COOL-I-O®

User Guide

Manual Version 1.22

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1 Introduction to COOL-I-O®

Thank you for purchasing COOL-I-O®. This is a measurement system for designing and measuring power systems. COOL-I-O® is perfect for students, consultants, hobbyists and teaching labs, and working design or applications engineers.

1.1 COOL-I-O® Shipment Contents

You will find the following items inside your COOL-I-O® package:

COOL-I-O® Main Unit

Two 60 MHz Oscilloscope Probes

USB A Cable

USB C Cable

USB stick with license key for your device

Any optional accessories ordered

Fig. 1.1: COOL-I-O® Package Contents

COOL-I-O® can be used as a frequency response analyzer, oscilloscope, spectrum analyzer, and signal generator. You can also choose to use RidleyWorks® software to work seamlessly with data from COOL-I-O®. (1-year license included with your purchase.)

First, however, let's cover some essential safety information points that are crucial to safe operation of this unique instrument. As the instrument user, your adherence to, and comprehension of these safety warnings are essential before you click the power button and begin setup. When using COOL-I-O®, please adhere to the safety warnings whether using as an oscilloscope or a frequency response analyzer.

1.2 Safety information

To prevent possible electrical shock, fire, personal injury, or damage to the product, read this safety information carefully before attempting to install or use this product. In addition, follow all generally accepted safety practices and procedures for working with and near electricity.

The oscilloscope within COOL-I-O® has been designed and tested in accordance with the European standard publication EN 61010-1 (Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use).

Definitions:

A **WARNING** ⚡ identifies conditions or practices that could result in injury or death.

A **CAUTION** ⚠ identifies conditions or practices that could result in damage to the product or equipment to which it is connected. Refer to this manual if you are unsure of the caution.

The term 'instrument' refers to COOL-I-O® and its internal components in the descriptions below.

1.3 Maximum Input Ranges

The following table indicates the full-scale measurement range and overvoltage protection range for the instrument. The full-scale measurement ranges are the maximum voltages that can be accurately measured by the instrument. The overvoltage protection ranges are the maximum voltages that will not damage the instrument.

⚡**WARNING**: To prevent electric shock, do not attempt to measure voltages outside the specified full-scale measurement range:

Full-scale Measurement Range	Overvoltage Protection (DC + AC peak)		
	Input Channels	External Trigger	Signal Generator
± 20 V	± 100 V	± 100 V	± 20 V

⚡**WARNING**: Signals exceeding the voltage limits in the table below are defined as “hazardous live” by EN 61010-1. This instrument is suitable for connection to voltages that are equal to or less than the EN 61010-1 limits in the table below:

Signal Voltage Limits of EN 61010-1		
± 60 V DC	30 V AC RMS	± 42.4 V pk max

The above EN61010-1 limits apply to any accessory that is not marked with a voltage rating on either connector, cable or body of if a protective finger guard is removed.

⚡**WARNING**: A signal voltage exceeding the current full-scale measurement rating is detected and indicated on the measurement display of the PicoScope Software screen. A red warning icon will appear in the upper left corner and next to the relevant channel’s vertical axis.

Under these conditions, displayed waveforms and measurements may be incorrect and the condition may be hazardous. Reduce the input sensitivity to achieve a within-range measurement and if the condition persists, to prevent injury or death, disable or otherwise safely disconnect from the source of overvoltage.

⚡**WARNING**: To prevent injury or death, do not connect the instrument directly to the mains (line power). To measure mains, use only a differencial isolation probe that is specifically CAT rated for mains or high-energy use. Appropriate safety training is essential and must be obtained.

⚠ **CAUTION**: Exceeding the overvoltage protection range on any connector can cause permanent damage to this instrument. Ensure that no voltage is present when selecting IEPE Interface Mode, and no voltage is applied when in use.

1.4 Grounding

⚡WARNING:

The instrument's ground connection through the USB cable is for measurement purposes only.

Never connect the ground input (chassis) to any electrical power source. To prevent personal injury or death, use a voltmeter to check that there is no significant AC or DC voltage between the instrument ground and the point to which you intend to connect it.

⚠ **CAUTION**: Applying a voltage to the ground input is likely to cause permanent damage to the instrument and other equipment.

1.5 External Connections

⚡**WARNING:** To prevent injury or death, use only the power cord and adaptor, if any, supplied with the instrument.

⚡**WARNING:** Take care to avoid mechanical stress or tight bend radii for all connected leads, including all coaxial leads and connectors. Mishandling will cause deformation and will degrade performance and measurement accuracy.

1.6 Environment

⚡**WARNING:** To prevent injury or death do not use in wet or damp conditins or near explosive gas or vapor.

⚠ **CAUTION:** To prevent damage, always use and store your instrument in appropriate environments.

	Storage	Operating	Quoted Accuracy
Temperature	-20 to +60 °C	0 to 40 °C	20 to 30 °C
Humidity	5 to 95% RH (non-condensing)	5 to 80% RH (non-condensing)	
Altitude	2000 m maximum		
Pollution degree	2 maximum		

1.7 Care of COOL-I-O®

For details on service, refer to Chapter 9. Your COOL-I-O® is inspected, tested and approved before being shipped to you. Upon receipt, inspect the instrument and all probes, connectors, cables and accessories before usage for signs of damage.

The case of COOL-I-O® can be cleaned using isopropyl alcohol. Do not use harsh cleaners or polish.

2 COOL-I-O® Hardware and Software

In this section, the COOL-I-O® hardware is described and the needed software to download and install is explained.

2.1 What's inside COOL-I-O®?

COOL-I-O® is a compact and convenient package for control measurements and component measurements:

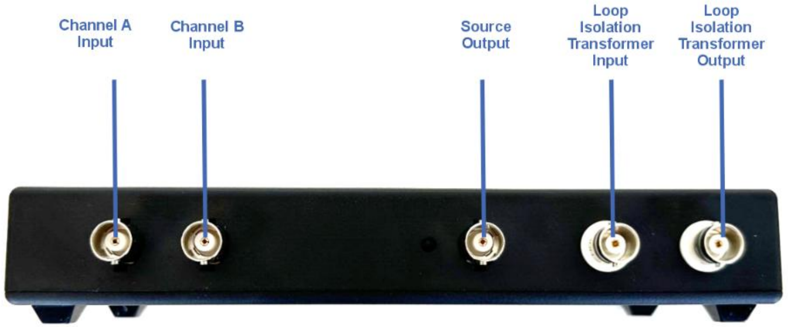
Two-Channel Frequency Response Analyzer controlled by COOL-I-O® software

1 MHz Injection Isolator built-in for loop and impedance measurements

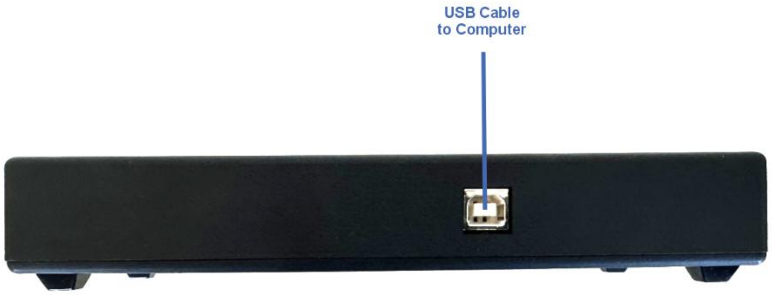
Two-Channel 50 MHz Oscilloscope controlled by PicoScope 7 Software

We also recommend Ridley Engineering's optional accessories described in Chapter 8 for other power supply related measurements.

2.2 COOL-I-O® Inputs and Outputs



Front View: Note that the two channel inputs are used for both oscilloscope and frequency response inputs.



A USB-A or a USB-C connector can be used to connect COOL-I-O® to your computer.

Fig. 2.1: COOL-I-O® Inputs and Output Connectors

2.3 Computer Requirements for COOL-I-O®

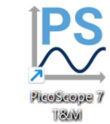
Your computer will need the following to operate with COOL-I-O®. Just about any modern laptop or desktop computer will suffice. If you have an Apple computer, you will need to create a Windows segment to run 64-bit Microsoft Excel properly.

Windows 11 or later Operating System
64-bit Microsoft Office Installed (Office 365 recommended for fastest performance)

2.4 ESSENTIAL Software Installation for Frequency Response Measurements

1. **COOLIO** download and **move** to the desktop folder. (Also on USB drive.)

2. Each COOL-I-O® device requires a unique key file (**ridleyboxinterface.dll**) to enable the hardware found on your USB stick. Please put this file in the folder Documents\RIDLEYBOX on your computer. You can also request this key by email by sending your Picoscope Serial number to info@ridleyengineering.com

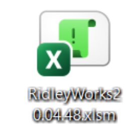


3. **Picoscope 7** download and **run** installation. You will then see this icon on your desktop.

4. **Picoscope SDK** (Software Developer's Kit) download and **run** installation. This will allow the COOL-I-O® software to connect to the Picoscope

2.5 OPTIONAL Software Installation for Design and Simulation

5. **RidleyWorks®INSTALL** download and **run** installation.
   Allow the installer to place all files in the default directories.
   The RidleyWorks®20.04.XX.xlsm run file will be in the directory C:\RIDLEYWORKS®. When you open this file, it will complete the registration for your free one-year licence.
   LTspice subcircuits and symbol files will be placed in the default path for LTspice 24

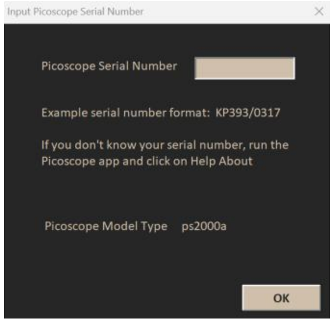


6. **LTspice 24** download and **run** installation. Be sure to use the default folder locations during installation. When installation is complete, you will see this icon on the desktop.

3 Making Frequency Response Analyzer Measurements

3.1a Starting COOL-I-O®

If you want to use COOL-I-O® directly, click on the desktop icon to begin. If macros are enabled, you will see the following welcome message. (If you don't see this, be sure to enable macros.)



You will then see this form to enter the serial number of the Picoscope. This should be on a sticker on the bottom of the unit. You can also start the Picoscope 7 software to get the serial number.

Make sure you enter the serial number exactly as shown, with no leading or trailing blank spaces. Save the COOL-I-O® file after entering the serial number so that it is stored for the future.

If you download a later release of COOL-I-O®, you will need to repeat this process for your serial number the first time that you use it.

3.1 COOL-I-O® Serial Number Request Form

3.1b Starting COOL-I-O® From RidleyWorks®

For many applications in the lab, you can run COOL-I-O® directly as described in the previous section of this manual. This is the fastest and simplest way to start getting measurements.

If you are working with switching power supplies, you have a **Free 1-year License** for RidleyWorks® to help you with all aspects of the design. All measurement data from COOL-I-O® will flow directly into RidleyWorks®, allowing you to compare measurements and predictions for impedances and all transfer functions.

To take full advantage of the power supply design features and Bode plot modeling in RidleyWorks®, open RidleyWorks® first by opening this file in the C:\RIDLEYWORKS® directory. (Feel free to copy this file to the desktop or any other location you wish.)

Click on the COOL-I-O® toolbar icon to start COOL-I-O®. If you don't see the icon, click on the gear wheel to enable COOL-I-O®

The latest manual for RidleyWorks® can be downloaded here.

3.2 COOL-I-O® Frequency Response Analyzer Page

Fig. 3.2: COOL-I-O® FRA Control Page

There are multiple preset measurements:

Click the **POWER** button on the software screen to connect to the Picoscope. The power indicator will turn green. Select the desired measurement.

Plant Transfer Function

Loop Gain

Magnetics Inductance

Leakage Inductance

10 Hz to 1 MHz Sweep

Magnetics Impedance

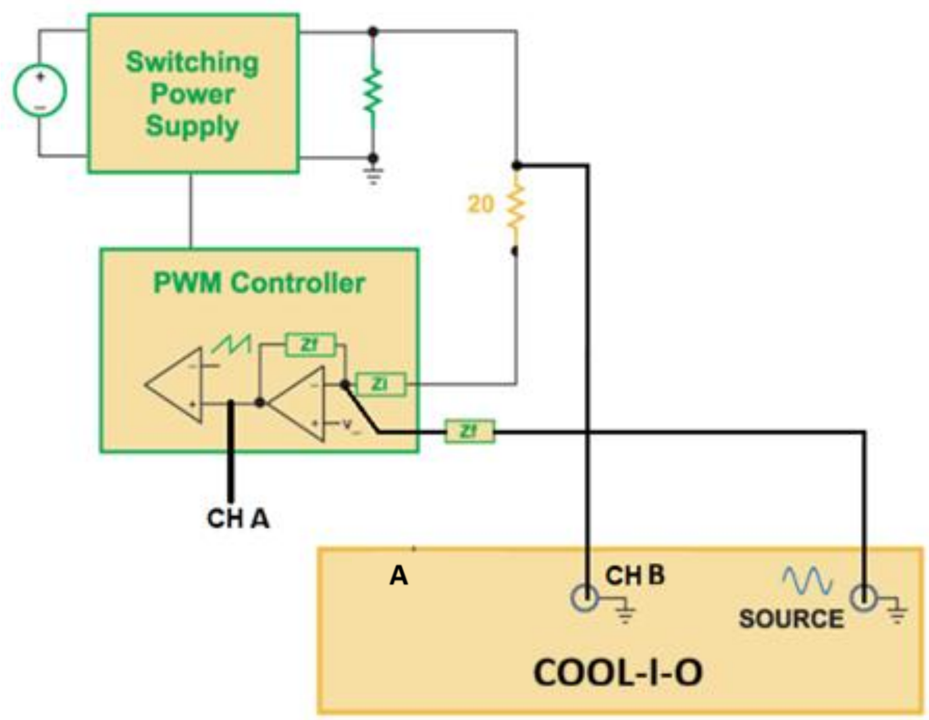
PSRR

Output Impedance

PFC Loop (click down arrow to show.)

Low Impedance

3.3 Power Stage Measurement



Click the **PLANT** button to set up COOL-I-O® for measuring the Power Stage. This will setup the measurement with a fixed 1 V source, and a 100 Hz bandwidth. This should be suitable for the relatively low gains that will be encountered in a power stage.

This schematic shows one of the techniques used at Ridley Engineering to measure power stage gain. This is the first step in designing a loop compensator. We use a large capacitor, 1 uF or more, in series with a 100 Ohm resistor for the feedback network. Zf. Zi is typically just a very large value resistor divider, designed to regulate the output voltage to the correct dc value. The resistor magnitudes are in the order of about 100 k Ohms. A second impedance branch equal to Zf is then connected to the source of COOL-I-O®. This gives unity gain from the source to the output of the error amplifier. It also allows a fixed signal size to be used across the entire frequency range.

Fig. 3.3: Making a Power Stage Measurement

3.4 Sweeping the Power Stage

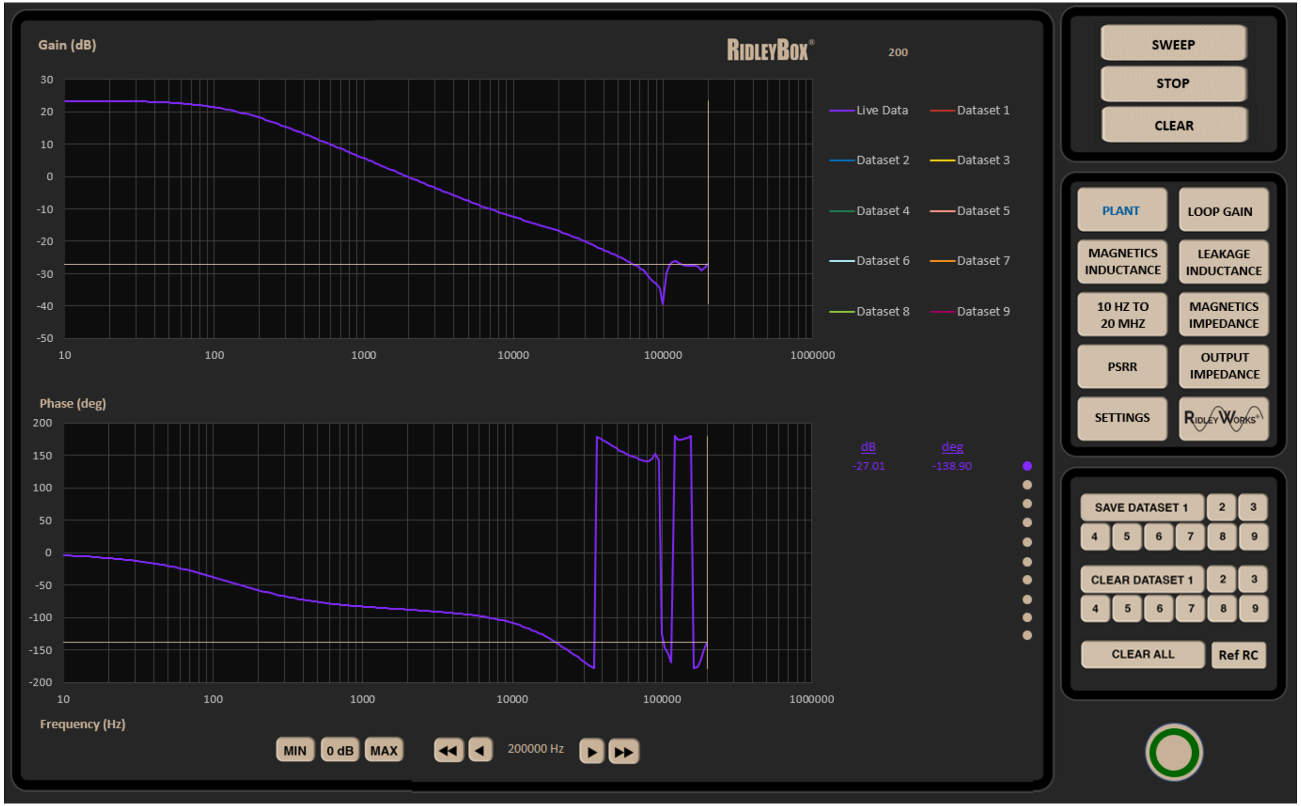
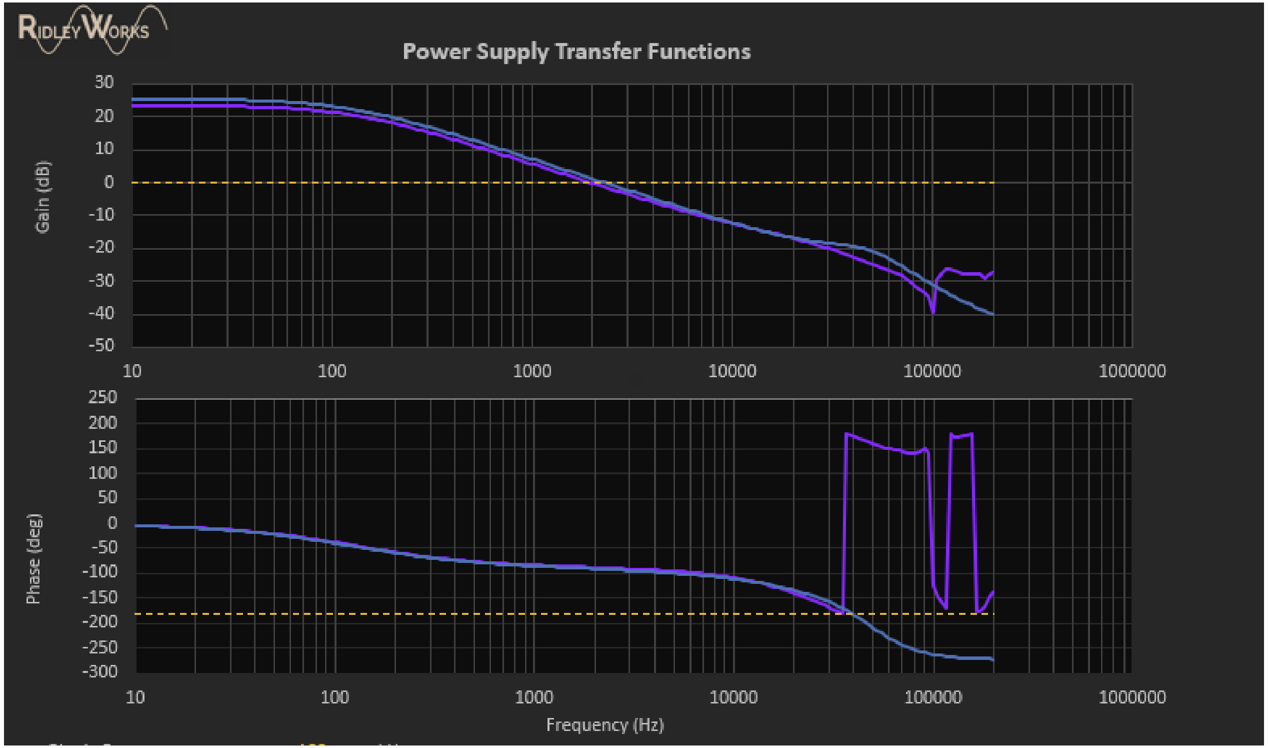


Fig. 3.4: Sweeping the Power Stage

Click the **SWEEP** button to start the measurement. A verbal message indicates that the sweep has initiated. To the right of COOL-I-O® logo is a counter that moves incrementally as the sweep progresses. The sweep may be stopped at any time by clicking the **STOP** button.

Each time a sweep is done the new trace will be shown in purple. When the sweep is finished, you will have the option to save the measurement with the **SAVE DATASET** buttons on the screen. Note: always save **DATASET 1** first since this also saves the frequency points.

3.5 Comparing the Power Stage Measurement with Predictions



If you have opted to use RidleyWorks®, you can click the **RidleyWorks®** button to see the data in the in RidleyWorks®.

COOL-I-O® measured data flows straight into RidleyWorks®, where it can be compared with predictions.

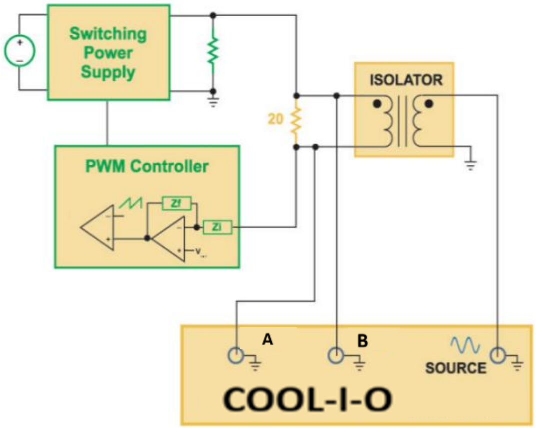
Verify the performance of your system against the best-available models in the industry.

There will always be differences between measurements and predictions.

Refine models as needed, depending on collected data sets for designs and verification.

Fig. 3.5: Power Stage Measurement and Prediction

3.6 Loop Gain Measurements



Loop gain measurements are fundamental to assuring rugged stability of a system. If you click the **LOOP GAIN** button, a graphic appears showing how to set up the measurement with two probes. The schematic of the measurement setup is also shown. We recommend using Channel B for the Output and Channel A for the Input of the loop.

The sweep frequencies, bandwidth, and signal injection sizes will be automatically set to the right values when you click the loop gain button and should produce a successful loop measurement.

Note: If you are unsure if your loop gain measurement is good, send the measurement screen capture to *info@ridleyengineering.com* for our engineers to review.

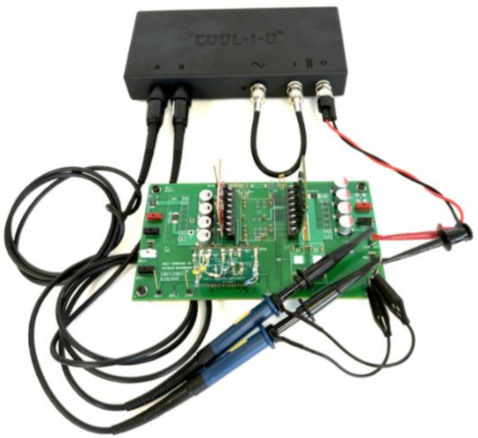


Fig. 3.6: Loop Gain Measurement Setup

3.7 Sweeping the Loop

Fig. 3.7: Sweeping the Loop

Click the **SWEEP** button to initiate the measurement. A verbal message will indicate that the sweep has initiated. The counter to the right of the logo will show the incremental sweep progress. The sweep may be stopped at any time by clicking the **STOP** button.

Each time the loop is swept, the new trace will be shown in purple. When the sweep is finished, you will have the option to save the measurement with the **SAVE DATASET** buttons on the screen.

Any of the stored datasets can be individually cleared, or a single **CLEAR ALL** button will remove all traces.

3.8 Comparing Loop Gain Measurements with Predictions from RidleyWorks®

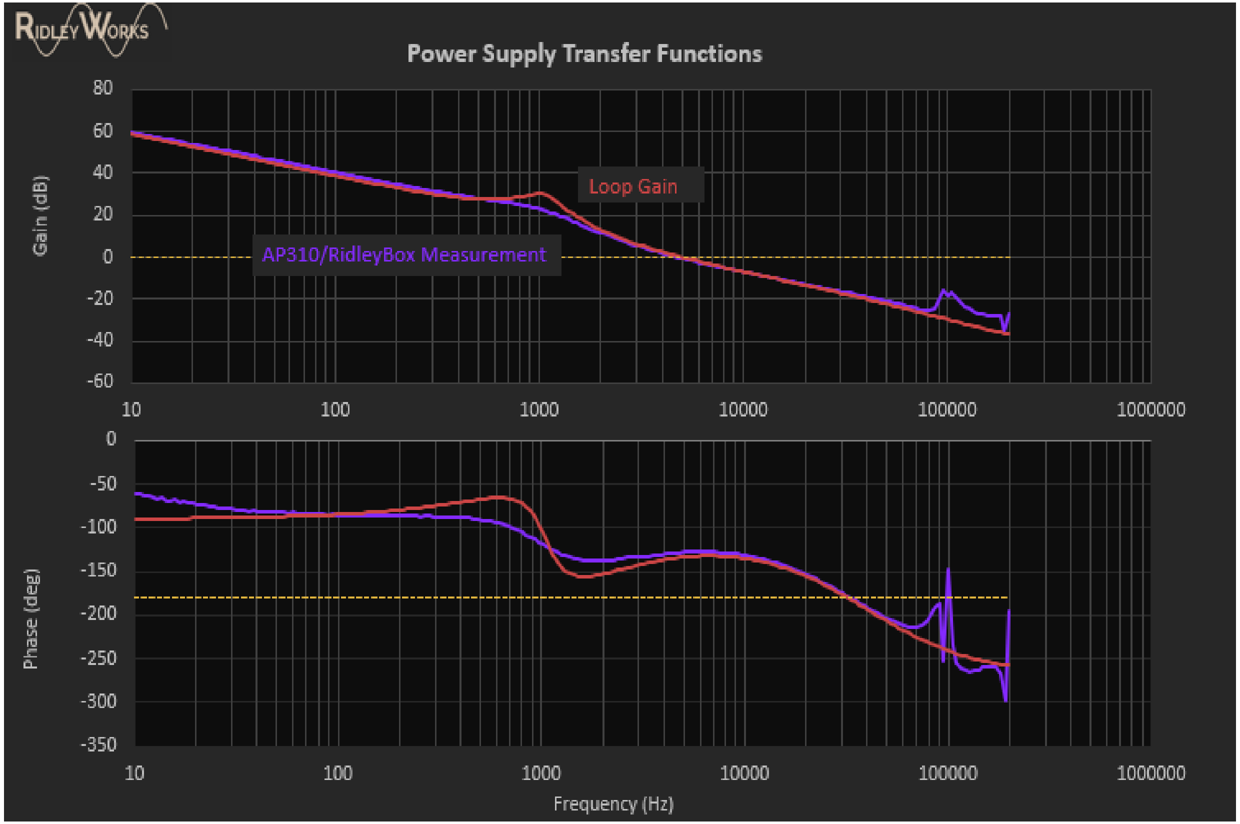
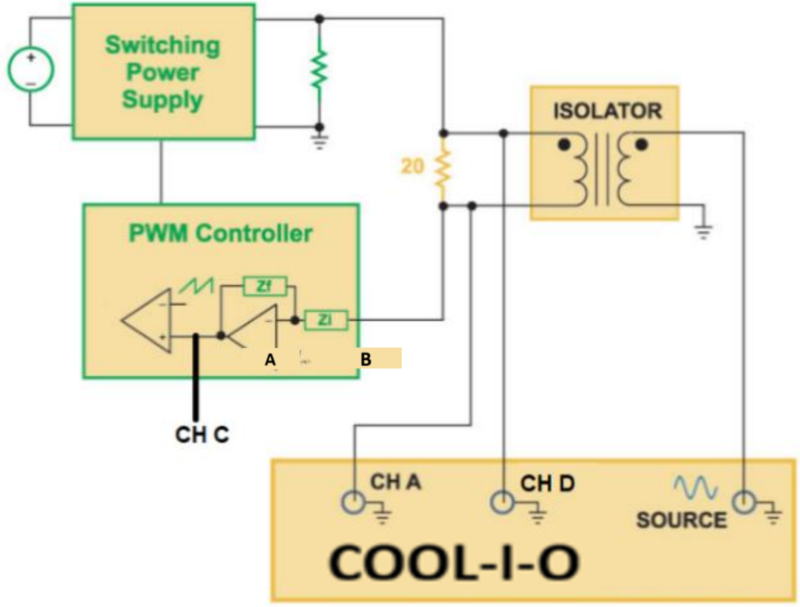


Fig. 3.8: Viewing Swept Loop Measurements Inside RidleyWorks®

Click the **RidleyWorks®** button to see the data in the Loop window on the Power Stage design sheet of RidleyWorks®. This allows verification of the performance of your system against the best-available models.

There will always be differences between measurements and predictions. That is one of the reasons that bode plot measurements persist in the power electronics industry. Power stages tend to be unpredictable. Controllers operate in high-noise environments. Modeling techniques are always simplifications, and the real-world hardware can be expected to deviate from theory.

3.9 Measuring Individual Loop Components



With the same injection technique used for measuring loops, you can use COOL-I-O® to measure the Power Stage Gain and the Controller Gain independently. Connect Channel C of COOL-I-O® to the output of the error amplifier as shown in the schematic. Three different measurements are possible without moving probes on the circuit by changing the input and output settings for COOL-I-O®:

Loop Gain – Input Channel A, Output Channel D

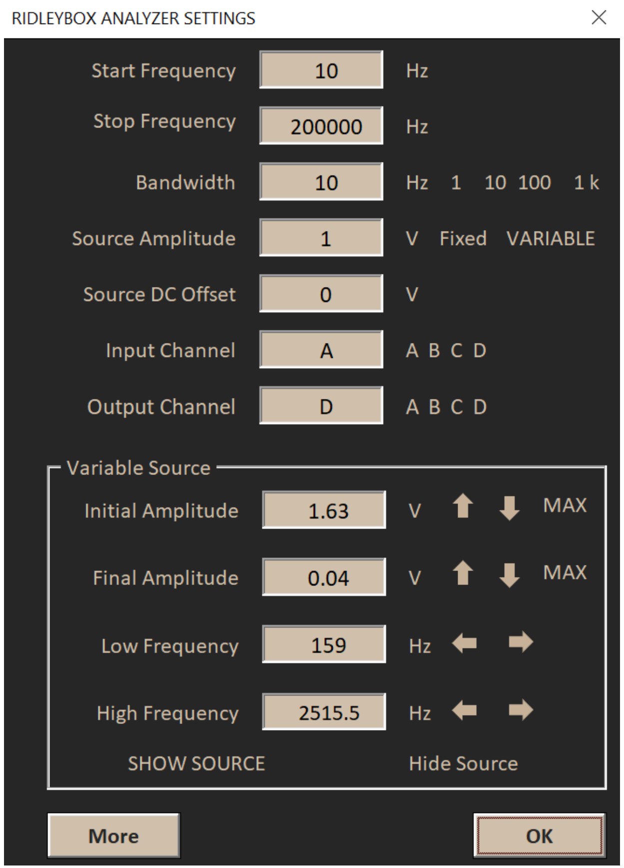
Power Stage – Input Channel C, Output Channel D

Compensator – Input Channel A, Output Channel C

Note that the signal injection is a kept as a Variable signal, as it would be for measuring the loop. To change individual input and output settings as needed, please see section 3.10.

Fig. 3.9: Measuring Individual Loop Components

3.10 Manually Adjusting Sweep Settings



Click the **SETTINGS** button to change the setup of the analyzer. This allows individual adjustment of every parameter.

Start and Stop Frequency – default is from 10 Hz to twice the switching frequency for loop gain measurements.

Bandwidth – default is 10 Hz for loop gain measurements. Lower bandwidths sweep slowly with better noise rejection.

Source Amplitude – a 0-4 V p-p fixed or variable source. Variable source is normally used for a loop gain.

Source DC Offset – zero offset is used for a loop gain

Input Channel – the plotted data is the output/input ratio. Specify any of the four channels.

Output Channel – Channel D/A is the default setting for loop gains.

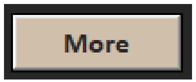
Variable Source Initial/Final Amplitude – When the Variable Source is selected these initial and final values are used.

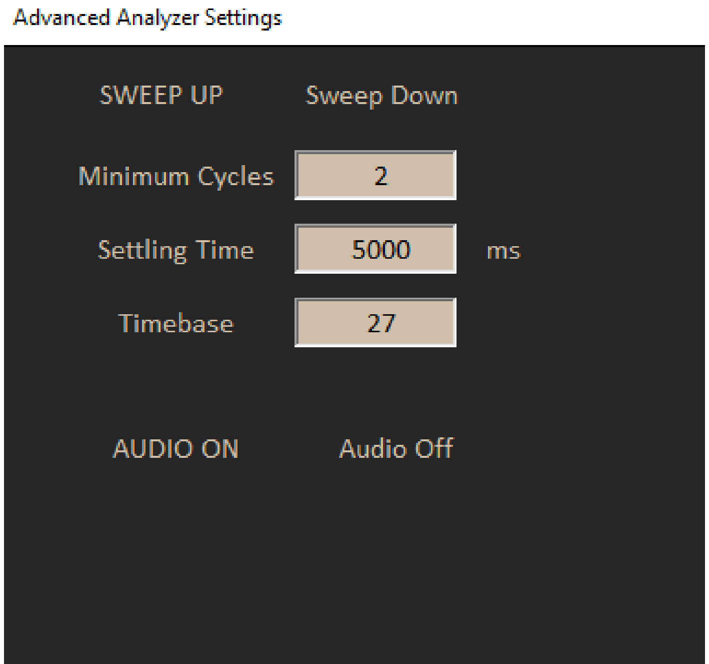
Variable Source Low/High Frequency Break Points – This specifies the frequencies at which the source level changes.

Fig. 3.10: Manual Sweep Setting Adjustments

3.11 Advanced COOL-I-O® Sweep Settings

Click the **MORE** button to see additional control settings for the analyzer. A second screen will offer more options.





SWEEP UP or Sweep Down – default is low to high frequency. It may be useful sometimes to reverse the direction of the sweep, especially if you are starting at very low frequencies.

Settling Time – It is important that the analyzer allows the circuit to return to steady state after starting each new frequency. Time to achieve that will depend on your control loop design. This value is automatically set depending on which kind of measurement you select. You can experiment with different values if you wish.

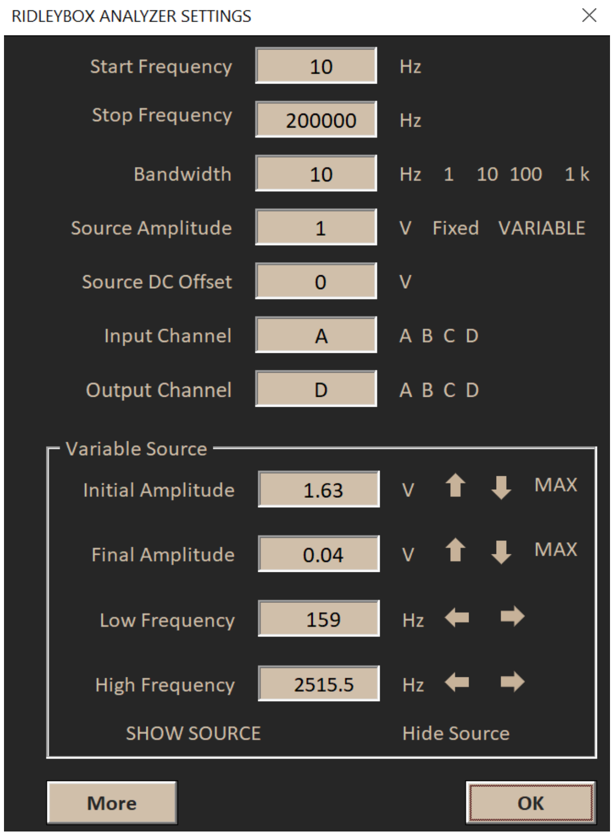
Timebase – This parameter will be set automatically. Do not change this unless you have experience.

Minimum Cycles – This sets the number of cycles for data collection. Do not change this unless you have experience.

AUDIO ON or Off – by default, COOL-I-O® will talk to you if you have sound capability in your monitor. Turn this off if you do not want verbal status notifications.

Fig. 3.11: Advanced Analyzer Sweep Settings

3.12 Visually Adjusting the Source Amplitude Profile



After clicking the *SETTINGS* button, you will see the option to show or hide the source profile. This allows you to see the size of the source versus frequency and to visually adjust it with the controls provided.

The initial and final amplitudes can be adjusted with the Up and Down arrows. It can be visually set anywhere in the range from 0.01 V to 4 V p-p. You can also set the signal size by typing in a number in the corresponding data entry box.

The low and high break frequencies can also be set visually with the left and right arrows that you see.

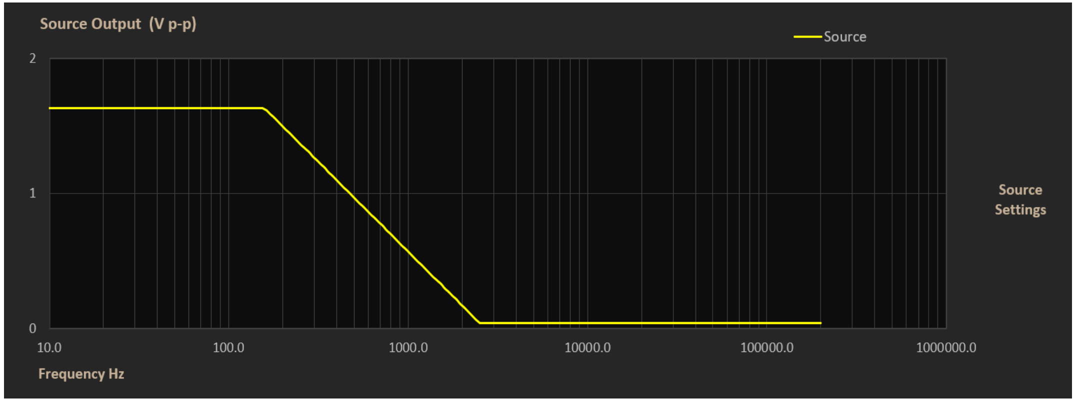


Fig. 3.12: Visually Adjusting the Source Profile

3.14 Reference Circuits

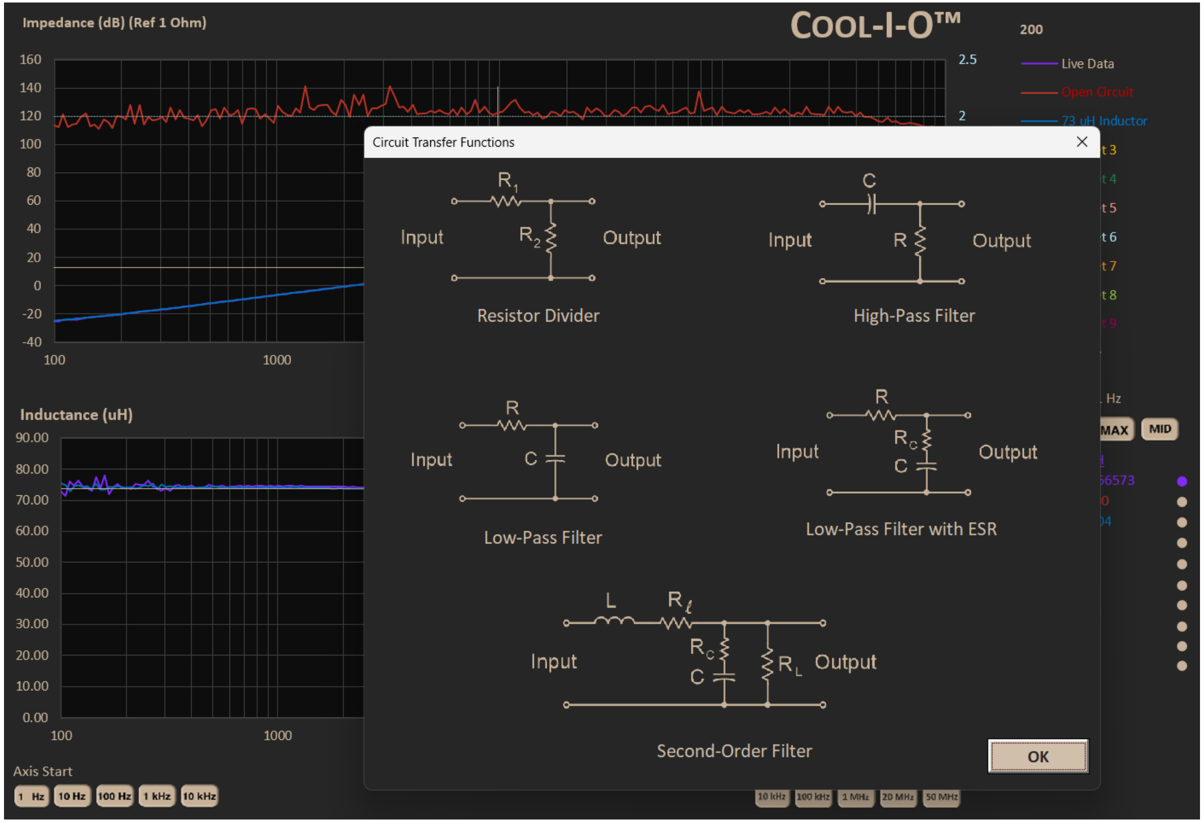


Figure 3.14: Passive Reference Networks

If you are doing frequency response analysis for the first time in your career, it can be useful to have a reference network to test. The analyzer software provides a reference trace where you can define component values.

Click on the *Circuits* button to pull up the reference networks. You can enter your own component values or use the ones that are predefined for you. Note: reference data is stored in *DATASET 9*.

4 Making Passive Impedance Measurements

4.1 COOL-I-O® Impedance Measurement Fixture

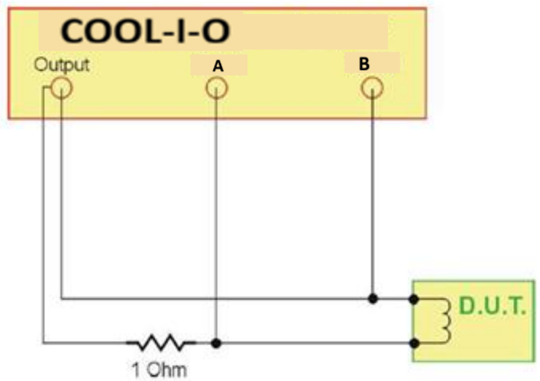


Fig. 4.1: Impedance Measurements (> 0.01 Ohm)

The COOL-I-O® impedance fixture measures two-terminal passive impedances above 0.01 Ohms. Use this test setup for inductors, transformers and capacitors (as low as 1 pF) or resistors. This is an essential part of the design and qualification process for custom or standard magnetics components and power capacitors.

To measure transformers or inductors, click the **MAGNETICS IMPEDANCE** button.

The impedance tester is connected to COOL-I-O® as shown.

4.2 Sweeping Magnetics Impedance

Here you can see three sets of data for the high-impedance fixture. The red line shows the open-circuit dynamic range, much higher than the 100 dB reference line shown in blue. At around 6 MHz, the curves intersect, corresponding to a capacitance resolution capability of less than 1 pF.

Click the SWEEP button to initiate the magnetics impedance measurement.

The yellow trace shows the measurement of a transformer primary winding. In the example, it has a resonance just below 2 MHz.

It is always recommended to measure the magnetics in Gain-Phase mode first. Then, use the Magnetics Inductance button, realizing that the inductance reading is only valid below the resonance.

Fig. 4.2: Impedance Dynamic Range and Transformer Measurement

4.3 Using RidleyWorks® to Analyze Magnetics Data

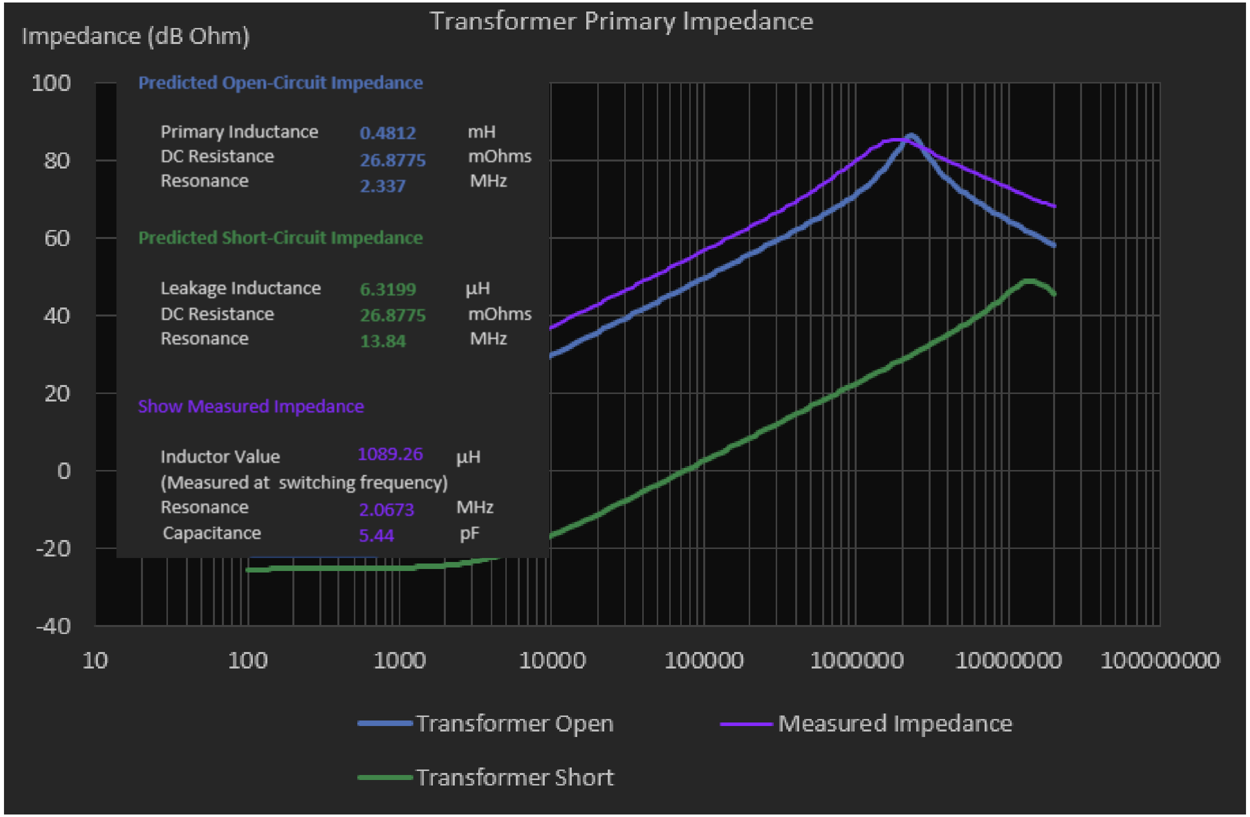


Fig. 4.3: Transformer Open Circuit Impedance Measurement

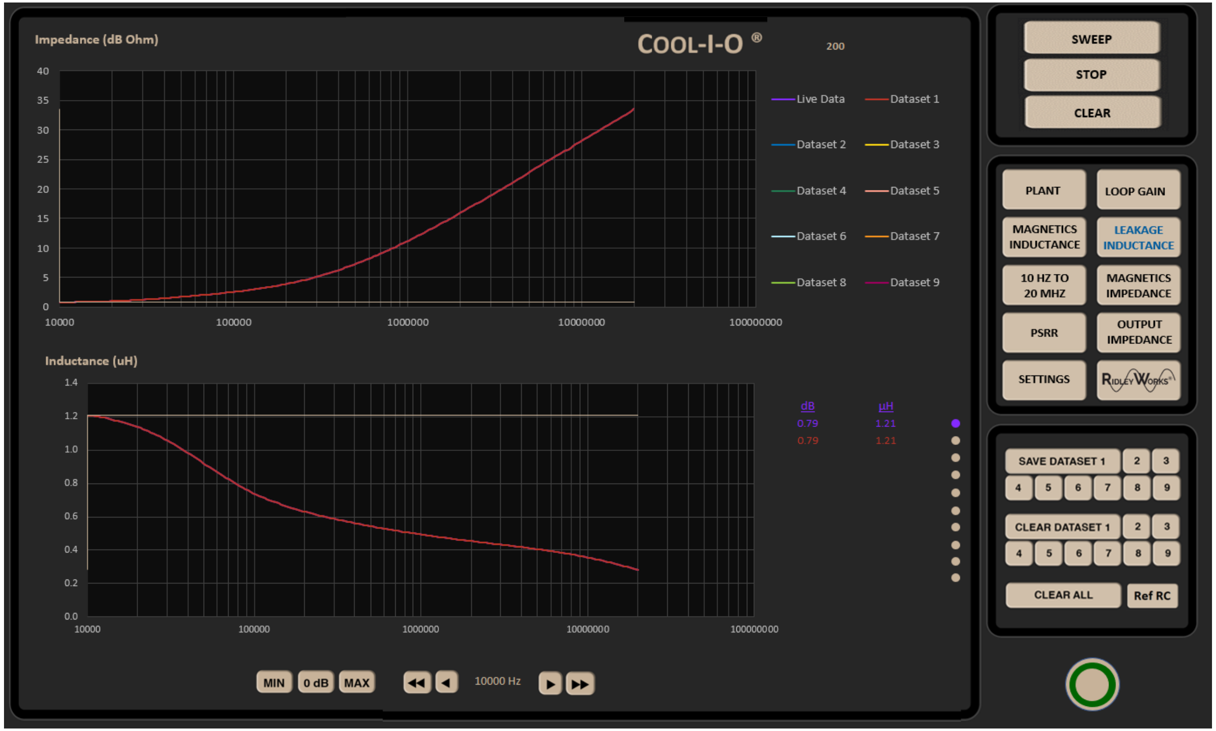
Clicking the RIDLEYWORKS® button to return to the RidleyWorks® program if you launched COOL-I-O® from there. On the Transformer Design page, you can compare predictions of the impedance (based on your design) with the measurements.

RidleyWorks® will extract the values of inductance, resonance, and capacitance from the measured data.

For ungapped ferrites, it is quite common to see the measured inductance higher than specified by the manufacturer. Most manufacturers are conservative in their estimates. This should not be a problem when the transformer is placed in the circuit because a higher inductance is usually fine.

A gapped transformer core should be within 5% of the specification for a good-quality manufacturer.

4.4 Sweeping Transformer Leakage Inductance

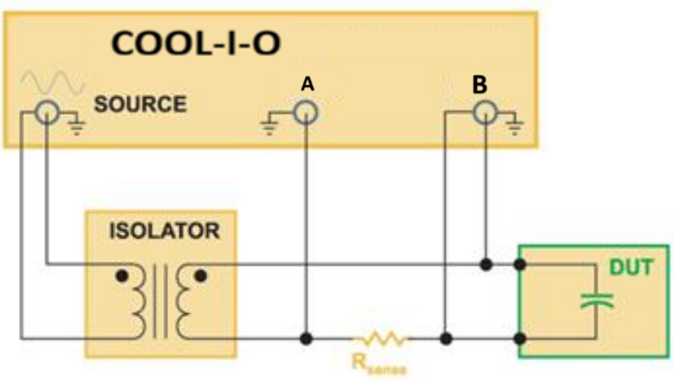


To measure leakage inductance, make sure that the transformer secondary is short-circuited. Connect as before and click the **LEAKAGE INDUCTANCE** button. This starts the sweep at 10 kHz and plots both the impedance of the shorted transformer and the calculated equivalent inductance.

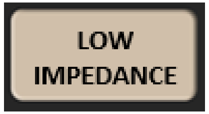
It is quite normal for the leakage inductance to be a function of frequency as shown here, with a substantial drop in value as the frequency increases. This is a sensitive indication of the onset of proximity effect in the windings.

4.4 Short Circuit Leakage Inductance Measurement

4.5 Low Impedance Measurements



The two-terminal, low impedance fixture measures impedances down to 1 mOhm.



To measure large capacitors, or other low impedance devices, click the **LOW IMPEDANCE** button. This is on the second panel of measurement options, accessible after clicking the down arrow.

The low impedance tester is connected to Channel A of COOL-I-O® and the isolated source is connected to the second terminal. A pair of minigrabber leads connect to Channel B as shown.

Fig. 4.5: Low Impedance Measurement Setup

4.6 Capacitor Measurement

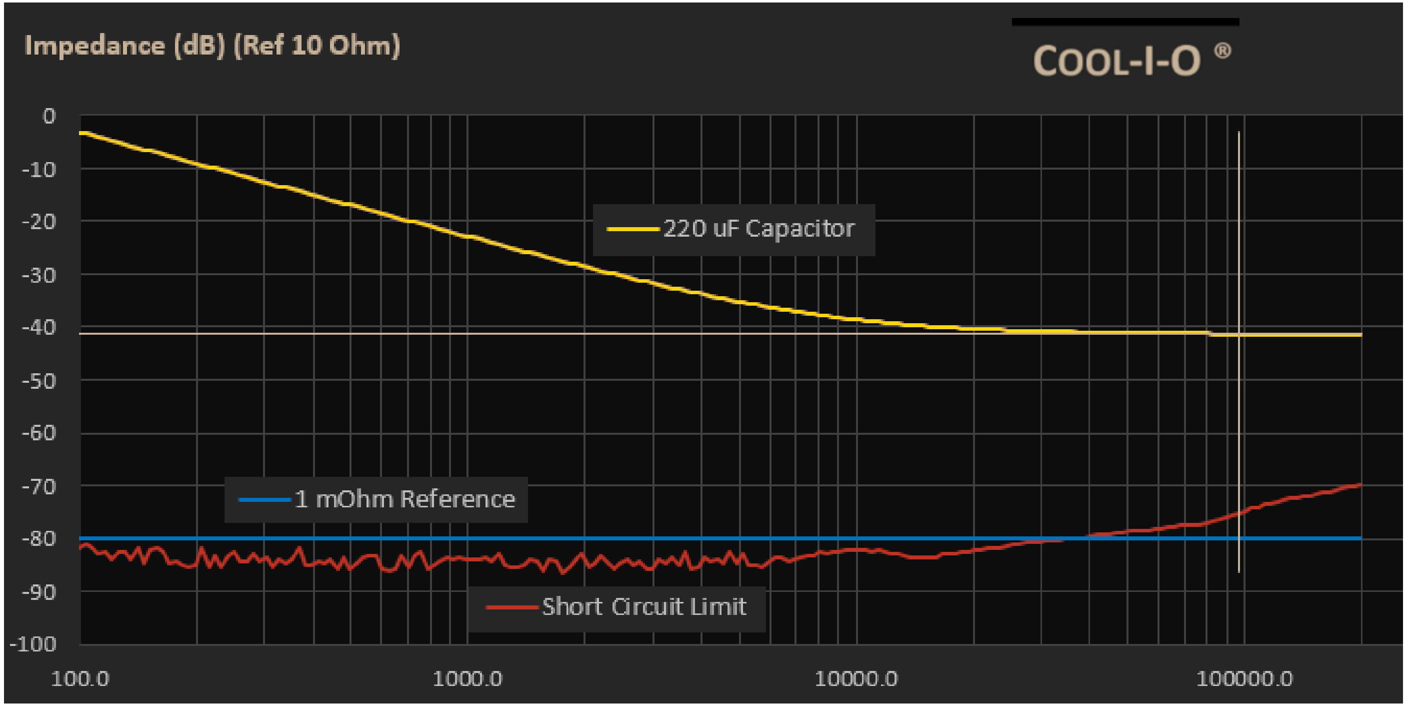


Fig. 4.6: Example Capacitor Measurement

This figure shows the measurement result for a 220 uF capacitor.

A reference 1 mOhm line is shown in blue, and the measurement limitation is shown in red.

While COOL-I-O® is useful for this kind of data, it does not work like a balanced bridge. That means that the resolution range is constrained by stray inductances and RF pickup. For most power capacitors, the measurements will be good.

4.7 Comparing Capacitors with RidleyWorks® Models

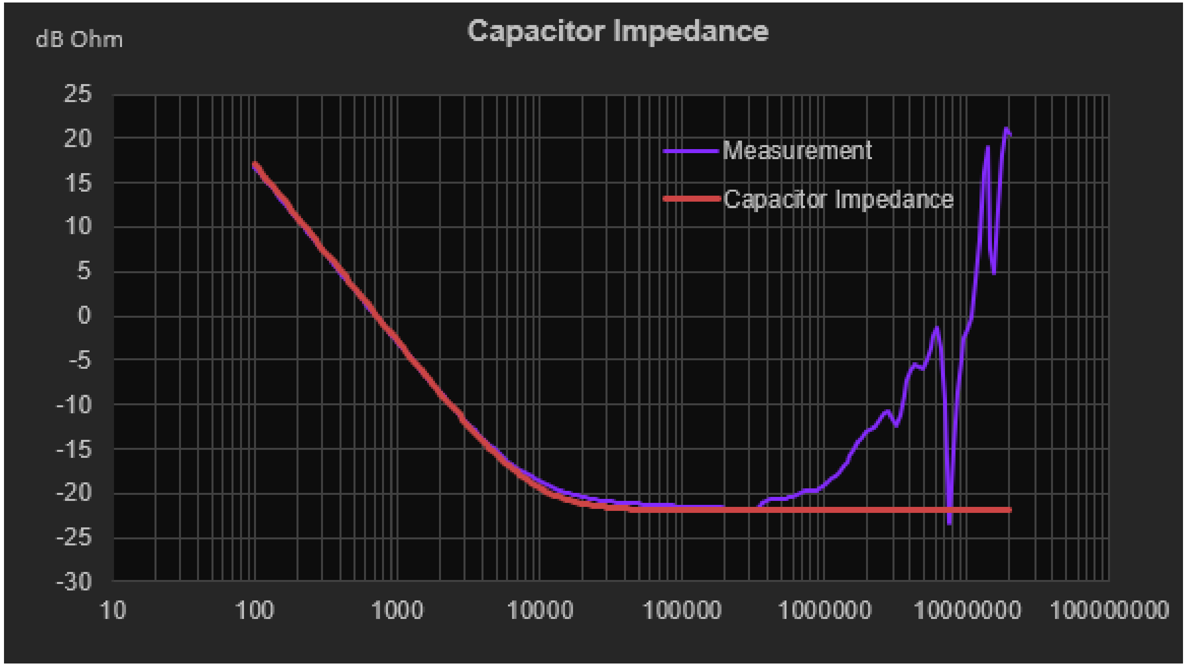
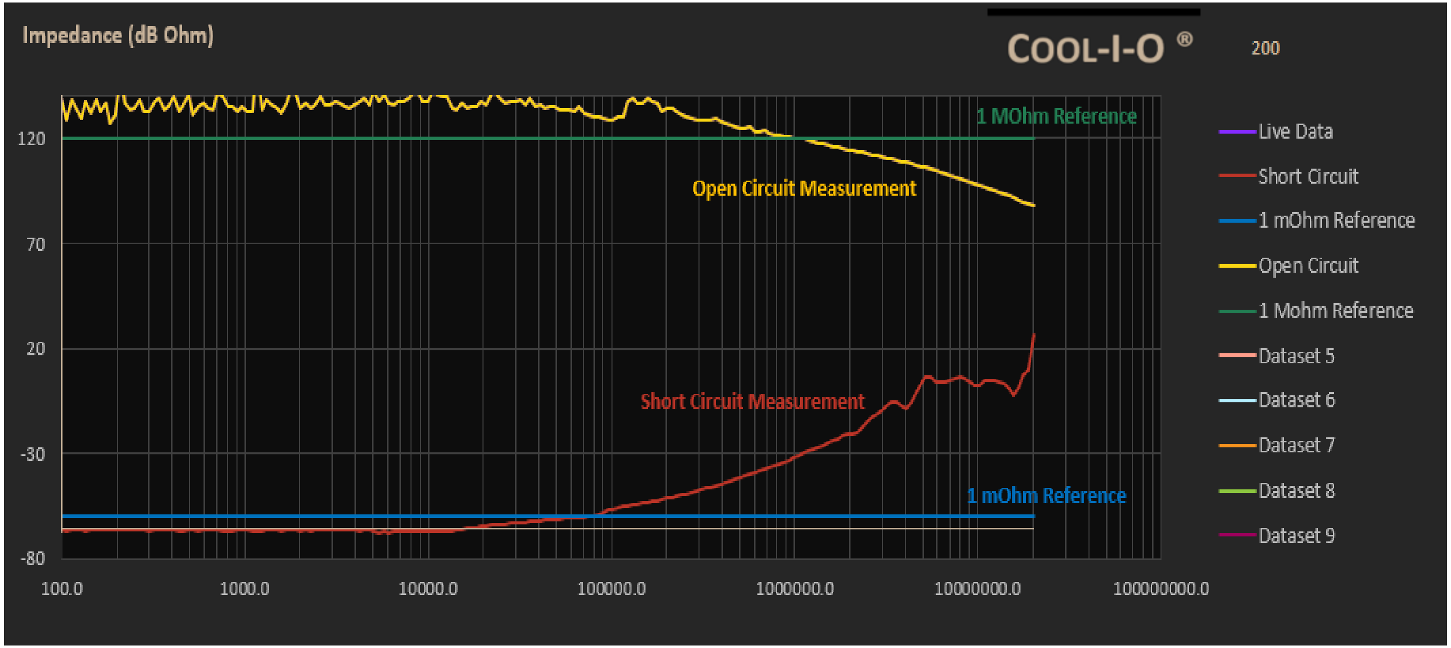


Fig. 4.7: Measured Capacitor Impedance Compared to RidleyWorks® Predicted Output Capacitor

If you click on the RidleyWorks® button, you can compare the measured capacitor impedance with the predicted impedance of the output capacitor.

Notice in this comparison the deviation after 300 kHz. This is due to the inductance of the capacitor and other parasitic elements. There is good agreement with the capacitor value and the ESR value.

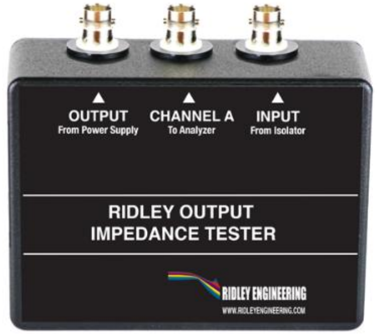
4.8 Total Impedance Measurement Range



You can measure below 2 mOhm up to about 70 kHz, and above 1 MOhm up to 1 MHz. This is a combined range of well above 180 dB, more than enough to cover most power components.

Fig. 4.8: Combined High and Low Impedance Measurement Capabilities.

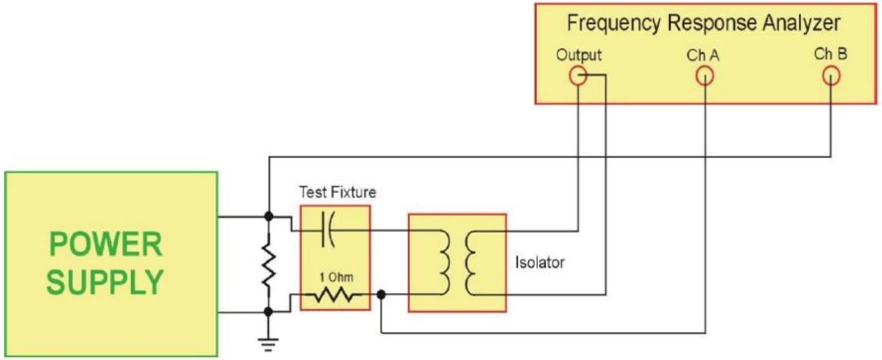
5 Making Active Impedance and PSRR Measurements



Ridley Output Impedance Tester. For the output impedance measurements in this section you will need the Ridley Output Impedance Tester. This is designed for measuring active power supplies or batteries up to 60 V. It is used to inject a current into the output of the power supply under test, and a reference current output is provided for the impedance measurements.

Ridley Line Injector. The Ridley Line Injector is used to add a perturbation signal to the input dc power supply. This is done with an active power device that can support up to 80 V input at 10 A (15 A for short periods, or with the addition of a fan or heatsink). Typical perturbation is about 1 V p-p.

5.1 Output Impedance Measurements



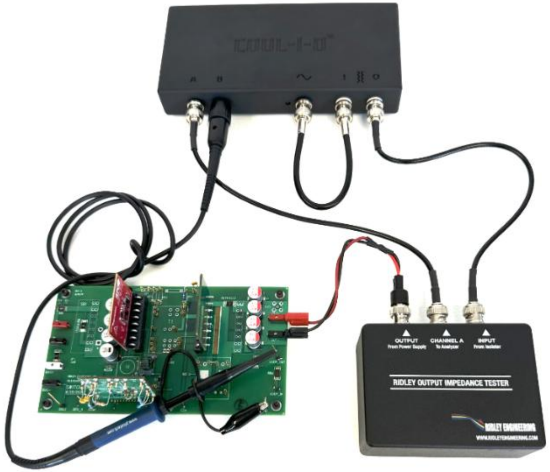


Fig. 5.1: Power Supply Output Impedance Setup

The Ridley Output Impedance Tester is connected as shown here to measure the impedance of an active power supply or battery. This setup establishes a 4-terminal Kelvin connection that can measure impedances below 1 mOhm.

Click the output impedance button to give the right settings for this measurement. The analyzer will use its maximum source level to drive as much current into the output terminals of the power supply as possible.

5.2 Output Impedance Sweep

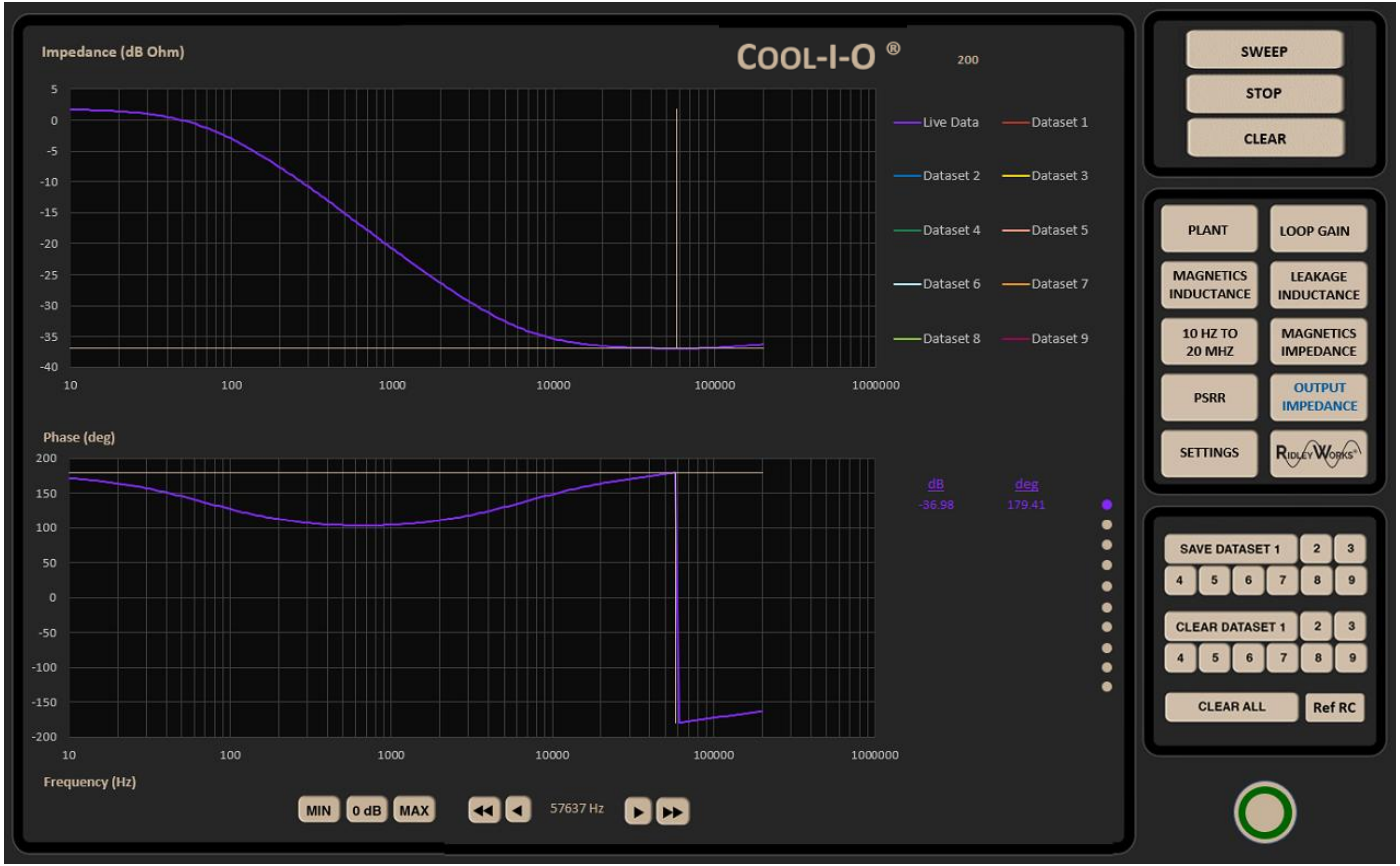
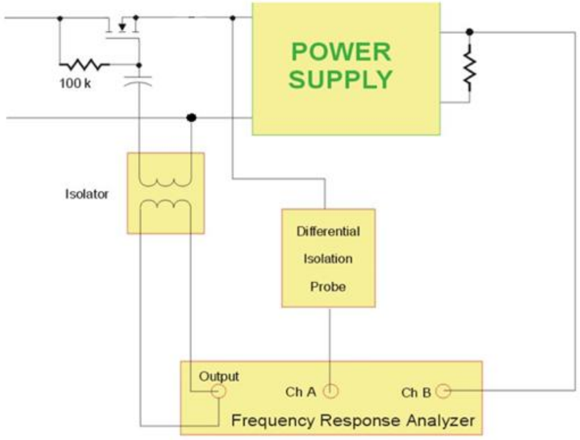


Fig. 5.2: Sweeping the Power Stage Output Impedance

Click the **SWEEP** button to initiate the output impedance measurement. The sweep will start at 10 Hz and finish at twice the switching frequency, by default.

The impedance shown is for a current-mode output stage with just the current loop closed. At low frequency the impedance is equal to the load resistance. At high frequency, the final fixed value is equal to the ESR of the output capacitor on the power supply.

5.3 PSRR Measurement



The Ridley Line Injector is connected as shown here to measure the line noise rejection of a power supply. The FET, resistor, capacitor and heatsinking are all included in the Ridley Line Injector. Use of the isolator is optional, depending on your grounding situation.

Click the **PSRR** button to give the right settings for this measurement. The analyzer will use its maximum source level to drive about 1 V into the input of your power converter.

For current-mode systems, the line rejection ratio can be very high (>80 dB) and this can be a challenging measurement to make. It is very important to ground your system properly – contact us if you are having problems with this measurement.

The differential isolation probe is only needed if you have high voltages at the input to your power supply. Otherwise, a 10x scope probe should suffice.

Fig. 5.3: PSRR Measurement Setup with the Ridley Line Injector

6 Optional Accessory Specifications

6.1 Impedance Accessory

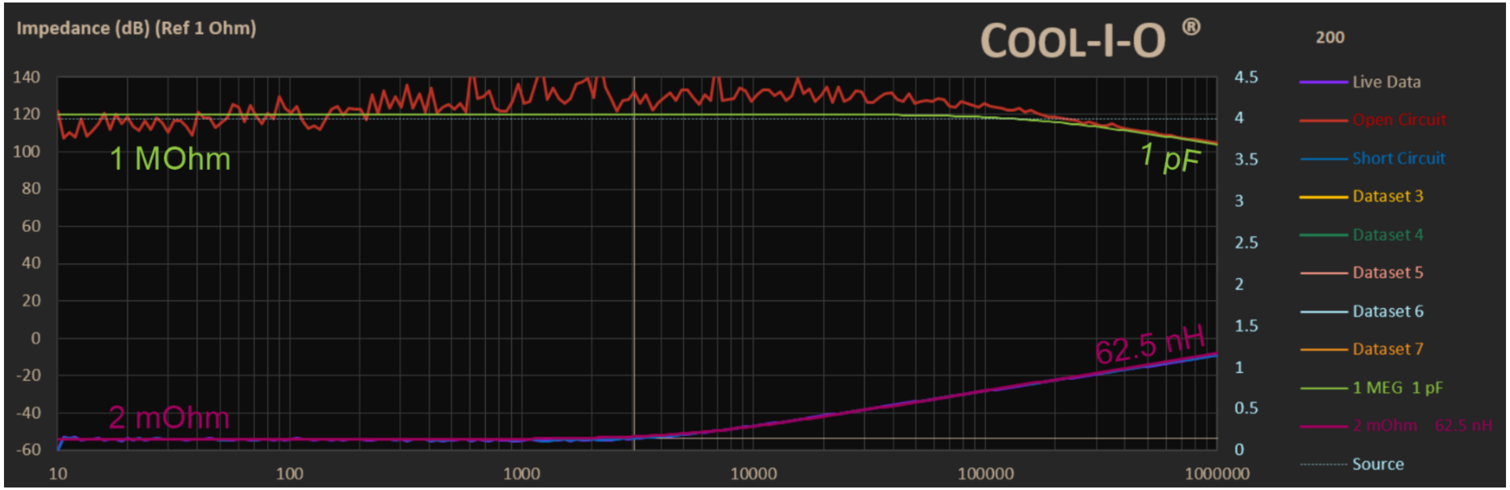
The COOL-I-O® impedance accessory allows you to measure the impedance of passive electronic components. This allows characterization of inductors, transformers, capacitors, resistors and other passive components.

Impedance Range > 0.01 Ohm to 0.5 MEG Ohm

Capacitance Range 1 pF to 0.01 F

Inductance Range 62 nH to 100 H

Current Sense Test Resistor 1 Ohm



6.1a Low Impedance Accessory

The COOL-I-O® low impedance accessory allows you to measure the impedance of passive electronic components. This allows characterization of inductors, transformers, capacitors, resistors and other passive components.

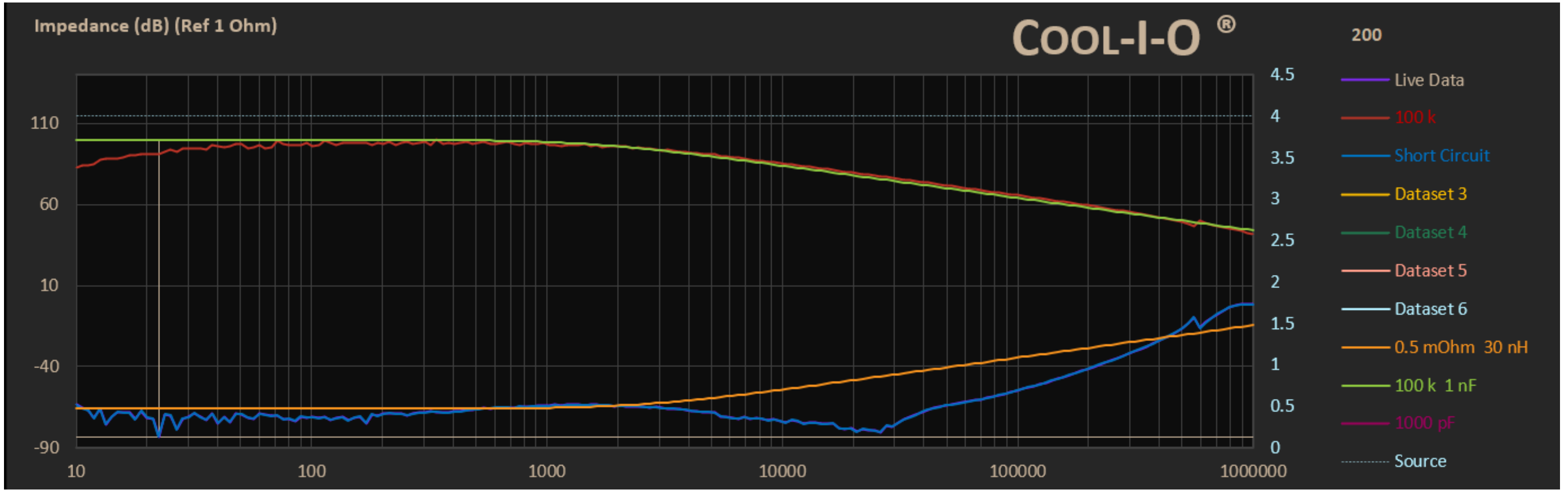
Impedance Range 0.5 mOhm to 100 kOhm

Inductance Range 30 nH to 1 H

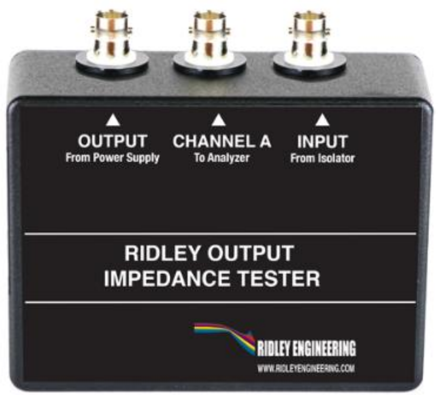
Capacitance Range 1 nF to 0.01 F

Current Sense Test Resistor 10 Ohm

For most applications, the low impedance accessory is not needed. You can use the Output Impedance Tester to achieve the same measurement range. The Output Impedance Tester also offers the advantage of being able to measure active devices.



6.2 Output Impedance Tester

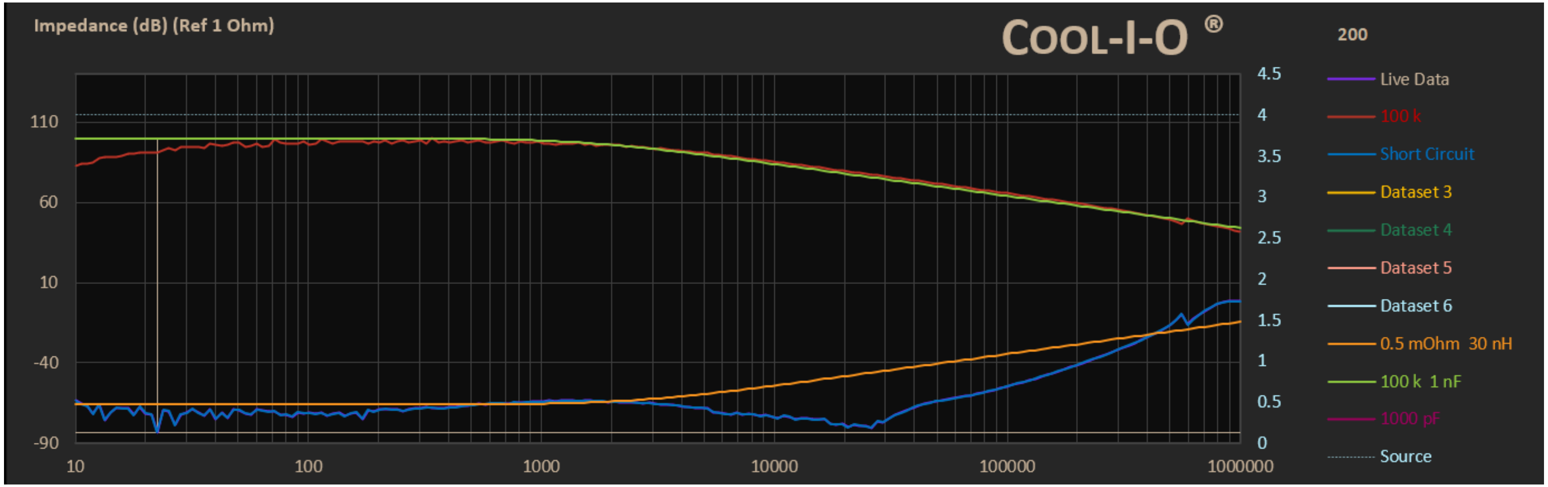


The output impedance tester is designed for measuring impedances of powered circuits and batteries. For example, use it to measure the output impedance of a switching power supply. A four-terminal measurement system is created with this test fixture.

Impedance Range 0.5 mOhm to 100 kOhm

Maximum voltage of DUT 63 VDC

Current Sense Test Resistor 1 Ohm



6.3 Ridley Line Injector

The Line Injector allows the addition of a perturbation signal to the input rail of a power supply for measuring noise rejection (PSRR) and input impedance.

Maximum Frequency	1 MHz
Maximum Signal	1 V typical (capacitive-load dependent)
Maximum Input Voltage	80 VDC
Maximum Load Current	10 A (15 A with Heatsink or Fan)
Typical Voltage Drop	1 VDC input to output

7. RidleyWorks® Overview

7.1 RidleyWorks® Features

RidleyWorks® is the only switching power supply design program which provides component design, large-signal simulation, feedback control design, and small signal analysis in one easy-to-use package. RidleyWorks® Release 14 features include:

Power stage designer

Magnetics designer (included in full version, not in Control and Simulation version) Library of cores

38 most popular topologies used in the industry. All topologies in one program allow you to compare quickly and easily

Industry's **fastest cycle-by-cycle simulation** shows true large-signal performance

SPICELaunch instantly creates LTspice files to continue design and more detailed simulation with all components selected

Unique **LTspice circuit models** for proximity loss and core loss

Control loop designer suitable for constant-frequency PWM

Current-mode control using the latest and most accurate modeling techniques

Voltage-mode control using the results of the PWM switch model

CCM and DCM converter simulation and analysis

Small-signal analysis of control system, including loop gain

Digital compensation delay calculation

Two-stage input filter design and analysis

Output impedance analysis

Audiosusceptibility or **PSRR analysis**

Second-stage LC output filter analysis and design

Snubber design and analysis

Switching loss analysis for power FETs and IGBTs

Direct Control interface to the AP310 Frequency Response Analyzer

Direct Control Interface to COOL-I-O® or RidleyBox® Frequency Response Analyzer

7.2 Working in Levels

There are three levels of application for this software. These levels are commensurate with experience to help you achieve the greatest value from RidleyWorks® without the burden of struggling with the **4000+** design equations involved in arriving at the solution.

Level 1 Basic Design: At this level, simply input the power requirements for the circuit. Click "OK", and the entire converter, including control loop, is designed automatically. The components are chosen based on the data. These are working values that can be applied to hardware with confidence. Examine the design with RidleyWorks® simulations, or convert designs to LTspice files with the SPICELaunch feature. Use the PSIM link to automatically generate simulation schematics.

Level 2 Intermediate Design: Level two designers have design experience and want to input their knowledge as the design progresses. They want to understand and further optimize their design. At this level, look carefully at the selected values from RidleyWorks® and change them as needed to improve the design.

Level 3 Advanced Design: Level three designers not only know how to design an effective power supply— they know how to get maximum performance out of their power system for very specific applications. They have a library of preferred parts that work well for their applications and use these to fully optimize the design.

The magnetics design section works similarly in levels. View the transformer or inductor on the main design schematic and

Choose from simplified parameters and refer to a magnetics design house for completion;

Choose your own cores, wire, and other components and give the completed design to a manufacturer for production; or

Design the magnetics from the ground up using your own parameters and knowledge.

Regardless of design experience, RidleyWorks® provides the ability to check and cross-check all parameters and results. Stop at any time during the process and view resulting waveforms and control parameters.

We hope you enjoy the benefits of this interactive design tool. To learn more about the powerful capabilities of the program, we highly recommend attending one of our Five-Day Power Supply Design Courses.

From the RidleyWorks® screen, you can launch the built-in frequency response analyzer for direct flow of live data from measurements. Compare with predictions of performance, design compensators, and to qualify power designs. This will be discussed in Chapter 5.

To engage the power of RidleyWorks® for power supply design capabilities, refer to the RidleyWorks® Manual on your desktop.

Additional software on COOL-I-O® computer includes LTspice 24. RidleyWorks® software will automatically generate schematic files for LTspice.

The functionality of PicoScope software, to operate COOL-I-O® as an oscilloscope, is explained in more detail in Chapter 4 and the PicoScope Manual on the desktop.

7.3 RidleyWorks® Software Updates

The latest version of RidleyWorks® software is always available for download here. This link is on the opening page of RidleyWorks®.

7.4 RidleyWorks® LTspice Links

RidleyWorks® will export schematics to LTspice for further circuit analysis. This is a powerful feature that will move you from specification to fully-working LTspice schematic in minutes.

8 PicoScope Overview

8.1 PicoScope Hardware Features

The hardware of the PicoScope 2206B has been custom-modified by Ridley Engineering to work properly with your COOL-I-O® product. It is a 50 MHz 2-channel oscilloscope. Unique characteristics of the 2206B make it the ideal model to use with better working performance than other products from Picoscope.

High Bandwidth, High Sampling Rate: The bandwidth, up to 50 MHz, is matched by a real-time sampling rate of 500 MS/s. For repetitive signals, the maximum effective sampling rate can be boosted to 5 GS/s using ETS mode.

DeepMeasure: DeepMeasure delivers automatic measurements of important waveform parameters on up to a million waveform cycles with each triggered acquisition. Results can be easily sorted, analyzed and correlated with the waveform display.

Waveform Buffer and Navigator: PicoScope can store the last ten thousand oscilloscope waveforms or spectrum plots in its circular waveform buffer.

Mask Limit Testing: Mask limit testing allows you to compare live signals against known good signals, and is designed for production and debugging environments. Use the Buffer navigator to find waveforms that violate the mask.

Advanced Digital Triggering: In 1991 Pico pioneered the use of fully digital triggering using the actual digitized data. This technique reduces trigger errors and allows our oscilloscopes to trigger on the smallest signals, even at the full bandwidth. Trigger levels and hysteresis can be set with high precision and resolution.

FFT Spectrum Analyzer: The spectrum view plots amplitude against frequency and is ideal for finding noise, crosstalk or distortion in signals. The spectrum analyzer in PicoScope is of the Fast Fourier Transform (FFT) type which, unlike a traditional swept spectrum analyzer, can display the spectrum of a single, non-repeating waveform.

8.2 PicoScope Software Features

Advanced Display: The software dedicates almost all of the display area to the waveform to seem the maximum amount of data at once. Create a customizable split-screen display, view multiple channels or different views of the same signal simultaneously. Zoom, pan, and filter settings for each wave form.

Digital Persistence Mode: Persistence mode superimposes multiple waveforms on the same view, with more frequent data or newer waveforms emphasized with deeper saturation or hotter colors. Use this mode for viewing complex or changing waveforms and you will be able to see glitches even if subsequent waveforms are drawn on top.

Math Channels and Filters: With waveform math, select simple functions such as addition and inversion, or open the equation editor to create complex functions involving filters (lowpass, highpass, bandpass and bandstop filters), trigonometry, exponentials, logarithms, statistics, integrals and derivatives. Plot live signals alongside historic peak, averaged or filtered waveforms.

Custom Probes: The custom probes feature allows you to correct for gain, attenuation, offsets and nonlinearities in probes, sensors or transducers that you connect to the oscilloscope. For example, it can scale the output of a current probe so that it correctly displays amperes. It can also transform the output of a nonlinear temperature sensor using the table lookup function.

Alarms: Program PicoScope to execute actions when it detects events such as mask limit failures, triggers and buffers full. Actions include saving a file, playing a sound, executing a program or triggering the arbitrary waveform generator.

The PicoScope 7 software has many powerful tools to help you acquire and analyze waveforms. While these tools can be used on their own, the real power of PicoScope lies in the way they have been designed to work together.

As an example, the rapid trigger mode allows you to collect 10,000 waveforms in a few milliseconds with minimal dead time between them. Manually searching through these waveforms would be time-consuming, so just pick a waveform you are happy with and let the mask tools scan through for you. When done, the measurements will tell you how many have failed and the buffer navigator allows you to hide the good waveforms and just display the problem ones.

Perhaps instead you want to plot changing duty cycle as a graph? How about outputting a waveform from the AWG and also automatically saving the waveform to disk when a trigger condition is met? With the power of PicoScope the possibilities are almost endless.

Detailed instructions can be found in the PicoScope User Manual located on.

8.3 Software Updates

The latest version of PicoScope software is always available for download at https://www.picotech.com/downloads

9 COOL-I-O® Specifications

9.1 Frequency Response Analyzer Specifications

Minimum Sweep Frequency	1 Hz
Maximum Sweep Frequency	1 MHz
Output Signal Amplitude	0 to 4 V p-p
Source Output Impedance	50 Ohm Fixed
Transformer Injection Isolator	2:1 Step Down, 10 Hz to 1 MHz. 240 VAC functional isolation, maximum input 4 VAC pk-to-pk, 1 VAC below 40 Hz.
Dynamic Range (Passive Components)	>105 dB typical
Dynamic Range (Active Switching Circuits)	>70 dB typical
Test Channels	2
Measurement Bandwidth	1 Hz to 1 kHz
Maximum Signal Input Channel A and Channel B	20 VDC (1x probe), 200 VDC (10x probe)
Stored Frequency Response Measurement Traces	10 Standard (Can Be Increased Upon Request or with Knowledge of Excel)
Measurement Sweep Time	1 Hz BW < 300 seconds 10 Hz BW Hz < 55 seconds 1 kHz BW <25 seconds (10 Hz to 200 kHz 200 points)
Input Channels	Grounded to Chassis
Data Interface	All data flows directly into Excel, can be copied and pasted into any other Windows program

9.2 Oscilloscope Specifications

Analog Input Channels	2
Input Type	Single-ended, BNC(f) Connector
Bandwidth (-3 dB)	50 MHz
Rise Time (calculated)	1.75 ns
Bandwidth Limiter	20 MHz, selectable
Vertical Resolution	8 bits
LBS Size (quanitization step size)	8 bit mode: <0.6% input range; 12-bit mode: <0.04% input range; 14-bit mode: <0.01% input range; 15-bit mode: <0.005% input range; 16-bit mode: <0.0025% input range
Enhanced Vertical Resolution	Hardware resolution + 4 bits
Input Ranges	± 10 mV to ± 20 V full scale, in 11 ranges
Input Sensitivity	2 mV/div to 4 V/div (10 vertical divisions)
Input Coupling	AC/DC
Input Characteristics	1 MΩ ± 1% II 14 ± 1 pF
Gain Accuracy	8-bit mode: ± of signal ± LSB
Offset Accuracy	± 500 µV ± 1% of full scale
Analog Offset Range	± 250 mV (10, 20, 50, 200 mV ranges); ±2.5 V (500 mV, 1 V, 2 V ranges); ± 20 V (5, 10, 20 V ranges)
Analog Offset Control Accuracy	± 0.5% of offset setting, additional to basic DC offset accuracy
Overvoltage Protection	± 100 V (DC + AC peak)

Additional specifications can be found in the PicoScope Manual.

10 Support and Service

10.1 Technical Support

Customer Support is provided by email, phone, and direct remote interface from Ridley Engineering.

If you are having issues with the setup or functions of COOL-I-O®—or any associated software from Ridley Engineering, please call or e-mail for help. If no one is immediately available, please leave a message, including your name and phone number, and your call will be returned as soon as possible. You can attach your Excel files to an email for assistance if you wish.

Phone: (US) 805 504 2212 E-Mail: info@ridleyengineering.com

(UK) +44 (0)1509 276 245

Your Ridley Engineering technician may request to access your COOL-I-O® by remote interface. With instructions over the telephone or by email, granting access with a unique identifier will help us look at and diagnose most issues. It will also help us determine which hardware or component inside your COOL-I-O® may be functioning improperly.

Group Support on Social Media: We recommend joining our Facebook and LinkedIN groups to discuss techniques and additional technical information regarding COOL-I-O®, PicoScope and RidleyWorks® functionality: **POWER SUPPLY DESIGN CENTER** on Facebook and LinkedIn.

Ridley Engineering Design Center: To view hundreds of educational tutorials, webinars, design tips and articles – visit **RIDLEY ENGINEERING'S DESIGN CENTER** at http://www.ridleyengineering.com/design-center-ridley-engineering.html

10.2 Service

No hardware parts within COOL-I-O® are user-serviceable items. Breaking the tamper-resistant seal will void the manufacturer's warranty if opened by anyone other than a Ridley Engineering licensed technician. For Warranty information, please refer to Chapter 11.

Repair, servicing and adjustment require specialized equipment and trained technicians and must only be performed by Ridley Engineering. If your COOL-I-O® needs to be returned for service, your Ridley Engineering Technician will provide an Authorization Number with instructions for return. Following these return instructions are especially important for units returning from outside the USA . All COOL-I-O® units are serviced only by our licensed technicians in Camarillo, California:

Ridley Engineering Inc.
725 W Ventura Blvd, Suite H
Camarillo, CA 93010

At Ridley Engineering, we assist with diagnostics and repair of all the components within the instrument. If we cannot repair it, and it is within warranty without signs of abuse or improper usage, we will replace it. In the event of improper usage or evidence of abuse, a quote will be rendered for standard repair charges or replacement charges.

In the event that servicing is required of the PicoScope Oscilloscope hardware, this component will be extracted by our technician and sent to Pico Technology or their licensed service provider for service by their technicians. Upon its return to Ridley Engineering, COOL-I-O® will be reassembled, tested and returned to you.

11 Warranty Information

11.1 Limited Warranties

COOL-I-O® houses multiple components, all of which are serviceable only by a licensed professional at Ridley Engineering Inc. There are no user-serviceable parts. Breaking the tamper-resistant seal on COOL-I-O® or opening the case of COOL-I-O® voids all warranties listed below.

The following list details the warranty period for each component. A charge may apply for services that are not covered by these warranties.

PicoScope 2206 Hardware-Modified Oscilloscope	5 years
Ridley 1 MHz Universal Injector	3 years

External Accessories manufactured by Ridley Engineering Inc.

Ridley Output Impedance Tester	3 years
Ridley Impedance Test Kit	3 years
Ridley Line Injector	3 years

RidleyWorks® software has a free 1-year license to the licensed user of COOL-I-O®. The licensed user receives software updates at no additional expense. The frequency response analyzer function is software-based and is included in the license updates by the manufacturer.

Ridley Engineering's entire liability, and your sole and exclusive remedy for any defective or nonconforming component of COOL-I-O® shall be, at Ridley's sole option: (a) repair or replacement of the defective or nonconforming component, or (b) return of the price you paid for COOL-I-O®. Such remedy shall be available only during the applicable warranty period. Any repaired or replaced component shall be subject to the original warranty period, which shall not be extended due to such repair or replacement, except to the extent required by any mandatory, nonwaivable provision of applicable law.

THE FOREGOING WARRANTY IS EXCLUSIVE, AND RIDLEY ENGINEERING MAKES NO OTHER WARRANTIES OF ANY KIND WHATSOEVER, EXPRESS OR IMPLIED, AND RIDLEY ENGINEERING HEREBY EXPRESSLY DISCLAIMS ALL OTHER IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR USE OR PURPOSE. EXCEPT FOR THE REPLACEMENT OF ANY DEFECTIVE COMPONENT AS SET FORTH ABOVE, RIDLEY ENGINEERING SHALL HAVE NO LIABILITY, RESPONSIBILITY, OR OBLIGATION FOR ANY OTHER DAMAGES, CLAIMS, OR REMEDIES, INCLUDING, WITHOUT LIMITATION, ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES FOR LOSS OF USE, REVENUE, OR PROFIT, OR FOR ANY OTHER DIRECT, INDIRECT, INCIDENTAL, SPECIAL OR CONSEQUENTIAL DAMAGES WHATSOEVER. RIDLEY ENGINEERING'S MAXIMUM LIABILITY FOR ANY AND ALL CLAIMS, LOSSES OR DAMAGES RESULTING FROM DEFECTIVE GOODS OR FROM ANY OTHER CAUSE WHATSOEVER, REGARDLESS OF THE FORM OF ACTION, WHETHER IN CONTRACT, TORT OR UNDER ANY PRODUCTS LIABILITY LAW, SHALL BE LIMITED TO THE PURCHASE PRICE PAID BY YOU FOR THE DEFECTIVE PRODUCT.

11.2 Warranty Exclusions

The above warranty on your COOL-I-O® will not apply to defects resulting from the following:

Customer-supplied software or interfacing

Damage by accident or abuse

Unauthorized modifications or misuse.

Operation outside the environmental specifications listed in section 1.6 of this manual.

Regarding your (end user's) particular purpose or usage of COOL-I-O®, its hardware, software, firmware or components embodied in or used in conjunction with this product:

Ridley Engineering does not extend to you, the end user, any express warranty or any implied warranty of merchantability, fitness for use or fitness for any particular purpose.

Ridley Enginering is not responsible for any damages or loss, whether direct incidental or consequential, which you as the end user may experience as a result of your purchase or usage.