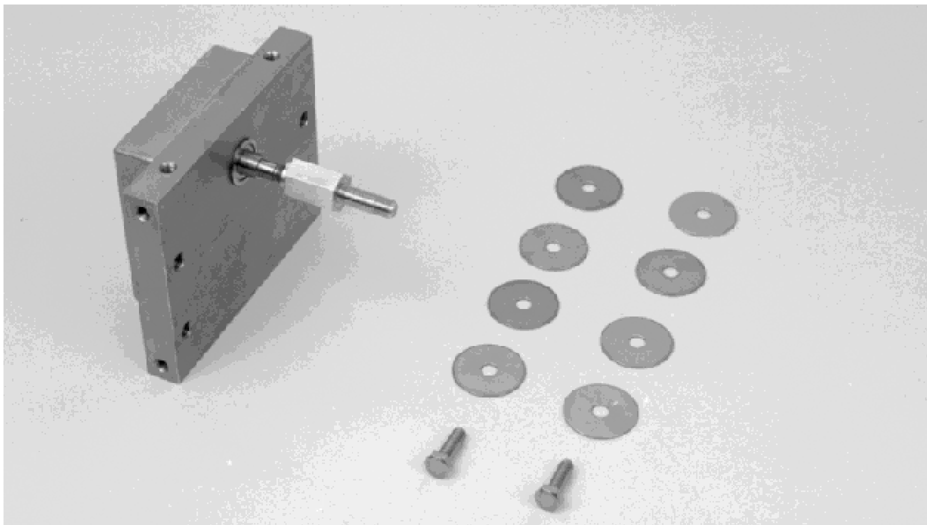


Figure H.13 GEC Alsthom HGF Series SF6 Gas Circuit Breakers

Figure H.14 shows the extended pin that replaces the normal drive pin. A tab slips over the pin extension and the transducer rod is threaded into a tapped hole in the tab. The transducer is clamped to the mechanism cabinet.

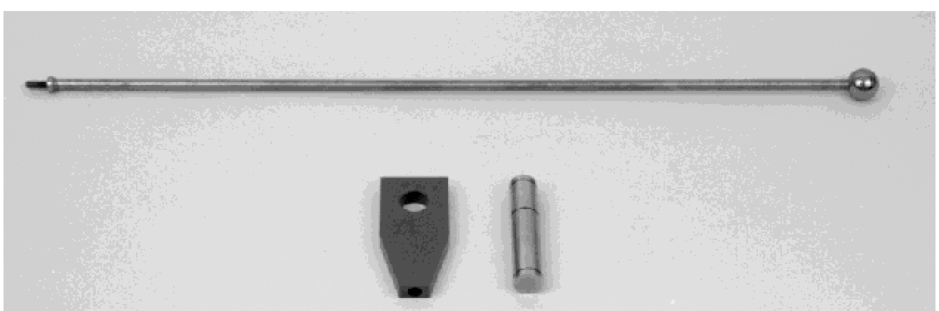


Figure H.14 Mitsubishi Electric Power Products 100 SFMT SF6 Gas Circuit Breakers

Figure H.15 shows the large *L* shaped plate that replaces the standard bottom plate on the TR3160 Transducer using the hardware that secures the standard base plate to the transducer body. The small *L* shaped bracket is attached to the moving element of the circuit breaker mechanism using metric cap screws. A shortened transducer rod completes the installation.

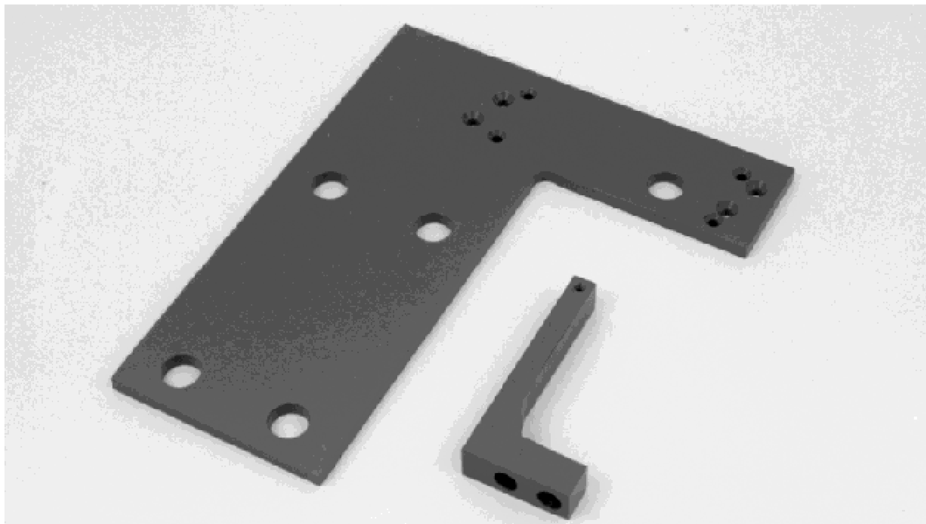


Figure H.15 Mitsubishi Electric Power Products SFMT SF6 Gas Circuit Breakers

Figure H.16 shows a general-purpose adapter, with reducers and spacers, to allow mounting of various size circuit breaker fittings. The reducers and spacers consist of a close nipple, a coupler, and a reducer.

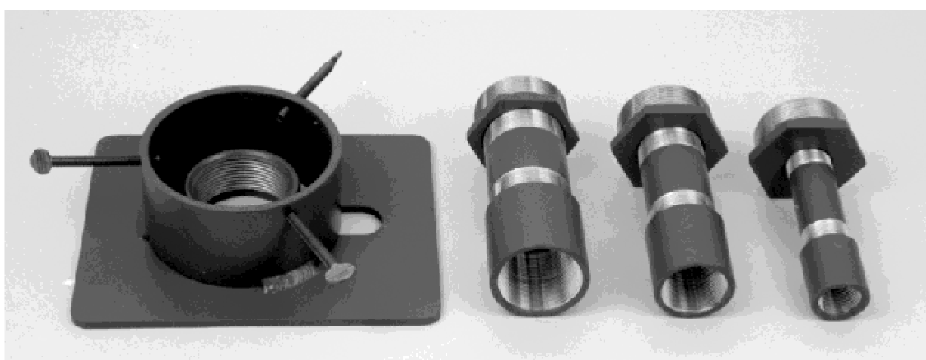


Figure H.16 General Purpose Adapter

Figure H.17 shows a general purpose spacer that is used where it is difficult or impossible to mount the transducer directly to the circuit breaker. The spacer is bolted to the circuit breaker using existing bolt holes and the TR3160 Transducer is clamped to the other end of the spacer using *C*-clamps. A hole through two ends of the space is provided for the transducer rod.

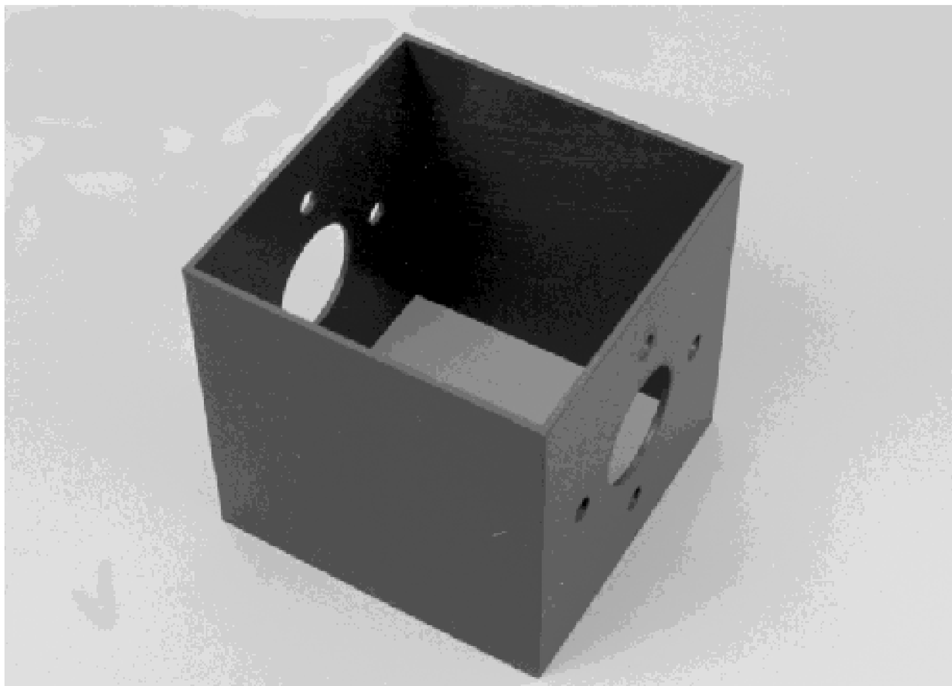


Figure H.17 General Purpose Spacer

Figure H.18 shows various clamps used to temporarily secure the transducer to a fixture.

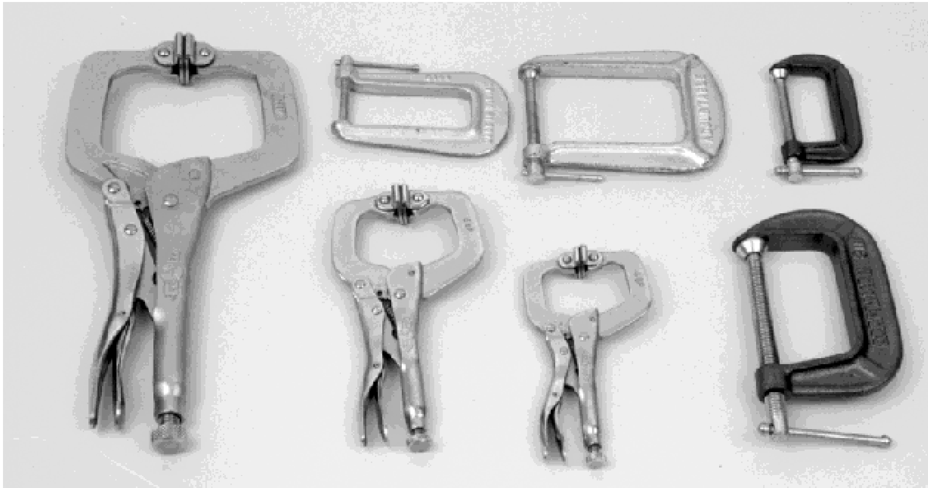


Figure H.18 Various Transducer Clamps

AN4: Contact Dynamics Resistor Measurement (TDR9000 Only)

Figure H.19 shows a schematic for the TDR9000 contact and resistor measurement.

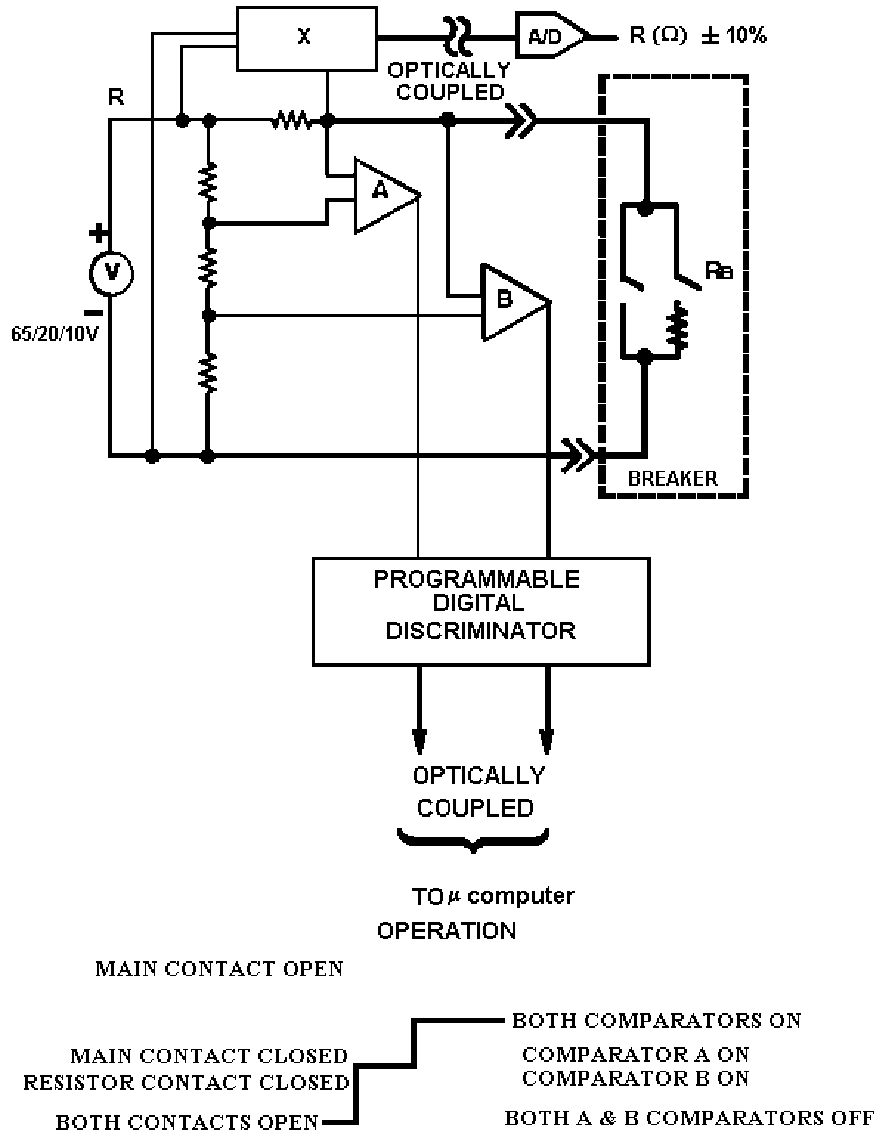


Figure H.19 Contact and Resistor Measurement

Figure H.20 explains contact and resistor timing.

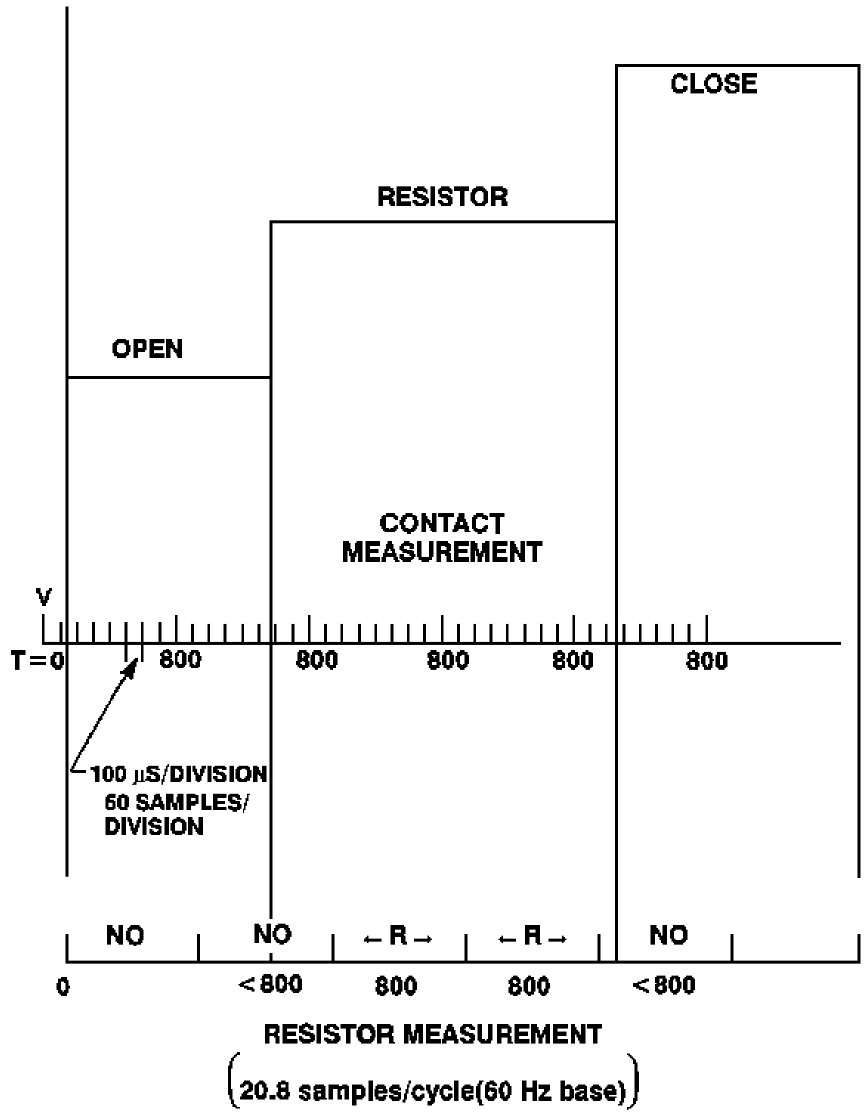


Figure H.20 Contact and Resistor Time Diagram

AN6: Velocity Measurements

The TDR instrument calculates average velocity during Trip and Close operations. These measurements are tabulated in the T-Doble Results page for each operation (see page 8-2).

Calculating Average Zone Velocity During a Close or Open

NOTE	**The reference for all distance measurements is the fully closed position of the circuit breaker, with a displacement value of zero.**

The TDR instrument calculates the average velocity for Zone 1 and Zone 2 during a Close or Open as follows:

1. The user selects one of the following zone types in the Average Velocity Limits table (see Figure 4.38 on page 4-35):
   - Distance – Distance
   - Distance – Time
   - Time – Time
   - Open – Time
   - Open – Distance
   - Open – Travel
2. The user specifies the beginning and ending points of each zone in which a travel velocity is desired, also in the Average Velocity Limits table.
3. When the transducer rod passes the selected beginning point, the TDR instrument records the time.
4. All subsequent movement of the transducer rod is summed until the transducer reaches the selected end point.
5. The end point time is recorded.

The following calculations are made:

- Travel Distance—The sum of the incremental travel distances
- Travel Time—The difference between the beginning and ending times
- Average velocity for a zone—The distance divided by the time. This value is displayed in the Motion Measurements table.

Calculating Average Velocity at Main Contact or Resistor Switch Open-Close

The average velocity at main contact or resistor switch Open-Close is calculated as follows:

1. The TDR instrument tags the time and the position of the motion transducer when the contact first makes or breaks.
2. The instrument averages nine samples centered on the contact operation event.

Effect of Displacement Values

In making velocity calculations, avoid displacement values near the beginning or end of travel. Displacement values affect Trip and Close tests as follows

- Trip tests—The circuit breaker remains closed for several milliseconds after the Trip signal is applied. If zero displacement is selected as the beginning of the zone, the TDR instrument starts timing at test inception and the several milliseconds that the breaker remains fully closed prior to circuit breaker movement are included in the time used for the calculation of average velocity for the specified zone. This delay in movement affects the expected result.
- Close tests—Zero is the fully closed position of the circuit breaker. If zero is chosen as the end point and the circuit breaker mechanism continues to move for the majority of the Close test, because of the dampening device, the time used for the average velocity is excessively long.

AN7: Monitoring Closing Coil Current with the Current Shunt in the Close Circuit

The TDR instrument uses one set of control leads to control the operation of the circuit breaker and to monitor the Trip or Close current.

NOTE

The TDR instrument close current measurement is rated for a maximum of 20 A.

Previous test sets used a relay to initiate the Trip or Close operation. Because the pickup time of the initial relay varies from test to test, a method to mark the time of test initiation was necessary. A second set of leads (sense channel) provided this function and enabled timing from that reference point on the trace. Because the TDR instrument uses its solid-state control circuitry to initiate operational tests, this sense circuit is not necessary. The Trip and Close circuits of the TDR instrument incorporate optional shunts that enable the instrument to monitor and measure Trip and Close currents.

Because most Close tests are initiated with the Close leads bridging a closing contact on a control switch or a push button, the current monitored is the current that is present in the *X* relay circuit rather than the Closing Coil circuit.

The current in the Close coil circuit can be monitored and measured if a few temporary clip-to-clip jumpers are added (Figure H.21).

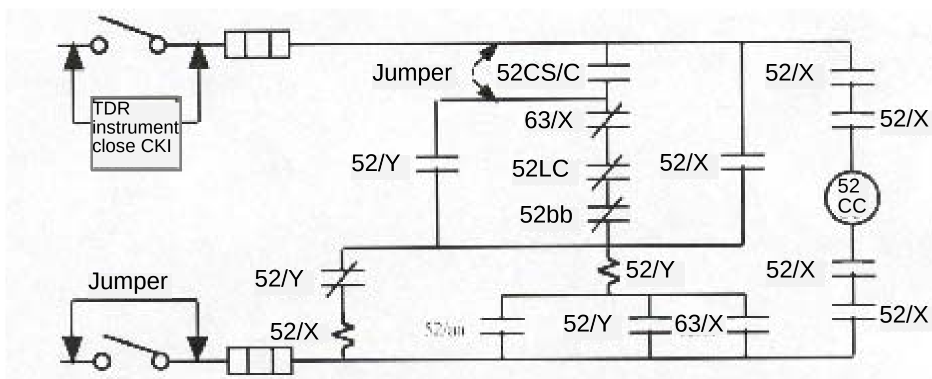


Figure H.21 Jumper Placement

Open the close circuit knife blades and add the two clip-to-clip jumpers as shown in Figure H.21. With the connection of the Close initiate leads as shown and the two additional clip-to-clip jumpers, the test set now monitors and measures the current that flows in the closing circuit without disabling any fusing or anti-pump protection.

The Close pulse length should be lengthened from the default value of 133.3 ms to approximately 300 ms to allow the close coil current to be interrupted by the X relay contacts. This is done in the Command Parameter portion of the test plan. If the same circuit is employed for Trip-free, Reclose, or O-C-O tests, then their close pulses should be lengthened accordingly.

The time from Close coil energization to main contact closure is determined using the graphical results. The time from test initiation (X relay energization) to main contact operation is tabulated and given in the test results.

AN8: Simultaneous Energization of Two Sets of Trip Coils in a Single Circuit Breaker

Many modern high voltage circuit breakers have two sets of trip coils that may have independent sources of power. To energize both sets of trip coils simultaneously from their respective power sources without electrically tying the battery banks together, proceed as follows:

1. Connect the pair of trip leads to energize Trip Coil #1 and connect the pair of close leads to energize Trip Coil #2. On the test plan, Command Parameters, TripFree Parameters, select a TripFree Delay of 0.0 ms.
2. Close the circuit breaker. When the TripFree test is initiated, both the Trip and the Close circuits are energized simultaneously.
3. The Trip current for Trip Coil #1 is displayed as Trip Current on the Breaker Performance Report and on the graphical results. Likewise, the Trip Current for Trip Coil #2 is displayed as Close Current on the Breaker Performance Report and on the graphical results.

If the circuit breaker opens, it has passed the test.

NOTE

The Close Circuit current maximum range is 20 A.

AN9: Use of the Auxiliary Wet/Dry Contact Monitor

The Auxiliary Wet/Dry Contact Monitor is used to obtain the times from Close Coil energization to Resistor Switch and Main Contact Closing. The Close Parameter has a Timing Event entry in addition to the Close Pulse duration entry. One of the following channels can be used for the T=O time: the Close circuit current as measured by the current shunt in the TDR instrument, a Wet/Dry Contact channel, or a current or voltage channel. The current and voltage channels have an adjustable trigger level that can be set in 10% increments. These increments are a percentage of the selected full scale of the channel. This enables the user to measure the time between the energization of the closing coil and the desired event.

The instrument monitors three states – Dry Contact Closed, Dry Contact Open, Wet Contact Open. To use this feature, connect the two leads from the contact monitoring channel across the circuit breaker's closing coil (observing lead polarity). Select **Analog** as the timing event and enter the channel number in the Timing Channel.

Prior to closing coil energization the instrument considers the closing coil as a Dry Contact Open. When the closing coil is energized, the instrument considers it a Wet Contact Open.

Using this procedure, the times obtained are compared to the specifications for closing time that were entered in the test plan.

AN10: Contact Sensing and Test Lead Connections (TDR9000 Only)

EHV main contact sensing circuitry of the TDR9000 applies a low DC voltage across the common lead at each contact lead. The actual voltage is dependent upon the resistor range selected. The EHV Contact Module applies 15 V DC when the 200 Ω to 500 Ω range is used and 7.5 V DC when the 100 Ω to 300 Ω range is used.

OCB main contact sensing circuitry in the TDR9000 applies 20 or 65 V DC across the common lead and the three contact leads. The Dead Tank/OCB Contact Module applies 48 V DC when the 300 Ω to 7,000 Ω range is used and 15 V DC when the 10 Ω to 400 Ω range is used.

The low sensing voltages are used to minimize the amount of cross talk and still maintain an adequate signal to noise ratio in areas where there may be up to 10 mA of interfering noise.

These low sense voltages make good connections a necessity. All places to which the Contact Cables are to be attached must be free of paint or corrosion. Wire brushing the point of connection is advisable. Connections to a hinge pin or similar device must be avoided. The crocodile clip grip should not be loose or wobbly. The weight of the suspended cables must not be supported by the crocodile clips; the contact cable should be draped around a fixed object that supports the weight of the cable.

On circuit breakers that have a very violent mechanical operation, a clamp type connection may be warranted. The crocodile clip is bolted to a metal tab at the cables' end and can be removed to facilitate adding another type of connector to the cables' end.

Table H.2 lists the voltages used for EHV and OCB channels for the TDR9000.

Table H.2 TDR9000 Contact Sensing Voltages

		Low Ohms	High Ohms	None
TDR9000	EHV	7.5V	15V	15V
	OCB	15V	48V	15V

AN11: Sampling Rates

The basic concept for digital sampling is that the sampling rate should be faster than the event that being captured. This sample rate captures the event. However, if there is a need to determine the actual length of the event, within 10%, then the sampling rate must be an order of magnitude faster than the event. To detect and determine the length of bounces of 1 ms with an accuracy of 10%, a sampling rate of 10 kHz (a sample every 100 µs) is necessary.

Sampling rates are a prime consideration in the resolution of motion and velocity. Slower sample rates affect measurements that involve a contact event and motion subsequent to that contact event. Measurement of Contact Wipe can be affected by slow sample rates.

Instantaneous velocity measurements from digital travel transducers are also affected by the sample rate.

Travel and velocity measurements on the new vacuum circuit breakers, which have very short travel and high velocities, are adversely affected by the slower sampling rates.

In a circuit breaker that has a velocity of 20 ft/s in the arcing zone, the following calculations are appropriate:

- 20 ft/s x 12 in/ft = 240 in/s
- or 24 thousandths of an inch every 100 µs.

For a sampling rate of 10 kHz (one sample every 100 µs) and a main contact closing just after the sample period, the main contacts travel 0.024" before the next sample period begins.

If the sample rate is 5 kHz (one sample every 200 µs) with a main contact closing just after the sample period, the main contacts travel 0.048" before the next sample period begins.

If the specified Contact Wipe is 0.5", then an error of 0.048" approaches a 10% error. Although Contact Closure is an asynchronous event with respect to the instruments sample period, higher sampling rates minimize these errors.

AN13: Safety Grounds, Close Connected Transformers, and the Use of the OCB/Dead Tank Contact Monitors

The power supplies used for the Doble TDR instrument contact monitors do not have a ground reference. However, because this is the source of voltage, it is necessary that the common lead of the contact monitor cable be connected to the side of the breaker that has the circuit breaker bushings tied together and has the safety ground.

When testing a circuit breaker that is close connected, there is no disconnect switch between the circuit breaker and the transformer, to the *Y* winding of a transformer whose neutral is grounded or to an Autotransformer. Therefore, the safety ground must be placed between the transformer and the circuit breaker.

In substations where one circuit breaker disconnect switch is adjacent to the circuit breaker to be tested and the other disconnect is physically separated from the circuit breaker, place the safety ground on the poles of the circuit breaker that is farthest from the disconnect switch.

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