Webinar Wednesday, March 10, 2021 10 am PDT

Downloads: FrequencyResponseMasterclass.pdf

Ridley Engineering

Frequency Response Measurements – the Players

Hedrik Wade Bode – Gave engineers the greatest possible gift with his Bode plot.

Dr. David Middlebrook. I took his Structured Analog Design course in 1981 and this launched a lifetime of measuring loops in the lab.

Dr. Fred Lee – created one of the best power electronics centers in the world with a strong emphasis on labs and measurements.

Dr. Vatché Vorpérian – one of the best minds in our industry, responsible for the PWM switch model amongst many other things.

Arthur Nace – retired aerospace engineer and programmer who automated LTspice models for us. Our longest user of RidleyWorks.

John Beecroft – tester and proponent of RidleyWorks for over 20 years. Ridley Course instructor.

Pathological Fear of Bode

Wikipedia for Bode Plots

$$y(t) = \int_0^t h(\tau)u(t-\tau)d\tau \ ,$$

of the input signal with the inverse Laplace transform of the transfer function $h(t)$. Assuming that the signal becomes periodic with mean 0 and period
we can add as many periods as we want to the interval of the integral

$$\lim_{t\to\infty} y(t) = \int_0^t h(\tau)u(t-\tau)d\tau \ + \int_t^{t+T} h(\tau)u(t-\tau)d\tau + \ldots = \int_0^\infty h(\tau)u(t-\tau)d\tau \ .$$

Thus, inserting the sinusoidal input signal one obtains

$$\lim_{t\to\infty} y(t) = \int_0^\infty h(\tau)\sin(\omega(t-\tau))d\tau \ = \int_0^\infty h(\tau)\mathrm{Im}\left(e^{\mathrm{j}\omega(t-\tau)}\right)d\tau \ .$$

Since $h(t)$ is a real function this can be written as

$$\lim_{t\to\infty} y(t) = \mathrm{Im}\left\{e^{\mathrm{j}\omega t}\left[\int_0^\infty h(\tau)e^{-\mathrm{j}\omega\tau}d\tau\right]\right\} \ .$$

The term in brackets is the definition of the Laplace transform of h at $s = \mathrm{j}\omega$. Inserting the definition in the form $H(\mathrm{j}\omega) = |H(\mathrm{j}\omega)|\exp(\arg H(\mathrm{j}\omega))$
output signal

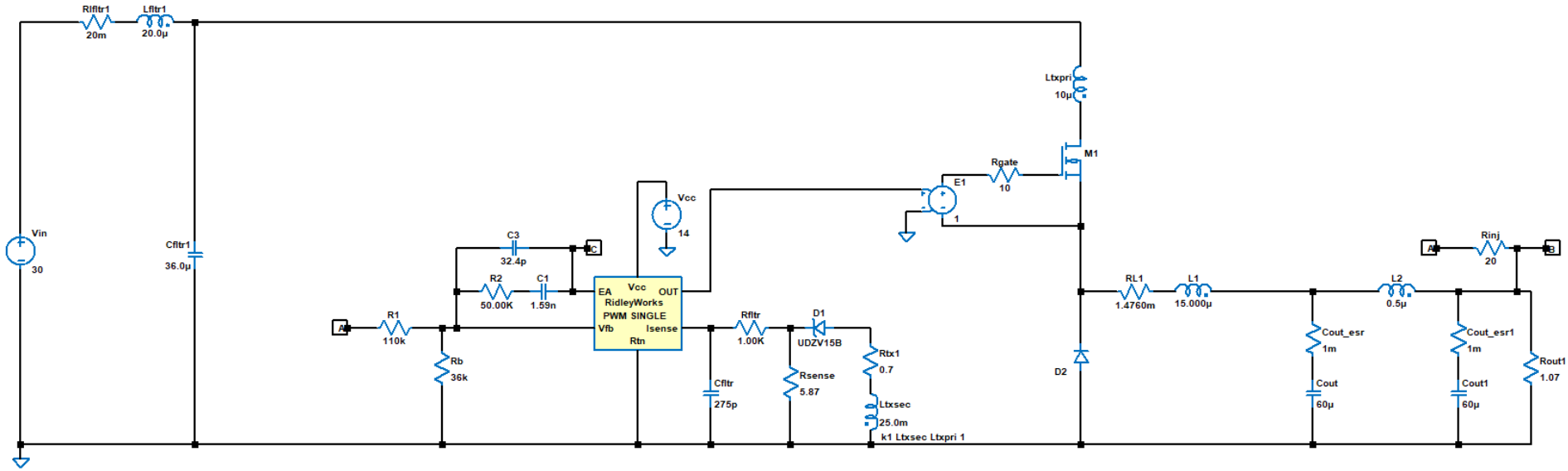
$$\lim_{t\to\infty} y(t) = |H(\mathrm{j}\omega)|\sin(\omega t + \arg(H(\mathrm{j}\omega)))$$

stated in Eqs.(1)-(2).

The Magic of Bode

APEC1 BUCK FILTERS

Vin = 30.0, Vout1 = 16.0V @ 15.0A, buck converter, current-mode



8 state variables

23 state variables if all ac winding resistance models included – these can really affect performance

46 state variables if core loss models are included….

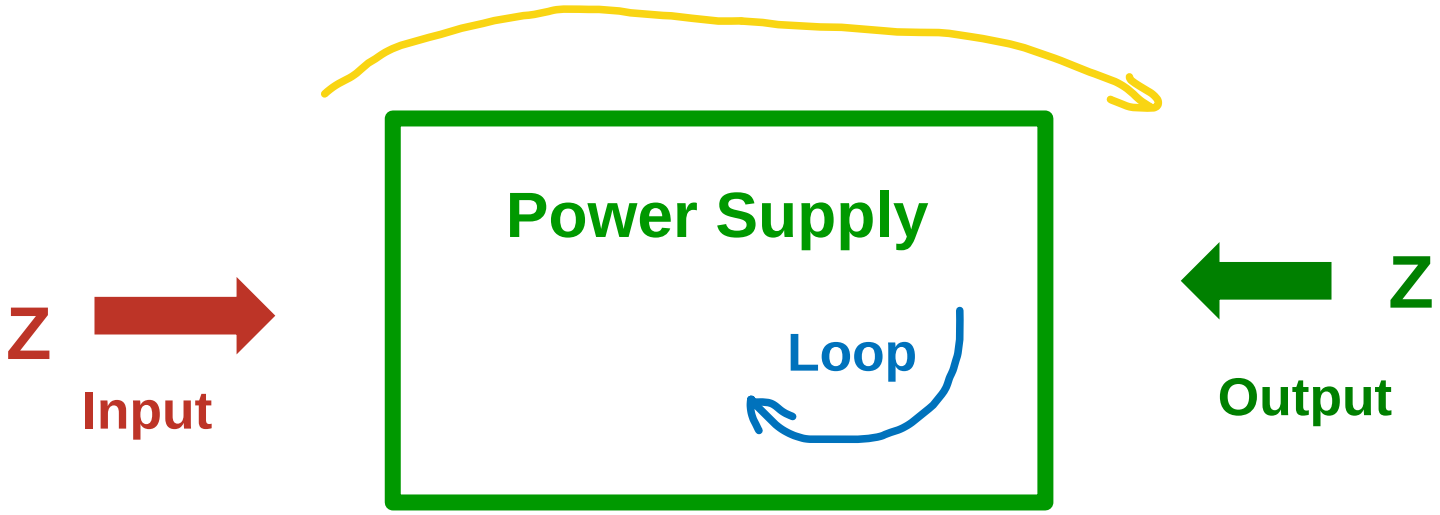
…….and this is just a buck converter.

Frequency Response Analyzers

1. Signal Generator/Scope Manual Frequency Response Measurement
2. HP narrowband voltmeter (Middlebrook)
3. Venable
4. Bafco 916XH (10 V source)
5. HP4194A
6. HP4195 (55k 1985)
7. HP3277
8. AP102A
9. AP102B
10. AP200
11. AP300
12. AP310
13. **RidleyBox 1000**

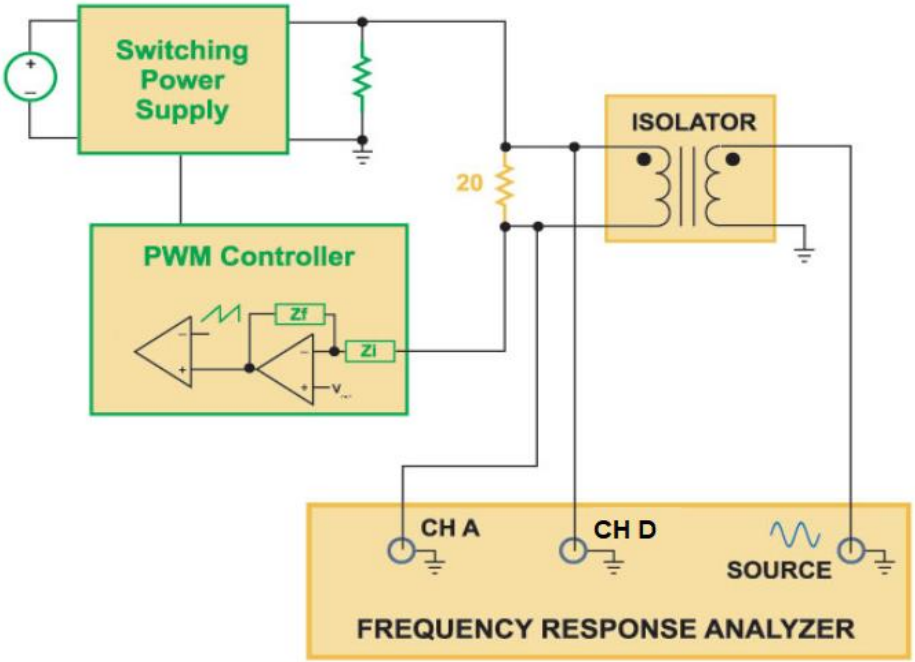
Scope: $2500
Isolator: $600
Computer: $1000
Design Software: $2400
Analyzer: -$500

The Four Essential Frequency Response Measurements



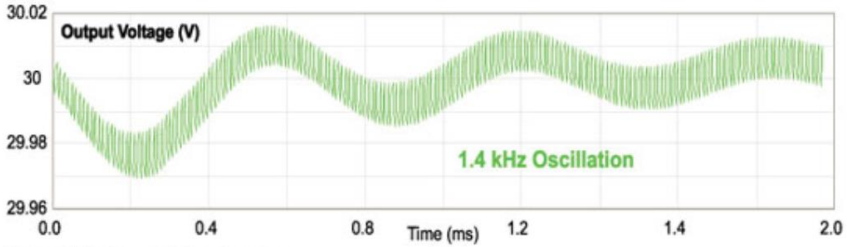
1. Control Loop Measurements
2. Output Impedance Measurements
3. Audiosusceptibility or PSRR Measurements
4. Input Impedance Measurements

MiddleBrook Insisted - Always Measure the Loop!
The Most Crucial and Rugged Measurement

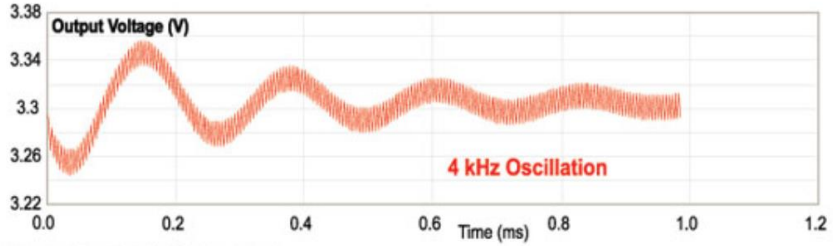


1. Design optimization
2. Manufacturing build verification
3. Maximize performance

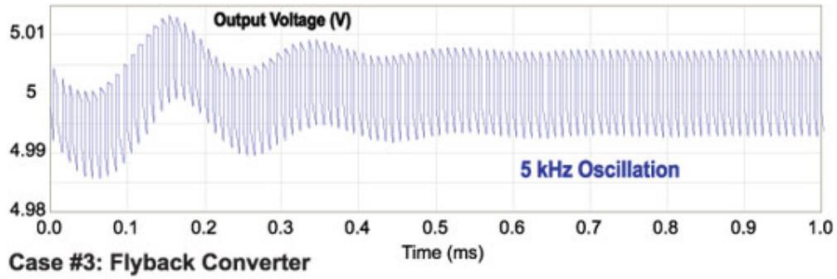
Don’t Rely On Step Load Testing



Case #1: Boost Converter



Case #2: Buck Converter



Case #3: Flyback Converter

[Read this Article]

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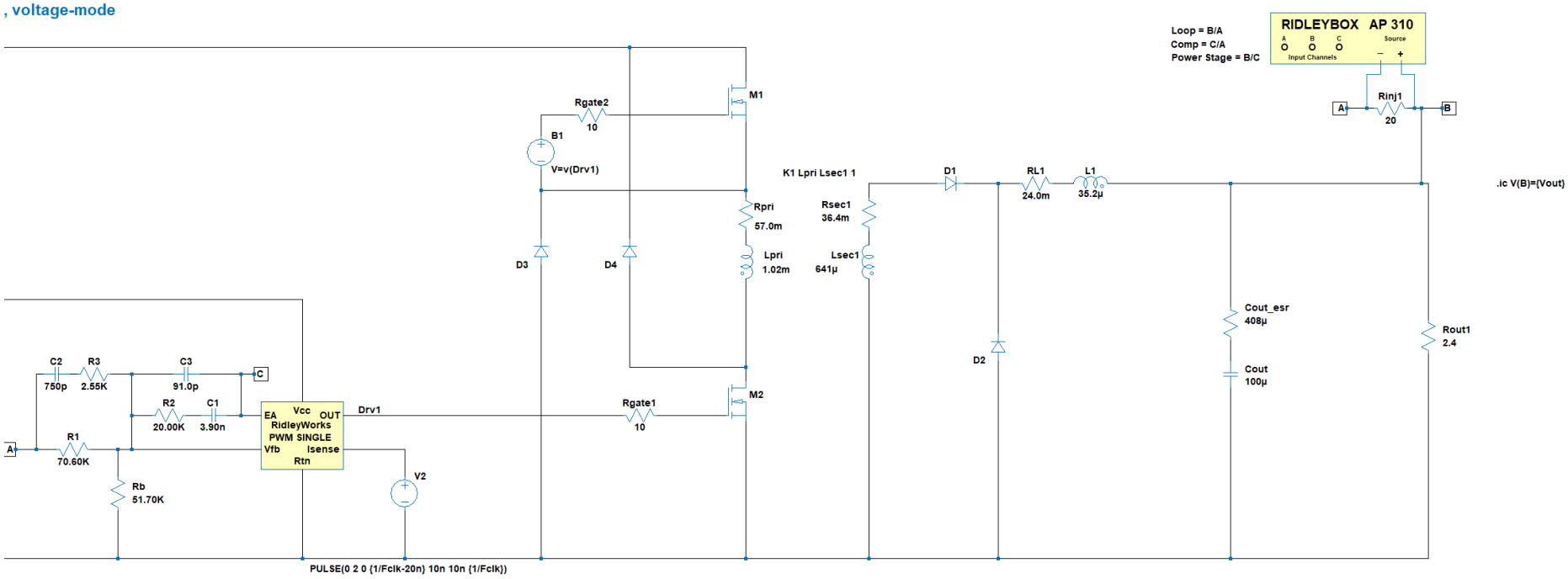
LTspice Can Sweep the Loop
Instructive to Understand the Process



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Make It Easy to Measure for the Engineer

Put the injection resistor in the design

Don’t make me do this

Not even thinking about this!

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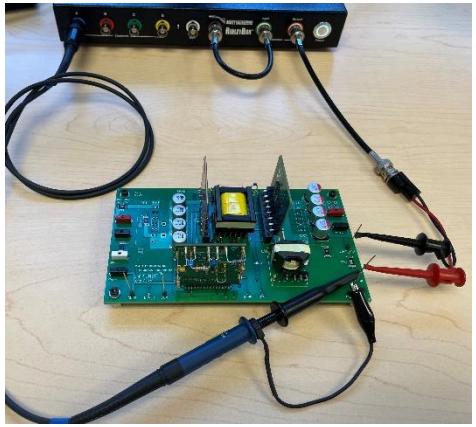
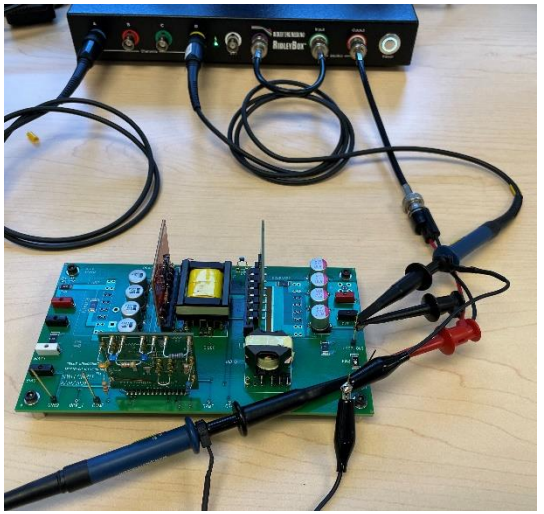
Loop Measurement Setup

1. Connect to the isolator

2. Inject into loop

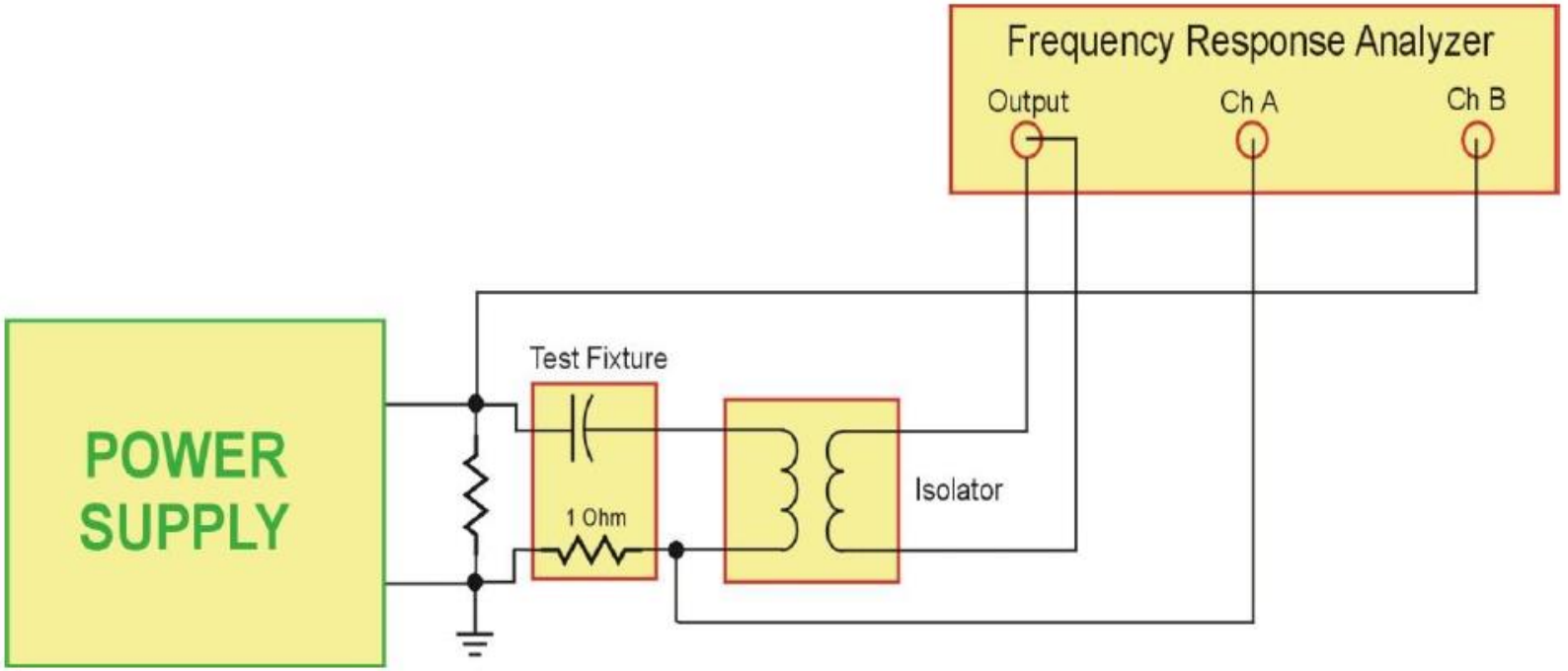


3. Connect Loop Input Channel A



4. Connect Loop Output Channel D

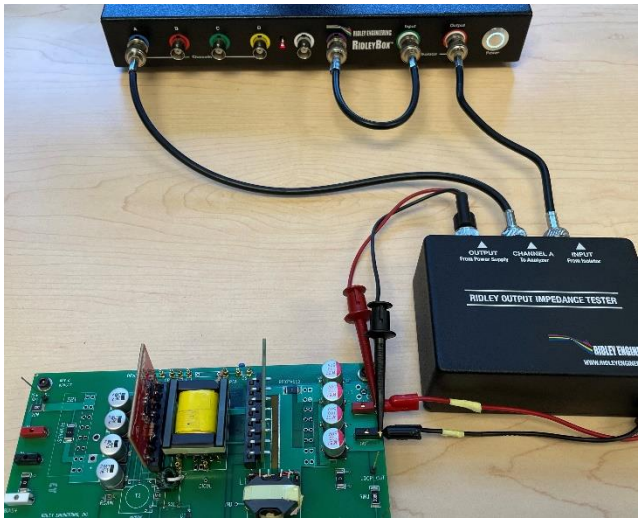
Output Impedance Test Setup



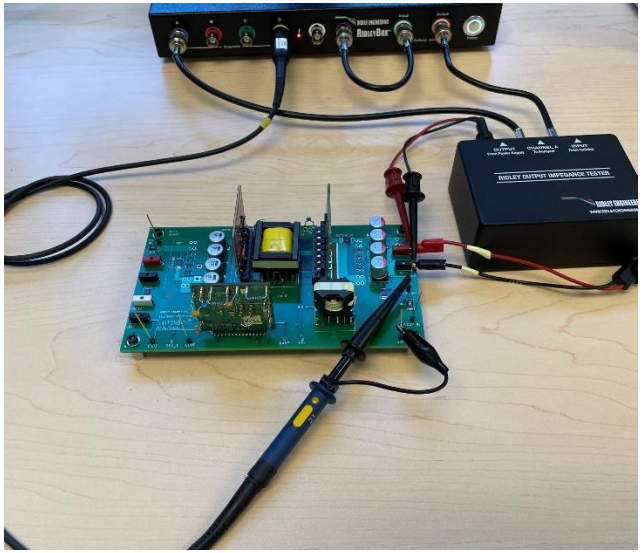
Output Impedance Test Setup

1. Connect isolator to Zout Tester

2. Connect Current Sense to Channel A



3. Inject into Output Terminals



4. Measure Output with Channel D

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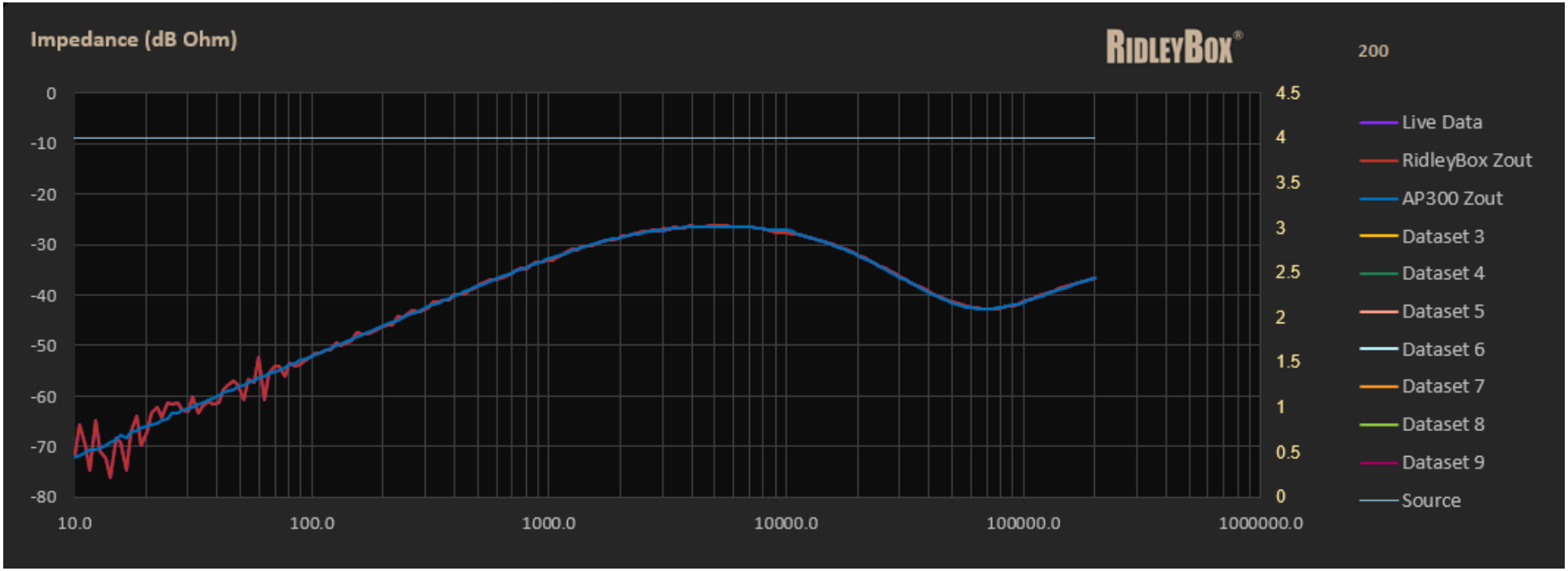
Output Impedance Measurement Comparisons
RidleyBox and AP310



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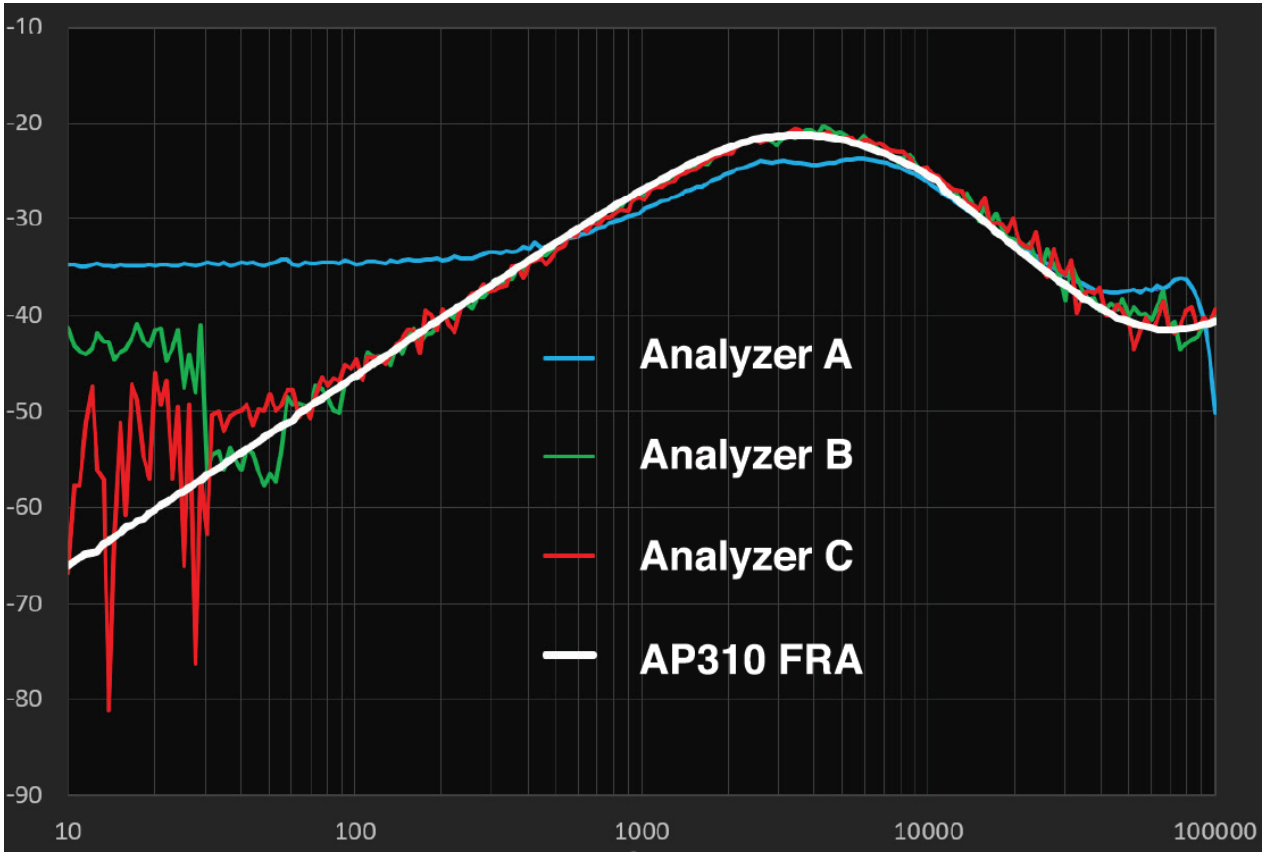
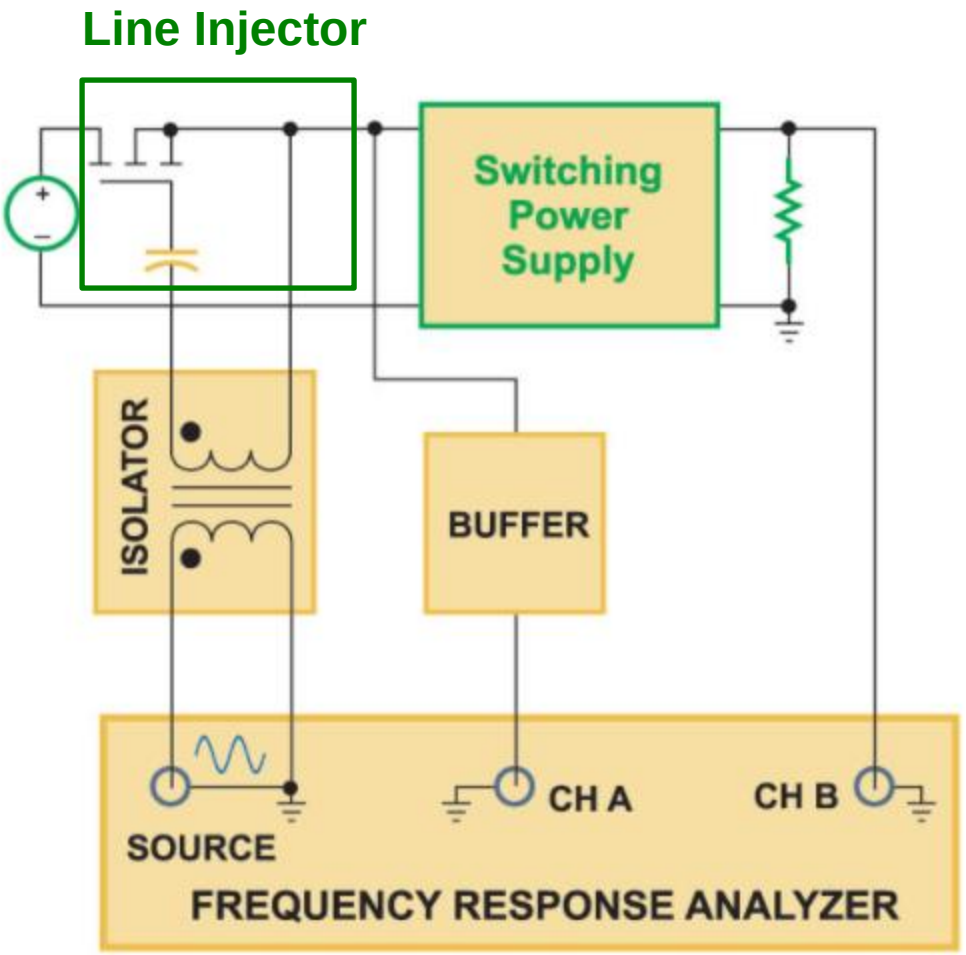
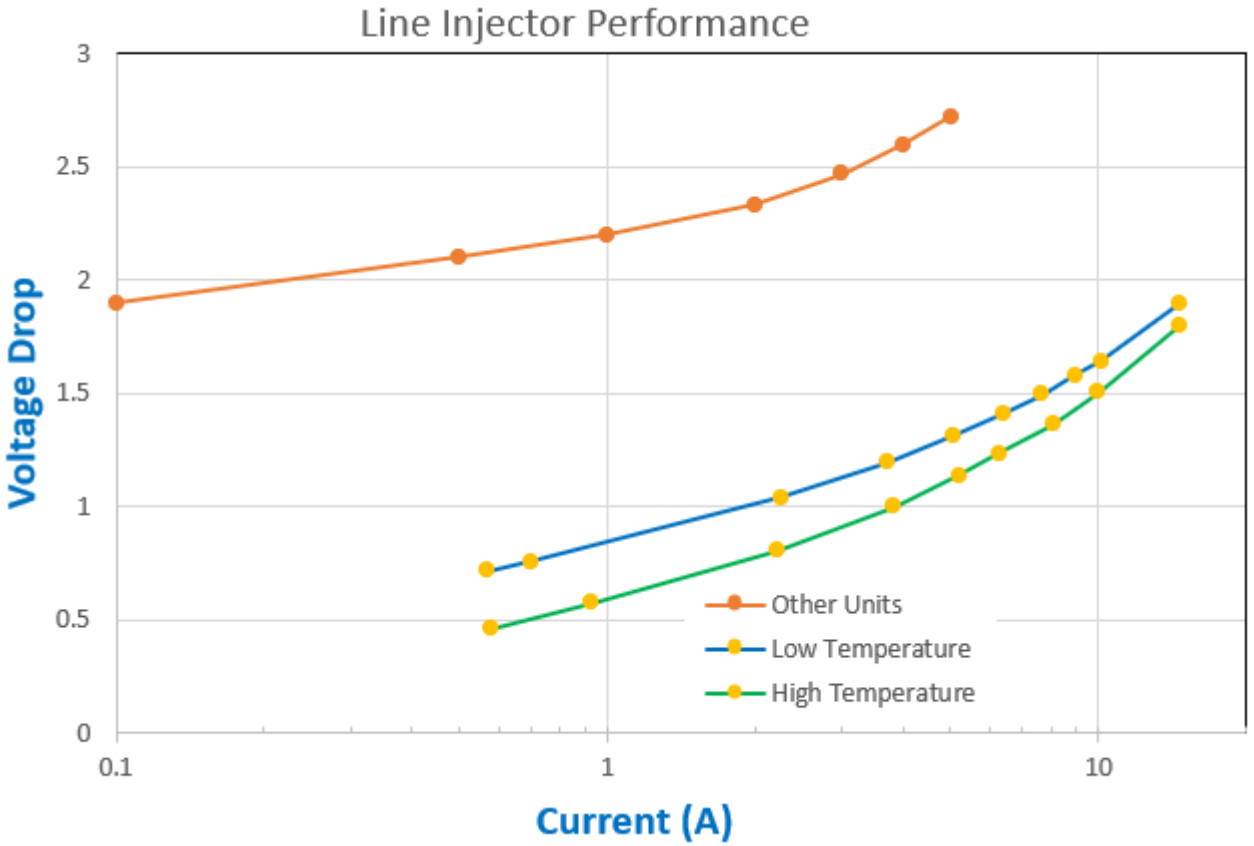
Output Impedance Measurement Comparisons
AP310 and Other Analyzers



PSRR (Audiosusceptibility) Line Injection Test Setup

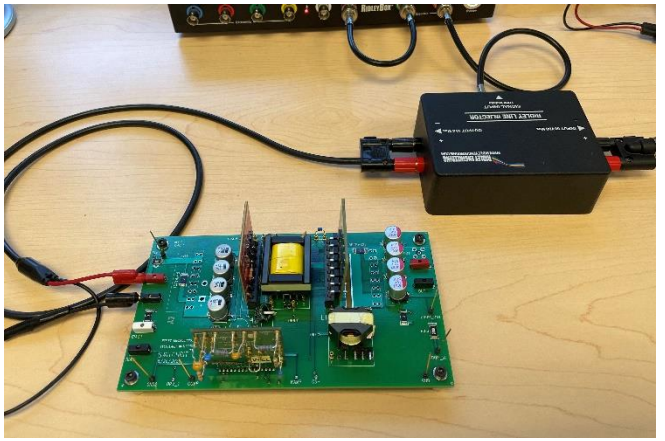


PSRR (Audiosusceptibility) Line Injector

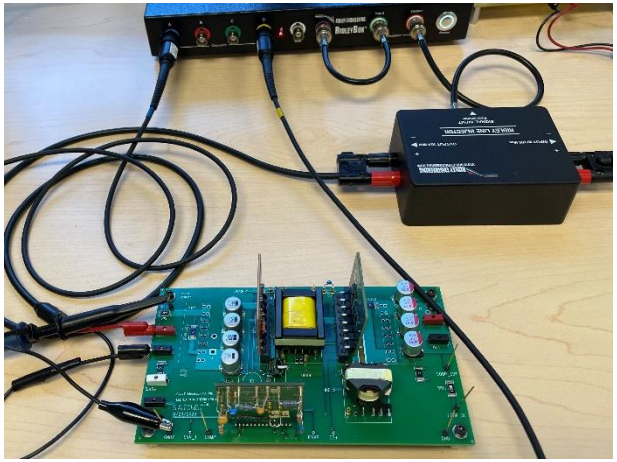


PSRR (Audiosusceptibility) Line Injection Test Setup

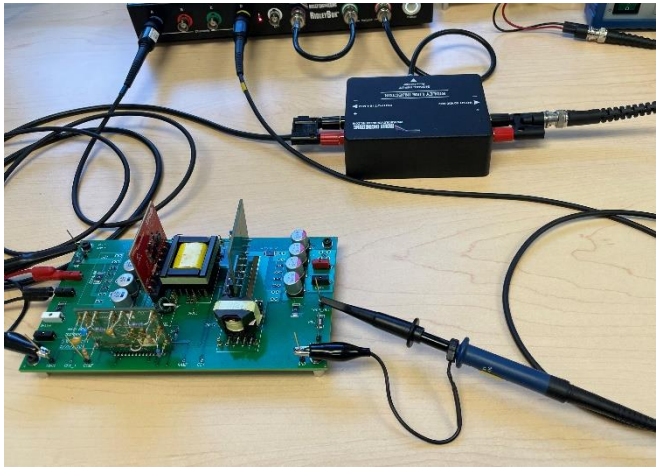
1. Connect isolator to Line Injector



2. Connect Line Injector to Input



3. Connect Channel A to Input



4. Connect Channel D to Output

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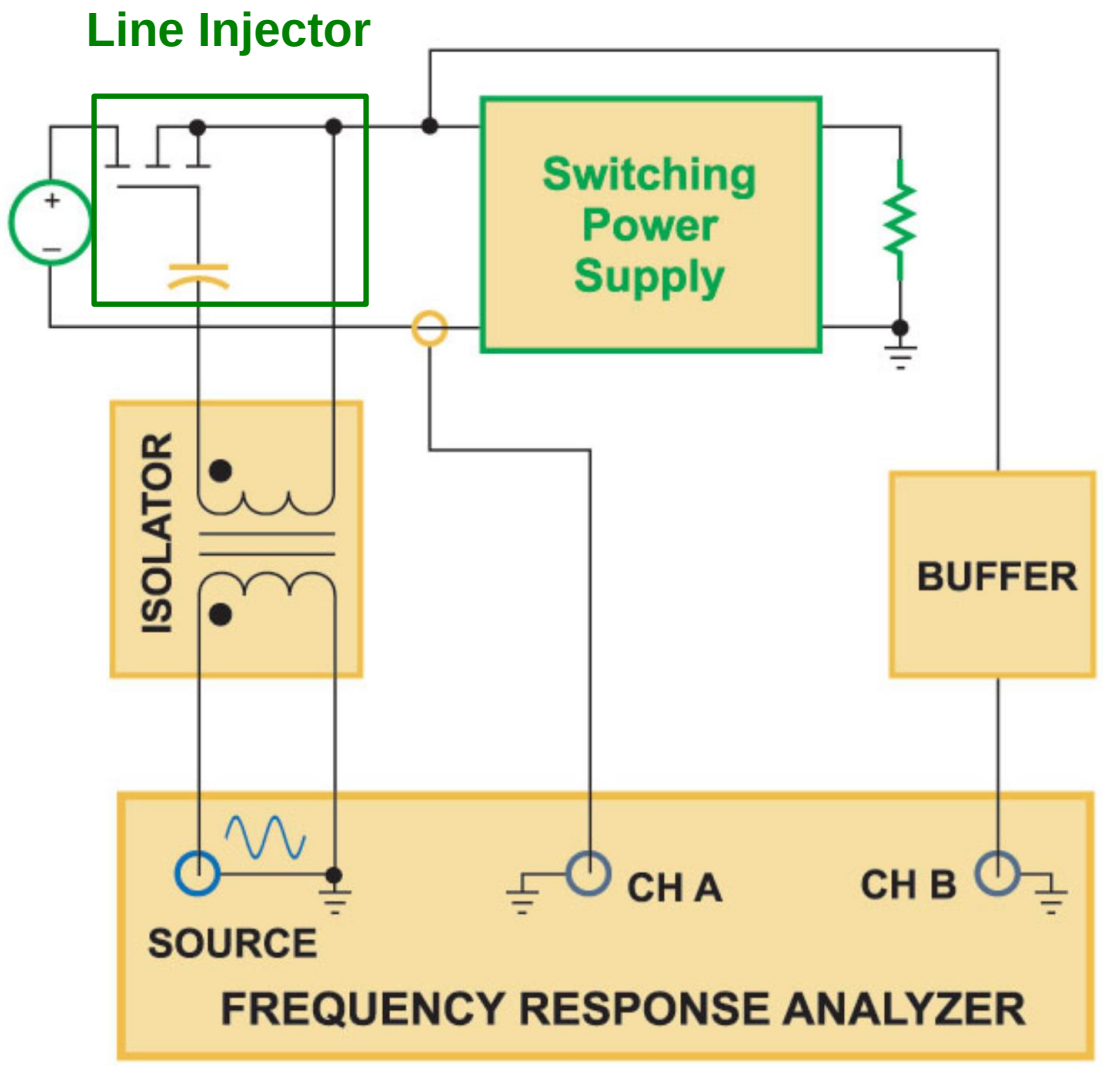
Input Impedance Test Setup



Hands-On Design Workshops

NEW! 4-Day Workshop

Online Format With 'live' feed to our instructors

Online 4-Day Workshop: DEC 7-10, 2020 - INDIVIDUAL

$3,000

NEW! 4-Day Workshop

Online Format With 'live' feed to our instructors

Online 4-Day Workshop: DEC 7-10, 2020 - TWO Colleagues

$5,000.00

Next Course Date

May 17 -21

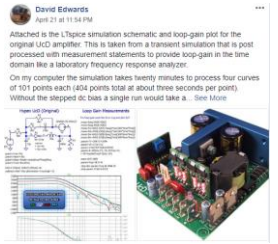
This is our brand-new workshop format where we ship you everything you need to design, test, and learn. Magnetics kits with cores, bobbins and wire, custom computer and software, oscilloscope, frequency response analyzer, power supplies, load banks, test boards and parts kits are included. It's a learning experience like no other where we teach real-time and monitor each of your individual test stations from our base in California.

All attendees receive course notes and their personal copy of RidleyWorks to greatly accelerate your design process.

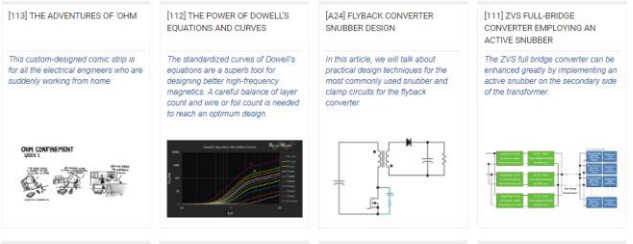
RIDLEY WORKS®

Email info@ridleyengineering.com
For full demo

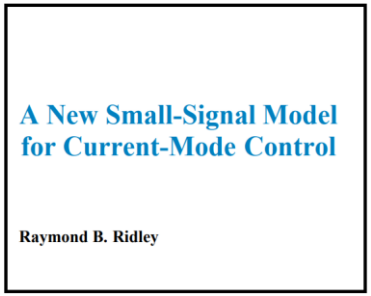
Power Supply Design Center Facebook Group



Frequency Response Analyzers

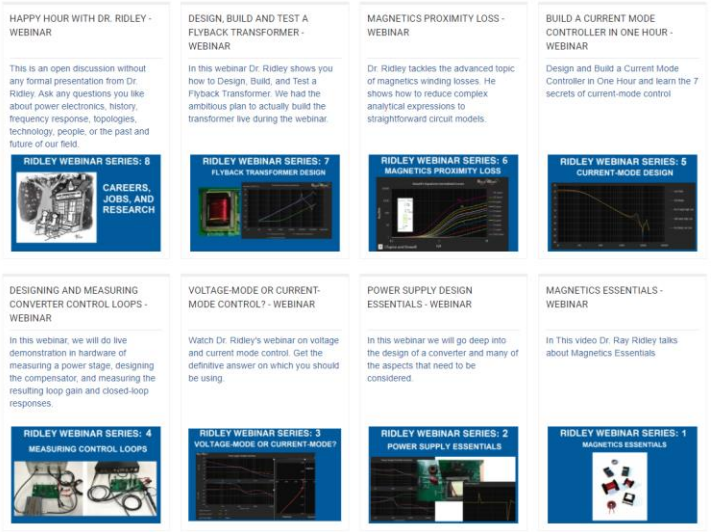


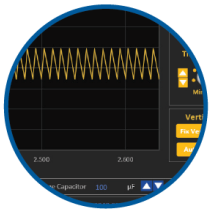
Power Supply Design Center Articles



Free Book

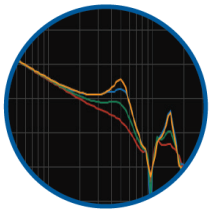
Webinar Series





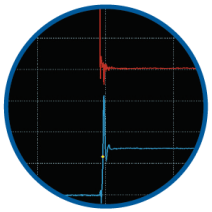
RidleyWorks® Lifetime License

- Power Stage Designer
- Power Stage Waveforms
- Magnetics Designer
- Transfer Function Bode Plots
- Closed Loop Design
- Automated FRA Control
- LTspice® Automated Link
- PSIM® Automated Link



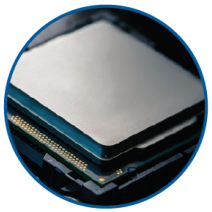
4-Channel Frequency Response Analyzer

- Frequency Range 1 Hz - 20 MHZ
- Source Control from 1 mV - 4 V P-P
- Built-In Injection Isolator
- Bandwidth 1 Hz - 1 kHz
- Automated Setup from RidleyWorks®
- Drect Data Flow into RidleyWorks®



4-Channel 200 MHz Oscilloscope

- Picoscope® 5444D 4-Channel Oscilloscope
- 200 MHz Bandwidth
- 1 GS/s at 8-bit res; 62.5 MS/s at 16-bit res
- Signal Generator up to 20 MHZ
- Computer Controlled



Embedded Computer

- Intel® Computer with 32 GB RAM, 256 GB SSD
- Intel® HD Graphics 620
- Integrated Dual Band Wireless, Bluetooth 4.2
- Dual HDMI and USB Ports, Ethernet

Differential Probes

Line Injector

Accessories

Output Impedance

Impedance Test Kit

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