RLC Software
User’s Manual

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Introduction

The RLC software allows you to measure the frequency response of RLC circuits using one of the Venable Instruments frequency response analyzers (FRA). You can calibrate your RLC box, run measurements through a range of frequencies, build a theoretical model based on the empirical data, and generate reports.

The RLC software is controlled mainly through the RLC Control Panel, which has four components: Setup, Measurement, Model, and Report.

Installation

1. Insert the NI-488.2 driver CD from National Instruments and install the driver for your GPIB-USB interface.
2. To test the interface, plug your GPIB-USB to an USB port on your computer (leave the GPIB connector unplugged).
3. In order to check that the driver was installed properly, launch the "Getting Started Wizard" application from the "National Instruments/NI-488.2" program group. Click on "Verify your hardware and software installation". The application should report that the NI-488.2 troubleshooting wizard was successfully completed. Hit "OK" and then exit the application.
4. Plug the GPIB connector to the back of your Venable analyzer.
5. Insert the RLC installation CD and install the software. Please read the following section on how to activate the RLC application.

Software Activation

The RLC software is protected against illegal copying and use. In order to run, first it must be activated. There are three ways to activate your RLC software:

- If you have an Internet connection, you may use the "Electronic Registration" button to validate your serial number. This is the fastest and easiest method.

- If you don't have an Internet connection but you have e-mail access, you can send your site code along with your name, company name, address, phone number, and Venable frequency response analyzer serial number (on the back of the instrument) to authorize@venable.biz. Your site code is shown when you select "Show site code" from the "License" menu.

- Otherwise, you can call Venable Instruments with your site code.

Setup Tab

The Setup tab consists of two sections: hardware, and default plot. In the "hardware" section, there are four parameters to define:

- Analyzer: currently the supported FRAs are the Venable models 350, 3120, 3215, and 3225.
- GPIB interface: if there are more than one GPIB interfaces connected to the computer, this field identifies the interface that is used with the current FRA.
- GPIB address: the address of the FRA.
- Reference resistor: this is the value, in Ohms, of the resistor used inside the RLC box to measure current. The Venable RLC boxes use 100 Ohm reference resistors.

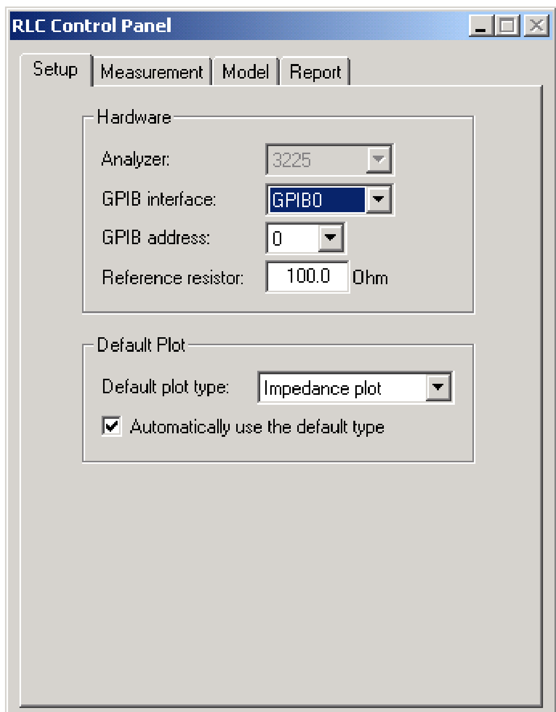

Figure 1. Setup window

In the "default plot" section you can choose the type of plot that will be used whenever you create a new document. Possible options are "Impedance plot" and "Nyquist plot". If the "Automatically use the default type" option is checked, you won't be prompted for a plot type every time that you create a new one.

Measurement Tab

Before measurements can be taken, the system must be calibrated. The purpose of the calibration process is to quantify the parasitic components that are present in the RLC box. With an estimation of the values of these parasitic elements, the actual measurements of RLC circuits can be corrected to improve accuracy. The parasitic components are usually modeled as two elements: one in series (of inductive nature), and one in parallel (of capacitive nature).

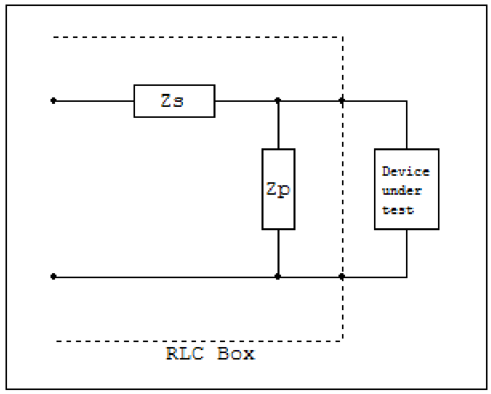

Figure 2. Parasitic model

The calibration process consists of two steps: an open-circuit sweep, and a closed-circuit sweep. Once the calibration process starts, the RLC software will prompt you to first open and then close the circuit in order to take the respective measurements.

Open Circuit Sweep

When the circuit is open, the impedance of the parallel parasitic element can be calculated (the impedance of the series element is so much smaller that its effect is negligible in the calculation).

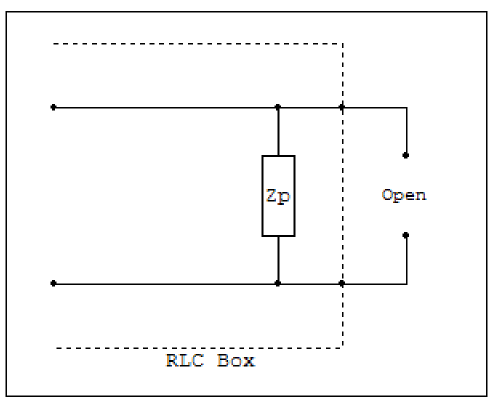

Figure 3. Open circuit model

Closed Circuit Sweep

After the open-circuit sweep is complete, a closed-circuit sweep is run. In this case, the parallel element can be removed from the equation, and the impedance of the series element can be calculated.

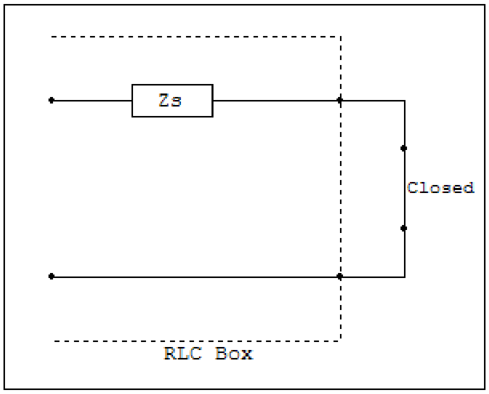

Figure 4. Closed circuit model

After the open-circuit and closed-circuit sweeps are complete, you can save the calibration data for future use. That way, it is not necessary to re-calibrate before every session of measurements.

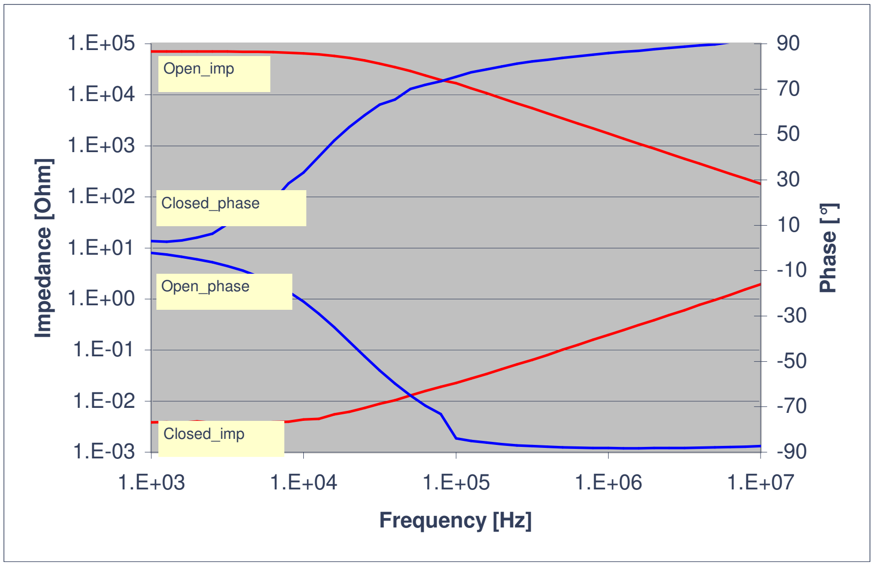

Figure 5. Example of open and closed circuit impedance and phase plots

Once the calibration is done, the system is ready to measure RLC circuits. After sweeping through the frequency range, the software will automatically correct the raw data and create another plot with the tag “w/o parasitics”. This plot is the result of subtracting the series and parallel parasitic elements from the raw data.

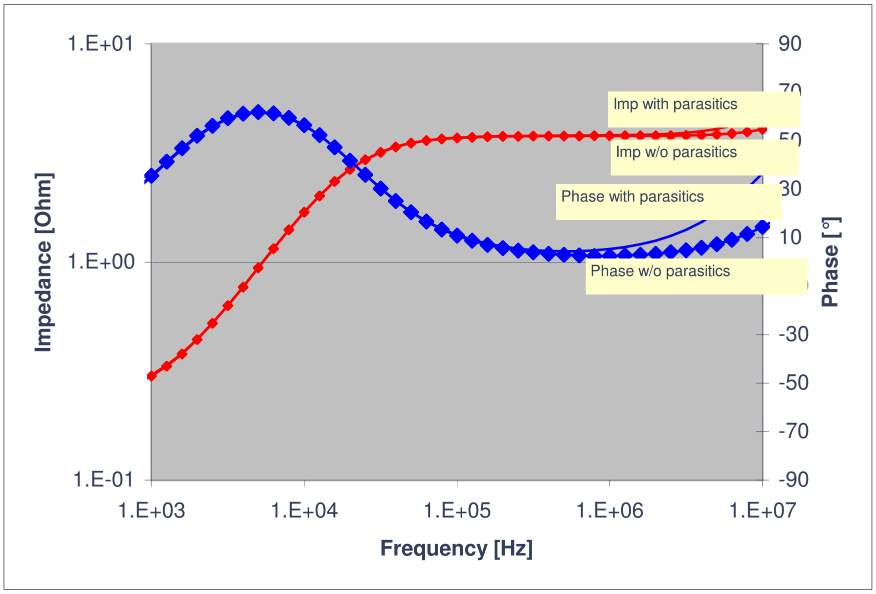

Figure 6. Uncorrected and corrected plots

The parameters related to measurements are in the "FRA Settings" section:

- Single point or sweep: a single point measurement is done at a specified frequency. A sweep is a series of measurements taken throughout a range of frequencies, from the start frequency to the stop frequency, and with a resolution of 10 steps per decade.
- Start and stop frequencies: they define the first and last points in the sweep. In the case of a single point setup, only the start frequency is relevant.
- Integration time: specifies the length of time over which each sample is taken. There are four possible settings: 10 s, 2.5 s, 0.33 s, and 0.05 s. A slower setting will take longer to run but will produce more precise results.
- A/C and D/C voltages: they specify the injection voltages.
- Input coupling: specifies whether the input coupling is A/C or D/C.
- Limit maximum phase change between data points: without this option, the software will always take 10 data points per frequency decade, regardless of the results. A possible problem arises when a sweep involves a resonant point, where the impedance changes abruptly from one frequency to the next. In this case, you can use this feature to mitigate the problem. If, for example, you set the maximum phase change at 20°, the software will adapt its frequency interval so that no two points will be more than 20° apart in phase.

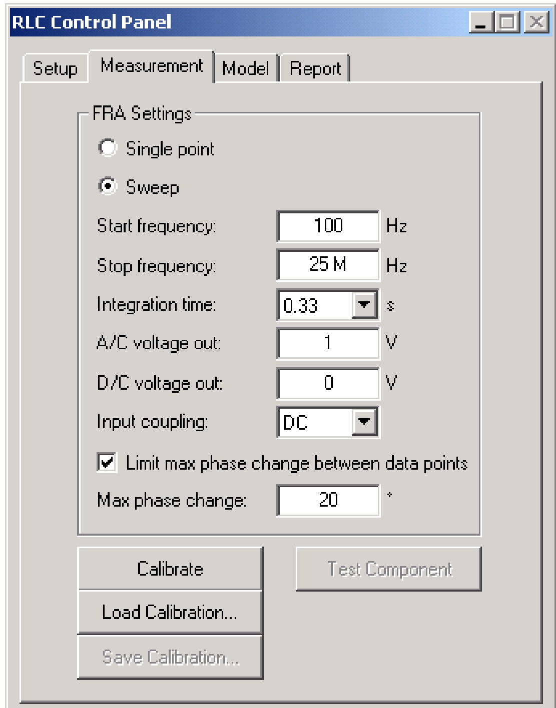

Figure 7. The Measurement tab

Modeling Tab

The modeling tab is used to create a theoretical model out of the circuit that was measured. You can choose the component type and the data set to model. The available component types are different combinations of a resistor, a capacitor, and an inductor, arranged in parallel or in series. After selecting the component type and data set, the calculated theoretical values for R, L, and C are displayed on the window. You can also override the values of R, L, and C by typing different values in the respective controls. You can create a plot that will represent the theoretical RLC circuit based on the values shown. If you wish to create a model with more than three components, you could create multiple models and combine them in series or in parallel using the math functions.

The theoretical values of the circuit components are calculated by attempting to fit the model to the measured data. In the case of components in series, the maximum or minimum values of susceptance (for capacitive or inductive circuits, respectively) are used to calculate the capacitance or inductance. In the case of components in parallel, the maximum or minimum values of reactance (for inductive or capacitive circuits, respectively) are used. In order to more accurately calculate the theoretical model, it is better to sweep through a wide frequency range.

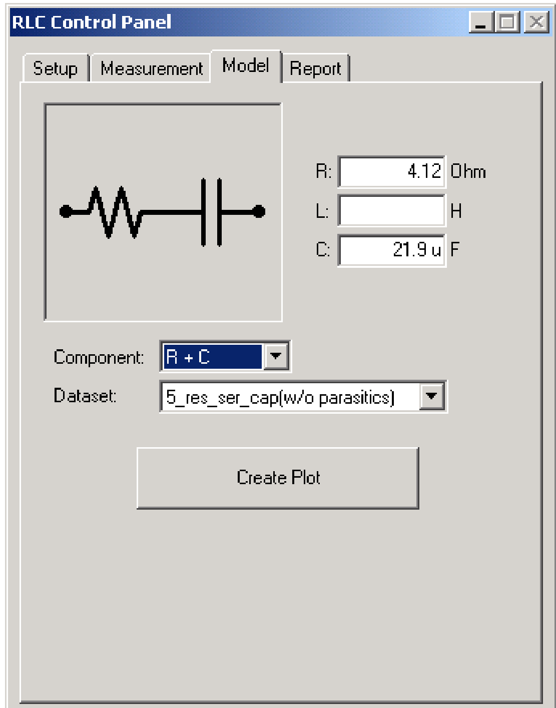

Figure 8. The modeling tab

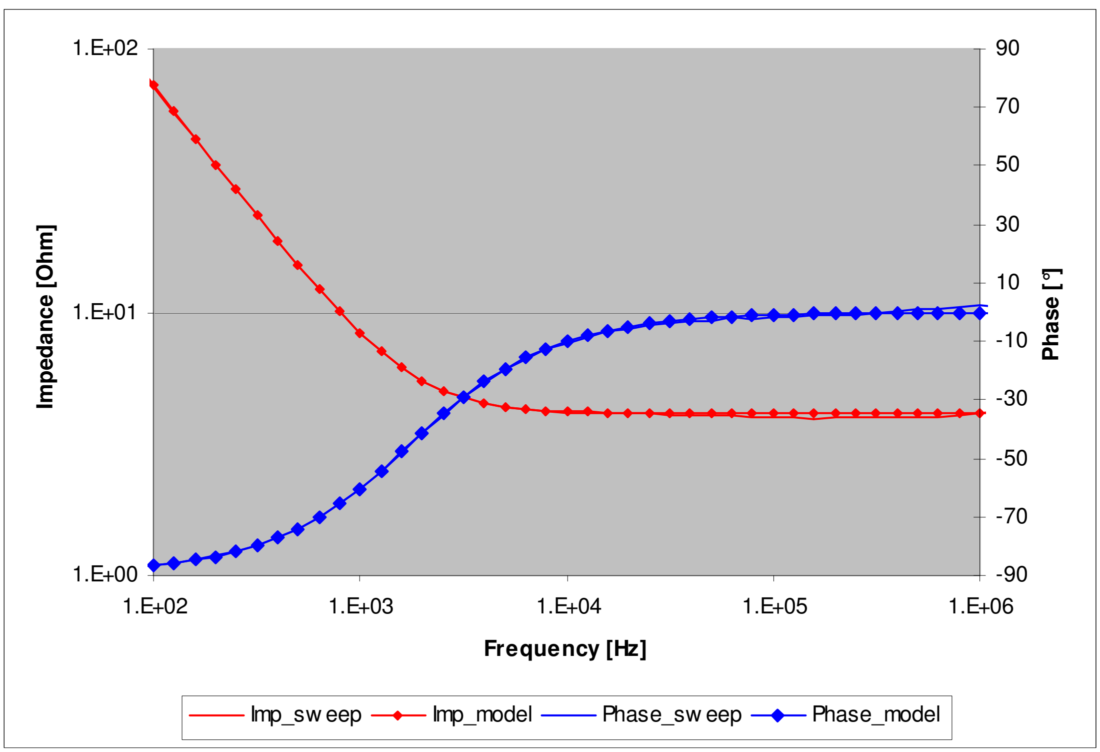

Figure 9. Example of a measured RC circuit and its derived model

Reporting Tab

The RLC application can generate reports in PDF format. The reports include a chart with uncorrected and corrected data, modeling information, and optionally a chart with the open and closed circuit calibration data, and a text version of all the plots in tabular format.

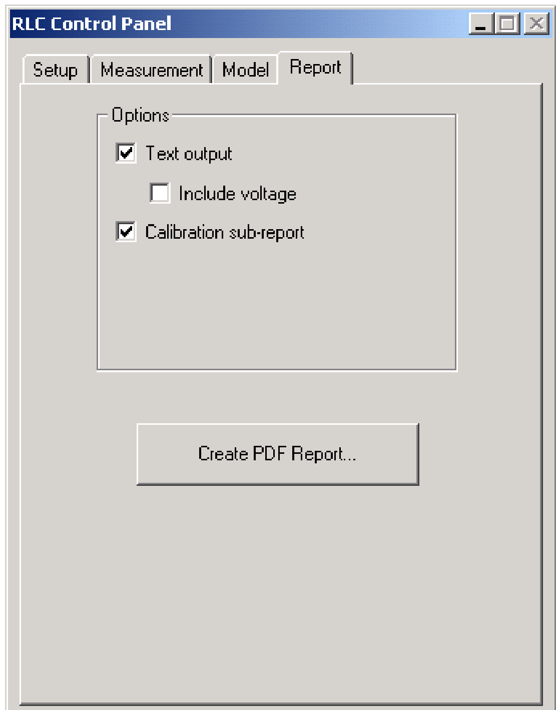

Figure 10. Reporting tab

Working with Documents, Views, and Data Sets

The RLC application can contain multiple documents. A document is a collection of one or more data sets (plots). The data contained in a document is shown to you through a view window. There are four different types of views:

- Impedance: impedance magnitude and phase versus frequency.
- Gain: gain magnitude and phase versus frequency.
- Nyquist: resistance versus reactance.
- Text: impedance magnitude and phase versus frequency.

When the application starts, it creates an empty document and shows an impedance view for that document. You can create new documents and open and save existing documents.

Manipulating Data Set Properties

A data set is a collection of data points obtained by running a sweep through a range of frequencies. A document can contain multiple data sets. To select a data set, simply click any part of the curve with the mouse pointer, or use the "up" and "down" keys to cycle through the collection of data sets. The properties of a data set can be viewed and edited by selecting "Data Set Properties" from the "View" menu. The Data Set Properties dialog shows the current data set number, name, type, and description. You can specify whether the data set should be visible, and whether the description should be shown on the screen. The colors are also editable. The "voltage node", "current node", and "scale factor" determine how the impedance is calculated, according to the formula shown on the dialog. For acquired data, the voltage node is by default channel #2, the current node is channel #1, and the scale factor is the negative of the reference resistor (defined in the "Setup" tab).

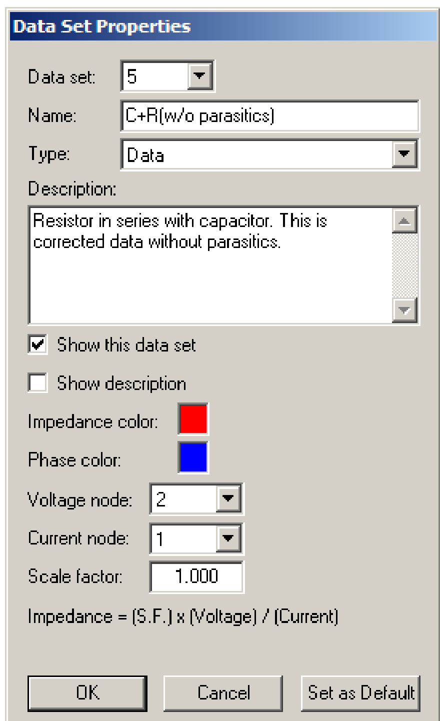

Figure 11. Data set properties

Manipulating Graph Properties

The properties related to a graph (view) can be edited by selecting the "Graph Properties" from the "View" menu.

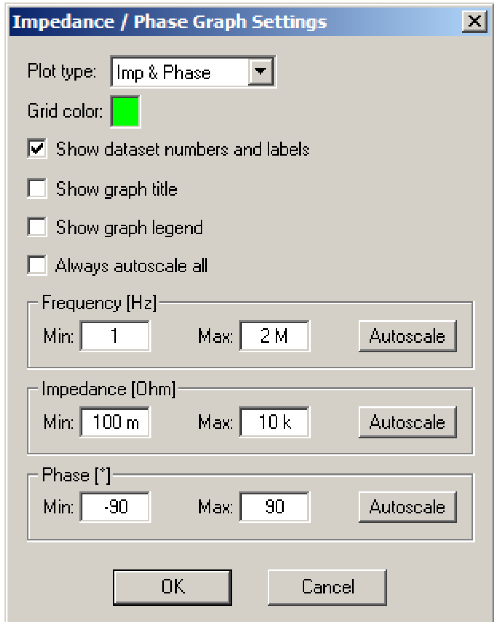

Figure 12. Graph settings

This window allows you to select the plot type, change the grid color, select whether the graph title and legend are shown, and define the scaling parameters.

Working with Slide Bars

Slide bars are useful for tracking and displaying data values at a specific frequency, represented by a vertical line, and a description box. To create a slide bar, select "Add Slide Bar" from the "View" menu. More than one slide bar may be opened at one time, either from the same or different data sets. "Add Slide Bar" is not available in a text display window.

The bar can be dragged using the mouse pointer (except in Nyquist plots, where only the *Left* or *Right* keys may be used), and the box will show the data at the selected frequency. The frequency can also be typed in, and the line will move to that frequency. The information shown on the slide bar window is frequency, impedance magnitude and phase, and calculated values for R and L or C for the equivalent RL or RC circuit. The "Equivalent Circuit" button determines whether the equivalent circuit is series or parallel.

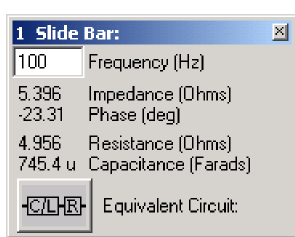

Figure 13. Slidebar example

You can use the *left* or r*ight* keys to move the slide bar between data points taken by the analyzer. The s*hift+left* or s*hift+right* key combinations find the 0 degree, +/-90 degree, or the +/-180 degree phase points if they exist. The c*trl+left* or c*trl+right* key combinations find the 0 dB crossing point if it exists.

Math Operations

The RLC application can apply math functions to one or two data sets. To do this, select the "Math Menu" item from the "Actions" menu.

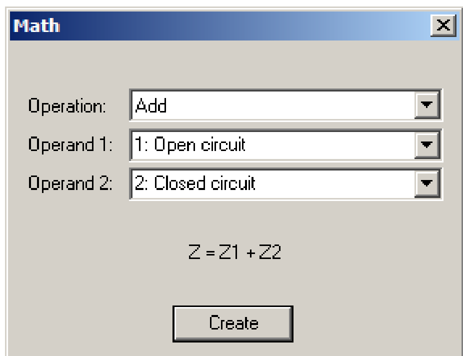

Figure 14. Math menu

The possible operations are: add, subtract, multiply, divide, add in parallel, subtract in parallel, invert, negate, and create transfer function. The "create transfer function" operation divides two plots and shows the result in a new gain/phase view.

Table 1. Math functions

Operation Name	Function	Application
Add	$Z = Z_1 + Z_2$	Cascading filters
Subtract	$Z = Z_1 - Z_2$	Removing series parasitic
Multiply	$Z = Z_1 \times Z_2$	Combining gain stages
Divide	$Z = Z_1 / Z_2$	
Add in parallel	$Z = (Z_1 \times Z_2) / (Z_1 + Z_2)$	Combining filters
Subtract in parallel	$Z = (Z_1 \times Z_2) / (Z_1 - Z_2)$	Removing parallel parasitic
Invert	$Y = 1 / Z_1$	Impedance to admittance
Negate	$Z = -Z_1$	180° phase shift
Create transfer function	$Z = Z_1 / (Z_1 + Z_2)$	Filter attenuation

Appendix - The RLC Box

The Venable FRA models 350, 3120, 3215, and 3225 have custom RLC boxes that plug directly into the analyzer in order to minimize parasitics. The following is a schematic of the circuit used in the Venable RLC boxes.

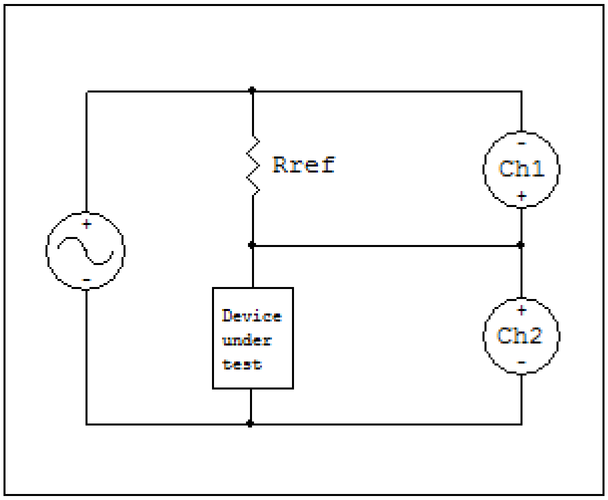

Figure 15. RLC Box Schematic