Sweep Frequency Response Analyzer (SFRA)

User Guide

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Preface

The *Sweep Frequency Response Analyzer User Guide* explains how to install, configure, and operate Doble's M5200, M5300, and M5400 Sweep Frequency Response Analyzer instruments.

Who Should Read This Guide

This guide is intended for engineers and field testers who work with an M5200, M5300, or M5400 Sweep Frequency Response Analyzer. It is assumed that the reader is familiar with professional standards and safety practices.

Document Conventions

Typefaces

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

- Bold Arial type identifies software controls and text you must enter:

  Example: Type in **1500 ms**.

- Monospaced type identifies text that is displayed in the user interface, such as an error message or prompt:

  `Uploading test results`.

Notes and Warnings

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

Notes

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

Cautions

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

Warnings

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

1. Introduction

This chapter describes the SFRA instrument hardware and software and introduces SFRA testing. It contains the following sections:

- "M5200, M5300, and M5400 SFRA Instruments" on page 1-1
- "Hardware Accessories" on page 1-3
- "Software" on page 1-4
- "PC Requirements" on page 1-4

M5200, M5300, and M5400 SFRA Instruments

Sweep Frequency Response Analysis (SFRA) testing is a nonintrusive way to identify mechanical changes inside a transformer. Changes in the internal configuration produce different frequency responses that indicate a range of failure modes. Performed in the field, without teardown or draining of oil, SFRA testing provides accurate and repeatable measurements.

The M5200, M5300, and M5400 Sweep Frequency Response Analyzers measure and record the frequency-response characteristics of transformer windings. Each unit consists of a robust molded shell housing a field controller and instrumentation module, an excitation source, and a measurement module. Table 1.1 describes the three SFRA instruments.

Table 1.1 M5200, M5300, and M5400 Instruments

Name	Description	Image
M5200	Requires an external laptop. Testing functions are identical to those of the M5300 and M5400.	
M5300	Has a built-in laptop, keyboard, and display. Testing functions are identical to those of the M5200 and M5400.	
M5400	A compact version of the M5200 that requires an external laptop. Testing functions are identical to those of the M5200 and M5300.	

Figure 1.1 M5200, M5300, and M5400 Instruments

Hardware Accessories

Table 1.2 describes the standard hardware accessories that come with the M520, M5300, and M5400. It also lists an optional test lead.

Table 1.2 Accessories for the SFRA Instruments

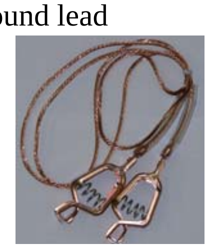
Item	Description	Part No.
Test Leads		
Standard lead 	Length: 18 m/60 ft Ground: 3.6 m/12 ft Application: ≤ 362 kV	05B-0659-04
Optional lead 	Length: 30 m/100 ft Ground: 5.4 m/18 ft Application: > 362 kV	05B-0659-07
Grounds		
Safety ground 	Length: 9 m/30 ft	02C-0019-01
Ground lead 	1.5 m/5 ft	02B-0026-02

Table 1.2 Accessories for the SFRA Instruments

Item	Description	Part No.
Communication Cables		
USB No picture available.	Has a square and an oblong connector.	181-0585
Ethernet crossover No picture available.	Has two Ethernet connectors. Required for SFRA. SFRA does not work with a standard network cable without a crossover adapter.	181-0646
Other Hardware		
Clamps 	Two plain copper clamps. These clamps connect to larger bushing studs or terminals that the normal connectors do not fit. The standard test cables then clip to these large clamps.	212-0444

Software

The M5200 and M5400 are controlled by a user-supplied laptop computer running Doble SFRA software (supplied with the instrument). The M5300 comes with a built-in PC, laptop keyboard, and preinstalled Doble SFRA software.

PC Requirements

To see the minimum requirements for the PC used with the M5200 or M5400, please go to “PC Requirements” on page E-4.

2. Safety

This chapter reviews the standards and procedures you need to follow to use the SFRA instrument safely. It contains the following sections:

- "Overview" on page 2-1
- "General Rules" on page 2-1
- "Grounding Requirements" on page 2-2
- "Personnel Safety Practices" on page 2-3

Overview

Safety cannot be over-emphasized when working on or around high-voltage electrical apparatus. Companies that generate, transmit, distribute, or use high-voltage electricity should, and do, have precise rules for safe practices and procedures. These practices are important for personnel whose working responsibilities involve testing and maintaining high-voltage apparatus and its associated lines, cables, conductors, and accessories.

General Rules

1. The transformer under test should be completely de-energized and isolated from the power system before performing any tests using an M5000-series SFRA instrument.
2. The method of testing a high-voltage apparatus (transformer) involves exciting the apparatus with the SFRA instrument. Take care to avoid contact with the apparatus being tested, its associated bushings and conductors, and the SFRA instrument's cables and connectors.
3. The test crew must make a visual check to ensure that the apparatus terminals are isolated from the power system. Because the apparatus under test may fail, take precautions (such as barriers or entrance restrictions to the test area) to avoid harm in case of violent failure.

4. All of your company rules for safe practice in testing must be strictly conformed to, including all practices for tagging and isolating apparatus during testing and maintenance work. State, local, and federal regulations, e.g., OSHA, may also apply.

Company rules and government regulations take precedence over Doble recommendations.

Personal protective equipment suitable for electrical testing of transformers is recommended.

Grounding Requirements

The apparatus under test, its tank or housing, and the SFRA instrument must be solidly and commonly grounded or earthed. This also applies to any mobile equipment being tested. Figure 2.1 shows a sample safety ground connection.

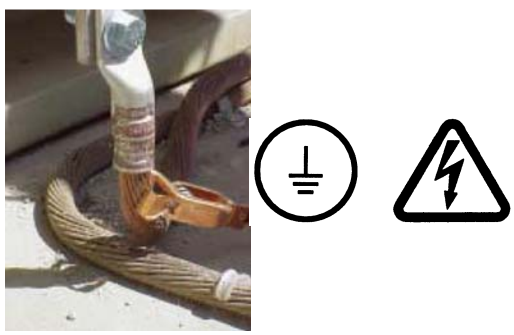


Figure 2.1 Connecting Safety Ground to Transformer

For detailed instructions on grounding the SFRA instrument, go to **“Step 2: Ground the Transformer” on page 3-12**.

Personnel Safety Practices

Make sure that test personnel follow these recommendations:

1. A pretest meeting is recommended. Frequently, other crews will be working on non-test-related tasks in close proximity to equipment being tested. The pretest meeting should include all personnel who will be working in proximity to the area where testing will be performed. In this meeting, review with crew members the tests to be performed, apparatus, voltage test levels involved, potential hazards, and individual assignments. Test personnel need to remain aware of the work activity taking place around them and alert to the possibility that non-test personnel may enter the test area.
2. Agree on a consistent and uniform set of signals, both visual and verbal. All crew members should follow them during testing.
3. While making the various types of connections involved in the tests, it may be necessary for personnel to climb up on the apparatus, but no one should remain on the apparatus during the test itself.

3. Setting Up and Running a Test

This chapter describes how to set up hardware and configure software for testing and run the test. It also describes typical test results. This chapter contains the following sections:

- "Measurement Types" on page 3-1
- "Step 1: Set Up and Run a Shorted-lead Test" on page 3-2
- "Step 2: Ground the Transformer" on page 3-12
- "Step 3: Prepare the Transformer for Testing" on page 3-14
- "Step 4: Select and Run a Test" on page 3-15
- "Sample Test Results" on page 3-25

Measurement Types

Open Circuit

An open-circuit measurement is made from one end of a winding to another, with all other winding terminals floating. For a delta winding, connections would be H1 to H3, for example. For a star (wye) winding, measurements are taken from HV terminals to neutral, such as X1 to X0.

Short Circuit

A short-circuit measurement is made with the same SFRA test lead connections as an open-circuit measurement, but with the difference that another winding is short- circuited. To ensure repeatability, Doble recommends that the three voltage terminals on the shorted winding be shorted together. This would mean, for example, shorting X1 to X2, X2 to X3, and X3 to X1. This ensures that all three phases are similarly shorted, ensuring a consistent impedance. **Do not include in the shorting process any neutral connections available for the shorted winding.**

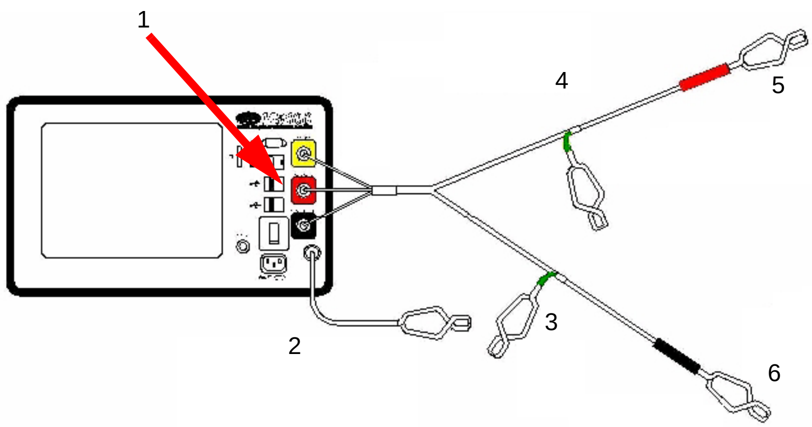
Step 1: Set Up and Run a Shorted-lead Test

This section describes how to connect the cables to the SFRA instrument and perform a basic shorted-lead test. **Do not omit this test.** If a cable or cable connection is bad, this test will save you hours of wasted effort.

Connect the Cable and Leads and Run SFRA 5.2

To connect the ground reference cable and test leads and run SFRA:

1. Follow Figure 3.1 to connect the reference ground and test leads to the instrument. This figure shows an M5300, but the connections are correct for all three instruments.



1	BNC yellow, red, and black connectors		4	Green reference ground 2 of 2
2	Instrument ground		5	Red source lead
3	Green reference ground 1 of 2		6	Black measurement lead

Figure 3.1 Cable and Lead Connections to the SFRA Instrument

If you are using an:

- M5200 or M5400—Go to step 2.
- M5300—Power up the M5300 and go to "Create a Transformer Listing and Associate a Test Template with It" on page 3-4.

2. Power up the PC. Run the SFRA program by double-clicking the icon or selecting **Start→All Programs→Doble Engineering→SFRA**.

The main SFRA window opens and displays the `Connect to Instrument` message (Figure 3.2 on page 3-3).

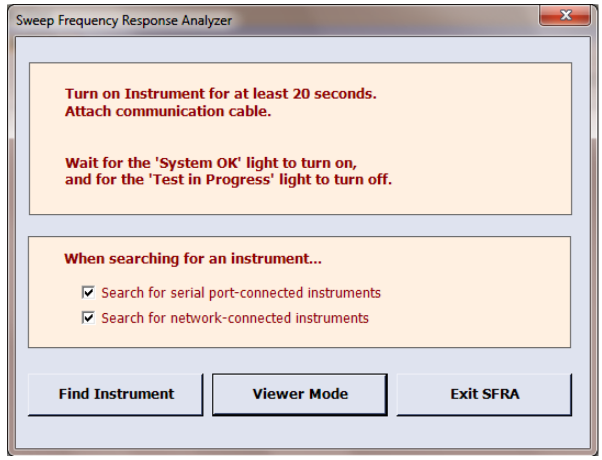


Figure 3.2 Connect to Instrument Message

3. Turn on the SFRA instrument and wait 20 seconds. During this time:

a. The power light comes on.

b. The Test in Progress and System OK indicator lights come on.

c. The Test in Progress and System OK indicator lights go out.

d. The System OK indicator light comes on and remains lighted.

4. Attach the Ethernet or USB cable to the instrument and the PC.

NOTE: You can shorten the search time by deselecting any communication type that is not in use.

5. Click the **Find Instrument** button shown in Figure 3.2.

The Select Instrument window lists all connected instruments (Figure 3.3).

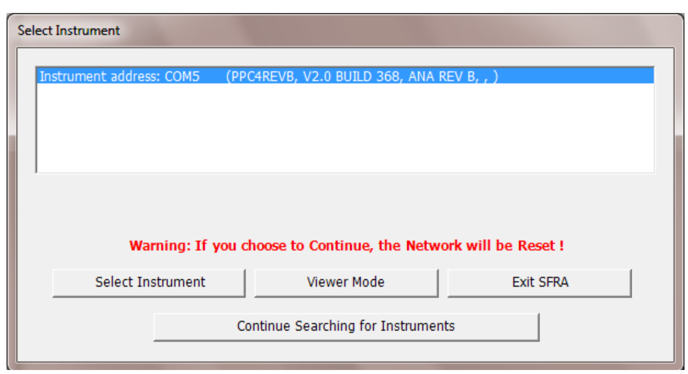


Figure 3.3 Select Instrument Window

If no instrument is listed:

- Check the connection between the instrument and the PC.
- Check the antivirus or firewall software for problems.
- If your instrument is connected to the PC through an Ethernet cable, confirm that the PC can see the instrument. To do this, see “Confirming the Ethernet Connection” on page 3-30.

6. Click **Continue Searching for Instruments**.
7. Highlight the instrument desired and click **Select Instrument**.

   The SFRA window displays the Data Manager tab (Figure 3.4).

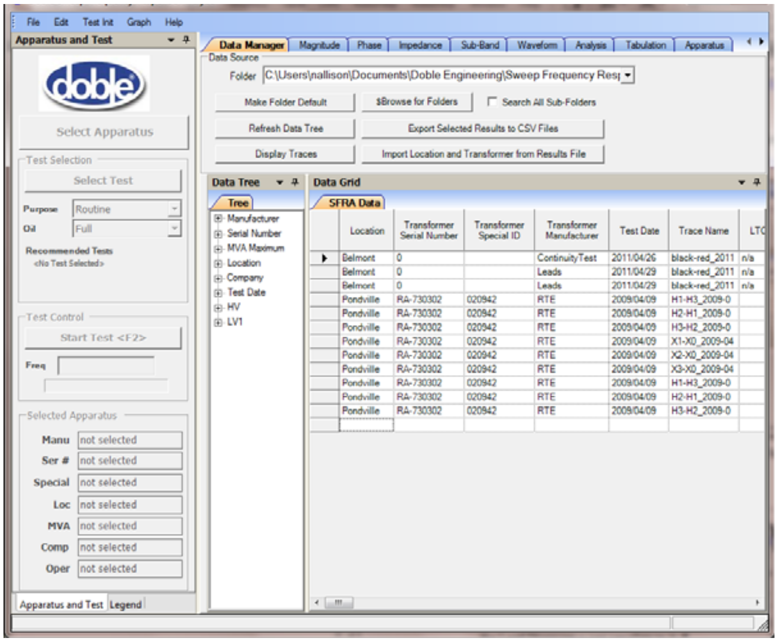


Figure 3.4 Data Manager Tab on Main Window

Create a Transformer Listing and Associate a Test Template with It

NOTE: If the shorted-lead test has already been set up in SFRA 5.2, skip this section and go to “Run the Shorted-lead Test” on page 3-8.

The shorted-lead test does not have an associated test template and is not performed on a transformer. However, SFRA 5.2 test setup requires a transformer name, under which the test results will be stored, and an associated test template. Therefore, in the following instructions, you:

- Create a dummy transformer called *Leads*
- Select a test template at random and associate it with the Leads transformer

To create a dummy transformer and associate a test template with it:

1. In the main window of the SFRA software, open the **Edit** menu and select **Edit Apparatus** (Figure 3.5).

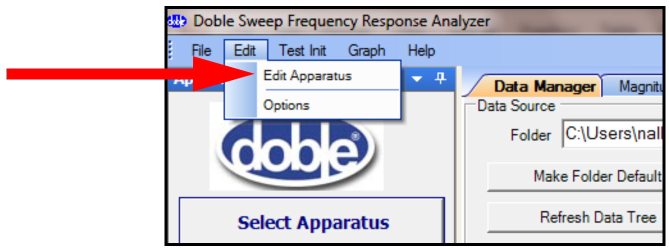


Figure 3.5 Edit Apparatus Option on Edit Menu

The Test Equipment Editor window opens (Figure 3.6).

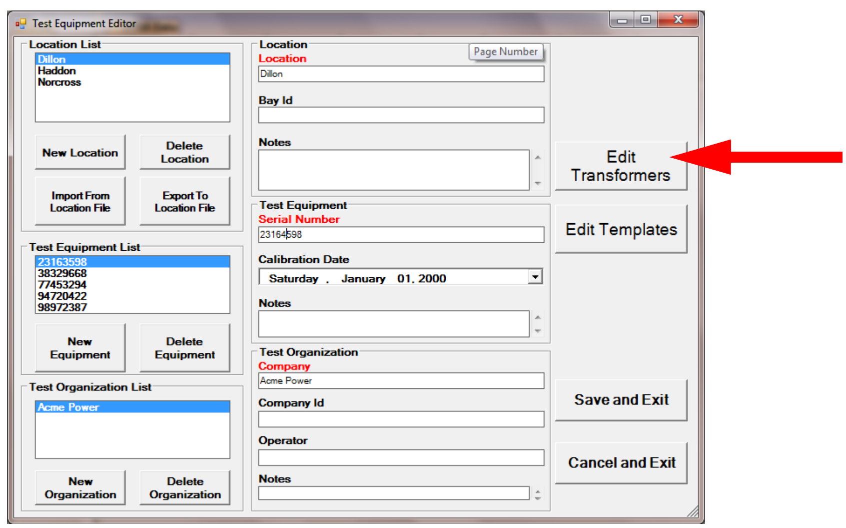


Figure 3.6 Test Equipment Editor

2. Click the **Edit Transformers** button on the right.

The Transformer Editor window opens, displaying the Transformer tab (Figure 3.7 on page 3-6).

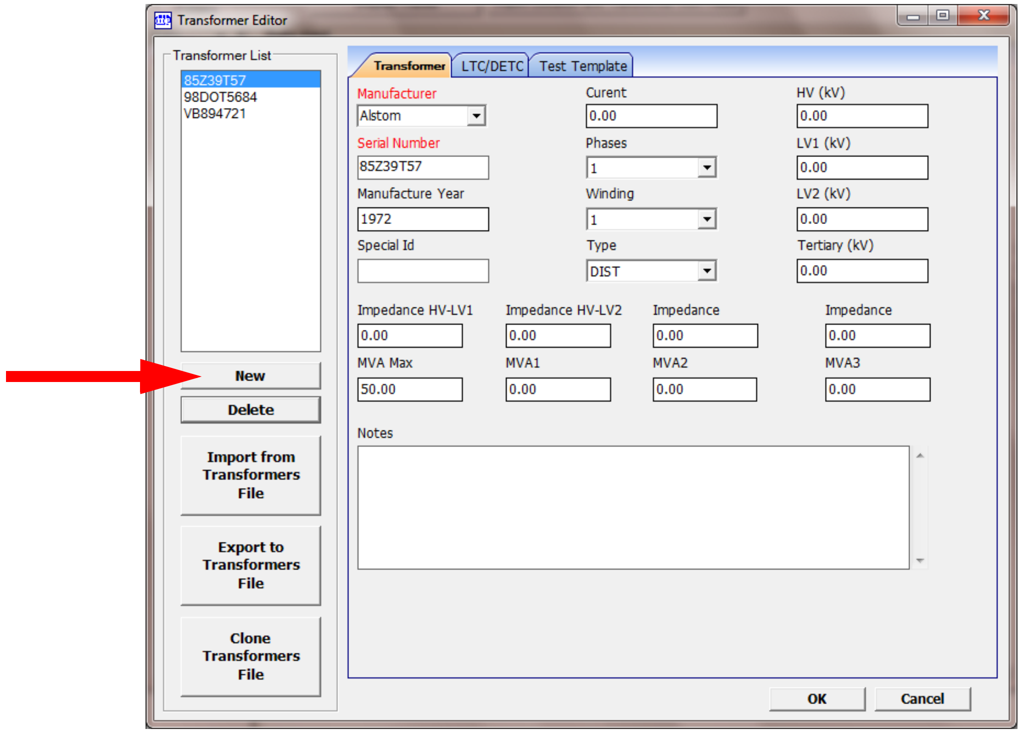


Figure 3.7 Transformer Tab of Transformer Editor Window

3. Click **New** (Figure 3.7).

The New Serial Number listing is highlighted (Figure 3.8).

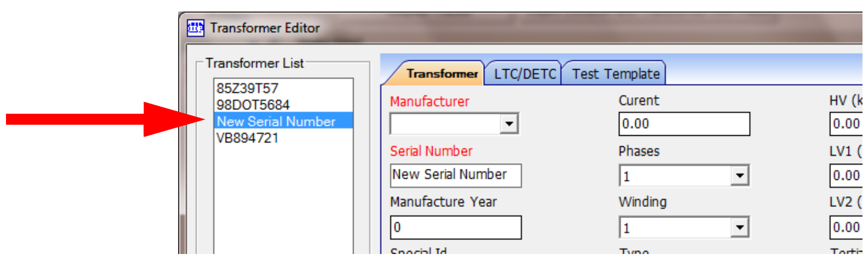


Figure 3.8 New Serial Number Listing

4. Enter **Leads** in the Manufacturer field.

5. Enter **0** in the Serial Number field.

6. Click the **Test Templates** tab.

Note that the new serial number, 0, appears in the Transformer list (item #1 Figure 3.9 on page 3-7).

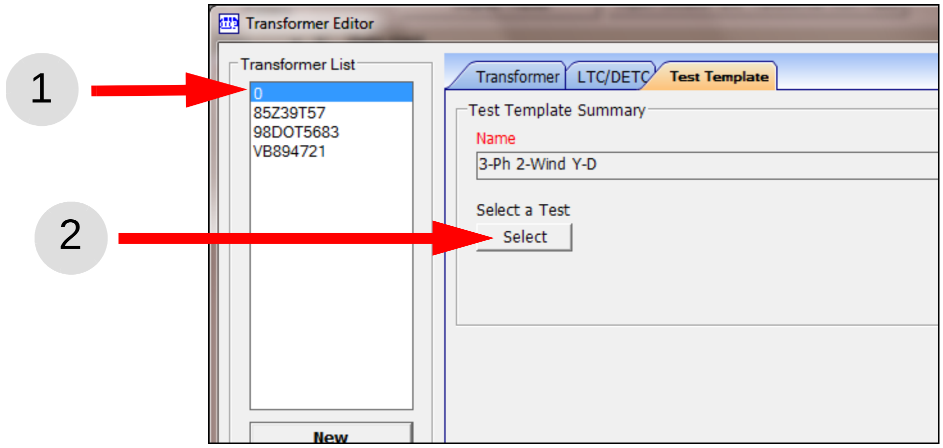


Figure 3.9 Test Templates Tab of Transformer Editor Window

7. Click **Select** (#2 in Figure 3.9).

   The Template Editor window appears (Figure 3.10).

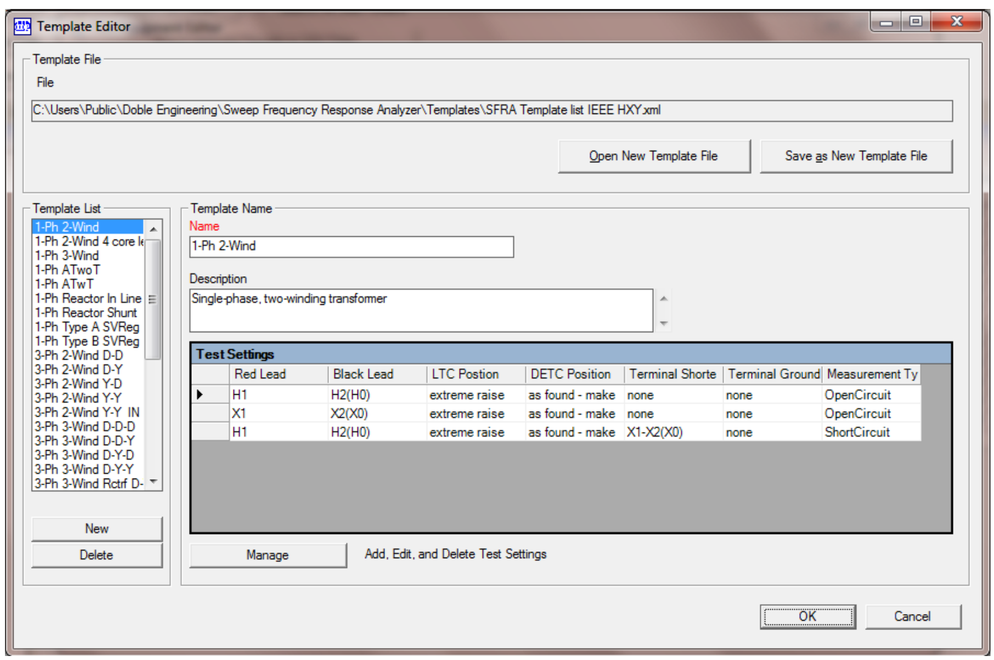


Figure 3.10 Template Editor Window

8. Select any test template in the Template list and click **OK**.
9. Click **OK** again to close the Transformer Editor window, and click **Save and Exit** to close the Test Equipment Editor.

Run the Shorted-lead Test

To run the shorted-lead test:

1. In the main SFRA window, click **Select Apparatus**.

   The Apparatus Selection window appears (Figure 3.11).

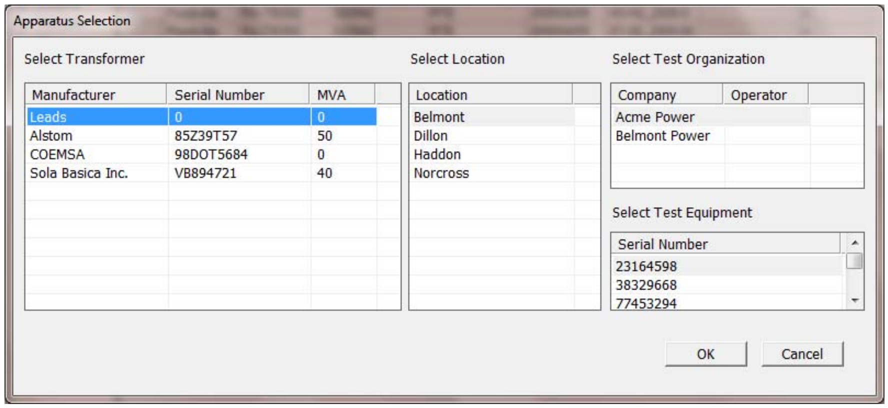


Figure 3.11 Apparatus Selection Window

2. Select **Leads** in the Manufacturer column and click **OK**.
3. Click **Start Test** (Figure 3.12).

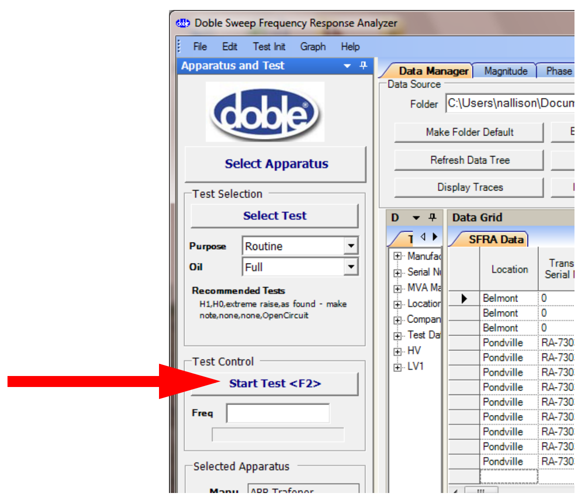


Figure 3.12 Location of Start Test Button

The Test Details window appears (Figure 3.13).

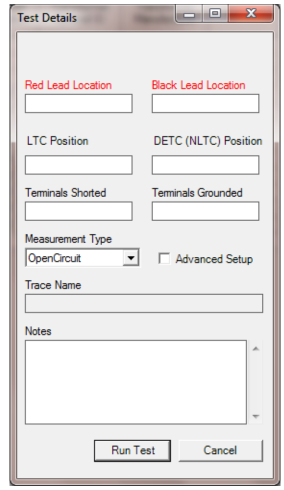
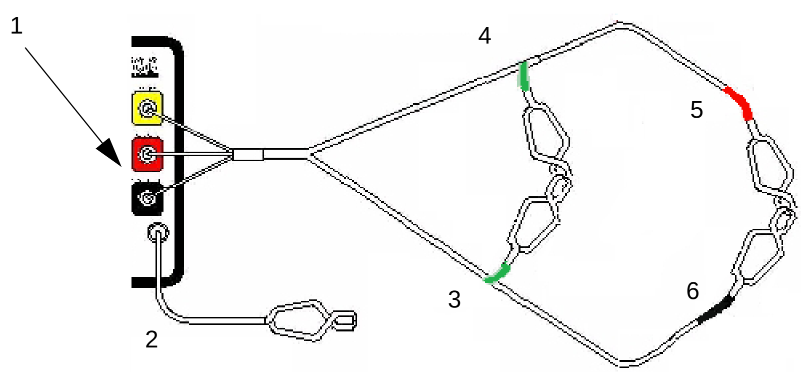


Figure 3.13 Test Details Window

4. Short the red source lead and black measurement lead by connecting the clamps to each other (Figure 3.14).

!	**CAUTION! Do not connect the measurement clamps to the ground clamps!**

5. Short the green reference grounds by connecting the clamps to each other (Figure 3.14).



1	BNC yellow, red, and black connectors		4	Green reference ground 2 of 2
2	Instrument ground		5	Red source lead
3	Green reference ground 1 of 2		6	Black measurement lead

Figure 3.14 Cable Connections for Shorted-lead Test

6. Click **Run Test**.

The Magnitude tab appears (#1 in Figure 3.15) and displays the trace as it develops. The Legend pane appears (#2) and a progress bar expands as the test progresses (#3).

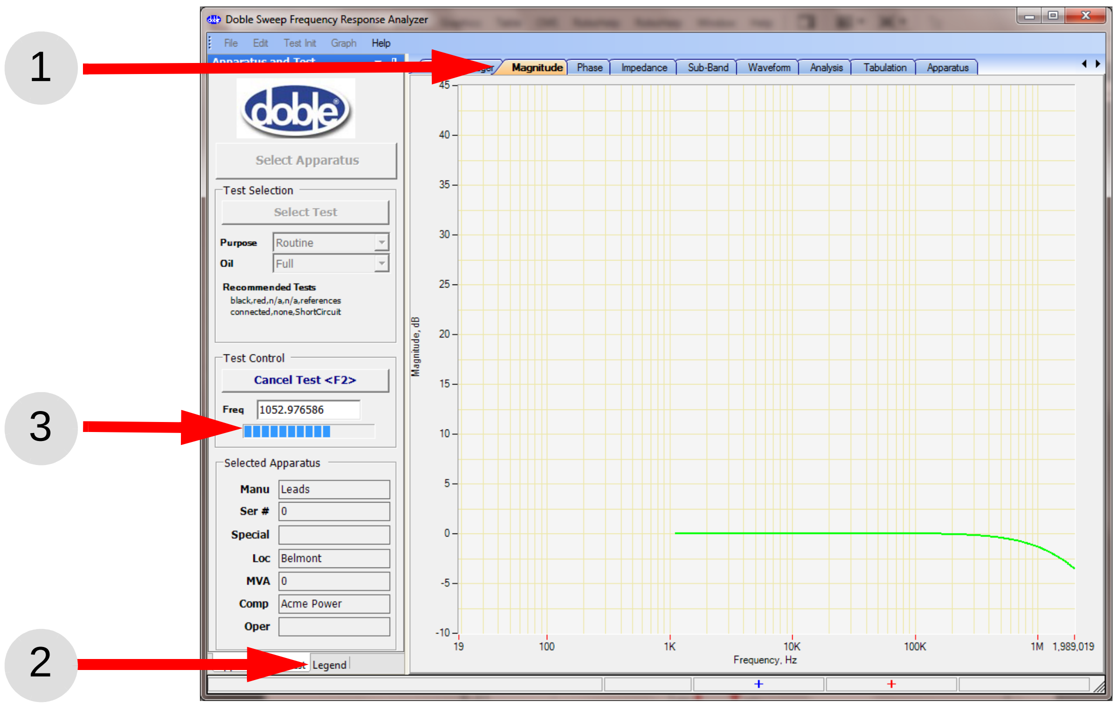


Figure 3.15 Shorted-lead Test in Progress

When the test finishes, the view auto-zooms so that the trace takes up most of the graph. The result should resemble the curve shown in Figure 3.16 on page 3-11.

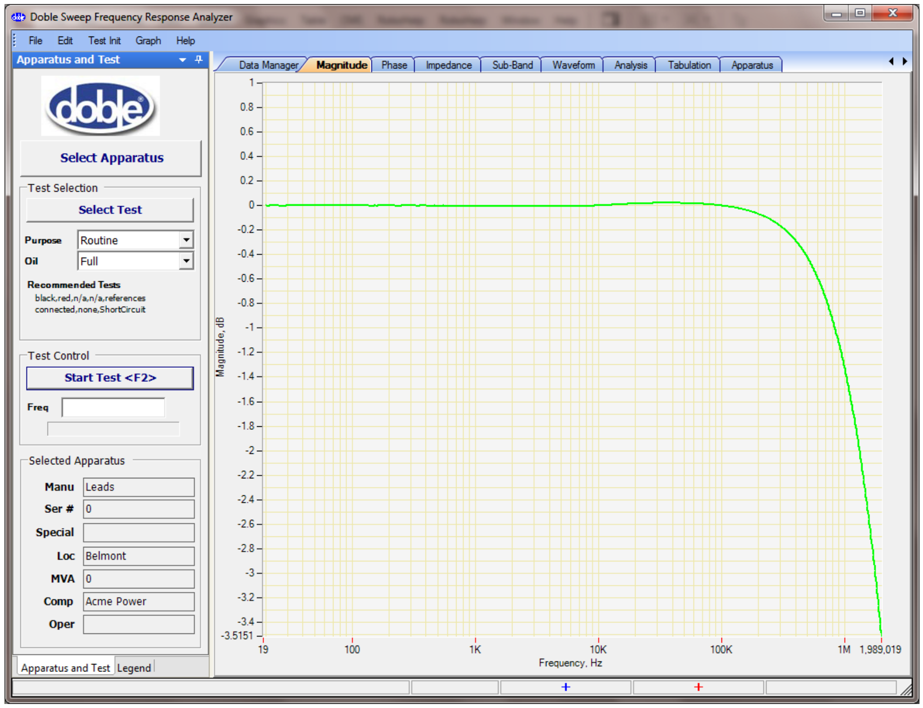


Figure 3.16 Correct Shorted-lead Response

If the result resembles Figure 3.17, examine the leads for an open circuit. The open-circuit response is clearly affected by noise.

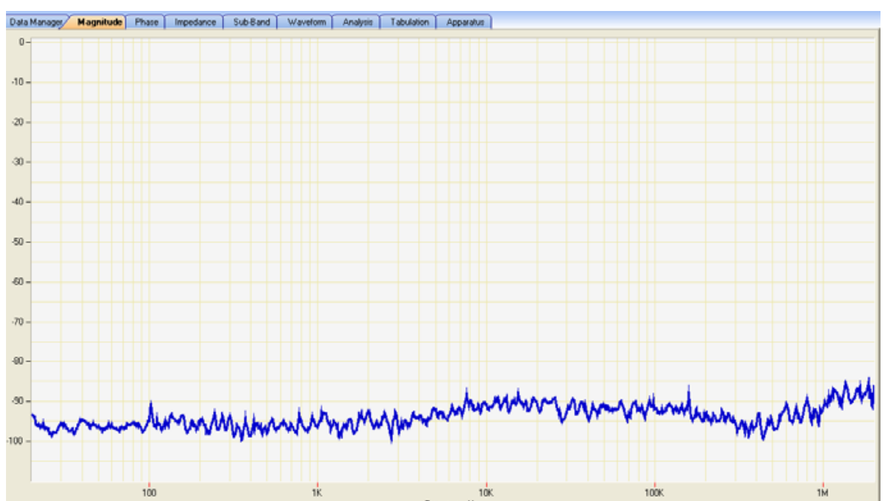


Figure 3.17 Open-Circuit Lead Response

7. When you are satisfied with the test results:

a. Disconnect the test lead clamps from each other.

b. Disconnect the reference ground clamps from each other.

8. Go to "Step 2: Ground the Transformer" on page 3-12.

Step 2: Ground the Transformer

Each time the SFRA test leads are connected, disconnected, or moved, apply temporary static-discharge grounds to:

- The bushings to which the SFRA test clamps will be applied

  and

- Any bushings to which jumpers will be applied

To ground a transformer for SFRA testing:

1. Open the switches to de-energize the transformer and disconnect it from the rest of the substation (Figure 3.18).

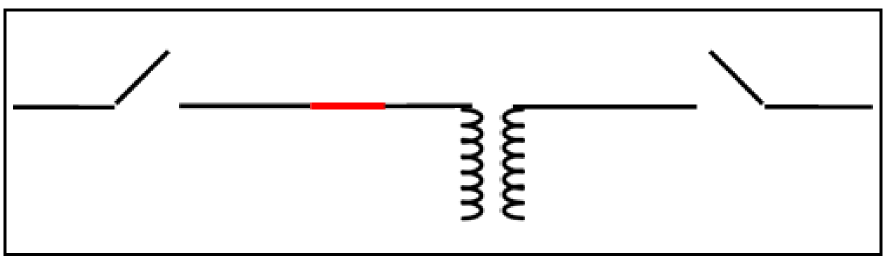


Figure 3.18 De-energized and Disconnected Transformer

2. Ground all conductor or bus still connected to the transformer terminals outside of the transformer bushings and windings (Figure 3.19).

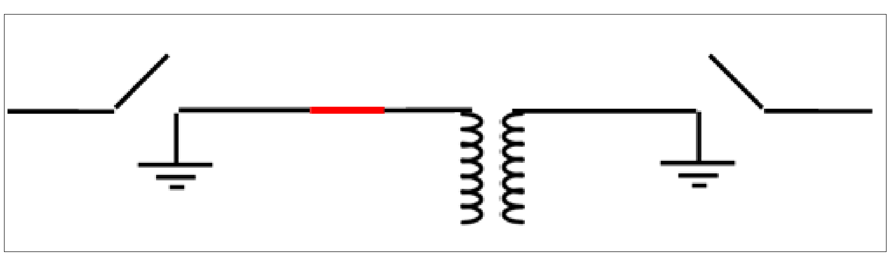


Figure 3.19 Grounded Transformer

3. Remove the Isophase or GIS link (Figure 3.20).

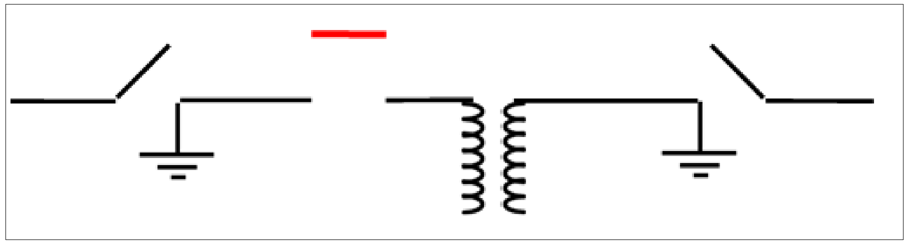


Figure 3.20 Removed Isophase or GIS Link

4. Apply temporary static-discharge grounds (Figure 3.21).

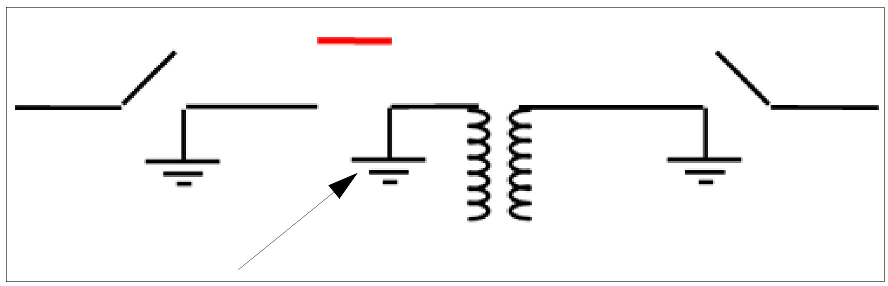


Figure 3.21 Added Temporary Static-Discharge Grounds

5. Attach the SFRA test leads (Figure 3.22).

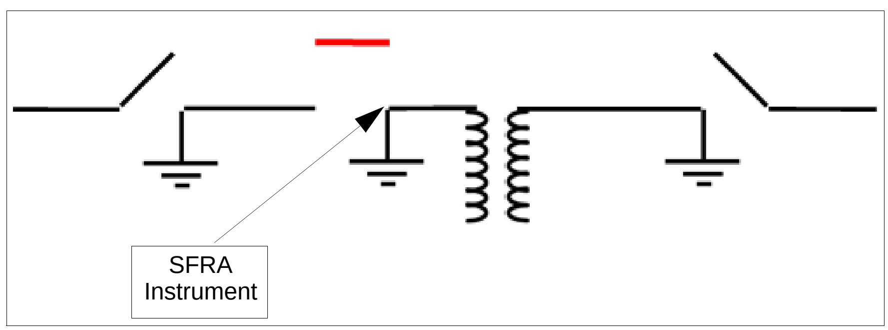


Figure 3.22 Connected SFRA Leads

6. Remove temporary static-discharge grounds (Figure 3.23).

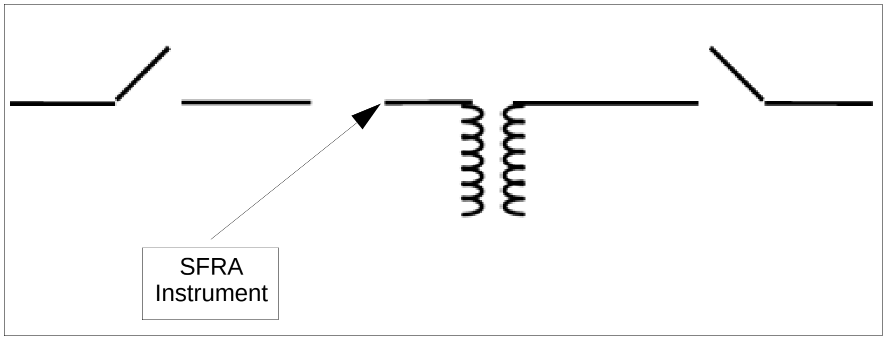


Figure 3.23 Removed Temporary Static-Discharge Grounds

7. Isolate terminals not under test and ensure that they are floating, unless otherwise specified in the test template.

Step 3: Prepare the Transformer for Testing

For optimal test results, always follow these practices:

- Make good electrical connections. Clean, file, or wire-brush connection points at bushing terminals and bases if necessary.
- Replicate the setup used the last time the transformer was tested. **Any change in setup affects the consistency of test results.** Do not change the tap position, DETC position, or core ground connections from one test to the next.
- Ensure that all three phases are solidly shorted together when you make short-circuit measurements.
- Attach the green reference leads to a stud or bolt at the base of the bushings under test and ensure that good electrical contact is established. Replicate the positions of the reference leads on all three bushings, if possible, to eliminate reference variation as a source of measurement.
- Record all relevant information, including tap position, oil level, test lead position (Black/Red), and terminals of other windings (grounded or shorted).

Step 4: Select and Run a Test

By running the shorted-lead test, you have already followed the complete procedure for running a test. This section provides a testing procedure for a transformer that has already been set up in SFRA and associated with a test template.

Requirements for This Test

Complete these actions before you run a test:

1. Perform the shorted-lead test. **Do not omit it.** To run the test, go to "Step 1: Set Up and Run a Shorted-lead Test" on page 3-2.
2. Set up the transformer in SFRA. To do this, go to "Entering a Transformer into the SFRA Database" on page 5-5.
3. Ground the transformer. Do not omit this procedure. If you have not already done so, go to "Step 2: Ground the Transformer" on page 3-12.
4. Prepare the transformer for testing. If you have not already done so, go to "Step 3: Prepare the Transformer for Testing" on page 3-14.

Associate the Transformer with a Test Template

A transformer must be associated with a test template before it can be tested. To do this:

1. In the main window of the SFRA software, open the **Edit** menu and select **Edit Apparatus** (Figure 3.24).

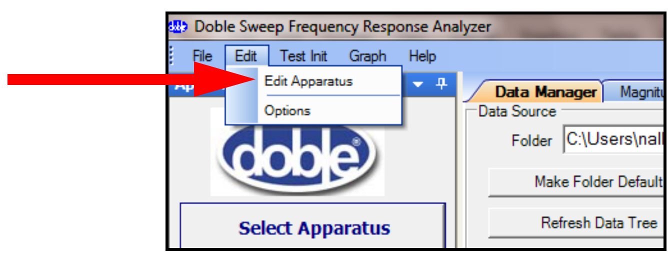


Figure 3.24 Edit Apparatus Option on Edit Menu

The Test Equipment Editor window opens (Figure 3.25 on page 3-16).

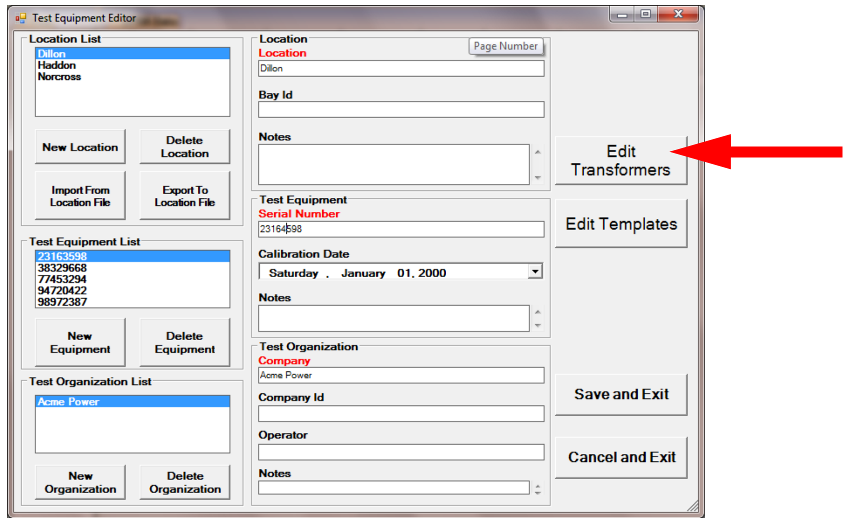


Figure 3.25 Test Equipment Editor

2. Click the **Edit Transformers** button on the right.

   The Transformer Editor window opens, displaying the Transformer tab (Figure 3.26).

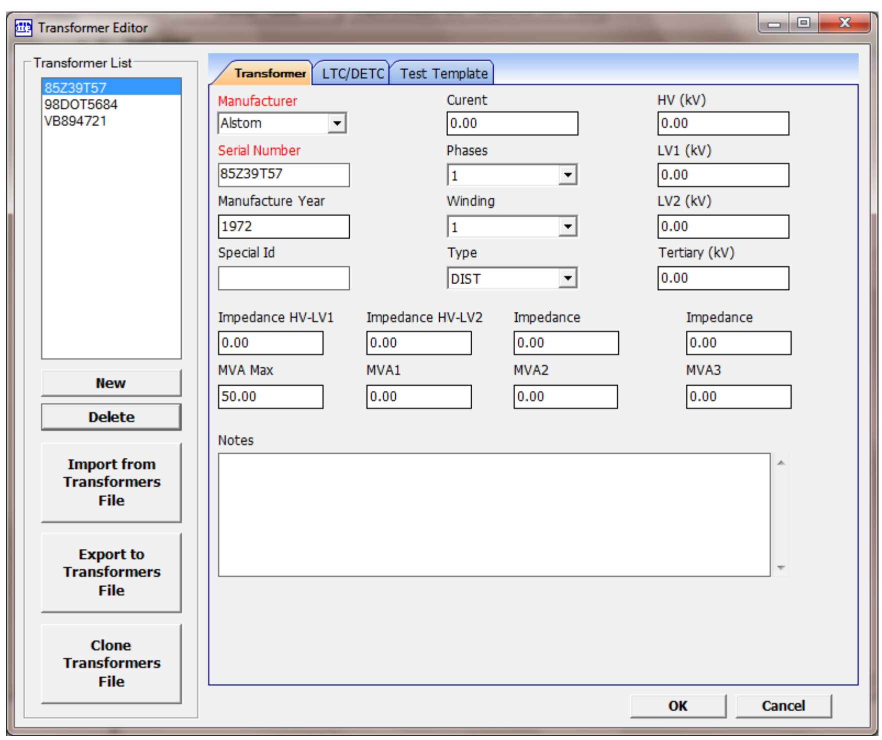


Figure 3.26   Transformer Tab of Transformer Editor Window

3. Click the **Test Templates** tab (Figure 3.27).

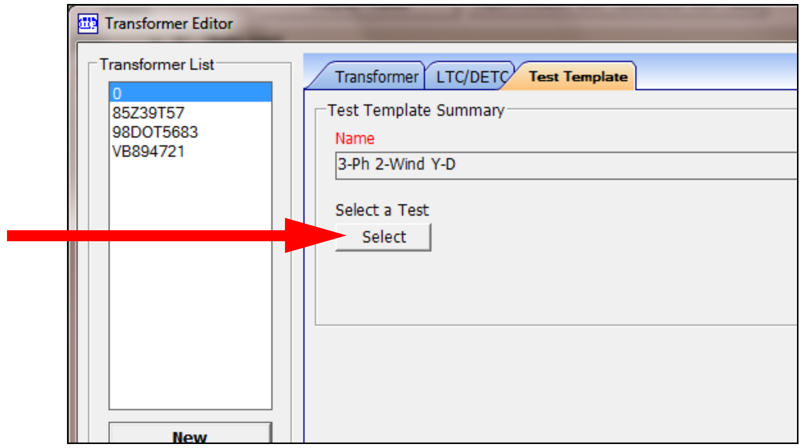


Figure 3.27 Test Templates Tab of Transformer Editor Window

4. Click **Select**.

The Template Editor window appears (Figure 3.28).

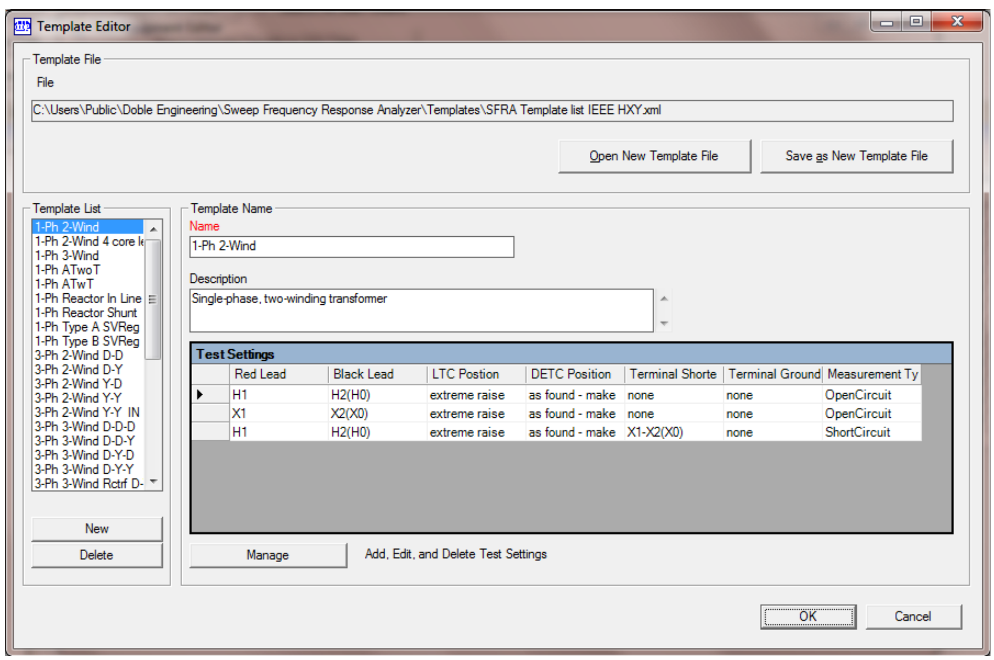


Figure 3.28 Template Editor Window

5. Select the template in the Template list and click **OK**.

6. Click **OK** again to close the Transformer Editor window, and click **Save and Exit** to close the Test Equipment Editor.

SFRA Test Procedure

To run an SFRA test on a transformer:

1. In the main SFRA window, click **Select Apparatus**.

   The Apparatus Selection window appears (Figure 3.29).

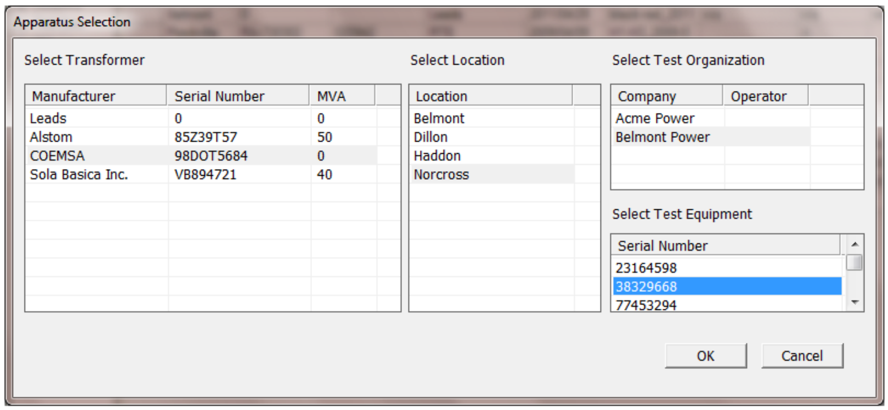


Figure 3.29 Apparatus Selection Window

2. Select the serial number of the transformer in the Manufacturer column and any other options you wish. The items you select remain highlighted as shown in Figure 3.29. Click **OK**.

3. In the Apparatus and Test pane, click **Select Test** (Figure 3.30).

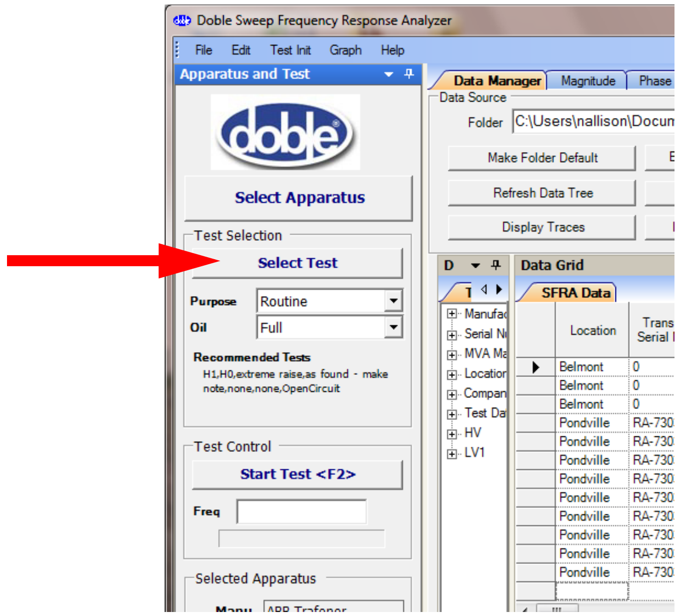


Figure 3.30 Location of Select Test Button

The Test Selection window displays the tests contained in the template (Figure 3.31).

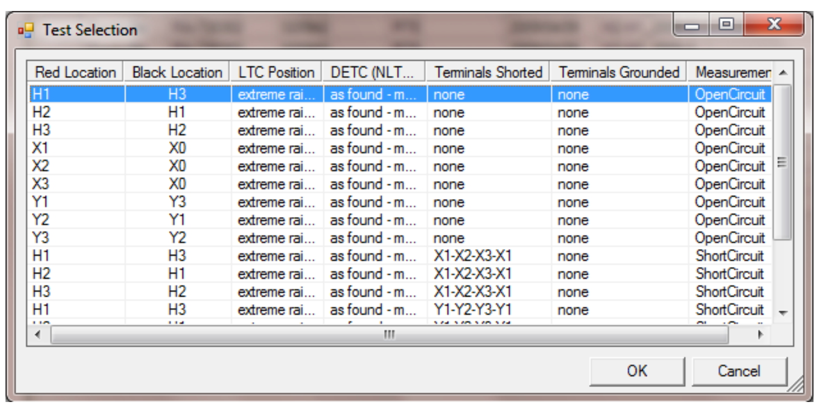


Figure 3.31 Test Selection Window

4. Click **Start Test** (Figure 3.32).

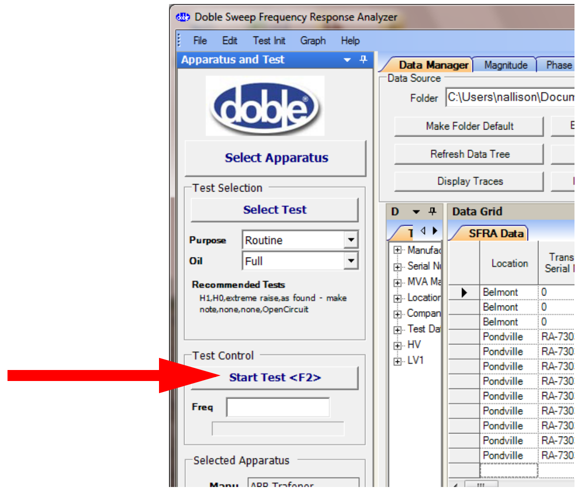


Figure 3.32 Location of Start Test Button

The Test Details window appears (Figure 3.33).

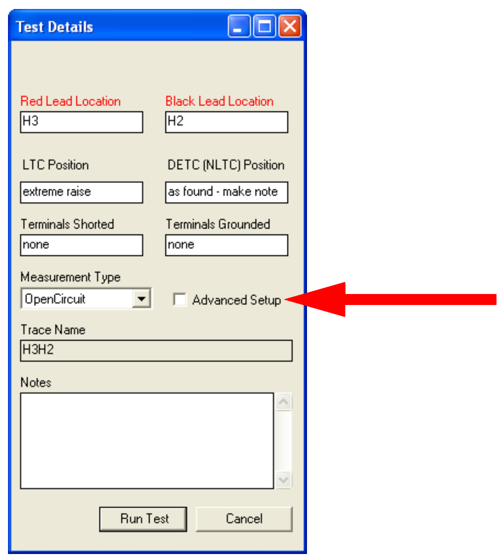


Figure 3.33 Test Details Window

5. Following the directions under the Red Lead Location and Black Lead Location headings in the template, connect the test leads and enter notes if required.

6. Do one of the following:
   - To perform a nonstandard test, go to step 7.
   - To perform a standard template test, skip to step 10 on page 3-22.
7. To perform a nonstandard test, select the **Advanced Setup** check box in the Test Details window (Figure 3.33 on page 3-20).

   A warning message appears (Figure 3.34).

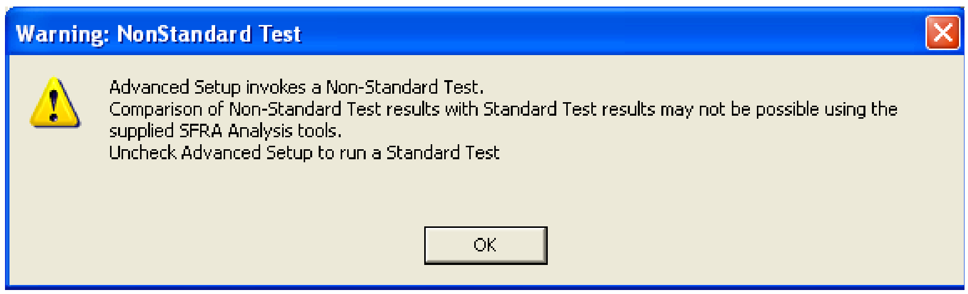


Figure 3.34 Nonstandard Test Warning

8. Click **OK**.

   The Test Details dialog box expands to display an Advanced Test Protocol section on the right (Figure 3.35).

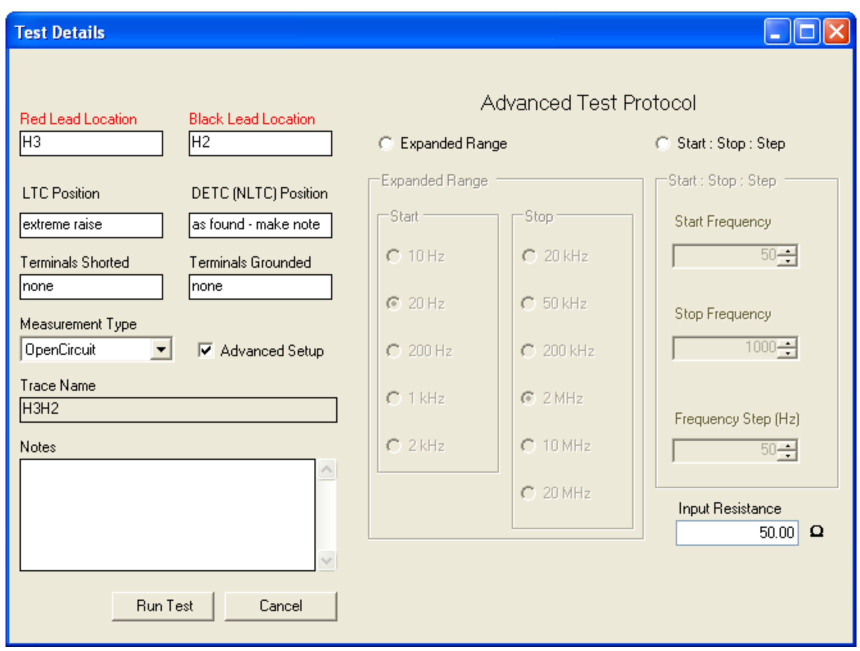


Figure 3.35 Test Details Dialog Box with Advanced Test Protocol

9. At the top of the Advanced Test Protocol section, click the option button for **Expanded Range** or **Start: Stop: Step** and make the desired selections.
10. Click **Run Test**.
11. The instrument first runs four self-tests to assess the condition of the setup. If it detects a problem, it may return one or more errors or warnings. For more information, see "Self-Test Error and Warning Messages" on page 3-22.

Self-Test Error and Warning Messages

The SFRA self-test can produce the following error and warning messages:

- **Error 950—Internal temperature exceeds acceptable limits.** M5000 instruments are designed to operate in a 50° C/ 122° F environment for extended periods. A high temperature may reduce component life and instrument reliability. If error 950 occurs, turn the instrument off and allow it to cool down before continuing the test.
- **Error 951—Noise levels on the test leads exceed safe levels for the instrument.** Excessive input noise may damage the instrument or cause excessive noise in the results. If error 951 occurs, stop the test, ground the bushing terminals momentarily to discharge stored energy, and restart the test. You can continue the test without changing your setup, but results may be noisy and in severe cases the instrument may be damaged.
- **Alert 952—Resistance between ground connections exceeds 1 ohm and may be too high (Figure 3.36).**

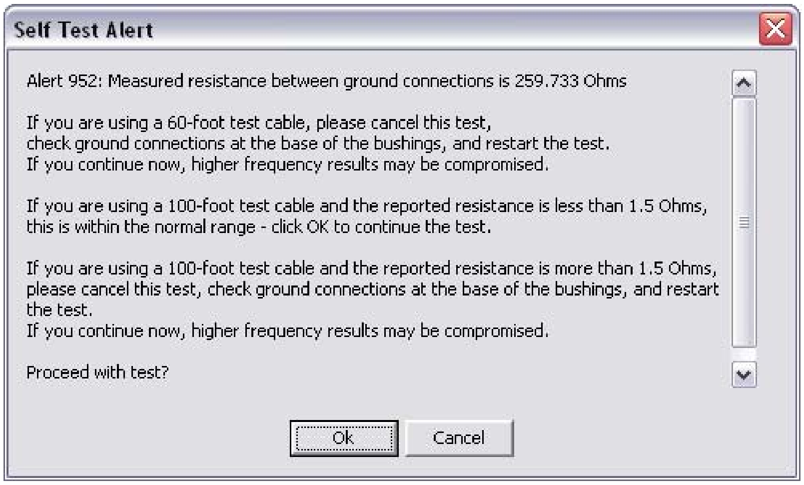


Figure 3.36 Alert 952

Excessive ground-loop resistance affects the shape of the traces, especially at higher frequencies. Acceptable values depend on lead length:

- 18 m (60 ft) leads—A value of less than 1 ohm is ideal. Attempt to clear the alert by checking all ground connections and restarting the test. Continuing to test with ground resistance above 1 ohm may compromise the results.
- 30 m (100 ft) leads—Results are normally as high as 1.5 ohms; if the resistance shown is below 1.5 ohms, continue the test. If the resistance shown exceeds 1.5 ohms, check all ground connections and restart the test. Continuing to test with ground resistance above 1.5 ohms may compromise results.

Causes of high ground-loop resistance include poor connections to bushing studs because of dirt, grease, or paint, or, occasionally, the stud itself not being grounded. Consider any measurement above 250 ohms an open circuit. If Alert 952 occurs, ensure that all connections are good.

- **Error 953—The internal M5000 performance check was unsuccessful (**Figure 3.37**).**

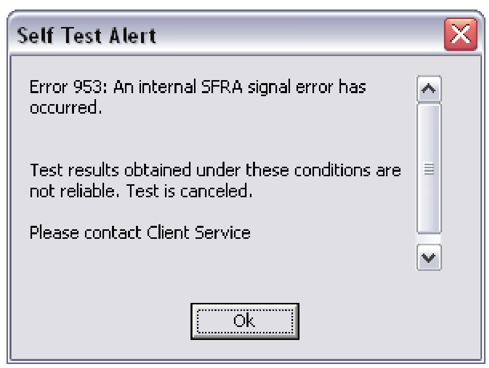


Figure 3.37 Error 953

The instrument generates signals at a number of frequencies and measures them without sending them through the test object. This signal verification test confirms that the device is performing as expected. If the test fails, results will be compromised. **You are not allowed to continue the test.** Contact Doble Engineering for troubleshooting and repair.

If each test is successful, the test begins and the Magnitude tab appears (#1 in Figure 3.38 on page 3-24) and displays the trace as it develops. The Legend pane appears (#2) and a progress bar expands as the test progresses (#3).

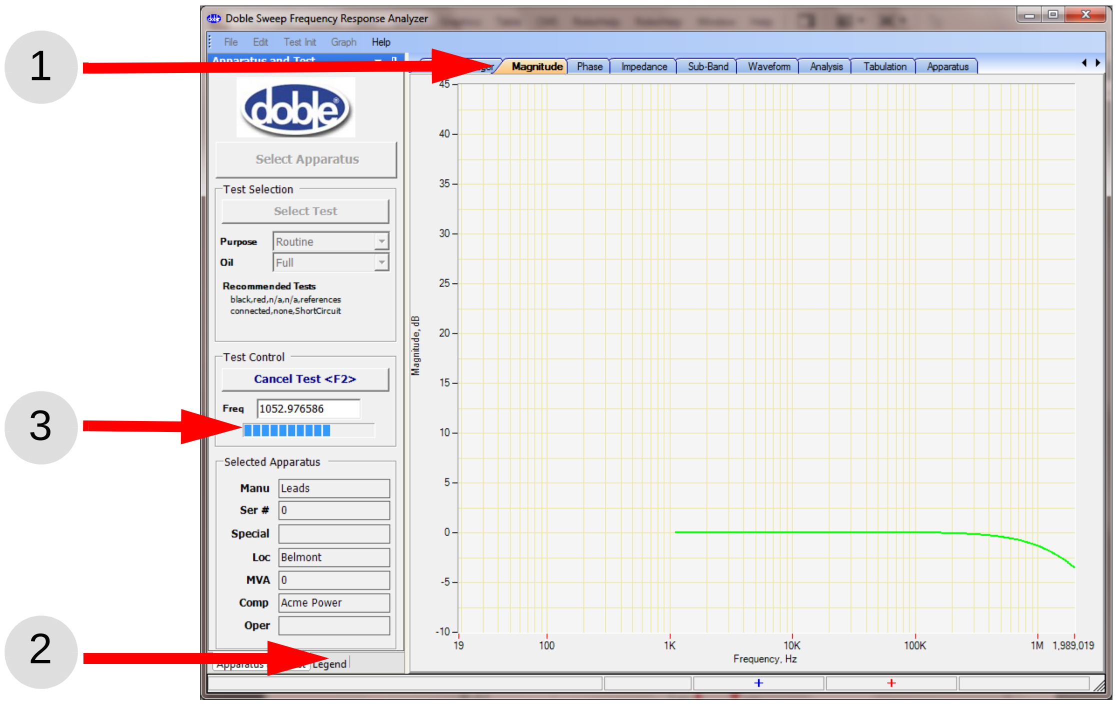


Figure 3.38 Test in Progress

When the test finishes, the view auto-zooms so that the trace takes up most of the graph.

Troubleshooting Test Results

SFRA is an easy test to perform, but simple problems can occur during a test. These have characteristic signatures, as described below.

Monitoring Waveforms

The instrument allows you to monitor the reference and measured waveforms as you run through a test. Click the **Waveform** tab to display waveforms. Both waveforms should appear. At very low dB response, the measured waveform may be small.

Diagnosing Open-Circuit Response

An open-circuit response may be caused by the black test lead dropping off the bushing, a poor connection, or damage within the test lead. The discrete change in the lower frequency range in Figure 3.39 on page 3-25 shows typical open-circuit behavior: about –90 to –100 dB. Investigate a test like this to see if the open circuit lies in the test setup or the transformer.

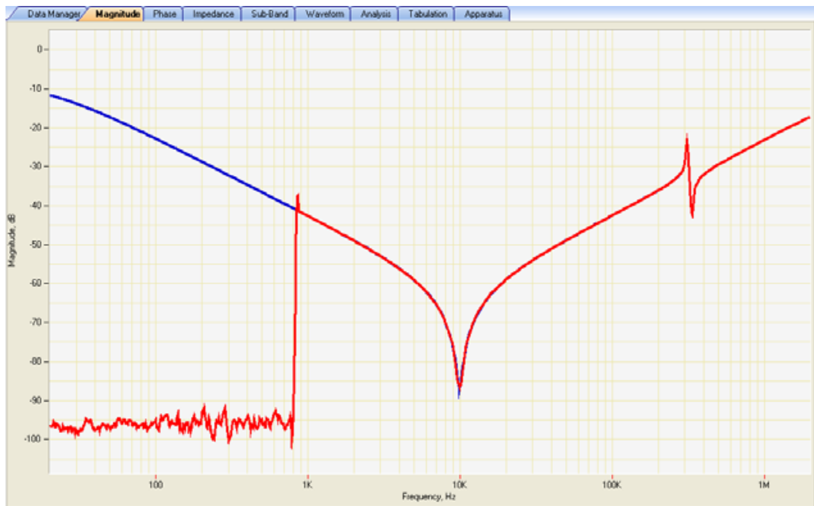


Figure 3.39 Typical Open-Circuit Trace

Sample Test Results

This section provides typical results from a number of transformer windings and designs. These are examples of how designs and phase results vary between transformers.

Three Responses for One Transformer

Figure 3.40 on page 3-26 shows the two open-circuit responses and the short-circuit response of one phase of an autotransformer. The three traces are clearly different at low frequencies.

Typically, the HV response starts at a much lower level than the LV response. The short-circuit response approaches 0 dB at low frequency but comes back in line with the HV response at higher frequencies.

1	Short Circuit
2	Open Circuit LV
3	Open Circuit HV

Figure 3.40 Responses for One Phase of a Transformer HV Delta Trace

Figure 3.41 shows the responses for three phases of a HV delta winding. This is a characteristic response at low frequencies:

- The center phase has a slightly higher impedance (more negative response) at lower frequencies.
- The center phase is different from the outer phases at the first resonance below 10 kHz.
- The center phase is similar to the outer phases as frequency rises.
- All three phases have the same basic shape above about 100 kHz.

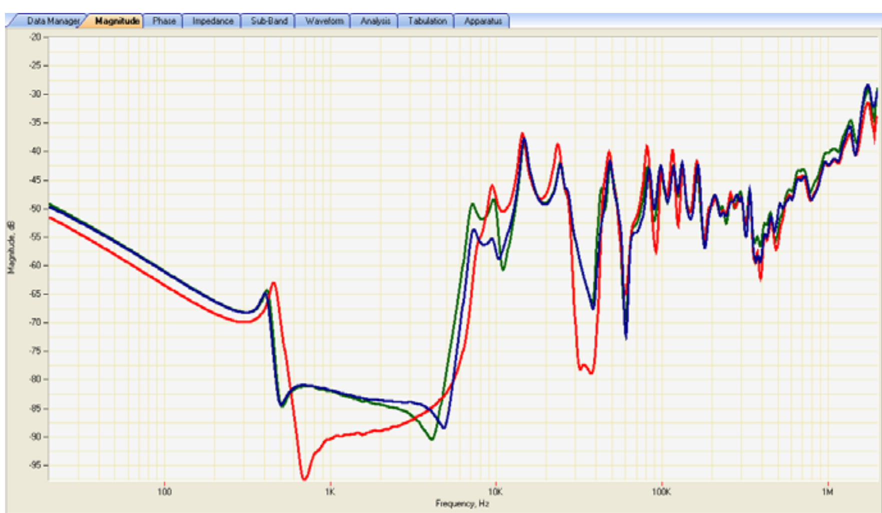


Figure 3.41 HV Delta Winding Traces

HV Wye (Star) Response

Figure 3.42 shows a typical HV wye (star) winding response. All three phases show similar responses at low frequencies, with the following characteristics:

- The center phase has a slightly increased impedance (more negative dB) at low frequencies.
- The center phase has one resonance and the outer phases two. The outer phases are similar at low frequencies.
- The three phases come back together as frequencies approach 10 kHz.
- The three phases show regions of similarity and regions of dissimilarity across the frequency range.

Figure 3.42 HV Wye Winding Trace

Short-Circuit Test Response

Figure 3.43 on page 3-28 shows the three short-circuit responses from the HV side of a transformer. As expected, the responses are similar.

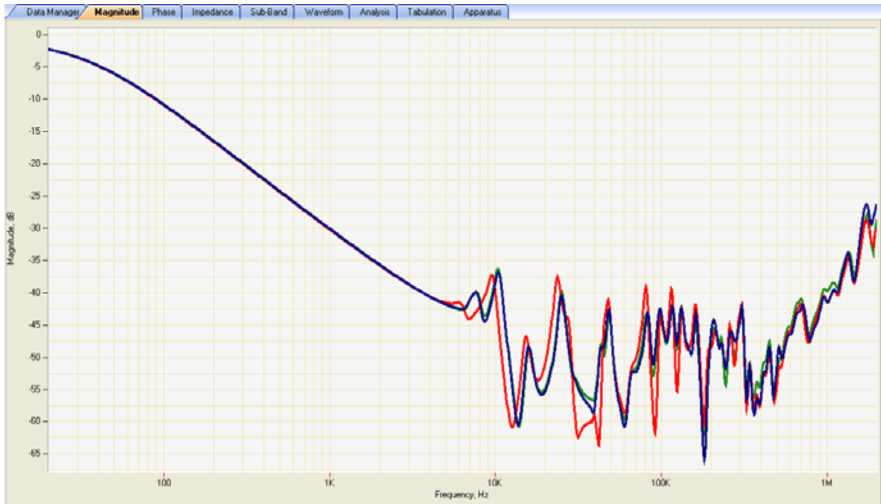


Figure 3.43 Short-Circuit Test Trace

Even when responses are shown in magnification (Figure 3.44), they are under the average divergence of 0.2 dB among phases. This is a useful diagnostic where no previous results are available.

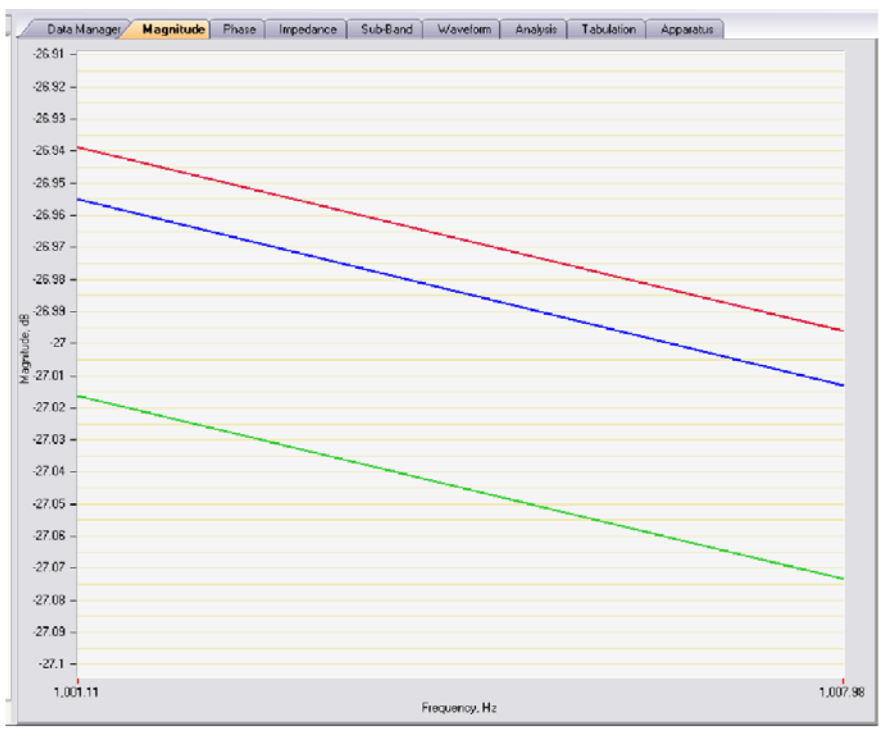


Figure 3.44 Short Circuit Trace – Detail

Repeat Results for One Phase at Different Times

The two responses in Figure 3.45 were taken 18 months apart. The original data was taken as a baseline set of results; the subsequent data was taken after an incident involving the transformer. The results are similar.

Figure 3.45 Repeat Results for One Phase

Low-frequency variation, below about 5 kHz, is characteristic of core magnetism affecting the results. The traces have the same basic shape, but one is offset compared to the other. They come back into line as they approach 10 kHz.

The higher-frequency results are almost identical. This is strong evidence that there has been no change in this transformer.

Results Showing a Shorted Turn

A shorted turn produces an effect similar to shorting the low-side windings for a short-circuit measurement. The effect is easy to see at low frequencies and does not require reference results.

The original results show the characteristic low-frequency response of a wye (star) winding. The subsequent results, taken a year later after a close-in fault, show the characteristic response of a short somewhere on that phase.

Figure 3.46 shows an example of a shorted turn on one winding.

Figure 3.46 Shorted Turn on One Winding

Confirming the Ethernet Connection

To confirm that the PC is connected to the instrument using the Ethernet connection:

1. Click the **Start** button in the lower left corner of the Windows Desktop.

   The Start menu appears (Figure 3.47).

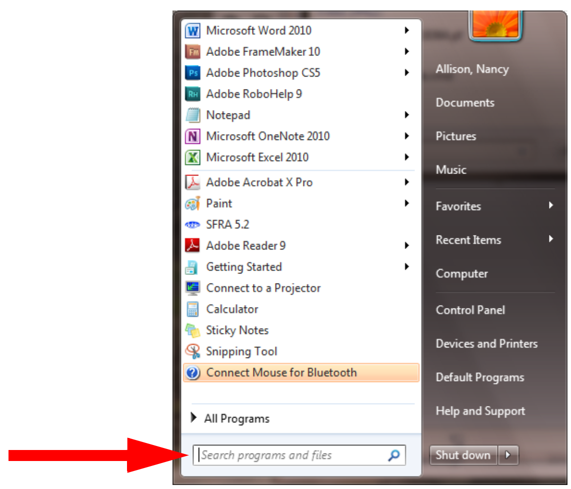


Figure 3.47 Start Menu

2. In the field at the bottom of the Start menu, type **CMD**.

   The search runs instantly and displays results immediately as you type.

3. Press **Enter**.

   The Command window appears.

4. At the prompt, type **ipconfig** (item #1 in Figure 3.48) and press **Enter**.

   The network information that is displayed includes your IP address.

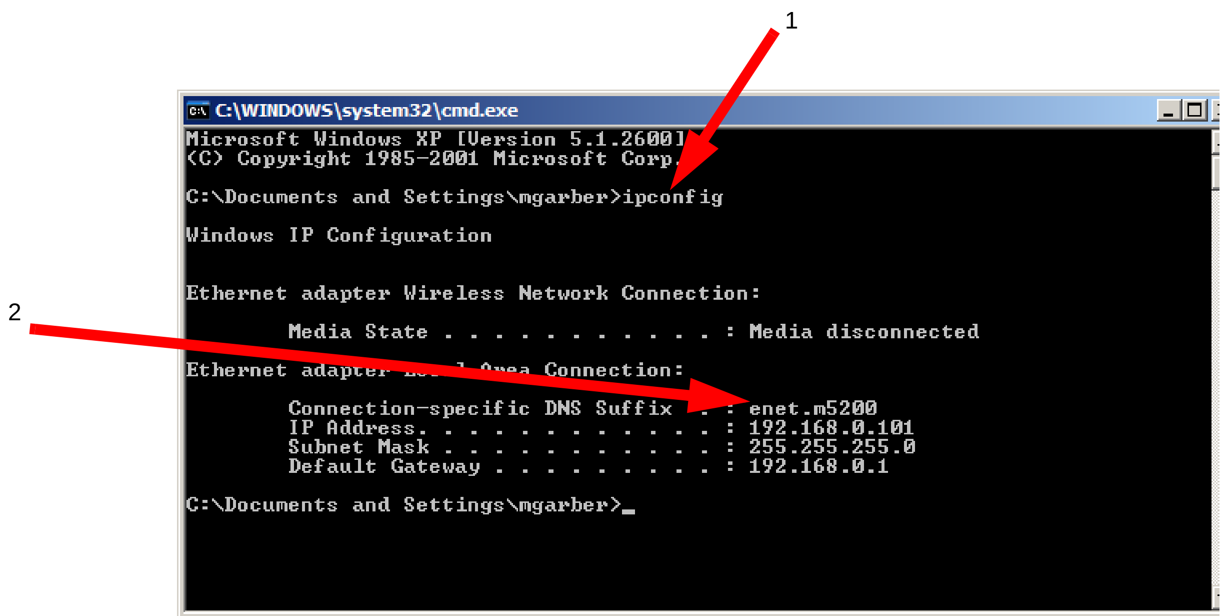


Figure 3.48 Command Window Displaying IP Address

5. Look at DNS suffix (item #2 in Figure 3.48):

   - **enet.m5200**—This suffix confirms that the instrument is connected to the PC. If SFRA still cannot find the M5000 instrument, contact your Doble representative for assistance.
   - **Anything else**—Any other suffix indicates that instrument is not communicating with the PC. Check the cable connections. If this does not solve the problem, you may want to contact your IT department for assistance with network connections. If they are functioning correctly, contact your Doble representative for assistance.

4. Managing Tests and Templates

This chapter describes the templates provided with SFRA 5.2 and explains how to use them. It contains the following sections:

- "Introduction" on page 4-1
- "Opening the Template Editor" on page 4-1
- "Creating a New Test Template" on page 4-2
- "Editing or Deleting a Template" on page 4-3
- "Adding, Editing, or Deleting Tests in a Template" on page 4-3

Introduction

SFRA software provides preconfigured templates in the Settings folder. A test template provides a list of recommended tests for a transformer. You can edit these template files, replace them, or import other templates using a simple procedure to merge template files (see "Merging Settings Files" on page 5-14).

The Template Editor enables you to create, edit, review, and delete test templates. Test templates are a means of grouping tests for a particular transformer design and are a flexible way to specify tests for use in the field. You can associate a template with a number of transformers or create it for future reference and not associate it with any transformer.

For information about the specific contents of each template, see Appendix B, "Test Templates."

Opening the Template Editor

To open the Template Editor:

1. Open the **Edit** menu and select **Edit Apparatus**.

   The Test Equipment Editor window opens.

2. Click the **Edit Templates** button.

   The Template Editor window opens (Figure 4.1 on page 4-2).

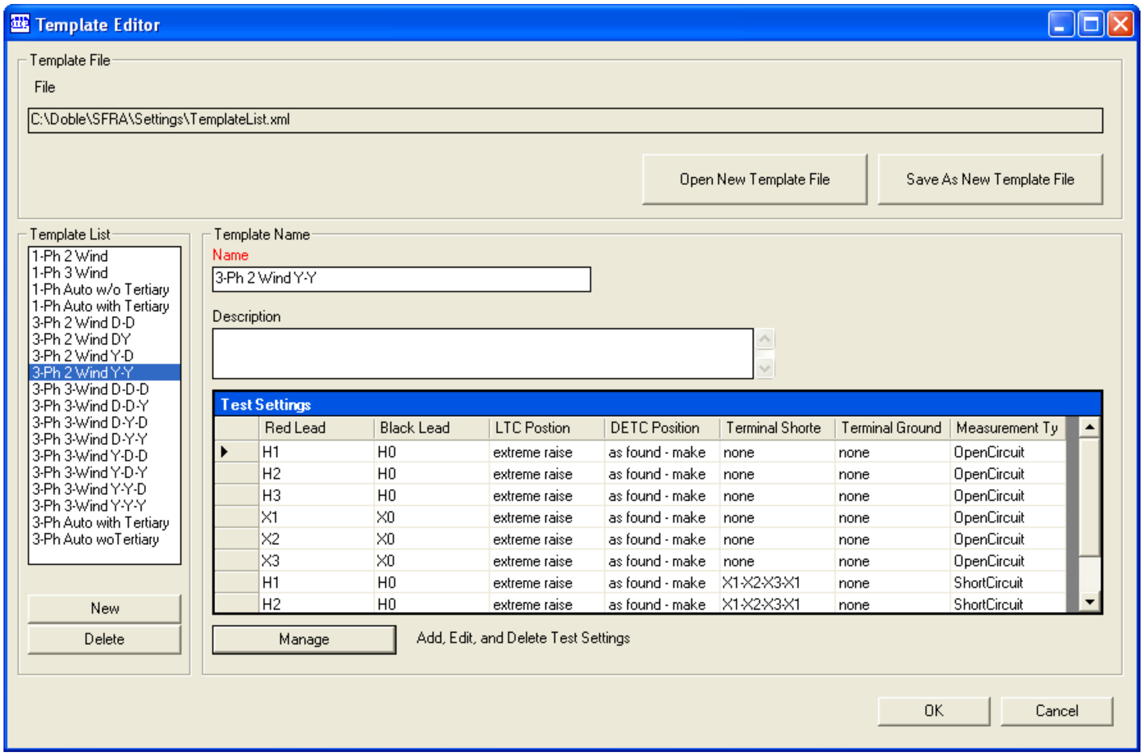


Figure 4.1 Template Editor

Creating a New Test Template

To create a new test template:

1. In the Template Editor window, click **New**.

   A New Template appears in the Template List.

2. Enter a name in the Name field (required) and a description if desired.

3. Click **Manage** or right-click a row or heading of the Test Settings table and click **Manage**.

   The Test Setting Editor appears (Figure 4.2 on page 4-3).

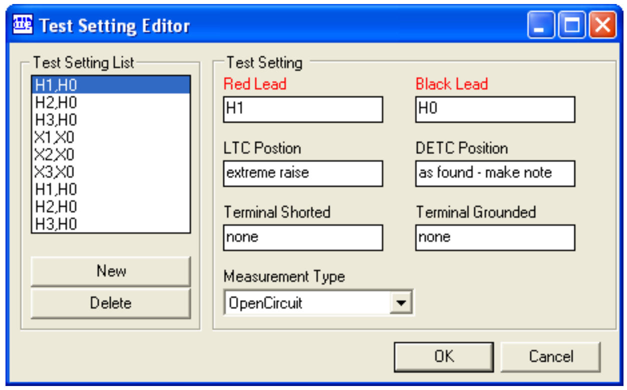


Figure 4.2 Test Setting Editor

4. Enter the appropriate settings. Red Lead and Black Lead are required.
5. Click **OK**.

Editing or Deleting a Template

To edit or delete a test template:

1. In the Template Editor window, select the template from the Template List.
2. Click **Manage** or right-click a row or heading of the Test Settings table and click **Manage**.

   The Test Setting Editor appears.
3. To edit a template, edit the contents of the fields on the right.
4. To delete a template, select it from the Template List and click **Delete**.

   The Confirm Delete dialog box appears.
5. Click **Yes**.
6. Click **OK**.

Adding, Editing, or Deleting Tests in a Template

The Test Setting Editor enables you to add, edit, or delete tests in a template.

To open the Test Setting Editor:

1. Open the **Edit** menu and select **Edit Apparatus**.

   The Test Equipment Editor window opens.

2. Click the **Edit Templates** button.

   The Template Editor window opens.

3. Click **Manager**.

   The Test Setting Editor window opens (Figure 4.2 on page 4-3).

   The name of each available test appears in the Test Setting List. The minimum required information is the position of the red lead (e.g., H1, A, or N) and the black lead (e.g., X0, n, or v). Together, these values provide the name of the test in the Test Setting List.

Creating a New Test Setting

To create a new test setting:

1. In the Test Setting Editor, click **New**.

   New Red, New Black appears in the Test Setting List.

2. Enter the appropriate settings. Red Lead and Black Lead are required.
3. Click **OK**.

Editing or Deleting a Test Setting

To edit or delete a test setting:

1. In the Test Setting Editor, select the test from the Test Setting List.
2. To delete a test, select it and click **Delete**.

   The Confirm Delete dialog box appears.

3. Click **Yes**.
4. To edit, edit the contents of the fields on the right.
5. Click **OK**.

5. Managing Data and Generating Reports

This chapter explains how to fill in the nameplate, create and maintain test templates, and manage results data. It contains the following sections:

- "Managing Location Information" on page 5-1
- "Adding or Deleting SFRA Instrument Information" on page 5-3
- "Adding or Deleting Organization Information" on page 5-4
- "Managing Transformer Information" on page 5-5
- "Managing Tap Changer Data" on page 5-7
- "Managing Results Data" on page 5-8

Managing Location Information

The location is the place, such as a substation, where the SFRA transformer test is performed. Location files store all location information in an XML file. SFRA enables you to add or delete location data, and to export or import location files.

To manage location information:

1. In the main window of the SFRA software, open the **Edit** menu and select **Edit Apparatus**.

The Test Equipment Editor window opens (Figure 5.1 on page 5-2).

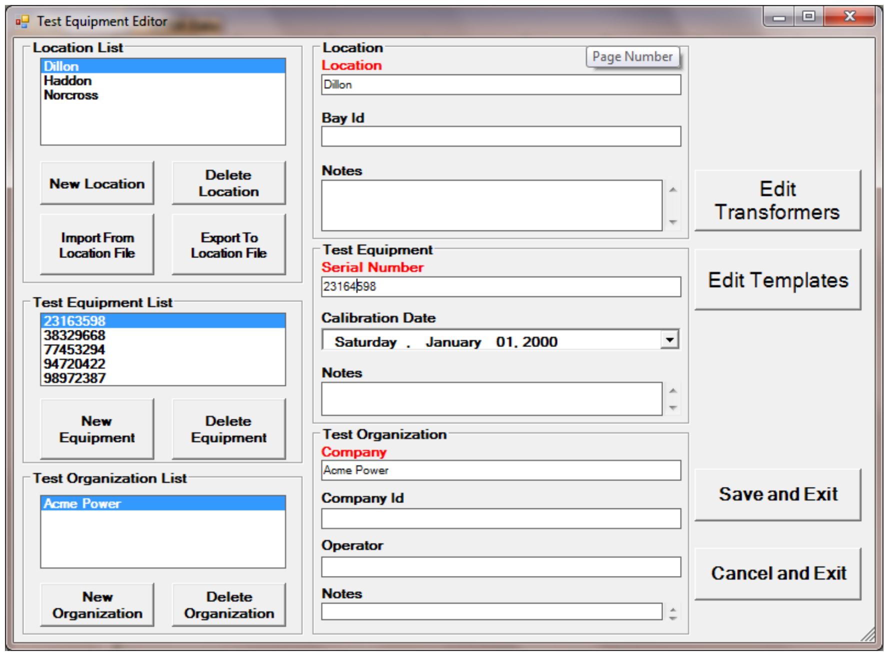


Figure 5.1 Test Equipment Editor

2. Click **New Location** to add information (Figure 5.2).

   The words **New Location** appear in the Location field and the Location List.

   Select and delete these words ***in the Location field*** and type in the new location.

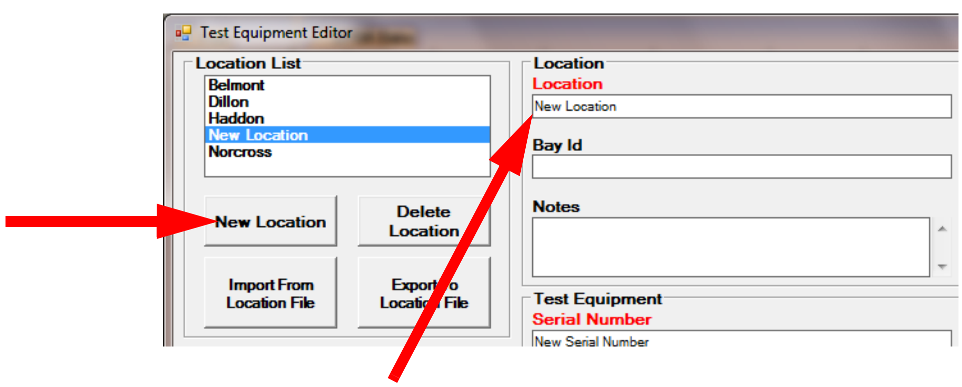


Figure 5.2 Entering a New Location

SFRA software enables you to import and export Location files. This helps ensure consistency of locations for different users.

3. To export a location file:
   a. Select the location in the Location List.
   b. Click **Export To Location File**.

      The Save As dialog box appears.
   c. If desired, enter a new filename in the File Name field.
   d. Click **Save**.
4. To import a Location file:
   a. Click **Import From Location File**.

      The Open dialog box appears.
   b. If necessary, navigate to the appropriate folder on your computer.
   c. Select the file.
   d. Click **Open**.

      The Import From Location dialog box appears.
   e. Click **OK**.
5. To delete a location, select the location and click **Delete Location**.
6. Save all changes by clicking **Save and Exit**.

Adding or Deleting SFRA Instrument Information

The Test Equipment List displays the serial numbers of Doble SFRA instruments that have been added into the SFRA database.

To add a serial number:

1. In the main window, open the **Edit** menu and select **Edit Apparatus**.

   The Test Equipment Editor window opens (Figure 5.1 on page 5-2).
2. Click **New Equipment** (Figure 5.3).

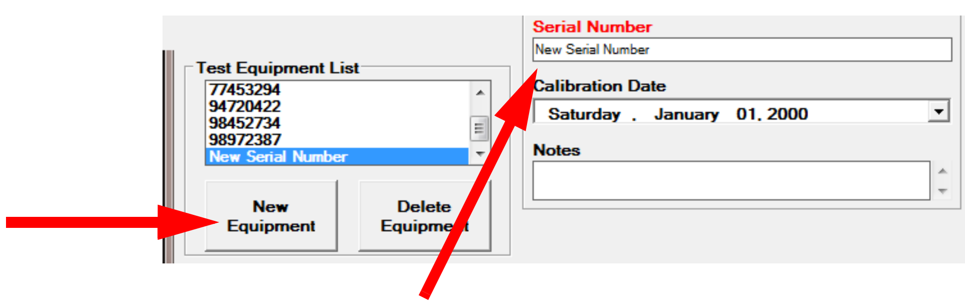


Figure 5.3 Entering a New Serial Number

The words **New Serial Number** appear in the Test Equipment List and Serial Number field.

3. Select and delete these words ***in the Serial Number field*** and type in the new serial number.
4. To delete a serial number, select the number in the Test Equipment List and click **Delete Equipment.**
5. Save all changes by clicking **Save and Exit**.

Adding or Deleting Organization Information

The organization is the owner of the transformer to be tested.

To add organization information in this window:

1. In the main window of the SFRA software, open the **Edit** menu and select **Edit Apparatus**.

   The Test Equipment Editor window opens (Figure 5.1 on page 5-2).

1. Click **New Organization**.

   The words **New Company** appear in the Test Organization List and Company field.

2. Select and delete these words ***in the Company field*** and type in the new company name (Figure 5.4).

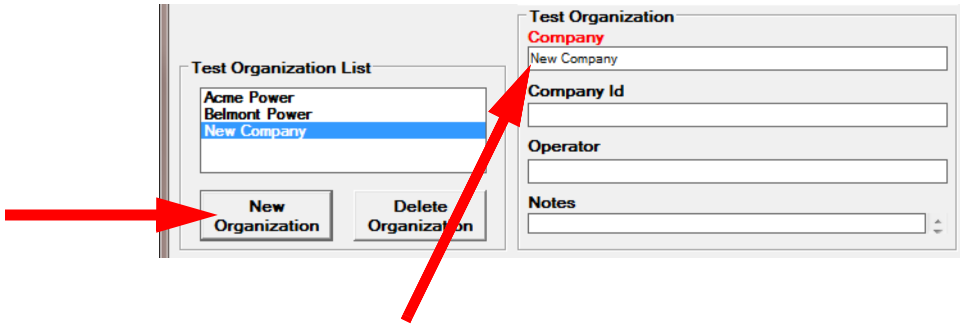


Figure 5.4 Entering a New Organization

3. To delete an organization, select it in the Test Organization List and click **Delete Organization.**
4. Save all changes by clicking **Save and Exit**.

Managing Transformer Information

The Transformer Editor enables you to create, edit, review, and delete detailed information about transformers.

To add or edit transformer information:

1. In the main window of the SFRA software, open the **Edit** menu and select **Edit Apparatus**.

   The Test Equipment Editor window opens (Figure 5.1 on page 5-2).

2. Click the **Edit Transformers** button on the right.

   The Transformer Editor window opens (Figure 5.5).

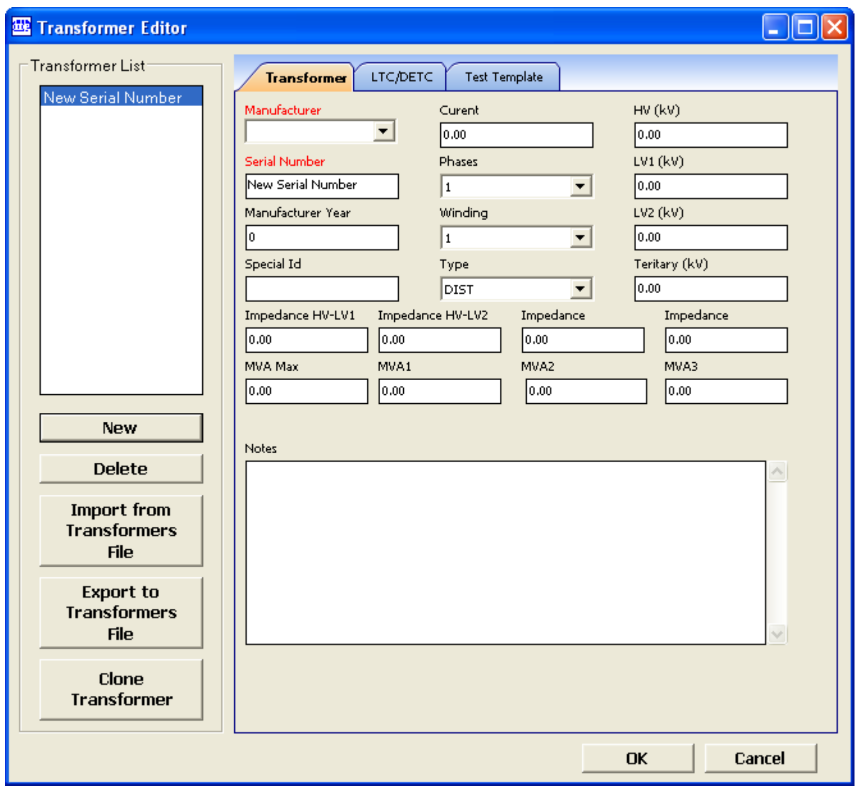


Figure 5.5 Transformer Tab of Transformer Editor Window

Entering a Transformer into the SFRA Database

To enter a transformer into the SFRA database:

1. Click **New**.

   The words **New Serial Number** appear in the Transformer List.

2. Select a manufacturer from the drop-down menu on the Transformer tab. This is a required field. If the manufacturer name is not available, select **No MFR Listed**.
3. Enter the serial number of the transformer. This is a required field. Each transformer must have a unique serial number; this is its key identifier.
4. Enter any other desired data on the Transformer tab or edit existing data.
5. Click **OK**.

Editing or Deleting Transformer Data

To edit or delete data about a transformer:

1. Select the transformer from the Transformer List.
2. To delete this transformer, click **Delete**.
3. To edit the information, edit the contents of the fields.
4. Click **OK**.

Cloning a Transformer

Cloning duplicates an existing transformer, so you can create a new entry without having to reenter all the data. Only the serial number is required.

To clone a transformer:

1. Click **Clone**.

   The Edit Serial Number dialog box appears (Figure 5.6).

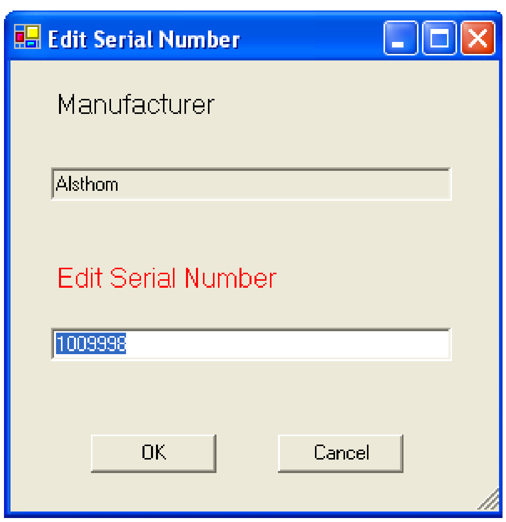


Figure 5.6 Edit Serial Number Dialog Box

2. Enter a new serial number.
3. Click **OK**.
4. Make any other necessary edits on the Transformer Editor tabs.
5. Click **OK**.

Importing and Exporting Transformer Files

SFRA software allows you to import and export Transformer files. This helps ensure consistency for different users. The files are saved in .XML format.

To export a transformer file:

1. Select the transformer from the Transformer List.
2. Click **Export To Transformers File**.

   The Save As dialog box appears.
3. If desired, enter a new filename in the File Name field.
4. Click **Save**.

To import a transformer file:

1. Click **Import From Transformers File**.

   The Open dialog box appears.
2. If necessary, navigate to the appropriate folder on your computer.
3. Select the file.
4. Click **Open**.

   The Import From Transformers File dialog box appears.
5. Click **OK**.

Managing Tap Changer Data

The LTC/DETC tab (Figure 5.7 on page 5-8) enables you to enter data associated with any load tap changer (LTC) or de-energized tap changer (DETC) that may be present on the transformer. This is not required but is useful reference data.

The Range fields are used to indicate the full range available for the LTC or DETC.

The position of the tap changer during a test is recorded in a separate table when a test is made.

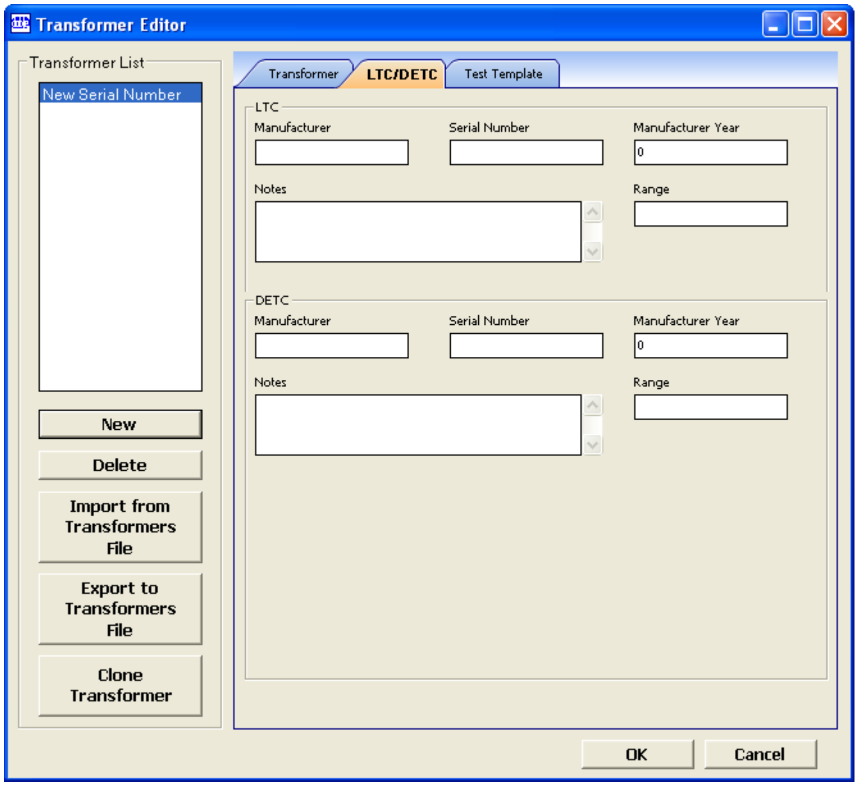


Figure 5.7 LTC/DETC Tab of Transformer Editor Window

Managing Results Data

This section explains how to store, export, and import data; transfer data files between machines; work with settings files; and configure and generate reports.

Default Data Locations

The Sweep Frequency Response Analyzer Settings dialog box (Figure 5.8 on page 5-9) enables you to change the folder for data from tests (Data Path) and the various Editors (Editors List Path).

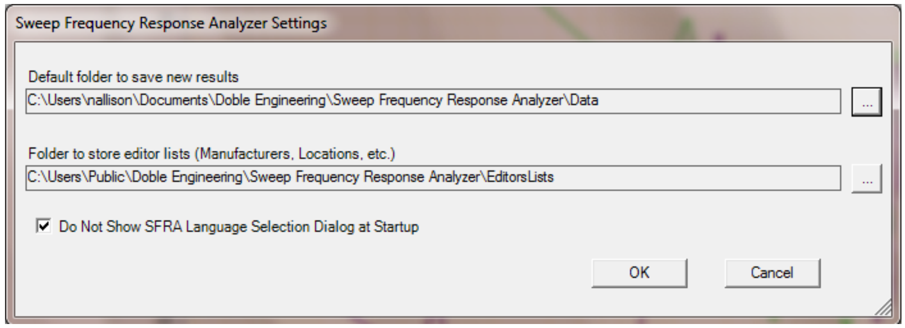


Figure 5.8 Sweep Frequency Response Analyzer Settings Dialog Box

To change the location of a data folder or template file:

1. Select **Edit** →**Options**.

   The Sweep Frequency Response Analyzer Settings dialog box (Figure 5.8) appears.

2. Click the ellipsis button at the right of the path you want to change.

   The Browse For Folder dialog box appears (Figure 5.9).

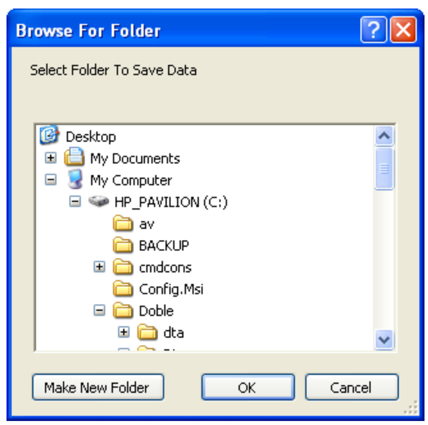


Figure 5.9 Browse for Folder Dialog Box

3. Navigate to the desired folder and click **OK**.

4. Click **OK**.

Selecting a Data Source

To select a folder for viewing data:

1. To search for files in all subfolders of the data folder, check the **Search All Sub-Folders** check box on the Data Manager tab.

Test results are date- and time-stamped and saved to the default folder automatically. You can set up additional data folders based on transformers, substations, manufacturers, or any other category.

2. To make the folder you select the default folder, click the **Make Folder Default** button.
3. Click **Browse for Folder**.

   The Browse For Folder dialog box appears (Figure 5.9 on page 5-9).
4. Navigate to the desired folder.
5. Click **OK**.

   The files appear in the Data Grid.
6. Click the plus sign to the left of a category in the Data Tree to display the options for viewing a subset of data in that category.

   Click **Refresh Data Tree** if you select a new data source or add SFRA traces to the default folder while the software is open.

   To rearrange the order of the columns in the Data Grid, click on a column head and drag it to the desired location.
7. Select one or more traces to view, using standard Windows commands to select the rows of interest. (For instructions, see "Data Manager Tab" on page A-11).
8. Click **Display Traces**.
9. View the traces on the Magnitude, Phase, or Impedance tabs.

Export Selected Results to .CSV Files

You can save test files in .CSV format for use in spreadsheets or the M5100 software viewer.

To save test files in .CSV format:

1. Select the file(s) in the Data Manager tab, using standard Windows commands to select the items of interest. (For instructions, see "Data Manager Tab" on page A-11)(For instructions, see "Data Manager Tab" on page A-11).
2. Click **Export Selected Results To CSV Files**.

   The Files Converted dialog box appears (Figure 5.10 on page 5-11).

Figure 5.10 Files Converted Dialog Box

3. Click **OK**.

Import Location and Transformer from Results Files

You can add the Location and Transformer entries from a file to your own settings files (`LocationList.xml` and `TransformerList.xml` in the Settings folder).

To import Locations and Transformers from data files:

1. In the Data Manager tab, select the files from which you wish to import locations and transformers. Use standard Windows commands to select the items of interest. (For instructions, see “Data Manager Tab” on page A-11).
2. Click **Import Location and Transformer From Results File**.

   If a Location or Transformer is imported, a Location Data Copied or Transformer Data Copied dialog box displays the name(s) of the imported Location or Transformer.

   If a Location or Transformer is not imported — typically because it is already in your settings files or is in the wrong format — a No Transformers Imported or No Locations Imported dialog box appears.
3. Click **OK** for each dialog box.

Saving and Deleting Traces

All completed traces are automatically saved to the default data location you can select in “Default Data Locations” on page 5-8. If the test is canceled, the data is not saved.

The SFRA software has no Delete option. To delete files, locate the file using the time-stamp in the folder where it is stored and delete it in Windows Explorer. The filename appears as the last column of each row in the Data Manager tab.

Automatic save and the procedure for deleting files are set up to help protect data from inadvertent replacement or loss.

Importing 1.x and 2.x M5100 SFRA Files

You can import data from M5100 versions 1.x and 2.x software by placing those files in the appropriate data source location. When opened, they will be parsed for content, converted to the new Doble SFRA format, and renamed with a different extension so as not to be reconverted subsequently. Be sure to back up copies of these files as a precaution against data loss.

Nameplate data in M5100 versions 1.x and 2.x format is not easily converted to M5200/M5300/M5400 format. A number of fields are the same, such as Transformer Serial Number and Location, but the location of test leads may be less obvious. Check imported data for accuracy and details, with no odd characters in any field, such as @, *,? etc.

Transferring Data between Machines or PCs

To transfer data between machines or PCs, copy the desired files to a network or suitable medium and use Windows Explorer to navigate to them in the target machine.

The software will try to identify duplicate files but is not foolproof. Make sure to retain a backup when copying and importing data.

Settings Files

Settings files contain entered data for:

- Transformers
- Locations
- Test Organizations
- Test Instrument
- Test Templates

The files are in XML format. To locate them on your computer, select **Edit→ Options**. The Sweep Frequency Response Analyzer dialog box (Figure 5.8 on page 5-9) displays the file paths.

To open a settings file, use a standard text editor such as Notepad. Do not use Microsoft Word or other word processors, because they will attempt to save files in their native formats, which are typically not compatible with SFRA software. This document assumes the use of Notepad.

Figure 5.11 displays a simplified view of a Transformer settings file that will be used to describe the file in detail.

```
Line #  XML Code
1       <?xml version="1.0" encoding="utf-8"?>
2       <transformerNameplates>
3         <transformerNameplate version="1">
4           <manufacturer>ABB</manufacturer>
5           <serialNumber>1234</serialNumber>
-           .
-           .
-           .
54          </transformerNameplate>
55          <transformerNameplate version="1">
56          <manufacturer>GE</manufacturer>
57          <serialNumber>xyz</serialNumber>
-           .
-           .
-           .
106         </transformerNameplate>
107     </transformerNameplates>
```

Figure 5.11 Simplified XML Transformer Settings File

Line numbers apply only to this example—they will vary for other settings files. What is important is the XML start and end tags for each section.

- Line 1 is always the XML declaration that describes the XML version and encoding used. This must not be modified.
- Line 2 contains a start tag that is the beginning of the container of all transformers in the file. It must have a matching end tag (line 107).

- Line 3 contains the start tag of the first transformer nameplate and must also have an end tag (line 54).
- Line 55 shows the start of another transformer, which ends on line 106.
- If another transformer were added, it would appear after line 106 and before **</transformerNameplates>** on line 107.

Merging Settings Files

The method for merging transformer settings files described here applies to all other settings files.

Use caution when merging, because an incorrect merge could corrupt your files and cause unpredictable results. Be especially careful to avoid duplicate entries in any settings file.

The manual merge described here is prone to cut-and-paste errors. Back up all data and settings files before performing a merge operation.

The following example concerns two SFRA users who want to share XML files.

Figure 5.12 shows a simplified transformer settings file from User A (as viewed in Notepad):

```
<?xml version="1.0" encoding="utf-8"?>
<transformerNameplates>
   <transformerNameplate version="1">
     <manufacturer>ABB</manufacturer>
     <serialNumber>1234</serialNumber>
   </transformerNameplate>
   <transformerNameplate version="1">
     <manufacturer>GE</manufacturer>
     <serialNumber>678</serialNumber>
   </transformerNameplate>
</transformerNameplates>
```

Figure 5.12 Transformer Settings File — User A

Figure 5.13 shows another simplified transformer settings file, this one from User B:

```
<?xml version="1.0" encoding="utf-8"?>
<transformerNameplates>
   <transformerNameplate version="1">
     <manufacturer>ACME</manufacturer>
     <serialNumber>9999</serialNumber>
   </transformerNameplate>
</transformerNameplates>
```

Figure 5.13 Transformer Settings File — User B

User A's file contains two transformers (underlined in the tables for clarity):

- ABB, with serial number 1234
- GE, with serial number 678

User B's file contains one transformer: ACME, with serial number 9999.

The safest method for merging is to combine the two files into a new file containing elements from both source files. The following procedure merges the contents into a new transformer settings file. It makes use of the fact that several versions of Notepad can be run simultaneously.

To merge settings files:

1. Back up all `TransformerList.xml` files.

2. Start an instance of Notepad and open User A's `TransformerList.xml` file.

3. Start another instance of Notepad and open User B's `TransformerList.xml` file.

4. Start a third instance of Notepad.

5. Select the entire text in User A's file and paste it into the blank Notepad.

6. Close User A's file.

7. Select just the transformerNameplate section from User B's file (Figure 5.14 on page 5-16).

```
<transformerNameplate version="1">
  <manufacturer>ACME</manufacturer>
  <serialNumber>9999</serialNumber>
</transformerNameplate>
```

Figure 5.14 TransformerNameplate Section of User B's Settings File

8. Close User B's file.
9. In the remaining Notepad, place the cursor at the beginning of line 3 and paste the text.
10. Check that the file has the correct format, with carriage returns and indents, to ensure readability of the document.
11. Save the file as `TransformerList.xml`.
12. Replace the existing `TransformerList.xml` file, either by saving the new file to in the default location or by dragging and dropping or copying using Windows Explorer.

Reports

The Reports feature of SFRA provides a variety of options that enable you to include only the information types you want.

To configure and print a report:

1. Display the traces you wish to include in the report.
2. Open the File menu and select **Configure Report**.

   The Report Designer window appears (Figure 5.15 on page 5-17).

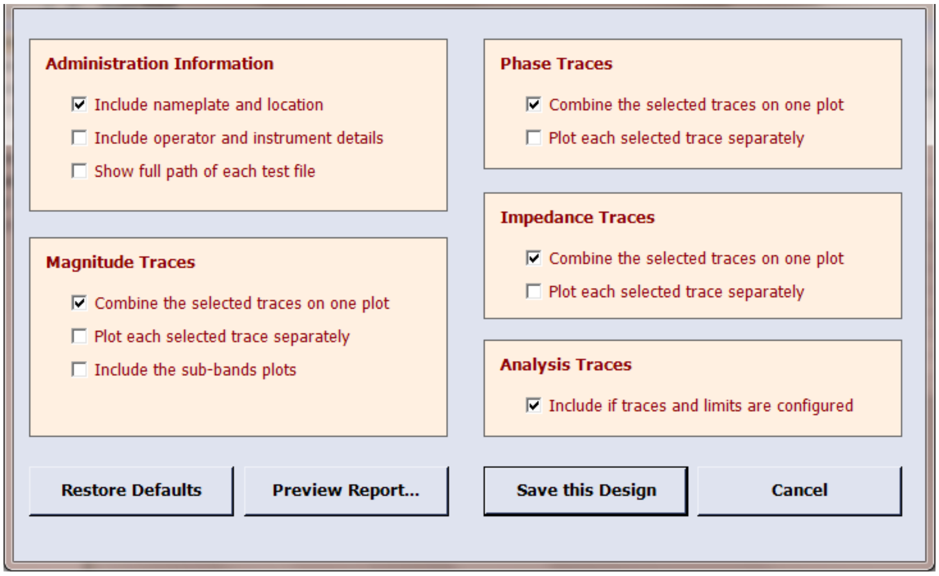


Figure 5.15 Report Designer Window

3. Select the report options you prefer and do any of the following:

- Click **Save this Design**. This saves the selections you have made in the Report Designer window and applies them to any report you create in the future. These settings can be edited at any time.
- Click **Preview Report.** You can expand the Print Preview window to read the text more easily, and you can click the printer icon to print the report.

A. Software Overview

This appendix explains how to install SFRA 5.2 and the appropriate USB driver and provides a complete overview of the SFRA 5.2 user interface. It contains the following sections:

- "Installing SFRA 5.2" on page A-1
- "Manually Install the USB Driver" on page A-5
- "SFRA 5.2 Software Overview" on page A-6
- "Apparatus/Test and Legend Panes" on page A-10
- "Tab Divisions in SFRA" on page A-11

Installing SFRA 5.2

These instructions explain how to install SFRA 5.2 under Windows 7 and Windows XP. You must have administrator privileges to install under either operating system.

Note: You can install SFRA 5.2 under Vista by following the steps provided for Windows 7, but SFRA software is not tested under Vista and compatibility is not assured.

To install SFRA 5.2:

1. Download the software from the Doble web site or run the installation CD provided by Doble.
2. Do one of the following:
   - Windows 7—Right-click **setup.exe** and select **Run as administrator**.
   - Window XP—Double-click **setup.exe**.

The Welcome screen appears (Figure A.1).

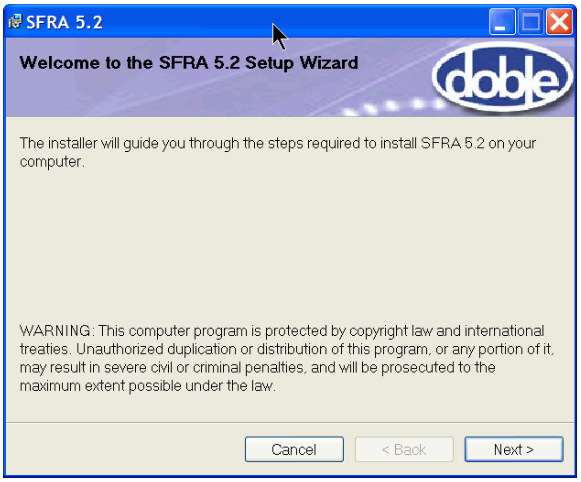


Figure A.1 Welcome Window of Setup Wizard

3. Click **Next**.

The Select Installation Folder window appears (Figure A.2).

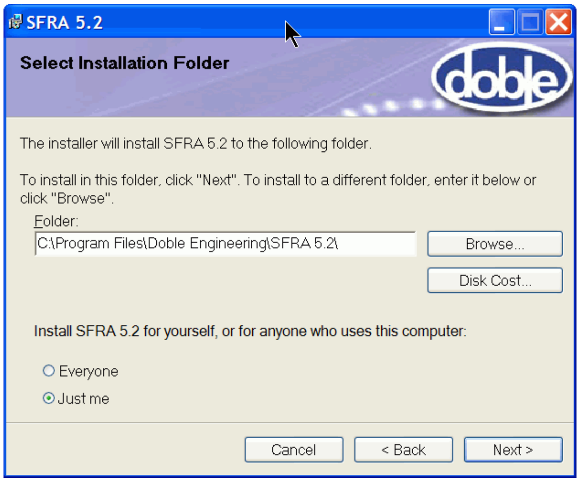


Figure A.2 Select Installation Folder Window

4. Make the following selections:

- Accept the default folder or browse to a folder of your choice.
- Choose **Just Me** if you are installing SFRA on your personal computer.
- Choose **Everyone** if you are installing SFRA on a general-use machine.

5. Click **Next**.

   The Confirm Installation window appears (Figure A.3).

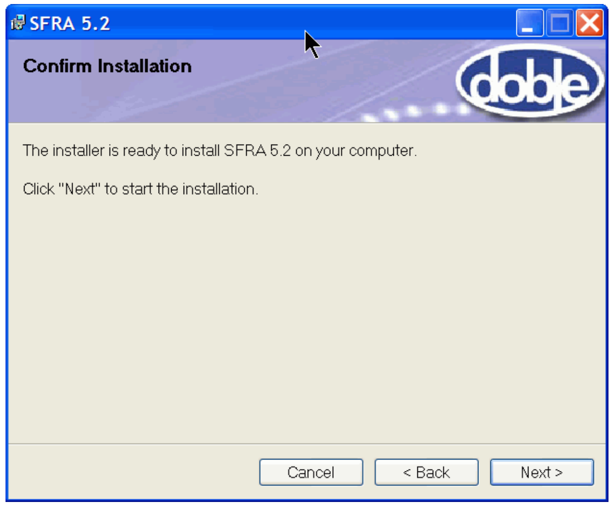


Figure A.3 Confirm Installation Window

6. Review your installation choices and go back to change them or click **Next** to confirm them.

   A progress bar appears (Figure A.4).

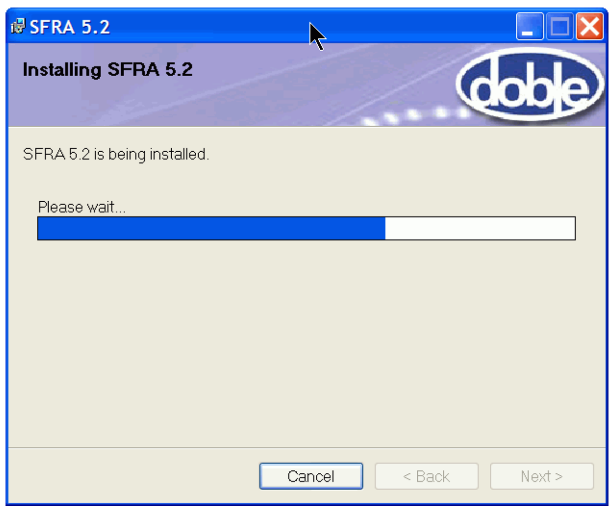


Figure A.4 Progress Bar in Installation Window

7. When the installation is complete, click **Close**.

   Two initial setup choices are made the first time the software is run.

8. Run SFRA 5.2 by double-clicking the icon on the desktop or running the program from within the Start menu.

   A message window asks whether your instrument is an M5300 (Figure A.5).

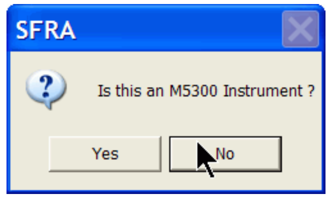


Figure A.5 Identifying an M5300

9. Click **Yes** or **No** as appropriate.

   The Select Default Template window appears (Figure A.6).

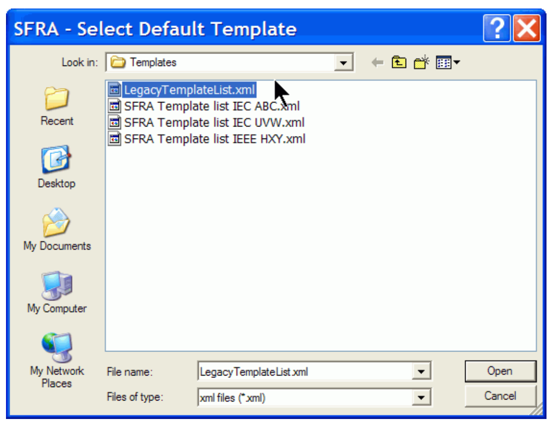


Figure A.6 Select Default Template Window

10. Select the appropriate template and click **Open**.

    If you have installed SFRA 5.2 over an earlier version of SFRA, the word **legacy** is appended to the names of your existing templates.

    Installation and initial setup of SFRA 5.2 is complete.

NOTE: For SFRA 5.2 to work with USB communications, the correct driver must be installed. Go to "Manually Install the USB Driver" on page 5 to ensure that the correct driver is installed.

Manually Install the USB Driver

It is crucial that you manually install a specific USB driver for your SFRA instrument. ***Do not rely on any pre-installed drivers that came with Windows.***

Where to Find the Driver

Made by Silicon Laboratories, the USB driver can be found in these locations:

- On the SFRA V5.2 CD.
- On a Doble FTP site. Doble provides different FTP sites for Internet Explorer Version 6 and Internet Explorer Version 7 or 8:
  - IE V6—`ftp://Dobleguest:Dob20066@ftp.doble.com`. Navigate to the SiLab driver folder and download the driver to any location on your hard drive.
  - IE V7 or 8—`ftp://ftp.doble.com/dobleguest/SiLab/`. Download the driver to any location on your hard drive.

Remove Previously Installed USB Drivers

To avoid conflicts, remove all previously installed Silicon Laboratories CP210x VCP drivers before installing the new one. The following procedure is for Windows 7; the procedure may vary slightly for other versions of the Windows operating system.

To remove previous versions of the USB driver:

1. Open the **Start Menu** and select the **Control Panel**.
2. In the Control Panel window, select **Programs** and Features.
3. In the Uninstall or Change a Program window, select and remove any earlier version of the **Silicon Laboratories CP210x VCP** driver that may be installed.

Install the Driver

To install the driver on your PC, double-click the **CP210xVCPInstaller** file and follow the installation prompts.

SFRA 5.2 Software Overview

This section provides a complete reference of all SFRA software controls. To find a control, look it up in the following tables by its physical location in the user interface, or look it up in the Index of this manual to find the page number.

File Menu

The File menu has no Save command, because all traces are automatically saved upon completion. Table A.1 lists and describes the File menu options.

Table A.1 File Menu Options

Command	Description
Print	Opens the standard Windows Print dialog box. Shortcut key: **Ctrl + P**
Print Preview	Previews the print format for the plot shown on the Magnitude tab. Click the up or down arrow at the upper right corner of the Preview window (to the right of the Page field) to view each page. Shortcut key: **Ctrl + Shift + P**
Exit	Exits the program. Shortcut key: **Alt + F4**

Edit Menu

Table A.2 lists and describes the Edit menu options.

Table A.2 Edit Menu Options

Command	Description
Edit Apparatus	Opens the Test Equipment Editor dialog box, enabling you to enter or edit apparatus, location, and company details.
Options	Opens the Sweep Frequency Response Analyzer Settings dialog box, enabling you to change the default location of test data and editor lists.

Test Init Menu

Table A.3 lists and describes the Test Init menu options.

Table A.3 Test Init Menu Options

Command	Description
Select Apparatus	Opens the Apparatus Selection dialog box, enabling you to select an apparatus for a test.
Start Test	Starts a test. Active only after you use **Select Apparatus** to choose an Apparatus/Location combination.

Graph Menu

To pan a graph, press **Ctrl** and use the left mouse button to drag the trace across the screen.

Table A.4 lists and describes the Graph menu options.

Table A.4 Graph Menu Options

Command	Description
Cursor 1	Displays a blue crosshair cursor on the Magnitude, Phase, or Impedance graph. You can also click the blue "+" field in the status bar to activate the cursor. Coordinates appear in the blue "+" field of the status bar. The cursor attaches to the nearest graph. Click and drag either cursor line to move it.
Cursor 2	Displays a red crosshair cursor on the Magnitude, Phase, or Impedance graph. You can also click the red "+" field in the status bar to activate the cursor. Coordinates appear in the red "+" field of the status bar. The cursor attaches to the nearest graph. Click and drag either cursor line to move it.
Center Cursors	Centers the cursor crosshairs in the graph. This is the center of the scale values, which may be offset on a log scale.

Table A.4 Graph Menu Options (Continued)

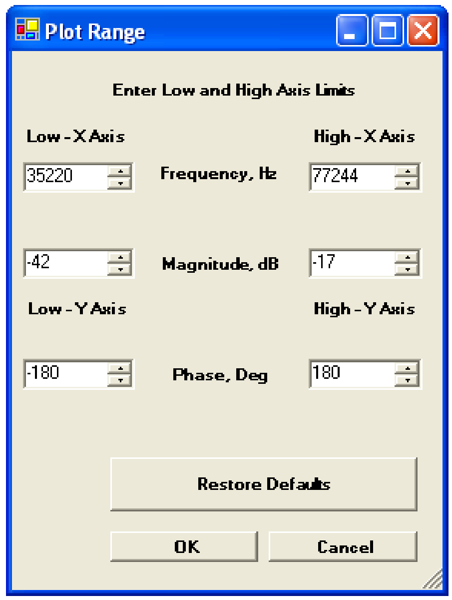
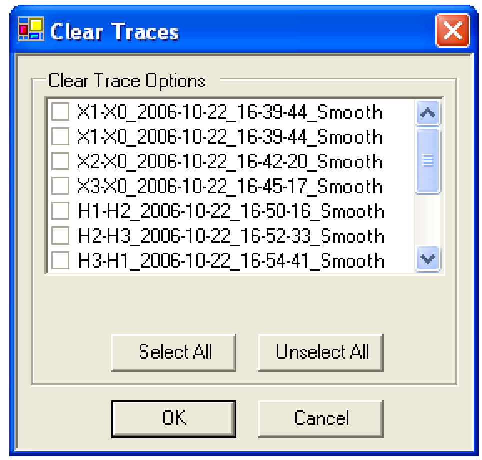
Command	Description
Zoom	Zooms on the graph section between cursor positions. Both cursors must be visible. Shortcut key: Shift + click. You can also shift, click, and drag diagonally to create a rectangle outlining the area you want to zoom on.
Unzoom	Resets the graph to the default view.
New Range	Opens the Plot Range dialog box, enabling you to set the low and high axis limits. This is useful when producing zoomed plots of graph areas for reports. 
Log	Displays the graph with a log x-axis scale. Typically emphasizes lower frequencies.
Linear	Displays the graph with a linear x-axis scale. Typically emphasizes higher frequencies.

Table A.4 Graph Menu Options (Continued)

Command	Description
Clear Traces	Opens the Clear Traces dialog box, allowing you to remove one or more traces from the display. Check the boxes of the traces you wish to remove and click **OK**.  Clearing traces is different from checking or unchecking boxes in the Legend pane, which leaves the trace there but merely shows or hides it on the tab. Clearing the trace here removes it from the Legend pane.

Help

Table A.5 describes the Help menu options.

Table A.5 Help Menu Options

Command	Description
Help	Opens the help file.
About	Opens the version information and copyright dialog box. The software version and build number are in the upper right corner. If your PC is connected to an instrument or if you are using an M5300, the Instrument Firmware Information field displays the instrument firmware version and related information.

Apparatus/Test and Legend Panes

Click the appropriate tab at the lower left of the main SFRA window to display the Apparatus/Test pane and the Legend pane.

Apparatus and Test Pane

Use the Apparatus and Test pane at the left of the main screen to select a transformer for test, set basic test parameters, and start a test. Subsequently, this pane shows which frequency is being measured and the progress of the test. When using an M5200 or M5400, this pane is active only when connected to the instrument.

Legend Pane

The Legend pane enables you to show or hide graphs on the Magnitude, Phase, and Impedance tabs and to set their properties. Check or uncheck the box at the left of the graph name to show or hide the trace. Right-click on a trace name and click Plot Property to display the Plot Property dialog box (Figure A.7).

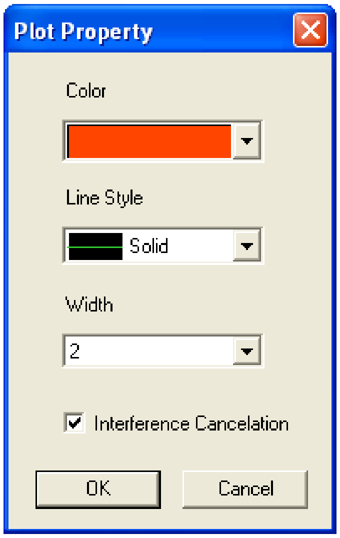


Figure A.7 Plot Property Dialog Box

Use the drop-down menus to change the color, line style, and width of the plot. Interference Cancellation filters the results if they contain noise. It applies only to plot views and does not alter the saved data. Leave it checked unless you need to identify noise frequencies within the results. This option is not available with results from M5100 version 1.x or 2.x software.

Tab Divisions in SFRA

This section describes the main tab divisions of the SFRA 5.2 user interface.

Data Manager Tab

The Data Manager tab (Figure A.8) displays test files grouped by folders (default or user-defined), with controls to select, display, and export those files.

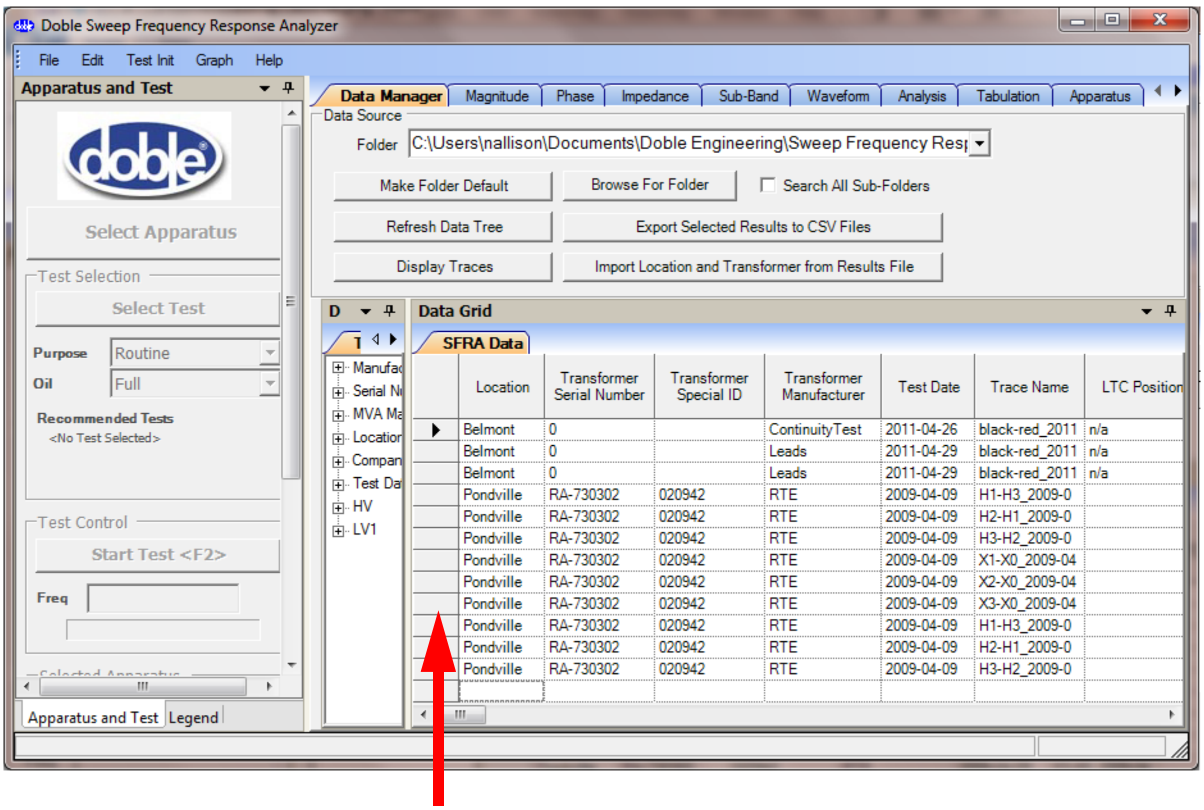


Figure A.8 Data Manager Tab

To select a row in this window, click in the grey column to the left of the row of interest. Use the standard Windows commands for selecting multiple contiguous rows or non-contiguous rows:

- To select two or more contiguous rows—Click the gray section at the left of the first desired row, hold down the **Shift** key, and click the gray section at the left of the last desired row.
- To select several non-contiguous rows, hold down the **Ctrl** key and click the gray section at the left of each desired row.

Magnitude Tab

The Magnitude tab (Figure A.9) displays magnitude versus frequency for the selected graph(s).

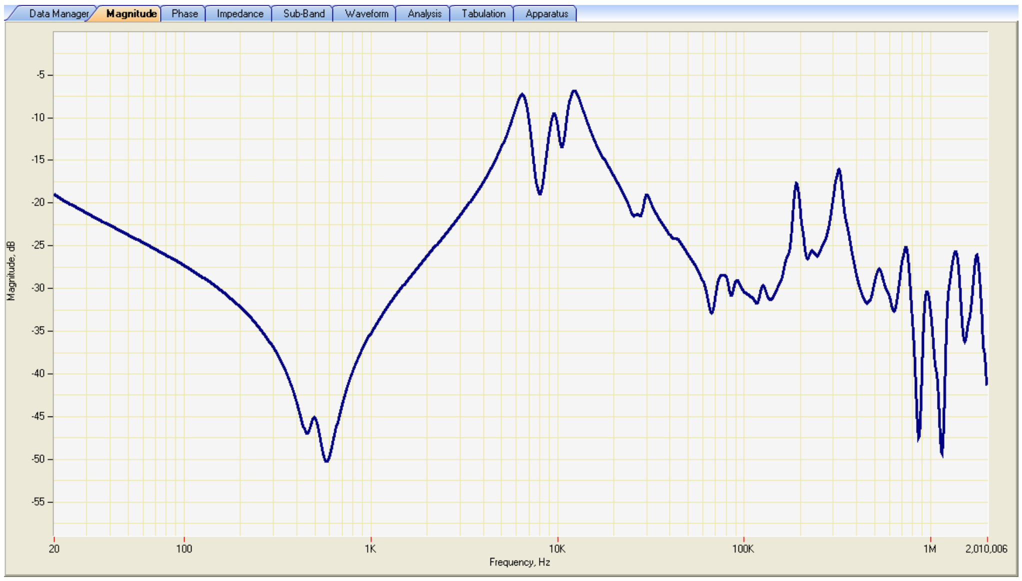


Figure A.9 Magnitude Tab

Figure A.10 shows the status bar at the bottom of the main screen. The coordinates reflect the last change you made to the cursor position on any of the three tabs. Click the blue or red “+” sign to show or hide the cursors. The field on the right (active only when both are on) displays the difference between the two.

Figure A.10 Status Bar

Phase Tab

The Phase tab (Figure A.11) displays phase versus frequency for the selected graph(s). Phase is rarely used but can occasionally be useful when looking at whether a measurement is more inductive or more capacitive.

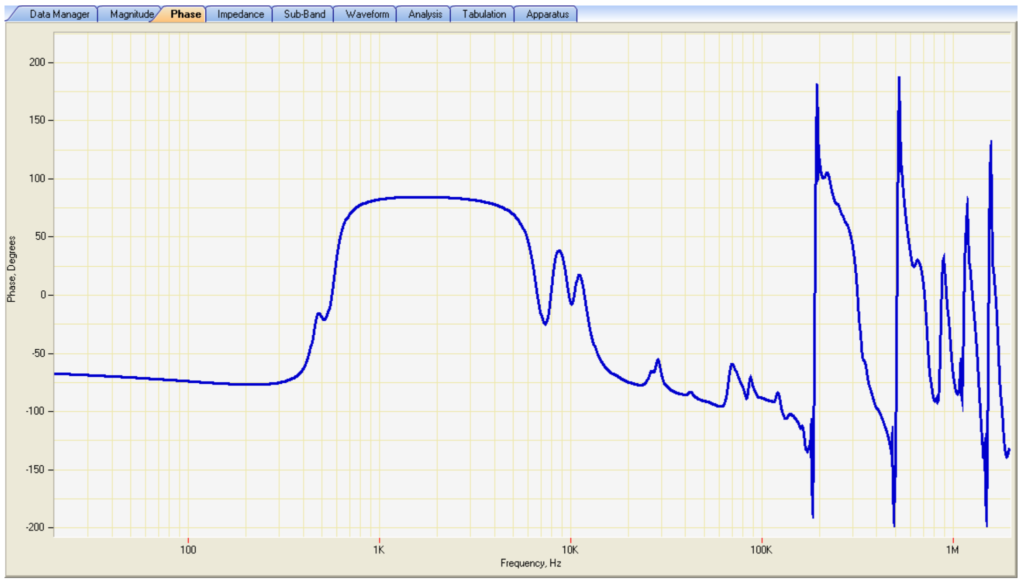


Figure A.11 Phase Tab

Figure A.12 shows the status bar at the bottom of the main screen. The coordinates reflect the last change you made to the cursor position on any of the three tabs. Click the blue or red "+" sign to show or hide the cursors. The field on the right (active only when both are on) displays the difference between the two.

Figure A.12 Status Bar

Impedance Tab

The Impedance tab (Figure A.13) displays Impedance (Z ohms) and Admittance (Y Mhos) representations, using the magnitude and phase results for calculation. Use the option button at the lower left to select the desired display type.

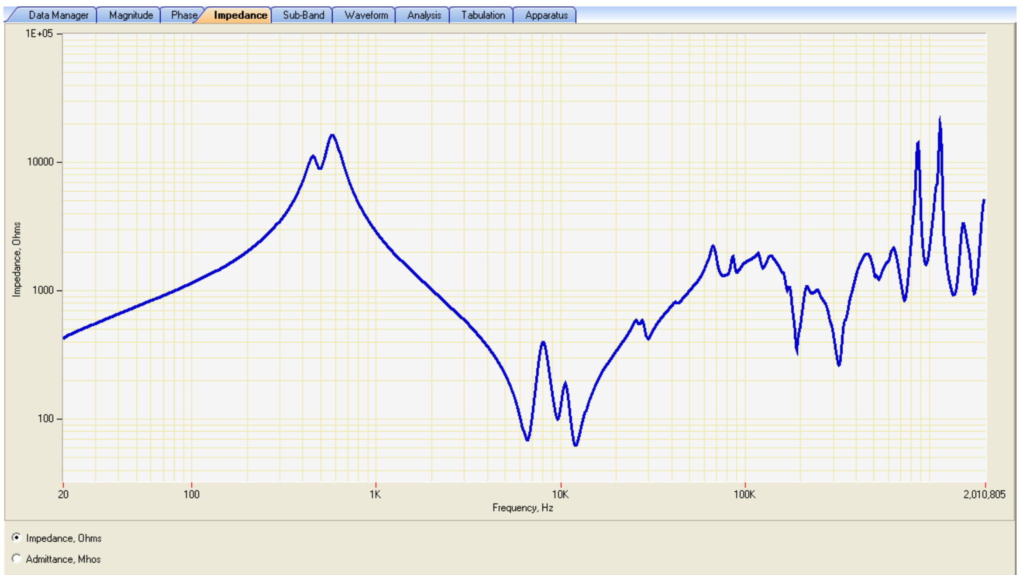


Figure A.13 Impedance Tab

Figure A.14 shows the status bar at the bottom of the main screen. The coordinates reflect the last change you made to the cursor position on any of the three tabs. Click the blue or red "+" sign to show or hide the cursors. The field on the right (active only when both are on) displays the difference between the two.

Figure A.14 Status Bar

Sub-Band Tab

The Sub-Band tab (Figure A.15) is included for historical continuity. Early work on SFRA required results displayed on graphs of 2 kHz, 20 kHz, 200 kHz, and 2 MHz. The last three of these are included here to permit viewing those graphs.

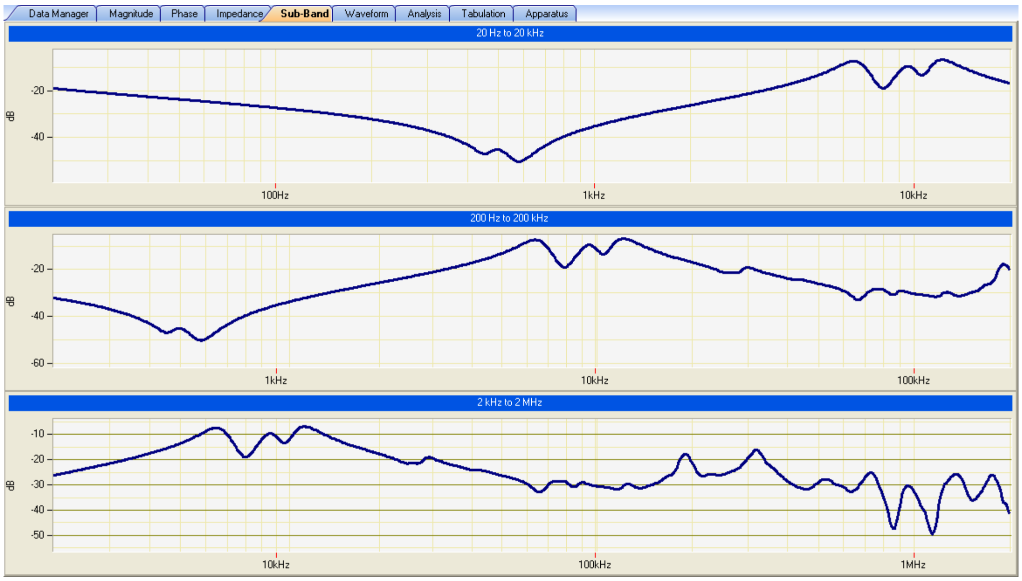


Figure A.15 Sub-Band Tab

Waveform Tab

The Waveform tab (Figure A.16) is useful when monitoring the progress of a measurement: it displays both the reference waveform generated by the test set and the measured waveform of the object under test. This tab displays a waveform only when a test is in progress.

It is also possible to use the Waveform tab to help diagnose a bad connection, which will appear as a low, noisy, non-sinusoidal signal.

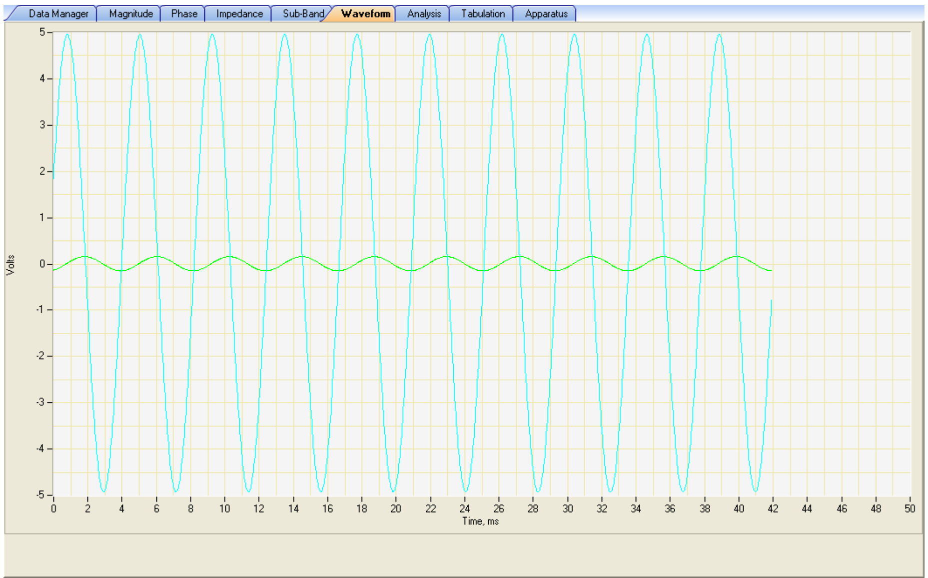


Figure A.16 Waveform Tab

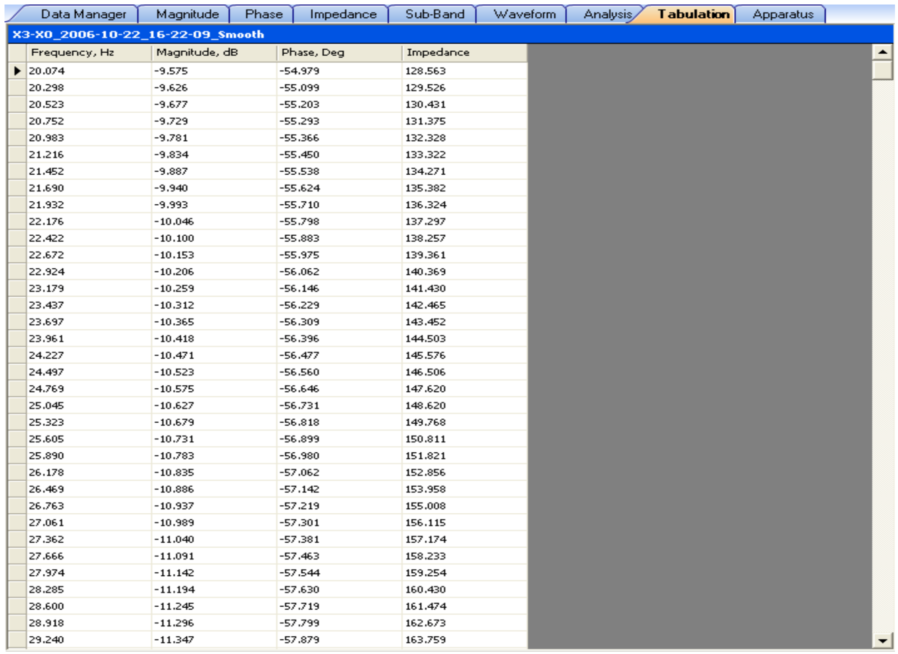
Analysis Tab

The Analysis tab (Figure A.17) enables you to compare two traces. The upper pane displays the two traces you select; the lower pane displays the difference between them.

Figure A.17 Analysis Tab

Tabulation Tab

The Tabulation tab (Figure A.18) displays graph data in tabular form. Check a box in the Legend pane to display the values for that graph.



Frequency, Hz	Magnitude, dB	Phase, Deg	Impedance
20.074	-9.575	-54.979	128.563
20.298	-9.626	-55.099	129.526
20.523	-9.677	-55.203	130.431
20.752	-9.729	-55.293	131.375
20.983	-9.781	-55.366	132.328
21.216	-9.834	-55.450	133.322
21.452	-9.887	-55.538	134.271
21.690	-9.940	-55.624	135.382
21.932	-9.993	-55.710	136.324
22.176	-10.046	-55.798	137.297
22.422	-10.100	-55.883	138.257
22.672	-10.153	-55.975	139.361
22.924	-10.206	-56.062	140.369
23.179	-10.259	-56.146	141.430
23.437	-10.312	-56.229	142.465
23.697	-10.365	-56.309	143.452
23.961	-10.418	-56.396	144.503
24.227	-10.471	-56.477	145.576
24.497	-10.523	-56.560	146.506
24.769	-10.575	-56.646	147.620
25.045	-10.627	-56.731	148.620
25.323	-10.679	-56.818	149.768
25.605	-10.731	-56.899	150.811
25.890	-10.783	-56.980	151.821
26.178	-10.835	-57.062	152.856
26.469	-10.886	-57.142	153.958
26.763	-10.937	-57.219	155.008
27.061	-10.989	-57.301	156.115
27.362	-11.040	-57.381	157.174
27.666	-11.091	-57.463	158.233
27.974	-11.142	-57.544	159.254
28.285	-11.194	-57.630	160.430
28.600	-11.245	-57.719	161.474
28.918	-11.296	-57.799	162.673
29.240	-11.347	-57.879	163.759

Figure A.18 Tabulation Tab

Apparatus Tab

The Apparatus tab (Figure A.19) displays test setup, apparatus location, and transformer nameplate information related to the trace selected in the Legend pane.

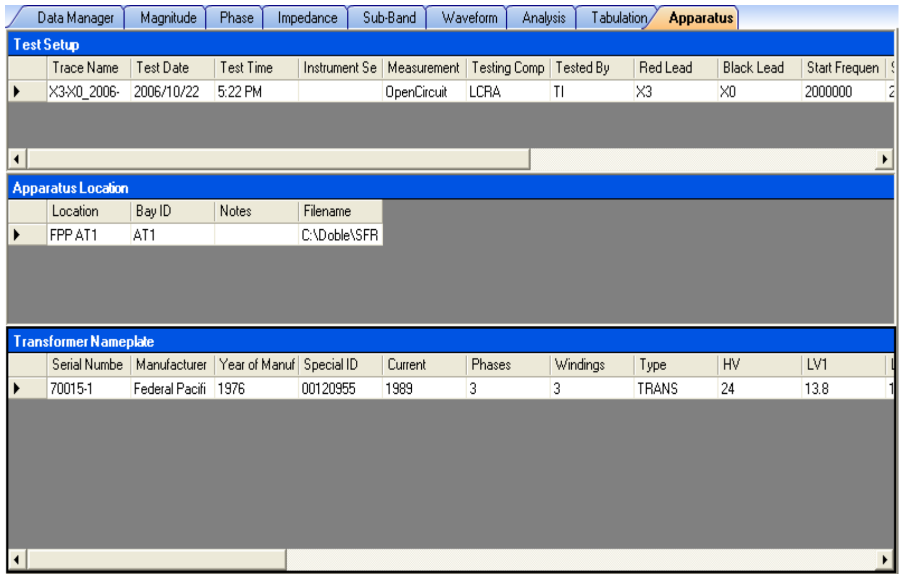


Figure A.19 Apparatus Tab

B. Test Templates

This appendix provides complete details for the test templates included with SFRA 5.2. It contains the following sections:

- "Introduction" on page B-1
- "Notes About the Test Templates" on page B-1
- "Two-Winding Transformers" on page B-2
- "Autotransformers" on page B-3
- "Three-Winding Transformers" on page B-4

Introduction

The test templates given here require the performance of open-circuit and short-circuit tests.

A *standard* set of tests, recorded when a baseline is needed and there is no question of the transformer's health, consists of a set of results taken only at extreme tap position. Doble recommends that the LTC be in the extreme raise position. However, if the transformer is being tested for post-event reasons, such as fault, this should be done in the as-found LTC position. Note the tap positions on the test report and apply them during the start of each test.

Doble recommends leaving the DETC in the as-found position. The DETC position should not be moved for an SFRA test until all options are exhausted. For new transformers in the factory, use the nominal DETC position, unless otherwise specified by the end-user.

Notes About the Test Templates

Keep the following information in mind as you refer to the test templates:

- **Leads**. Each table gives the recommended tests with the position of the red lead and black lead clearly identified. **Reversing these test leads may provide small variations in higher-frequency response.** Therefore, take care to attach test leads appropriately.

- **LTC position**. Changing LTC affects SFRA response. Before you move the tap changer into neutral position, record the previous tap position so that you can identify possible influences from the LTC reversing switch.
- **DETC position**. Transformers in service occasionally have problems due to DETC movement. Doble does not recommend altering the DETC position for an SFRA test. The exception is in factory tests on a new transformer, where it can be assumed that the DETC is in operating condition and tests can be performed on nominal tap.

Two-Winding Transformers

Table B.1 Two-Winding Transformers — 9 Tests

Test Type	Test #	3ϕ Delta-Wye	3ϕ Wye-Delta	3ϕ Delta-Delta	3ϕ Wye-Wye	1ϕ
HV Open Circuit (OC) All Other Terminals Floating	Test 1	H1-H3	H1-H0	H1-H3	H1-H0	H1-H2(H0)
	Test 2	H2-H1	H2-H0	H2-H1	H2-H0	
	Test 3	H3-H2	H3-H0	H3-H2	H3-H0	
LV Open Circuit (OC) All Other Terminals Floating	Test 4	X1-X0	X1-X3	X1-X3	X1-X0	X1-X2(X0)
	Test 5	X2-X0	X2-X1	X2-X1	X2-X0	
	Test 6	X3-X0	X3-X2	X3-X2	X3-X0	
Short Circuit (SC) High (H) to Low (L) Short [X1-X2-X3]*	Test 7	H1-H3	H1-H0	H1-H3	H1-H0	H1-H2(H0) Short X1-X2(X0)*
	Test 8	H2-H1	H2-H0	H2-H1	H2-H0	
	Test 9	H3-H2	H3-H0	H3-H2	H3-H0	

* Indicates short-circuit tests where the terminals are shorted together with three sets of jumpers, to provide symmetry (X1-X2, X2-X3, X3-X1) OR (Y1-Y2, Y2-Y3, Y3-Y1). The neutral is not included for 3ϕ wye connections, but may be included for 1ϕ test connections.

Autotransformers

Table B.2 Autotransformer without Tertiary or with Buried Tertiary — 9 Tests

Test Type	Test #	3ϕ	1ϕ
Series Winding (OC) All Other Terminals Floating	Test 1	H1-X1	H1-X1
	Test 2	H2-X2	
	Test 3	H3-X3	
Common Winding (OC) All Other Terminals Floating	Test 4	X1-H0X0	X1-H0X0
	Test 5	X2-H0X0	
	Test 6	X3-H0X0	
Short Circuit (SC) High (H) to Low (L) Short [X1-X2-X3-X1]*	Test 7	H1-H0X0	H1-H0X0 Short [X1-H0X0]*
	Test 8	H2-H0X0	
	Test 9	H3-H0X0	

* Indicates short-circuit tests where the terminals are shorted together with three sets of jumpers, to provide symmetry (X1-X2, X2-X3, X3-X1) OR (Y1-Y2, Y2-Y3, Y3-Y1). The neutral is not included for 3ϕ wye connections but may be included for 1ϕ test connections.

Table B.3 Autotransformer With Tertiary — 18 Tests

Test Type	Test #	3ϕ	1ϕ
Series Winding (OC) All Other Terminals Floating	Test 1	H1-X1	H1-X1
	Test 2	H2-X2	
	Test 3	H3-X3	
Common Winding (OC) All Other Terminals Floating	Test 4	X1-H0X0	X1-H0X0
	Test 5	X2-H0X0	
	Test 6	X3-H0X0	
Tertiary Winding (OC) All Other Terminals Floating	Test 7	Y1-Y3	Y1-Y2 (Y1-Y0)
	Test 8	Y2-Y1	
	Test 9	Y3-Y2	

Table B.3 Autotransformer With Tertiary — 18 Tests (Continued)

Test Type	Test #	3ϕ	1ϕ
Short Circuit (SC) High (H) to Low (L) Short (X1-X2-X3-X1)	Test 10	H1-H0X0	X1-H0X0 Short [X1-H0X0]
	Test 11	H2-H0X0	
	Test 12	H3-H0X0	
Short Circuit (SC) High (H) to Tertiary (Y) Short (Y1-Y2-Y3-Y1)	Test 13	H1-H0X0	X1-H0X0 Short [Y1-Y2]
	Test 14	H2-H0X0	
	Test 15	H3-H0X0	
Short Circuit (SC) Low (L) to Tertiary (Y) Short (Y1-Y2-Y3-Y1)	Test 16	X1-H0X0	H1-H0X0 Short [Y1-Y2]
	Test 17	X2-H0X0	
	Test 18	X3-H0X0	

Three-Winding Transformers

Table B.4 Three-Winding Transformer Table – 18 Tests (Part 1)

Test Type	Test #	3ϕ Delta-Delta-Delta	3ϕ Delta-Delta-Wye	3ϕ Delta-Wye-Delta	3ϕ Delta-Wye-Wye	1ϕ
HV Open Circuit (OC) All Other Terminals Floating	Test 1	H1-H3	H1-H3	H1-H3	H1-H3	H1-H2 (H1-H0)
	Test 2	H2-H1	H2-H1	H2-H1	H2-H1	
	Test 3	H3-H2	H3-H2	H3-H2	H3-H2	
LV Open Circuit (OC) All Other Terminals Floating	Test 4	X1-X3	X1-X3	X1-X0	X1-X0	X1-X2 (X1-X0)
	Test 5	X2-X1	X2-X1	X2-X0	X2-X0	
	Test 6	X3-X2	X3-X2	X3-X0	X3-X0	

Table B.4 Three-Winding Transformer Table – 18 Tests (Part 1) (Continued)

Test Type	Test #	3ϕ Delta-Delta-Delta	3ϕ Delta-Delta-Wye	3ϕ Delta-Wye-Delta	3ϕ Delta-Wye-Wye	1ϕ
Tert Open Circuit (OC) All Other Terminals Floating	Test 7	Y1-Y3	Y1-Y0	Y1-Y3	Y1-Y0	Y1-Y2 (Y1-Y0)
	Test 8	Y2-Y1	Y2-Y0	Y2-Y1	Y2-Y0	
	Test 9	Y3-Y2	Y3-Y0	Y3-Y2	Y3-Y0	
Short Circuit (SC) High (H) to Low (L) Short [X1-X2-X3-X1]*	Test 10	H1-H3	H1-H3	H1-H3	H1-H3	H1-H0 Short [X1-X2]*
	Test 11	H2-H1	H2-H1	H2-H1	H2-H1	
	Test 12	H3-H2	H3-H2	H3-H2	H3-H2	
Short Circuit (SC) High (H) to Tertiary (T) Short [Y1-Y2-Y3-Y1]*	Test 13	H1-H3	H1-H3	H1-H3	H1-H3	H1-H0 Short [Y1-Y2]*
	Test 14	H2-H1	H2-H1	H2-H1	H2-H1	
	Test 15	H3-H2	H3-H2	H3-H2	H3-H2	
Short Circuit (SC) Low (L) to Tertiary (T) Short [Y1-Y2-Y3-Y1]*	Test 16	X1-X3	X1-X3	X1-X0	X1-X0	X1-X0 Short [Y1-Y2]*
	Test 17	X2-X1	X2-X1	X2-X0	X2-X0	
	Test 18	X3-X2	X3-X2	X3-X0	X3-X0	

* Indicates short-circuit tests where the terminals are shorted together with three sets of jumpers, to provide symmetry (X1-X2, X2-X3, X3-X1) OR (Y1-Y2, Y2-Y3, Y3-Y31). The neutral is not included for 3ϕ wye connections but may be included for 1ϕ test connections.

Table B.5 Three-Winding Transformer Table – 18 Tests (Part 2)

Test Type	Test #	3ϕ Wye-Wye-Wye	3ϕ Wye-Wye-Delta	3ϕ Wye-Delta-Wye	3ϕ Wye-Delta-Delta
HV Open Circuit (OC) All Other Terminals Floating	Test 1	H1-H0	H1-H0	H1-H0	H1-H0
	Test 2	H2-H0	H2-H0	H2-H0	H2-H0
	Test 3	H3-H0	H3-H0	H3-H0	H3-H0

Table B.5 Three-Winding Transformer Table – 18 Tests (Part 2) (Continued)

Test Type	**Test #**	**3ϕ Wye-Wye-Wye**	**3ϕ Wye-Wye-Delta**	**3ϕ Wye-Delta-Wye**	**3ϕ Wye-Delta-Delta**
LV Open Circuit (OC) All Other Terminals Floating	Test 4	X1-X0	X1-X0	X1-X3	X1-X3
	Test 5	X2-X0	X2-X0	X2-X1	X2-X1
	Test 6	X3-X0	X3-X0	X3-X2	X3-X2
Tert Open Circuit (OC) All Other Terminals Floating	Test 7	Y1-Y0	Y1-Y3	Y1-Y0	Y1-Y3
	Test 8	Y2-Y0	Y2-Y1	Y2-Y0	Y2-Y1
	Test 9	Y3-Y0	Y3-Y2	Y3-Y0	Y3-Y2
Short Circuit (SC) High (H) to Low (L) Short [X1-X2-X3-X1]*	Test 10	H1-H0	H1-H0	H1-H0	H1-H0
	Test 11	H2-H0	H2-H0	H2-H0	H2-H0
	Test 12	H3-H0	H3-H0	H3-H0	H3-H0
Short Circuit (SC) High (H) to Tertiary (T) Short [Y1-Y2-Y3-Y1]*	Test 13	H1-H0	H1-H0	H1-H0	H1-H0
	Test 14	H2-H0	H2-H0	H2-H0	H2-H0
	Test 15	H3-H0	H3-H0	H3-H0	H3-H0
Short Circuit (SC) Low (L) to Tertiary (T) Short [Y1-Y2-Y3-Y1]*	Test 16	X1-X0	X1-X0	X1-X3	X1-X3
	Test 17	X2-X0	X2-X0	X2-X1	X2-X1
	Test 18	X3-X0	X3-X0	X3-X2	X3-X2

* Indicates short-circuit tests where the terminals are shorted together with three sets of jumpers, to provide symmetry (X1-X2, X2-X3, X3-X1) OR (Y1-Y2, Y2-Y3, Y3-Y1). The neutral is not included for wye connections.

C. Theory of Operation

This appendix presents the theoretical underpinnings of SFRA testing. It contains the following sections:

- “Transformer Damage and SFRA Testing” on page C-1
- “How SFRA Identifies Damage to Transformers” on page C-2
- “Test Cable Lengths” on page C-4
- “Transformer” on page C-5

Transformer Damage and SFRA Testing

Although power transformers are specified to withstand the mechanical forces arising from shipping and subsequent in-service events, damage sometimes still occurs.

- **Transportation damage** can occur if the clamping and restraints are inadequate; such damage may lead to core and winding movement.
- **In-service damage** can occur from events such as faults and lightning. The most severe in-service forces arise from system faults and are axial and radial in nature. If the forces are excessive, radial buckling or axial deformation can occur. With a core form design, the principal forces are radially directed, whereas in a shell-form unit, they are axially directed. This difference is likely to influence the types of damage found.

Once a transformer is damaged, even if only slightly, its ability to withstand further short circuits is reduced. Utility personnel need to identify such damage. Most methods have distinct drawbacks. Visual inspection is costly and does not always produce the desired results. During a field inspection, the oil has to be drained, and confined-entry rules apply. Since so little of the winding is visible, little damage can be seen, other than displaced support blocks. Often, a complete teardown is required to identify the problem.

There is a relationship between the geometric configuration of the internals of a transformer and the distributed electrical elements inside the winding and core assembly. These elements can be represented as an RLC network, and such a network will have a frequency dependent transfer function. Changes to the geometric configuration will affect the impedance of the RLC network, and thus produce a different frequency response.

How SFRA Identifies Damage to Transformers

The primary objective of SFRA is to determine how the impedance of a test specimen behaves over a specified range of frequencies. The impedance is a distributive network of real and reactive electrical components. The components are passive and can be modeled by resistors, inductors, and capacitors. The reactive properties of a given test specimen depend on, and are sensitive to, changes in frequency. The change in impedance versus frequency can be dramatic in many cases. This behavior becomes apparent when we model impedance as a function of frequency. The result is a transfer function representation of the RLC network in the frequency domain.

Frequency response analysis is generally applied to a complex network of passive elements. For practical purposes, we will consider only resistors, inductors, and capacitors as passive circuit elements, and they are assumed to be ideal. These three fundamental elements are the building blocks for various physical devices, such as transformers, motors, generators, and other electrical apparatus.

It is important to understand the difference between the physical device and the mathematical model we intend to use. When large and complex systems are electrically analyzed, we are often faced with a poorly defined distributed network. A distributed network contains an infinite number of infinitely small RLC elements. For example, transmission lines are generally distributed in nature.

It is practical to model such distributed systems by lumping the basic RLC components together, resulting in a lumped network. Lumping elements together for a single frequency is a trivial task, but when system modeling requires spanning a significant frequency interval, producing a suitable lumped model becomes difficult.

When a transformer is subject to SFRA testing, the leads are configured to use four terminals. These four terminals can be divided into two unique pairs—one pair each for the input and output. These terminals can be modeled in a two-terminal pair or a two- port network configuration (<Hypertext>Figure C-1).

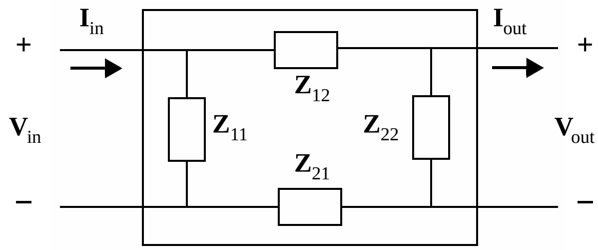


Figure C-1 Two-Port Network

Solving for the open-circuit impedance for each lumped element forms the impedances Z11, Z22, Z12, and Z21. It should be noted that the negative terminals are short- circuited when transformers are tested. The transformer tank is common for both negative and lower terminals. The transformer tank and lead ground shields must be connected together to achieve a common-mode measurement. This assures that no external impedance is measured. Applying the connection in this manner helps reduce the effects of noise. It is important to obtain a zero impedance between the lower or negative terminals to assure a repeatable measurement.

The transfer function of an RLC network is the ratio of the output and input frequency responses when the initial conditions of the network are zero. Both magnitude and phase relationships can be extracted from the transfer function. The transfer function helps us better understand the input/output relationship of a linear network. The transfer function also represents the fundamental characteristics of a network and is a useful tool in modeling such a system.

The transfer function is represented in the frequency domain and is denoted by the Fourier variable $H(j\omega)$, where $(j\omega)$ denotes the presence of a frequency-dependent function, and $\omega = 2\pi f$. The Fourier relationship for the input/output transfer function is given by:

$$H(j\omega) = \frac{V_{output}(j\omega)}{V_{input}(j\omega)}$$

When a transfer function is reduced to its simplest form, it generates a ratio of two polynomials. The main characteristics, such as half-power and resonance, of a transfer function occur at the roots of the polynomials.

The goal of SFRA is to measure the impedance model of the test specimen. When we measure the transfer function $H(j\omega)$, it does not isolate the true specimen impedance
$Z(j\omega)$. The true specimen impedance $Z(j\omega)$ is the RLC network, which is positioned between the instrument leads, and it does not include any impedance supplied by the test instrument.

It must be noted that when using the voltage relationship, $H(j\omega)$ is not always directly related to $Z(j\omega)$. For $Z(j\omega)$ to be directly related to $H(j\omega)$, a current must be substituted for the output voltage and then ohm's Law can be realized. However, SFRA uses the voltage-ratio relationship to determine $H(j\omega)$. Since SFRA uses a 50-ohm impedance- match measuring system, the 50-ohm impedance must be incorporated into $H(j\omega)$. The next equation shows the relationship of $Z(j\omega)$ to $H(j\omega)$:

$$H(j\omega) = \frac{50}{Z(j\omega) + 50}$$

It is often useful to plot the magnitude and phase relationship of the transfer function in logarithmic format. The units of magnitude and phase are in decibels (dB) and degrees, respectively. Magnitude and phase are represented as follows:

$$A(dB) = 20 \log_{10}(H(j\omega))$$
$$A(\theta) = \tan^{-1}(H(j\omega))$$

This format takes advantage of the asymptotic symmetry by using a logarithmic scale for frequency. Plotting the phase relationship with the magnitude data helps determine whether the system is resistive, inductive, or capacitive. It is often useful to compare resonance in the magnitude plots with the zero crossings in the phase relationship.

Test Cable Lengths

The cables and connectors supplied with the M5000 instruments are made from low- loss RG-58 RF coaxial cable, with the shields grounded to the instrument chassis through a standard connector. The instrument requires a matched impedance signal cable and performs a single-end measurement—that is, the signal is measured with respect to the instrument ground. The shield of the signal cable must be connected to the chassis using a 50-ohm impedance-matched RF BCN connector. The test leads should not be modified in any manner.

Practical field experience indicates that the leads be 18 m / 60 ft. This is the shortest length useful to test the largest transformers from a location on the ground, adjacent to the unit. Nevertheless, lead length determines the maximum effective frequency.

The standard cable shield grounds connect the cable shields to the transformer ground at the base of the bushing. These ground connections are 3.6 m / 12 ft back from the terminal connection, on the measurement ends of the cables. If this is not long enough to reach from the bushing terminal to the base of the bushing, a 30 m / 100 ft cable is available, with ground connections 5.4 m / 18 ft back from the terminal connection.

Transformer

SFRA tests measure only the RLC network of the transformer. To maintain consistency and repeatability of measurements, make sure that all terminals not under test are isolated and floating. To maintain a balanced and symmetrical approach, where a delta winding is completed and grounded external to the transformer tank, the delta should be complete but floating. Such windings are frequently used for regulation; where such windings are grounded internal to the tank, it is necessary to leave that ground in place — but we should expect asymmetry in the results.

We could measure a frequency response with the remaining terminals grounded, but it could not be compared to a response measured with floating terminals, which would display a different RLC response.

D. Repairs and Replacement Parts

This appendix provides instructions for replacing a fuse and part numbers for replacement parts and accessories. It contains the following sections:

- "Replacing a Fuse" on page D-1
- "Repairs" on page D-3
- "Replacement Parts" on page D-3

Replacing a Fuse

The fuses are located above the AC power connector on the front of the SFRA instrument. Figure D.1 shows the location in an M5400.

Figure D.1 Location of Fuses on M5400

To replace a fuse:

1. Insert a flat blade behind the top of the fuse cover (Figure D.2).

Figure D.2 Blade in Top of Fuse Cover

The fuse cover is hinged at the bottom.

2. Pull the fuse cover out and down (Figure D.3).

Figure D.3 Open Fuse Cover with Fuses in Place

Note that the arrows on the fuses match the arrows printed on the inside of the cover.

3. Replace the fuses, making sure to match the arrows on the fuses to the arrows on the cover, and close the cover.

Repairs

All repairs to the SFRA instruments must be done by Doble.

For support, contact Doble customer service at 617-926-4900 or email customerservice@doble.com.

Before returning an instrument to Doble, call or email Doble customer service to receive an RMA number. Return the unit in padded, protective packaging.

The shipping address is:

Customer Service Manager
Doble Engineering Company
85 Walnut Street
Watertown, MA 02472-4037
USA

Replacement Parts

Contact Doble Customer Service to order replacement parts.

M5200 and M5400

Table D.1 lists cables and adapters available for use with the M5200 and M5400.

Table D.1 M5200 and M5400 Cable and Adapter Parts List

Qty	Description	Part No.
1	Bag, Cable, Large	2FB-3449-01
1	Cable, Ground, 9 m / 30 ft, M4K / M2H / MEU	02C-0019-01
4	Cable, Ground, 1.5 m/5 ft	02B-0026-02
1	Cable, RJ45 / Cat 5E, Crossover, 2 m / 7 ft	181-0646
1	Cable, Specimen Test, 18 m / 60 ft	05B-0659-04
1	Cable, Specimen Test, 30 m / 100 ft	05B-0659-07
1	Cable, USB, A/B, 1.8 m / 6 ft	181-0585
2	Clip, Solid Copper, 400A	212-0444

Table D.1 M5200 and M5400 Cable and Adapter Parts List (Continued)

Qty	Description	Part No.
1	Cord, Power	Country-specific. Contact your Doble representative.

Table D.2 lists other components shipped with the M5200 and M5400.

Table D.2 M5200 and M5400 Additional Components

Qty	Description	Part No.
1	CD, SFRA, Product Information	08A-0151-01
1	CD, SFRA Software	08A-0152-01
2	M5200 Fuse: 3.0 Amp, 250 V, 3 AG, SLO-BLO	384-0002
2	M5400 fuse: 0.75 Amp, 250 V, 3 AG, Slo-Blo	384-0084
1	SFRA Quick Start Guide	72A-2499-01
1	SFRA User Guide	72A-2570-01

M5300

Table D.3 lists cables and adapters available for use with the M5300.

Table D.3 M5300 Cable and Adapter Shipping/Replacement List

Qty	Description	Part No.
1	Bag, Cable, Large	2FB-3449-01
1	Cable, Ground, 9 m / 30 ft, M4K / M2H / MEU	02C-0019-01
4	Cable, Ground, 1.5 m / 5 ft	02B-0026-02
1	Cable, Specimen Test, 18 m / 60 ft	05B-0659-04
1	Cable, Specimen Test, 30 m / 100 ft	05B-0659-07
2	Clip Solid Copper, 400A	212-0444
1	Cord, Power	Country-specific. Contact your Doble representative.

Table D.4 lists other components shipped with the M5300.

Table D.4 M5300 Additional Components

Qty	Description	Part No.
2	Fuse: 3.0Amp, 250 V, 3 AG, SLO-BLO	384-0002
1	USB Keyboard	401-0295

E. M5200/M5300/M5400 Technical Specifications

NOTE! Specifications are subject to change without notice.

This appendix provides specifications for the M5200, M5300, and M5400 instruments. It contains the following sections:

- "Instrument Specifications" on page E-1
- "Lead Specifications" on page E-3
- "PC Requirements" on page E-4

Instrument Specifications

These specifications apply to all three SFRA instruments.

Table E.1 Instrument Specifications

Feature	Definition
Excitation Source	
Channels	1
Frequency Range	10 Hz to 25 MHz
Output Voltage	20 V peak-to-peak at 50 ohms
Output Protection	Short-circuit protected
Source Impedance	50 ohms
Calibration Interval	3 years
Measurement Channels	
Channels	2

Table E.1 Instrument Specifications (Continued)

Feature	Definition
Sampling	Simultaneous
Frequency Range	10 Hz to 25 MHz
Max. Sampling rate	100 MS/s
Input Impedance	50 ohms
Calibration Interval	3 years
Data Collection	
Test Method	Sweep frequency
PC Communication	USB/Ethernet
Frequency Range	10 Hz to 25 MHz
Number of Points	1000 (default); up to 1800 (extended range)
Point Spacing	1.2% logarithmic
Dynamic Range	>90 dB
Repeatability	±1 dB to –80 dB
IF Bandwidth	< 10% of active frequency
Data Display	
Scaling	Linear/Log
Frequency Range	10 Hz to 25 MHz, user-defined within frequency range
Plotting	Frequency vs. magnitude / phase
Analysis	Difference, Sub-band cross-correlation
Physical Specifications	
Dimensions	**M5200:** 10.0 H x 16.0 W x 15.5 D in. (25 H x 41 W x 40 D cm) **M5300:** 10.0 H x 16.0 W x 15.5 D in. (25 H x 41 W x 40 D cm) **M5400:** 18.2 H x 13.4 W x 6.7 D in. (46.2 H x 34.0 W x 17.0 D cm)

Table E.1 Instrument Specifications (Continued)

Feature	Definition
Weight	M5200: 14.6 lb / 6.6 kg M5300: 22.5 lb / 10.2 kg M5400: 13.1 lb / 6.0 kg
Power	115–230 VAC, 50/60 Hz
Current	M5200: 1 Amp M5300: 1 Amp M5400: 0.5 Amp
Temperature	Operating: 0° to 50° C / 32° to 122° F Storage: –25° to +70° C / –13° to 158° F
Relative Humidity	0–95% non-condensing

Lead Specifications

Table E.2 Test Lead Specifications

Feature	Definition
Test Lead Construction	
Integrated three-lead system in single cable set	Standard (≤ 362 kV): 60 ft / 18 m Optional (> 362 kV): 100 ft / 30 m

PC Requirements

Table E.3 PC Requirements

SFRA Instrument	PC Requirement
M5200 and M5400	Minimum configuration: • Ethernet/USB • Windows XP or Windows 7 • 500 MHz processor • 256 MB RAM • 20 MB hard-drive free space • DVD-RW
M5300	Built-in PC configuration: • Windows XP • Intel Celeron 1.3 GHz • Minimum 512 MB RAM • Minimum 40 GB HDD

The M5200 and M5300 come with a carrying strap for easy transportation. The M5400 case has a handle.

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