AP 200 Parallel

Frequency Response Analyzer

Application Notes

Ridley Engineering

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1 Introduction

Congratulations on your purchase of the AP 200 Parallel Frequency Response Analyzer - the world's first truly portable frequency response measurement system. This is an invaluable tool for the design and testing of switching power supplies, and other analog circuits.

The main uses for the Frequency Response Analyzer are in measuring system frequency responses, and for characterizing power components such as inductors, transformers and capacitors. These application notes show you how to measure loop gains and impedances with this Frequency Response Analyzer. As with any such instrument, this takes some practice and skill. These notes will help you, and we always are ready to give you assistance when you are having difficulty.

Detailed instructions on how to install and use the AP 200 Parallel Frequency Response Analyzer are included in the instruction manual. As always when measuring power equipment, please take care in connecting probes from the analyzer to the circuit that you are measuring. Remember that the signal ports of the analyzer, and the host PC are **AT GROUND POTENTIAL**, and probe grounds must not be tied to any potential other than ground unless you are using differential isolation probes.

Please also take care not to overload the input ports of the analyzer. The differential isolation probes provide up to 1000 VAC common-mode and differential-mode isolation when needed.

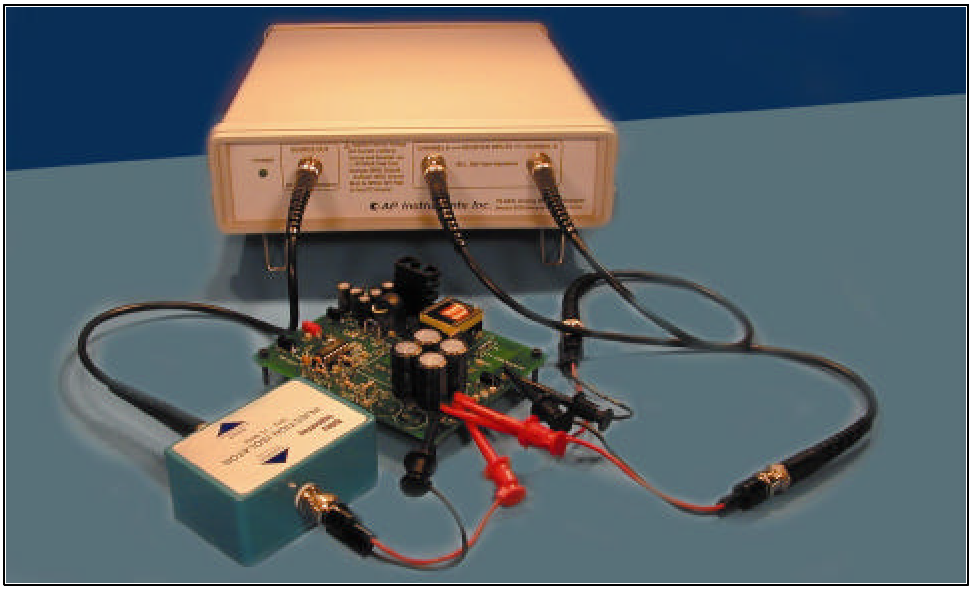
Please call if you need further assistance in setting up your measurements, or if you just have questions about frequency response measurements in general. We have more experience in measuring and modeling power supply feedback systems and components than any other company in the world, and we are happy to provide you with any assistance you need.

For updated information on using the Frequency Response Analyzer, visit the Ridley Engineering web site at www.ridleyengineering.com.

You can contact us for help with your analyzer by phone at 770 642 1918 or by e-mail to RidleyPower@aol.com.

2 Loop Gain Measurements

Switching power supplies typically have feedback networks with a crossover frequency in the 1-30 kHz range, and very high dc gain. It is usually necessary to measure the gain of such a system with the feedback intact. The figure below shows a typical setup for loop gain measurement.



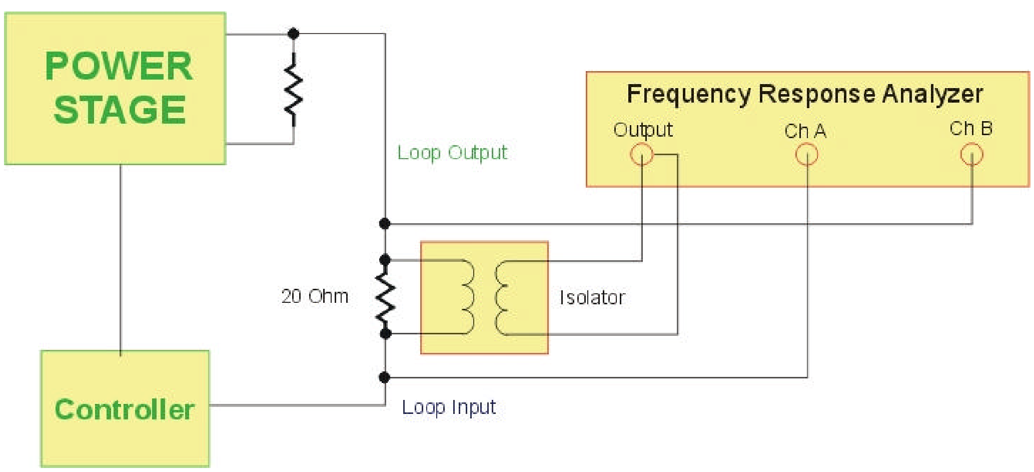


Fig 1: Loop Gain Setup for Ground-Referenced, Low-Voltage Power Supply (<15 V)

The output of the frequency response analyzer is coupled via a small-signal transformer (optional accessory) across a 20 ohm resistor directly in series with the feedback loop. The measurement probes are connected on either side of the injection resistor to measure the loop gain. (Note: they can be moved to other points in the circuit to measure just the power stage, or the feedback compensator gain.)

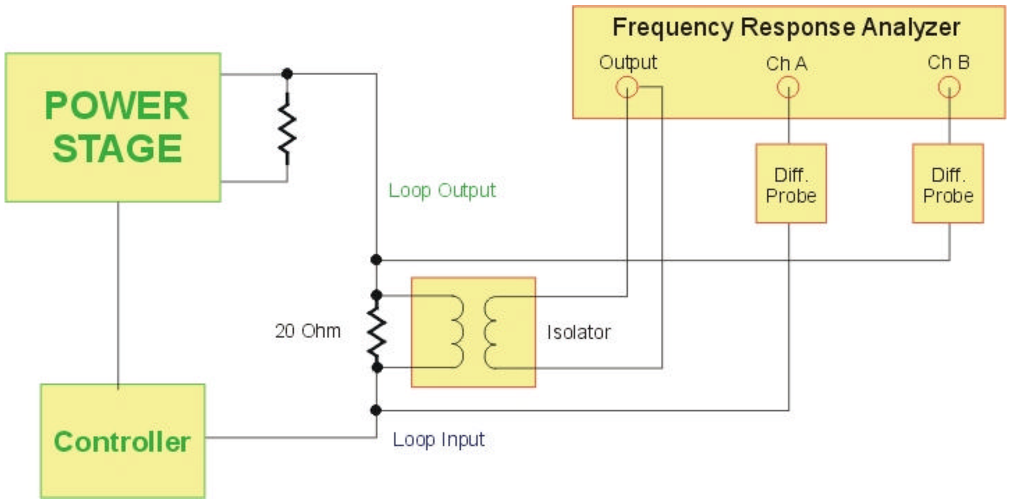


Fig 2: Loop Gain Setup for non-Ground-Referenced, or High-Voltage Power Supply

Once set up as shown, the Frequency Response Analyzer will sweep a range of frequencies (typically from about 10 Hz to the power supply switching frequency), and measure the amplitude and phase of the signal at the injected frequency coming into channel A and channel B. It takes just a few seconds to complete the measurements. The graphs below show measurements and predictions for a switching power supply.

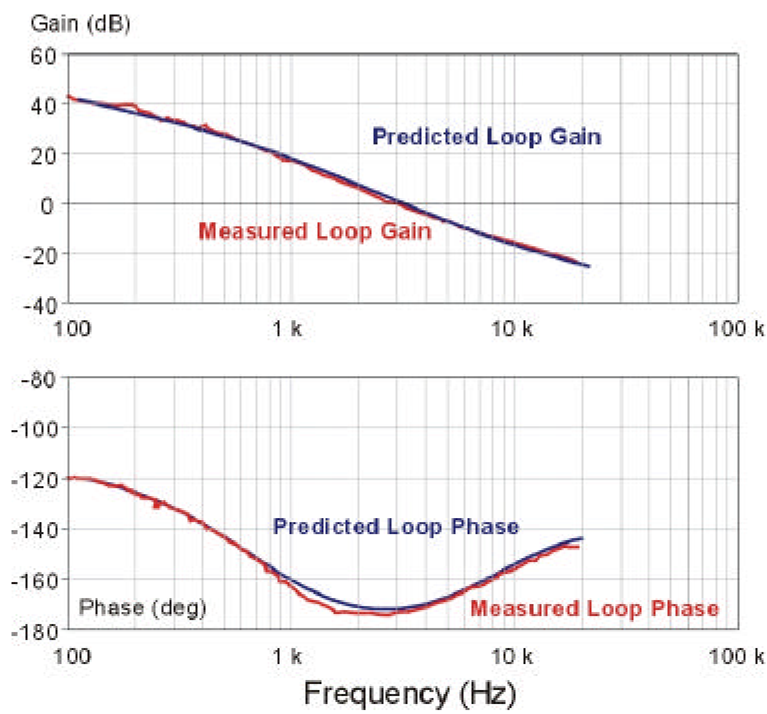


Fig 3: Example Loop Gain Measurement with Predictions

Tips for Successful Loop Gain Measurement

- **Ground the control circuit** being measured whenever possible for both safety and noise immunity. If the circuit is ac-line referenced, use an isolation transformer to provide the power supply input, and ground the circuits appropriately.

- If it is impossible to ground the control circuit, the signals to the Frequency Response Analyzer must be isolated. Do not rely on capacitors to achieve this isolation since they can cause catastrophic failures, especially during transients. Ridley Engineering has differential probes as an optional accessory to the analyzer to provide this isolation.

- Be sure that the instrument has been run through the full calibration menu, including dc offset. If you are using the differential probes, include them in the calibration setup.

- When starting at low frequencies, use a large signal from the Frequency Response Analyzer oscillator (1 V).

- As the sweep frequency approaches the loop crossover frequency, reduce the amplitude of the oscillator signal. Monitor critical parameters such as amplifier outputs to make sure that the control circuit is not being limited due to over-modulation. The latest software with the Model 200 Parallel Analyzer will automatically adjust the injected signal level with repeated loop sweeps.

- When measuring switching power supplies, use the lowest bandwidth (1 Hz) for the best noise rejection.

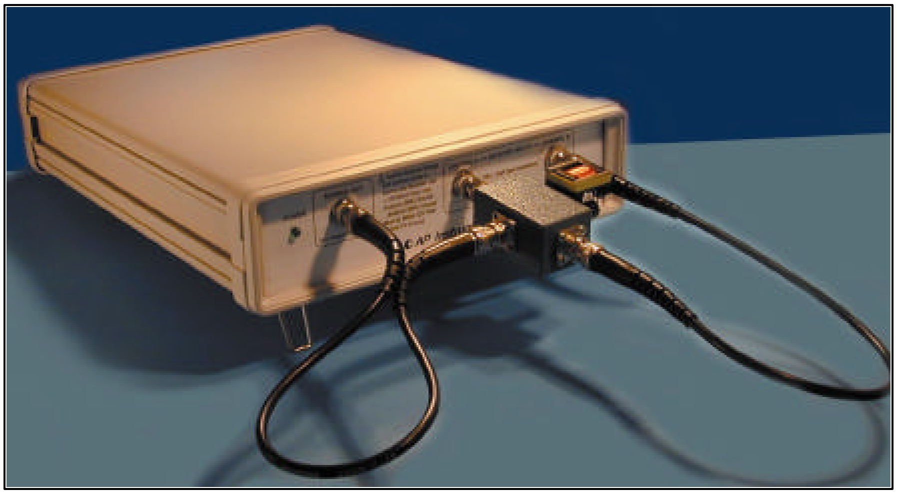
- For final documentation and reports, use the averaging function to produce the smoothest curves.

- Loop measurements above 30 kHz can be difficult due to instrument grounding and high-frequency crosstalk between cables on injected and return channels. This is true of any frequency response analyzer, and great care must be taken to extend measurements beyond this frequency. Keep all cable lengths as short as possible.

- Inject the signal into a low-ripple part of the circuit if at all possible.

3 High Impedance Component Measurement

The setup below shows how to get the most accurate measurements at frequencies up to 15 MHz for relatively large impedances. In this setup, a standard sense resistor is soldered in series with the two-terminal device to be measured. A 1-ohm resistor will allow you to measure impedances from 1 ohm to 100 kOhm with good resolution.



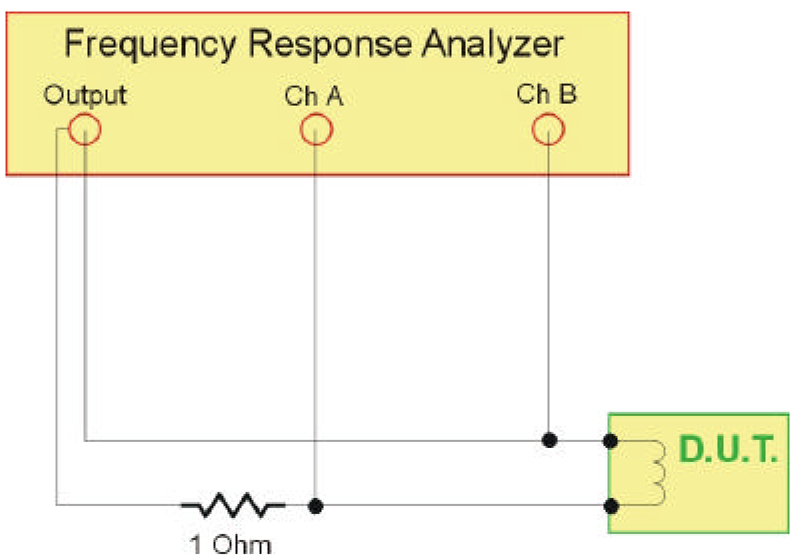


Fig. 4: Measurement Setup #1 - High Impedances 1 Ohm to 100 kOhm

The resulting measurement is the sum of the sense resistor and the device under test, so the sense resistor should be chosen to be smaller than the DUT in the frequency range of interest. With this test setup, and short cables to the Frequency Response Analyzer, device capacitances in the range of 5 pF can be measured at up to 15 MHz.

With the setup above, use the AP 200 Parallel Analyzer in gain-phase mode to plot the impedance. The magnitude of the measurements is in dB, relative to the value of the sense resistor (in this setup, 1 ohm, or 0 dB). Hence 0 dB corresponds to 1 ohm, 20 dB to 10 ohms, etc.

Power Transformer Measurements

The graphs below show example measurements on power transformers. The first is an example of open and short-circuit measurements which allow the extraction of essential component parasitics.

The second curves show how frequency response of a transformer can be used to detect subtle changes in transformer construction which lead to improper operation of a converter circuit. In this case, a flyback transformer measurement is shown with and without proper taping between consecutive layers of the primary winding.

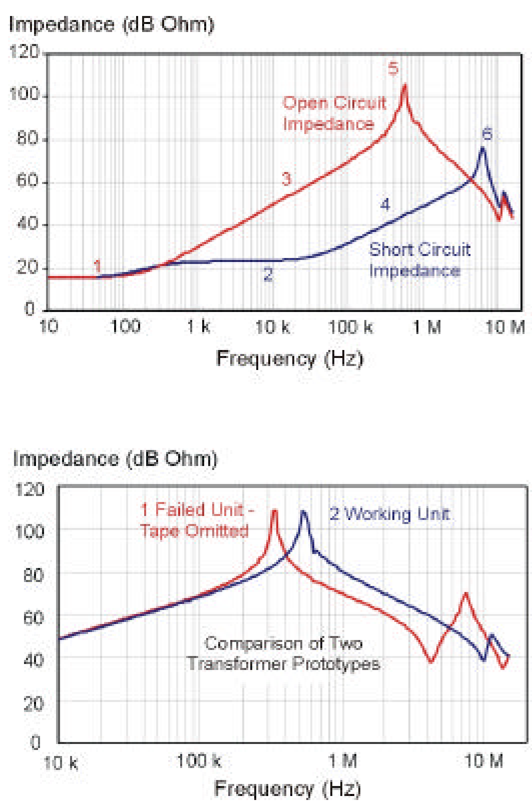
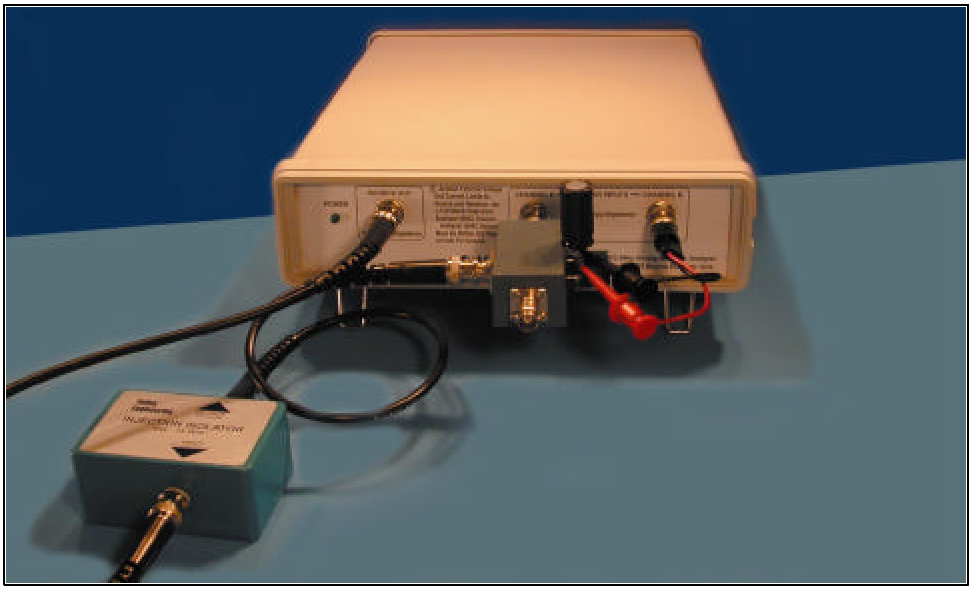


Fig 5: Example power transformer measurements made with the AP 200 Parallel Analyzer

4 Low Impedance Component Measurement

The setup below shows how to get the most accurate measurements at frequencies up to 15 MHz for relatively small impedances. In this setup, a standard sense resistor is soldered in series with the two-terminal device to be measured. A 10-ohm resistor will allow you to measure impedances from 0.01 ohm to 100 Ohm with good resolution.



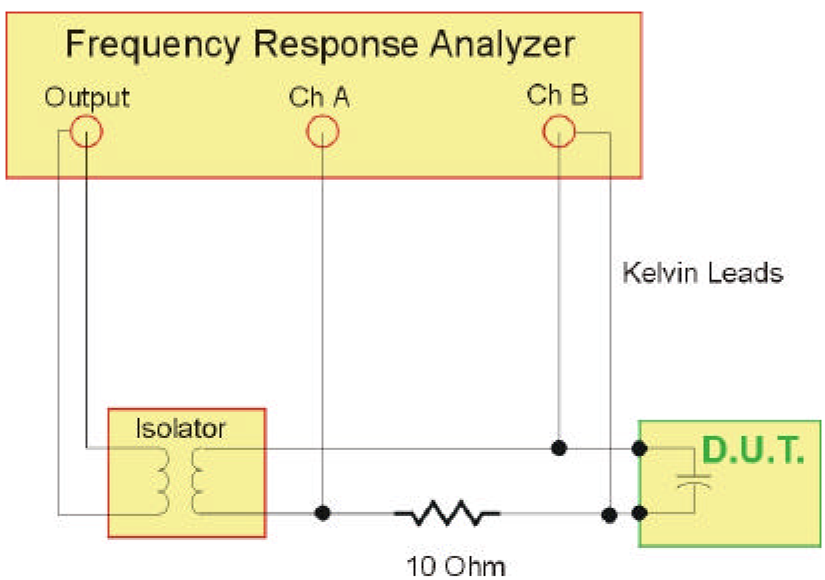


Fig 6: Measurement Setup #2 - Low Impedances 0.001 ohm to 100 Ohm

Note: it is essential to establish a low impedance ground path back to the oscillator for good accuracy. BNC to SHORT clip lead connectors should be used for the input channels.

With the setup above, you should use the AP 200 Parallel analyzer meter in **gain-phase mode** to plot the impedance. The amplitude is now normalized with respect to 10 ohms. Hence 0 dB corresponds to 10 ohms, -20 dB to 1 ohm, -40 dB to 0.1 ohm, etc.

Example Capacitor Impedance Measurements

The curves below show the impedance of three different types of capacitor. (Normalized to 1 ohm). Measurements like this are essential for selecting the proper balance of high frequency, low ESR (and usually expensive) capacitors, and large value, lower cost capacitors.

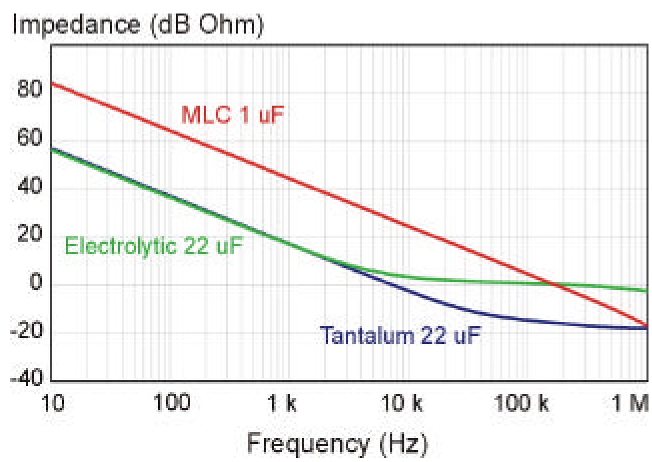


Fig 7: Example capacitor measurements made with the AP 200 Parallel Analyzer

Impedance Measurement Range

The two impedance setups described above allow the AP 200 Parallel Frequency Response Analyzer to cover a wide range of impedance measurements. The approximate limits with the given sense resistors are shown in the graph below. The ranges can be extended if the values of the sense resistors are changed. The values chosen above are selected to cover the most common range of impedances that you are likely to encounter when measuring power circuit components.

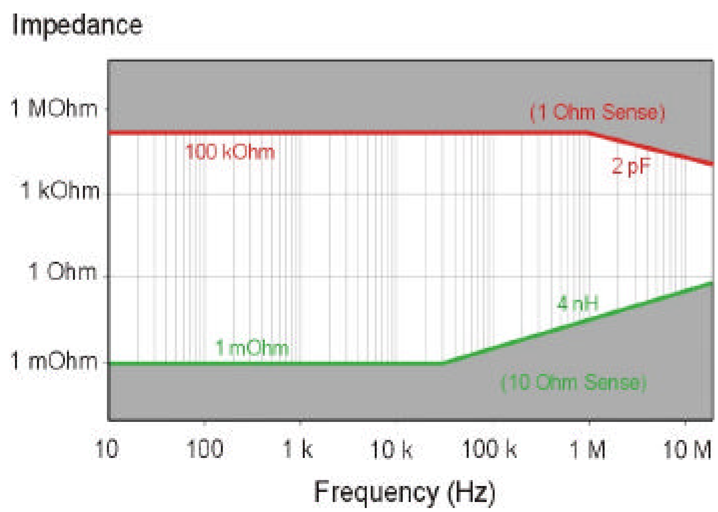
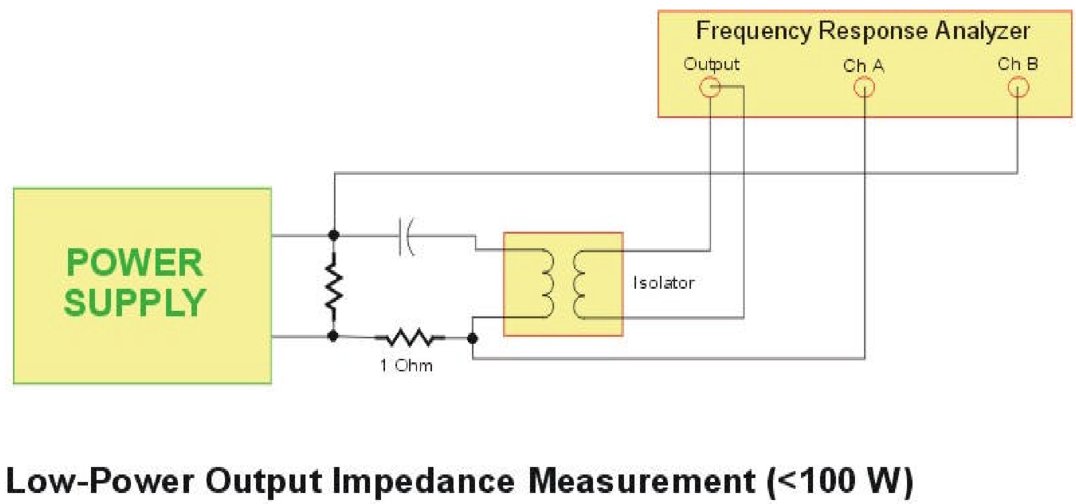


Fig 8: Range of Impedances that can be accurately measured with the selected sense resistors

5 Output Impedance Measurements

The AP 200 Parallel Frequency Response Analyzer can also be used to measure the output impedance of an active circuit such as a switching power supply. The measurement requires the injection of a test current into the output terminals of the supply.

For low power circuits, this can be done with the simple passive circuit shown below. For higher power where a larger signal injection level is needed, an active device (suitable heatsinked) can be used as shown in the lower circuit.



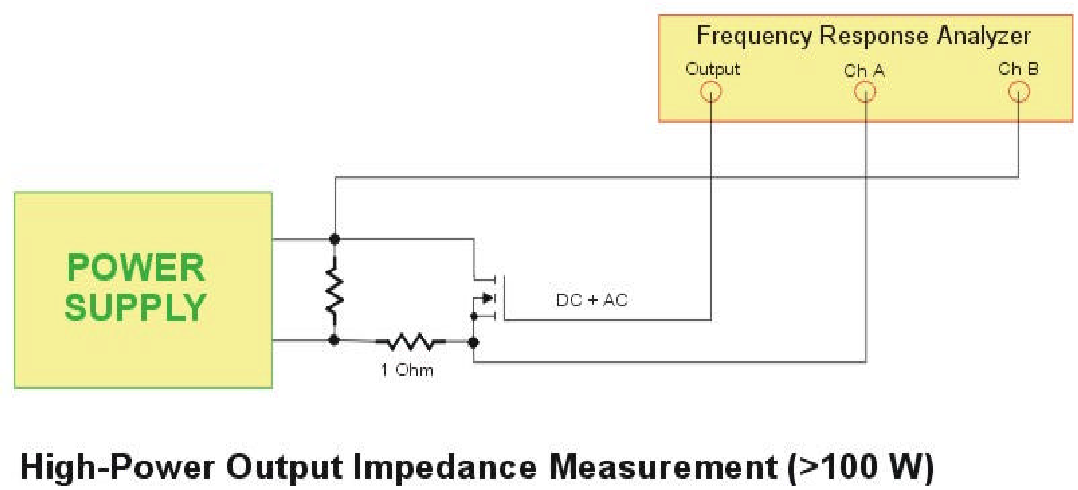


Fig 9: Measurement setups for output impedance

6 Audiosusceptibility Measurement

Line-to-output, or audiosusceptibility measurements can be made with the circuit below. This is the most invasive of all tests, requiring a signal perturbation to be injected on the input bus to the supply. Care must be taken with the test circuit layout, thermal management, and isolation to the analyzer to ensure proper and safe measurements.

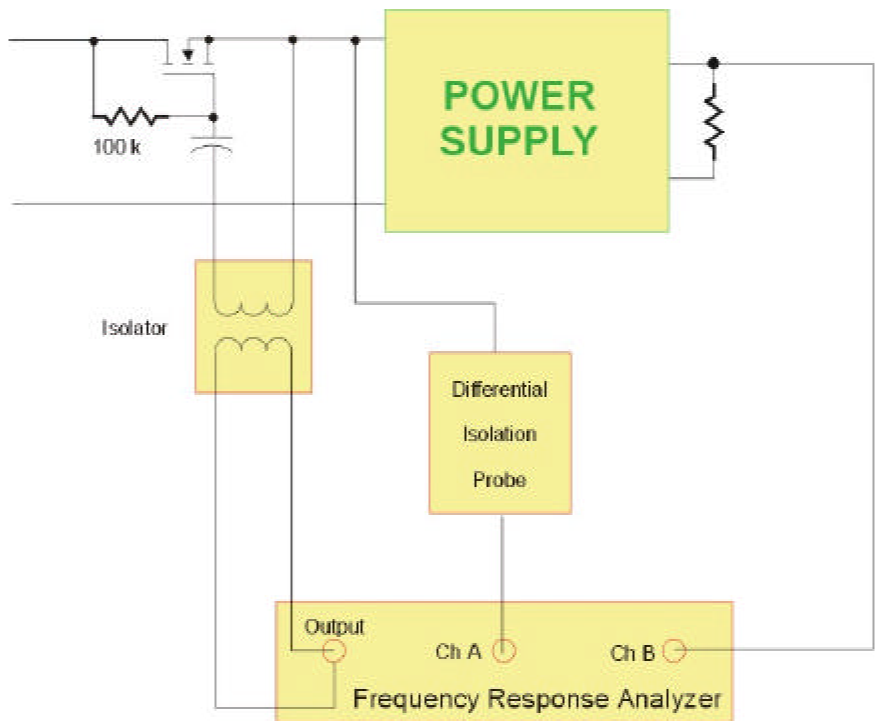


Fig 10: Measurement setups for audiosusceptibility

7 Input Impedance Measurement

The injection circuit for input impedance measurement is the same as for audiosusceptibility. Only the signal measurement point changes, and a differential probe is often needed due to the higher voltages at the input to the power supply.

The magnitude of the current sensing device must be included in the impedance scaling.

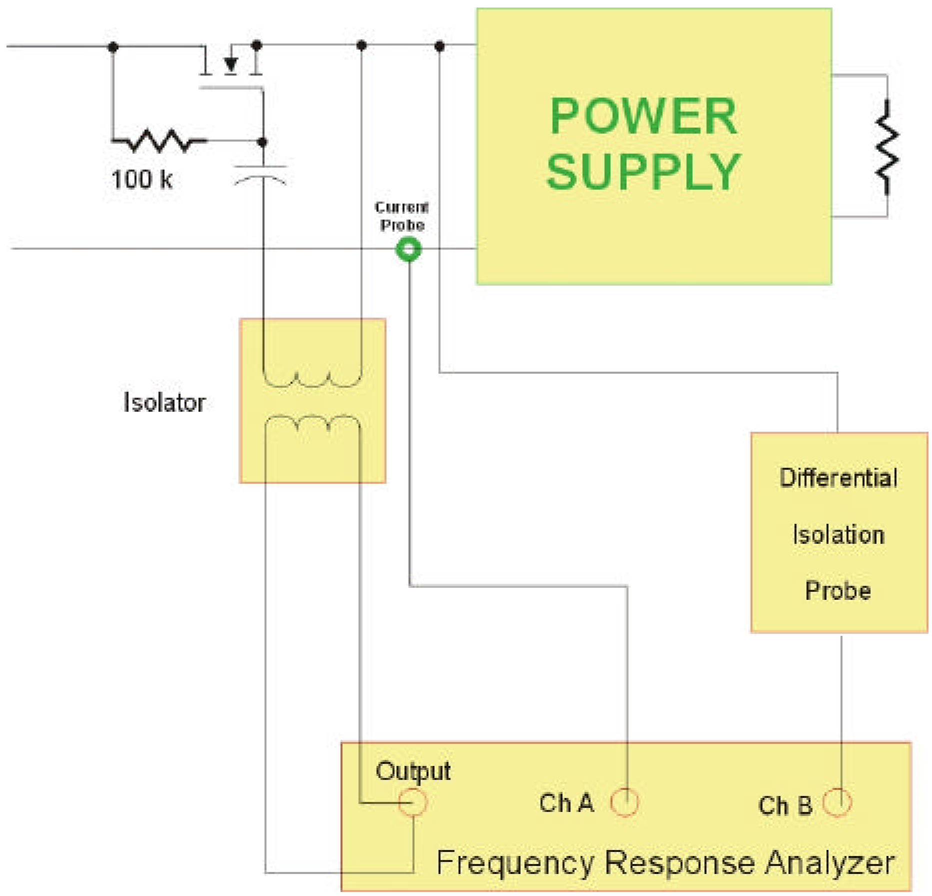


Fig 11: Measurement setups for input impedance

8 Line Current Harmonics Measurement

The AP 200 Parallel Frequency Response Analyzer can also be used as a spectrum analyzer up to 10 kHz to measure the harmonic current into a power supply, or any other piece of electronic equipment. This measurement is essential to design and check conformity to IEC 1000 standards (formerly IEC 555-2). Be sure not to connect the instrument directly to the line to make such measurements. Use a current transformer or some other accurate sensing device to interface safely to the Frequency Response Analyzer inputs. You should also setup a frequency point list (.fpl) to force the analyzer to exactly measure the line harmonic frequencies.

The analyzer is set to measure absolute values when used for this function.

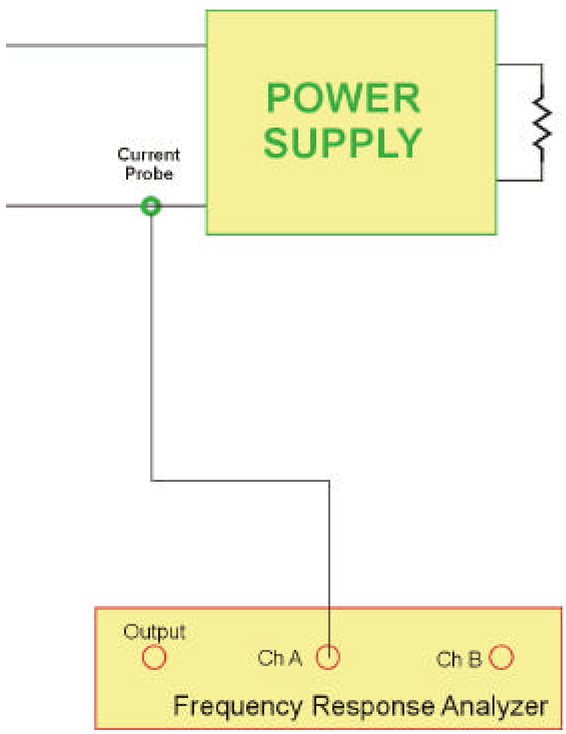


Fig 12: Measurement setups for line harmonics up to 10 kHz

Please note that this is not the intended function of the analyzer – it cannot replace the full function of a spectrum analyzer. But it does allow you to quickly characterize the line harmonic spectrum with a reasonable degree of accuracy before proceeding with formal (and more expensive) compliance testing in a fully calibrated and certified test lab.

The analyzer uses an IF bus above 10 kHz, and will not function properly as a spectrum analyzer at higher frequencies.

AP 200 Parallel Optional Accessories

Signal Injection Isolator

An optional accessory for your AP 200 Parallel Frequency Response Analyzer is an injection isolator for coupling the oscillator signal into your circuit. The specifications for this isolator are as follows:

Frequency Range:	5 Hz to 15 MHz (+/- 2 dB)
Attenuation:	-10 dB into 50 Ohm Load, +/- 2 dB
Input Signal:	1 V rms at 5 Hz, 1.77 V rms 10 Hz to 15 MHz
Isolation Withstand:	240 VAC
Protection:	Input and output fused, user accessible (0.5 A fuse). Isolator is transformer coupled - application of dc voltage may open fuses.

Differential Isolation Probes

Differential Isolation Probes are also available as an accessory for your AP 200 Parallel analyzer. These probes are useful for high voltage measurements, or measurements on systems with separate grounds. They will also provide a high degree of protection for the inputs of the analyzer.

To use these probes, simply connect them to the circuit with the red and black clip leads. Connect the BNC cable to the Channel A and Channel B of the analyzer. There is no need to connect the ground cable, although you may experiment with grounding this if you are experiencing high noise levels.

You should run the analyzer calibration with the differential probes in place if you plan on using them for measurements

Partial specifications (Complete specifications are included with probes):

Frequency Range:	DC to 25 MHz (+/- 3 dB)
Output:	1/20 or 1/200 ratio selectable
Max Differential Mode:	+/- 140 V for 1/20 ratio +/- 1400 V for 1/200 ratio
Max Common Mode:	+/- 1400 VDC (or 1000 VAC rms)
CMRR:	50 Hz -86 dB; 20 kHz -66 dB; 200 kHz -56 dB