RidleyWorks™

Release 11

User Manual 64 and 32-Bit Versions

Manual Version 11.6
May 18, 2018

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1 Introduction to RidleyWorks™

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. Features of **RidleyWorks™**, Release 11 include:

- **Power stage designer**
- **Magnetics designer** (included in full version, not in Control and Simulation version.)
- **12 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.
- **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 and coefficient 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
- Power stage loss and stress analysis for all major components
- Switching loss analysis for power FETs and IGBTs
- Control design and analysis on a single power stage schematic
- Library of cores for transformers and inductors

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 **3800+** design equations involved in arriving at the solution.

Level 1: Basic Design

At this level, you can simply input the power requirements for your circuit. When you click "OK", the entire converter, including control loop, is designed for you. The components are chosen for you based on your data, and these are working values which you can put into hardware with confidence. You can then examine the design with the simulations of RidleyWorks™, or convert designs to LTspice files with our **SPICELaunch™** feature.

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, you will look carefully at the selected values from RidleyWorks™, and change some of them 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 their 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. You can view the transformer or inductor on the main design schematic and

1. Choose from simplified parameters and refer to a magnetics design house for completion;
2. Choose your own cores, wire, and other components and give the completed design to a manufacturer for production; or
3. Design the magnetics from the ground up using your own parameters and knowledge.

Regardless of your design experience, RidleyWorks™ allows you to check and cross-check all parameters and results. You can 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 Four-Day Power Supply Design Courses.

For more valuable learning about power supply design, please also visit our Power Supply Design Center.

1.1 Computer System Requirements (PC-Based)

To run RidleyWorks™ effectively, any modern computer with at least **Excel 2013 or later** installed will work. The RidleyWorks™ code is extremely efficient, and it does not need a high-powered computer. It is also very compact, taking up only 13 MB of disk space.

You can select the **32-bit or 64-bit version of Excel** when installing.

RidleyWorks™ will work with Windows XP, Windows 7, Windows 8, or Windows 10.

1.2 Computer System Requirements (MAC-Based)

Microsoft Office is available to run on the MAC, but Excel does not work as it should. You will be able load RidleyWorks™, but the formatting will not show everything properly.

In order to use RidleyWorks™ on the MAC, you will need to install a Windows partition and the normal PC-based version of Excel (either **32-bit or 64-bit**).

1.3 RidleyWorks™ Software Download

The latest version of RidleyWorks™ is available for download at

http://ridleyengineering.com/software-ridley/download-RidleyWorks.html

If you are installing for the first time, you should download the full install version, and if you are upgrading, download the update version.

In order to download the software, you will need a software product key which looks like

RIDLEYWORKS-XXXX-XXXX-XX

1.4 RidleyWorks™ Software Installation

Overview

Install **RidleyWorks™** in **c:\Users\<username>\Documents** directory

Install **LTspiceXVII** in the default directory. You should see library files installed in **c:\Users\<username>\Documents** directory

Detailed Procedure

1. If you have an earlier version of RidleyWorks™, you should first remove it using the Windows Uninstall utility.
2. You should have downloaded a zip file RIDLEYWORKSINSTALL on your computer. Inside this zip file, you will see the installation file:

   RIDLEYWORKSINSTALL.EXE
3. Double click on the RIDLEYWORKSINSTALL application. This will install the RidleyWorks™ software in your Documents folder.

   In the target directory, you should see the following files when the installation program is done:

   RidleyWorks11xx.xlsm
   Transfer.xlsm
   ridleyworks_to_ltspice.xlsm

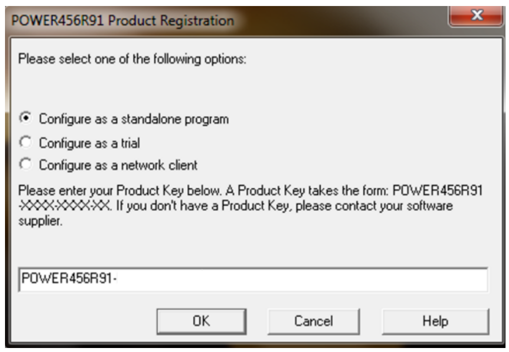
   You will also see a Config directory which contains the license files:
   RIDLEYWORKS.dll
   RIDLEYWORKS.dll.cm
   RIDLEYWORKS dll.cm.ini
   RIDLEYWORKS.dll
   RIDLEYWORKS.dll.cm
   RIDLEYWORKS dll.cm.ini
   CMInstall.exe

   The filename in blue with the extension .xlsm is the main RidleyWorks™ program which will run under Excel. The six files shown in green contain the permission code to work with your specific password for the program, provided to you when you purchased RidleyWorks™.

   If you do not see all of the six green files in your directory, the software will not be allowed to run. In this case, right click on the filename shown in red, and select **Run As Administrator**. Answer OK to any questions, and at the end of the process, the extra green files in the list above should appear in the directory.

4. To use the SPICELaunch™ feature of RidleyWorks™, you will need to install LTspiceXVII. You can download that from [Linear Technology's site](). Please install LTspicexvii in the c:\Users\<username>\Documents folder (this is usually the default.) Additional LTspice file and subcircuits will be placed in the appropriate folders on your computer when you install RidleyWorks™ in step 3 above.

5. Double click on the blue file name to launch RidleyWorks™. When the program begins to load, you may get the message that it contains Macros. Click **Enable Macros**. The first time that you load RidleyWorks™, there will be a registration process.



Select the file to be configured as a standalone program and enter the password which you should have received upon purchase. After this, you will be asked to enter registration information, including address and contact information.

1.5 RidleyWorks™ Software Upgrade

If you have already installed RidleyWorks™ Release 10, select the upgrade version at http://ridleyengineering.com/software-ridley/download-RidleyWorks.html

This is a zipped excel file and it should be unzipped and placed in the same directory as the previous version of the software that you had.

1.6 Loading Workbooks

After registration, Excel will then proceed to open the specified workbook, and a page like that shown in Fig. 1.1 will appear on your screen after a few seconds. Once you see this screen, and the words "License Verified" in the bottom left corner, your product is fully registered.

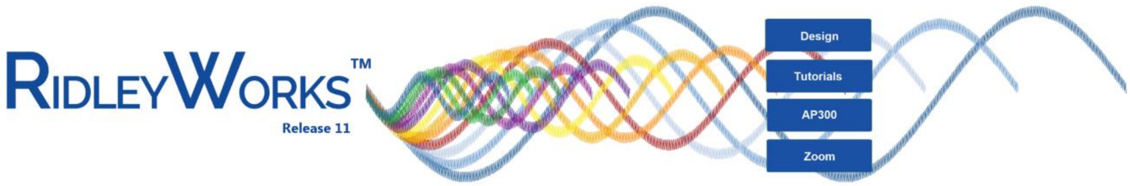


Fig. 1.1: RidleyWorks™ Guide Page

To make sure sizing is correct for your display, click on **Zoom,** and select the option that fit your system. The pages will fit optimally on the screen when you select the toolbars option. You can also use the zoom slide bar at the bottom right to adjust individual worksheets.

1.7 Saving Workbooks

Your design in RidleyWorks™ can be saved just like any Excel workbook. It is recommended that you save a project under a different name from the original file. To do this, click on File Save As, and specify a name for your project.

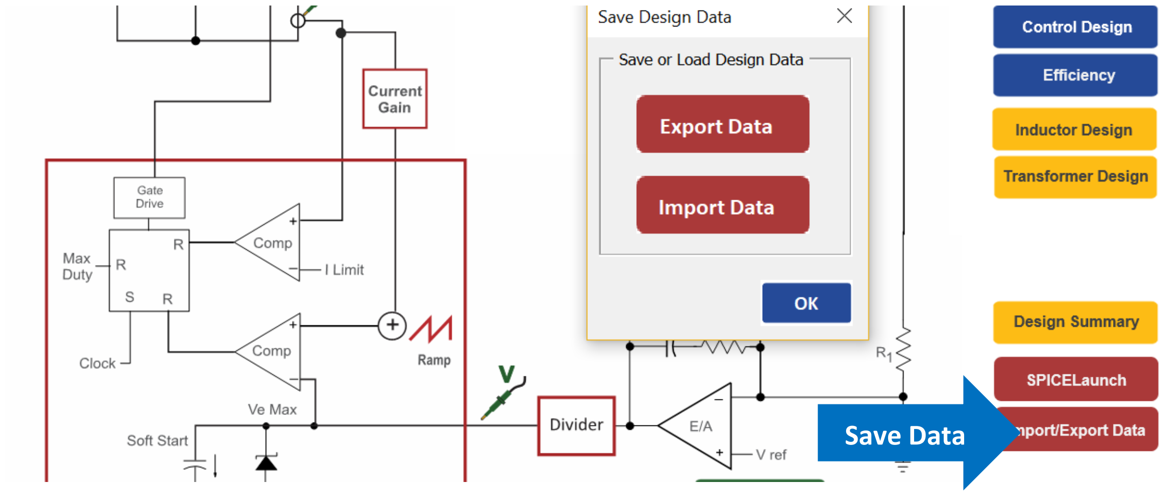
Every time you do this, you will be saving a complete copy of RidleyWorks™ together with the simulator, designer, and all the features of the program. It is a live copy of your design, constantly analyzing and simulating any changes you make, not just the data.

You can save the design workshop in any directory you wish on your computer. However, please note that you **must move a design workshop to the original RidleyWorks™ directory to open it** with the proper permissions working.

1.8 Saving Data Only and Transferring Data to New Version

It is possible to save just the data from your design in a much smaller file. This feature has been added to allow you to easily transition your design to a new version of the program without having to re-enter all of your design choices. You can also send a design to your colleagues in a very small file.

To take advantage of this feature, it is necessary to have two files open – RidleyWorks11.xlsm and TRANSFER.xlsm. Once you have opened these files, go to the Power Stage page of RidleyWorks™ and click on the Export/Import Data button. When you then click the Export button, your data that you have entered will be placed in the TRANSFER.xlsm file. Clicking on Import will load data from the TRANSFER.xlsm file into your RidleyWorks™ worksheet.



If you have an older version than 9.56, and you wish to upgrade and transfer your data this can also be done. Open your older version of RidleyWorks™, for example RidleyWorks™11.xlsm. Then open the file TRANSFER.xlsm. go to the Power Stage design page of RidleyWorks™ and enter Alt-F8 to select macros. In the box "Macros in" select Transfer.xlsm, select the macro transfer.xlsm!xfersave and hit Run. This will save your data in the Transfer worksheet.

You can then open the latest version of RidleyWorks™ and follow the process above to reload your data into the new version.

1.9 Which Version Do I Have?

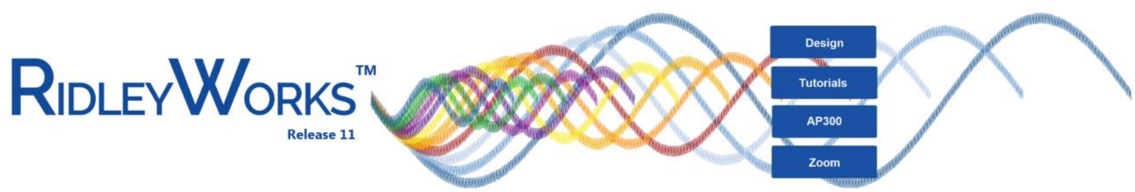


Fig. 1.2: RidleyWorks™ Version Number and Recent Updates.

To find out which version you have installed, click on the RidleyWorks™ name on the opening screen. You can also see the recent changes and upgrades by clicking on the **Updates** button.

1.10 Help Notes

RidleyWorks™ has extensive on-line help inside the program. Click on any of the help buttons to access notes about a particular feature of RidleyWorks™. A wealth of design information is contained in the program, together with power supply design tips.

1.11 Software Support

If you are having problems installing or running RidleyWorks™, 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 file to an email for assistance.

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

(UK) +44 (0)1509 276 245

1.12 LinkedIn and Facebook Support Groups

If you are a part of LinkedIn or Facebook, there are groups dedicated to power supply design with over 8000 industry members. Whenever a new version of the software is available, a posting will be placed on this site, immediately notifying you. You can also ask questions about the software at this site. The groups are called

POWER SUPPLY DESIGN CENTER and they can be found at

https://www.linkedin.com/groups? =&gid=4860717

https://www.facebook.com/groups/ridleyengineering/

2 Design and Simulation

RidleyWorks™ has the fastest closed-loop power supply simulator available. It can accurately simulate 400 cycles of closed-loop operation of a converter with almost instantaneous results. There is no more tedious waiting for Spice to finish working on a simulation. Change parameter values, control design, or power stage elements and see the results on true large-signal waveforms instantly.

To begin you first design and simulation, click on **Design**, and you will see be taken to the schematic page to select which features you want to use.

Fig. 2.1: RidleyWorks™ Guide Page with Start Menu

RidleyWorks™ has a wealth of features for design. You can click on the If you are just getting started, do not check any of the boxes for now. You can add more options for design and analysis later. Click OK and you will be taken to the schematic page to begin your design and analysis.

2.1 Entering Specifications and Topology

Most of the time you will be working on the schematics page as shown below. This will let you see waveforms and small-signal measurements while interactively changing power parts and control parts. An automatic expert-system design routine will help you with all component choices. If you are a new designer, you may choose to let RidleyWorks™ choose every parameter for you and you can expect a good working design.

On the schematic page, you will see a power topology (a buck converter in the figure below), a controller with all the setting needed to implement most constant-frequency options, and a feedback compensator. Of course, the compensator and controller may all be in one chip, but you have full control of all of the parameters.

Schematic components in red are clickable, and you can edit their values and see components stresses. This will be demonstrated in more detail later. First, though, you will want to enter your particular specification for your power system. The blue buttons on the page will enable different forms and options for design.

To enter your power specifications, click on the top blue button as shown below.

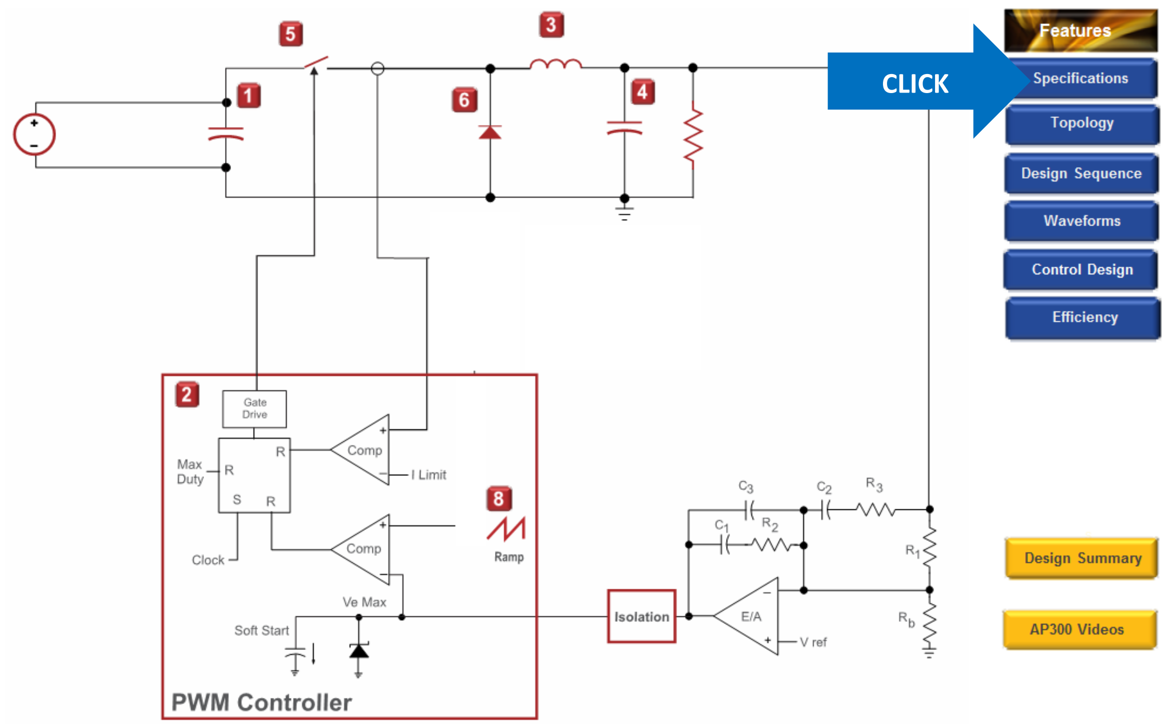


Fig. 2.2: RidleyWorks™ Schematic Page

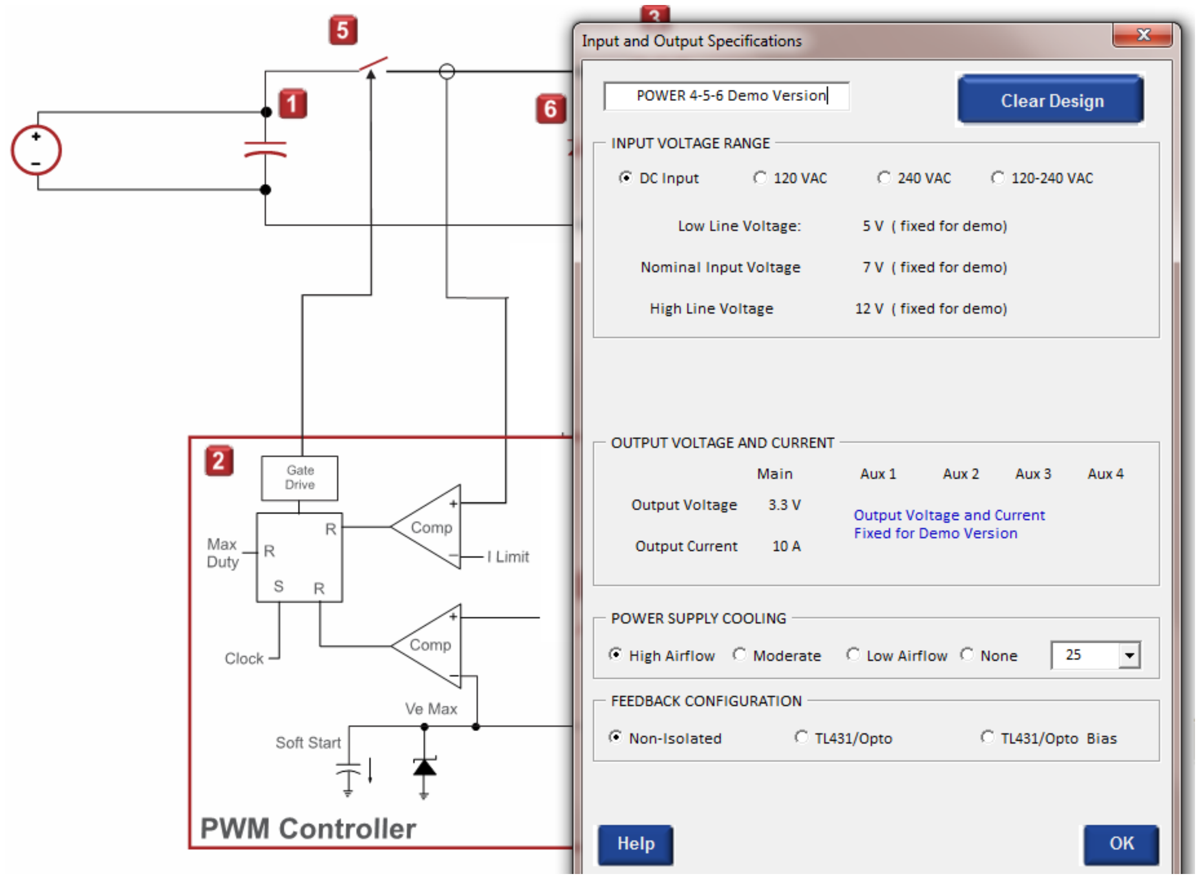


Fig. 2.3: RidleyWorks™ Specifications Entry Form

The first area of the Specifications form lets you choose either DC or AC input. For the demo version, AC input is disabled, and the dc input range is set to 5-12 V. In the full version, you can enter both AC and DC options, and select the input voltage range as you wish.

In the demo software, the output voltage is fixed with a 3.3 V 10 A setting. Airflow and temperature ranges will impact magnetics design, and the feedback can be configured with or without isolation.

Once you click OK on this form you will see a summary of your inputs to check, then you will be presented with a set of choices for the topology of the power stage.

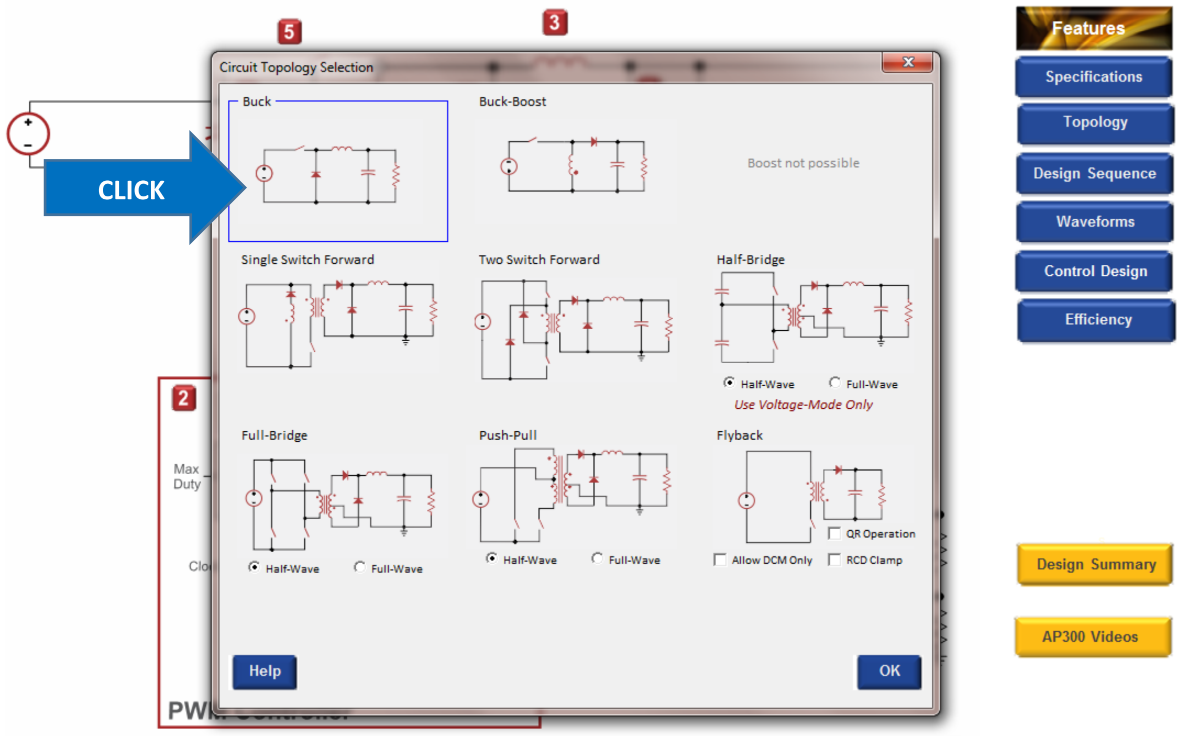


Fig. 2.4: RidleyWorks™ Topology Choices

Figure 2.4 shows the set of topologies available for the input and output voltage specifications. Notice that the boost topology is not possible since the output voltage is lower than part of the input range of the converter.

To follow along with this guide, select the buck converter by clicking on the area shown above.

Once you have done this, RidleyWorks™ will proceed to do an amazing amount of work. First, all the power components will be selected. A controller will then be optimized around the power stage to give good transient performance and stability. Loop gains will be plotted and analyzed. Finally, 400 cycles of large-signal operation will be simulated. All of this is done in a few hundred milliseconds. You will find that this greatly speeds up and changes your entire design experience. No longer will you have to wait ten minutes or so for Spice to predict waveforms every time you make a circuit change. Your design procedure will become much more interactive, trying far more options and repetitively simulating as if you had a live breadboard.

Before digging deeper into design values, it is very valuable to look at circuit waveforms to see how the converter is operating. At this point, you have had no input to design values and RidleyWorks™ will provide you with fully automated results for a realistic converter. You can verify this by looking at the waveforms of the circuit.

2.2 Running Waveform Simulations

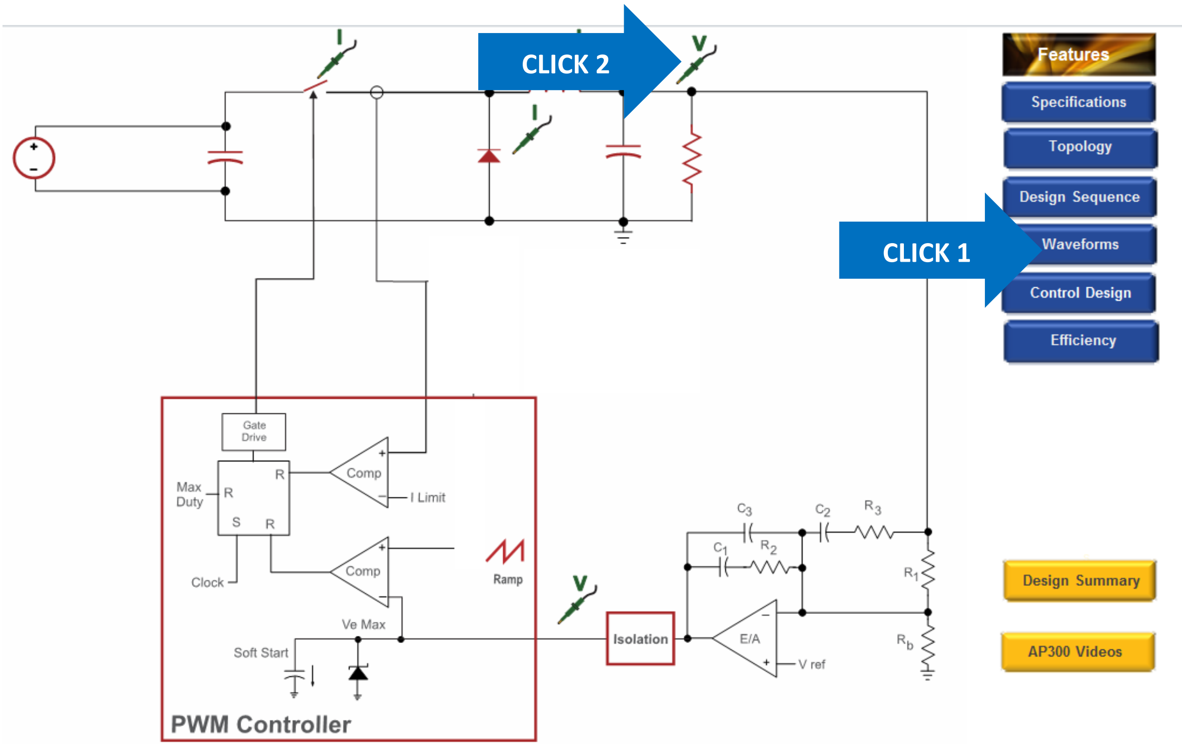


Fig. 2.5: RidleyWorks™ Waveform Choices

Figure 2.5 shows the selection of voltages and currents that can be probed with RidleyWorks™. The simulation algorithm inside RidleyWorks™ is so fast that you will routinely run hundreds of simulations during a design session, never having to wait for the results. Every time a component is changed, another 400-cycle simulation is run to confirm that the converter is operating properly.

To begin doing this click on the blue button labeled Waveforms, then click on the scope probe at the output of the converter, as shown above.

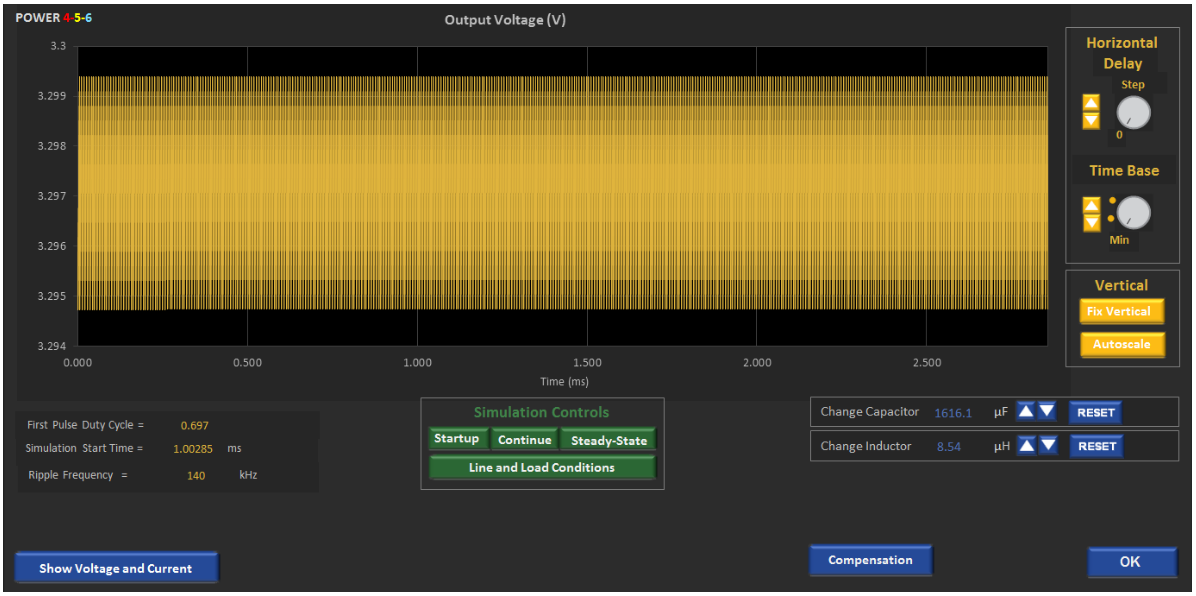


Fig. 2.6: RidleyWorks™ Output Voltage Waveform

Figure 2.6 shows simulation of the output voltage for 400 cycles. (Version 11.07 onwards shows 800 cycles.) To zoom in on this waveform, treat the controls of RidleyWorks™ just like a scope. Turn the time-base dial clockwise to zoom in by clicking on the up arrow next to the dial, as shown below.

Fig. 2.7: RidleyWorks™ Expanded Output Voltage Waveform

Each time you click on the up arrow, the number of complete waveforms will be cut in half. You can quickly turn the dial back to the original setting by clicking on the Min setting.

2.3 Startup Simulation

Fig. 2.8: RidleyWorks™ Start Up Simulation Voltage Waveform

Startup of your converter can be simulated by clicking the green button as shown above. This will start with zero output voltage, and zero inductor current, and simulate the converter into regulation as shown. It takes over 200 cycles to get the output voltage into regulation in the example shown. It can be instructive to click on button to add the current waveform of the converter to show what effect the current limiting has on the performance of the startup.

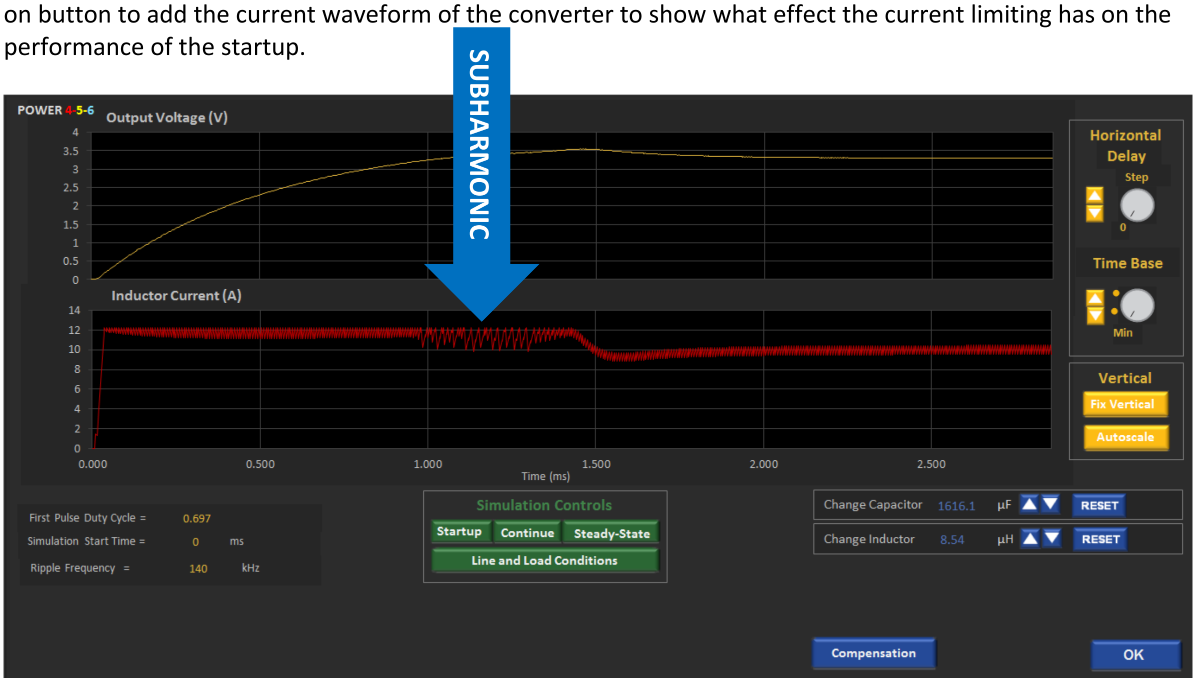


Fig. 2.9: RidleyWorks™ Start Up Simulation Voltage and Current Waveforms

In the red waveform of Figure 2.9, you can see that the converter enters current limiting during startup, and later on you can actually see subharmonic oscillation in the current sensing (current limit is like current-mode control with no ramp added) and this slows down the rise of the output voltage.

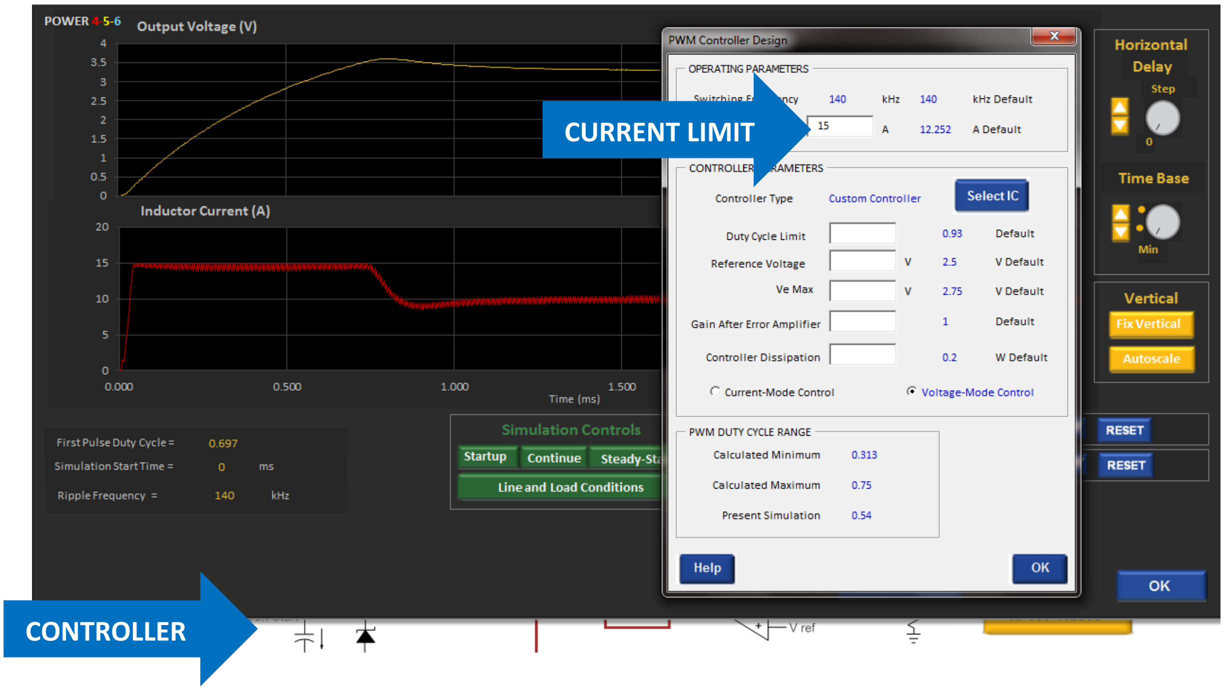


Fig. 2.10: RidleyWorks™ Start Up Simulation with Increased Current Limit

If you click on the controller part of the schematic below the simulation, as shown above, you can pull up the form to change controller parameters. In the case shown, the current limit is raised from 12.25 A to 15 A. This relatively small change in peak current limiting eliminates the subharmonic oscillation and the converter reaches regulation much more quickly. Once you click on OK, the new simulation will run and you can immediately see the changes in performance.

Determining the proper values of parameters such as current limit is absolutely crucial at the very early stages of design. The peak current will impact the design of magnetics and sense resistors, and you don't want to discover this kind of effect later in the design cycle. RidleyWorks™ is ideal for this kind of work since it automatically designs all compensation parameters at the very beginning of a design, and this is essential for proper simulation.

2.4 Step-Load and Load Transient Simulation

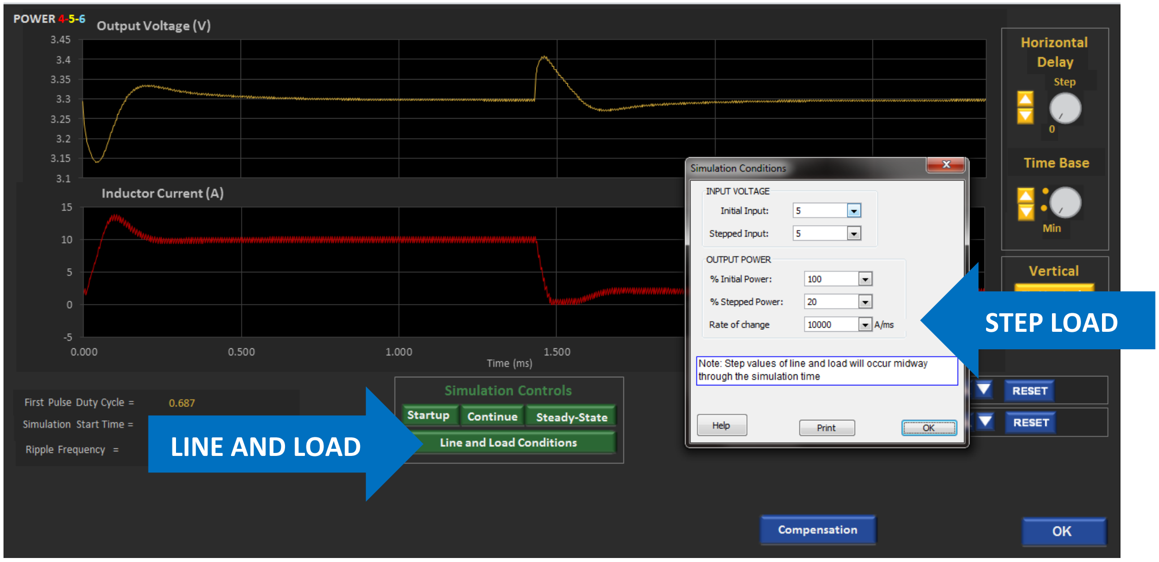


Fig. 2.11: RidleyWorks™ Step-Load Transient Simulation

The line and load conditions can be set as shown. Two values of load are shown. The first 200 cycles are run with 100% load, the second 200 cycles with 20% load. Simulation of both the voltage and current are shown, with the inductor current entering DCM on the second transient when the load falls to 20%.

2.5 Adding Input Voltage Modulation

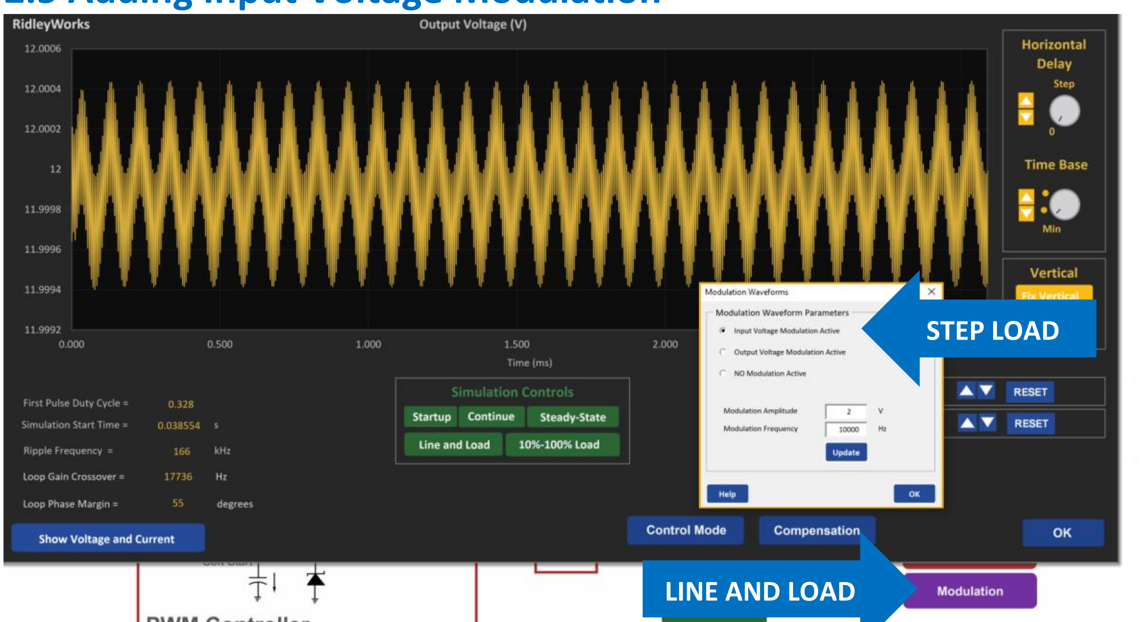


Fig. 2.12: RidleyWorks™ Step-Load Transient Simulation

RidleyWorks™ has the capability to add sinusoidal modulation on top of the input dc voltage. It can also be used to add modulation to the reference voltage to drive the output.

2.5 AC Input Simulation

With the full version of RidleyWorks™ you can select an AC input and perform a simulation of the input rectifier. Three choices of range are available to you. When you check one of these buttons, as shown below, the expected low, nominal, and high-line voltages will be filled in for you. You can change these values if you wish. Once you have checked an AC input, the schematic will change on the input, showing you the input rectifier block.

After clicking OK, click on the rectifier at the input to see the simulated input waveforms.

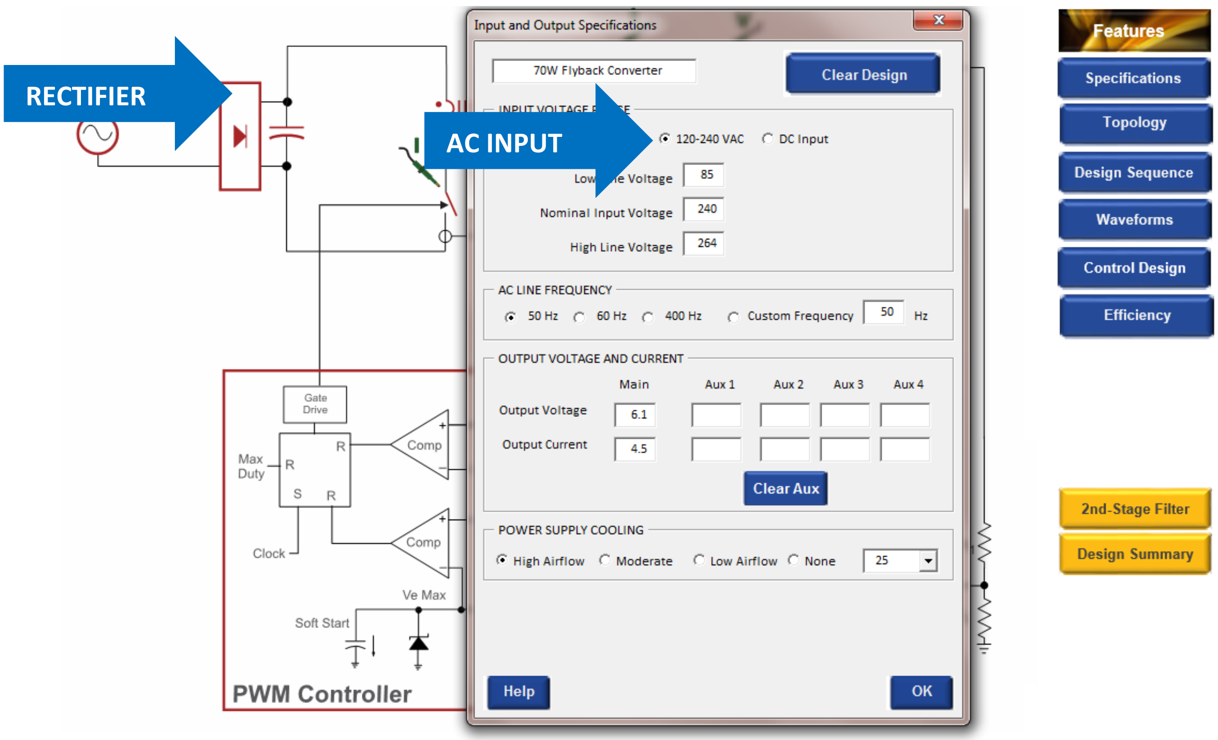


Fig. 2.13: Choosing AC Input on the Specifications Form (not available in Demo Version).

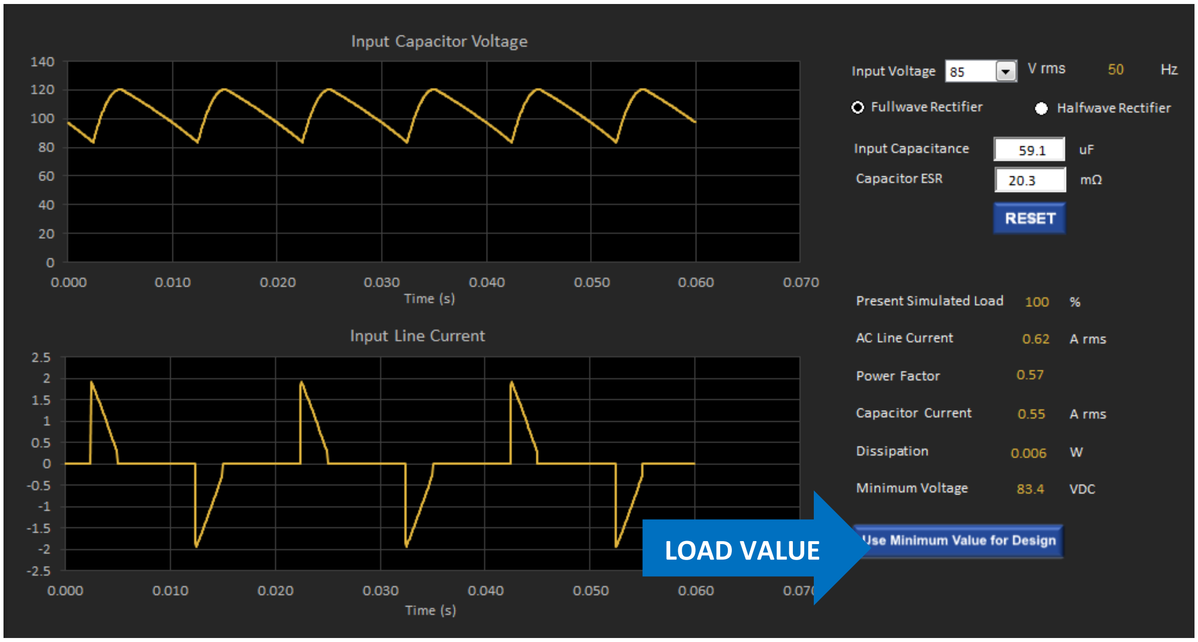


Fig. 2.14: AC Input Waveforms for a 27 W Flyback Converter (not available in Demo Version).

The simulation of input line current and input capacitor voltage are shown in the figure above.

2.6 Exploring Further Simulation Options

Many more simulation options are possible within RidleyWorks™ and you are encouraged to try them. For example, with the transient load simulation in Fig. 2.11, you can interactively see the change in transient performance with different value inductors and capacitors. You can move these values up and down while watching the change in the waveforms. This is a truly unique feature of RidleyWorks™ that will change the way that you do your designs and greatly speed up the process.

You are encouraged to try all these options in RidleyWorks™. Let us know what you see, and tell us if there are additional features of that you would like to see included in the program in the future. Once you have a license for the software, all upgrades are free as long as your license is current.

Please contact us to let us know what you would like to see included in the program in the future. We are constantly upgrading the software to respond to user’s needs. Once you have a license for the software, all upgrades are free as long as your license is current.

3 Control Analysis Transfer Functions

RidleyWorks™ has unsurpassed techniques for designing and analyzing the control system for a switching power supply. The analysis techniques and design routines have evolved over a period of 25 years to give you all of the control information that you need to optimize the performance of your power supply.

3.1 Turning On Control Options

When you click on the **Control Design** blue button you will see the green options buttons below appear on the power stage schematic. (If you don't see the **Z Out** and the **Audiosusceptibility** buttons, make sure these features are checked when you click on the Features button.)

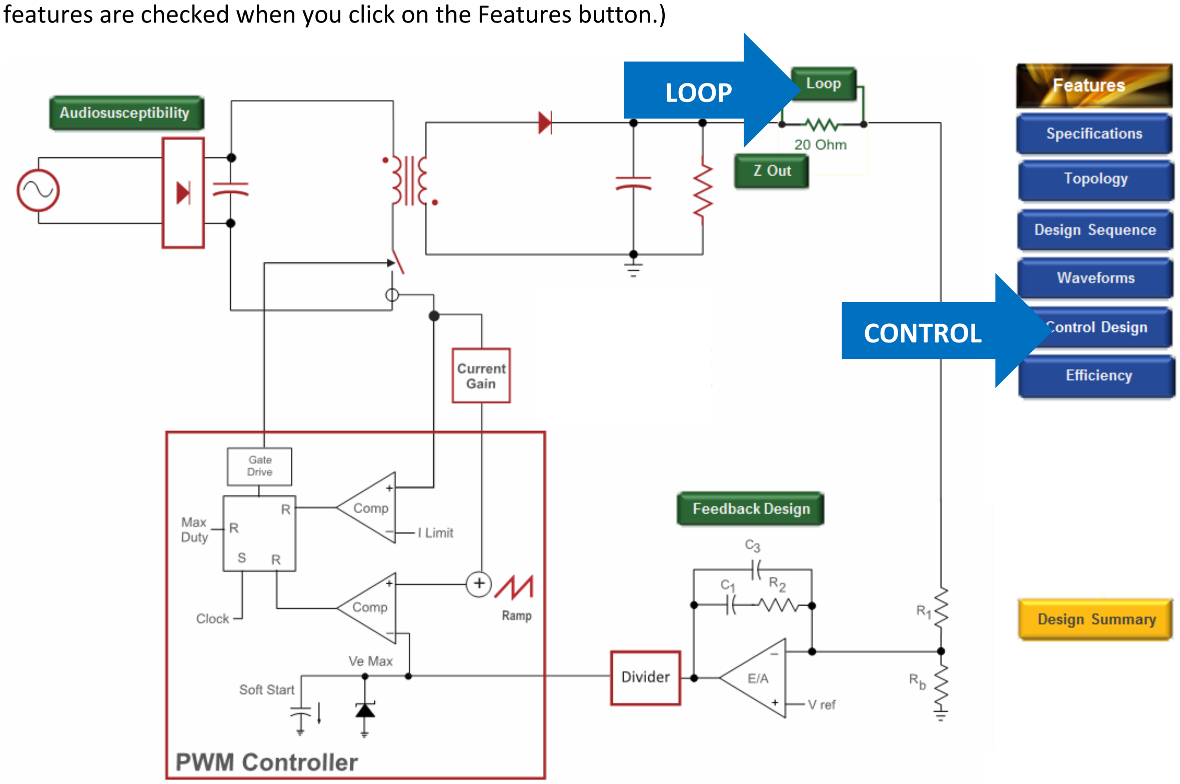


Fig. 3.1: Control Design Options in RidleyWorks™

Once you see the green control buttons, click on the **Loop** button to see the main control transfer functions.

3.2 Current-Mode and Voltage-Mode Control

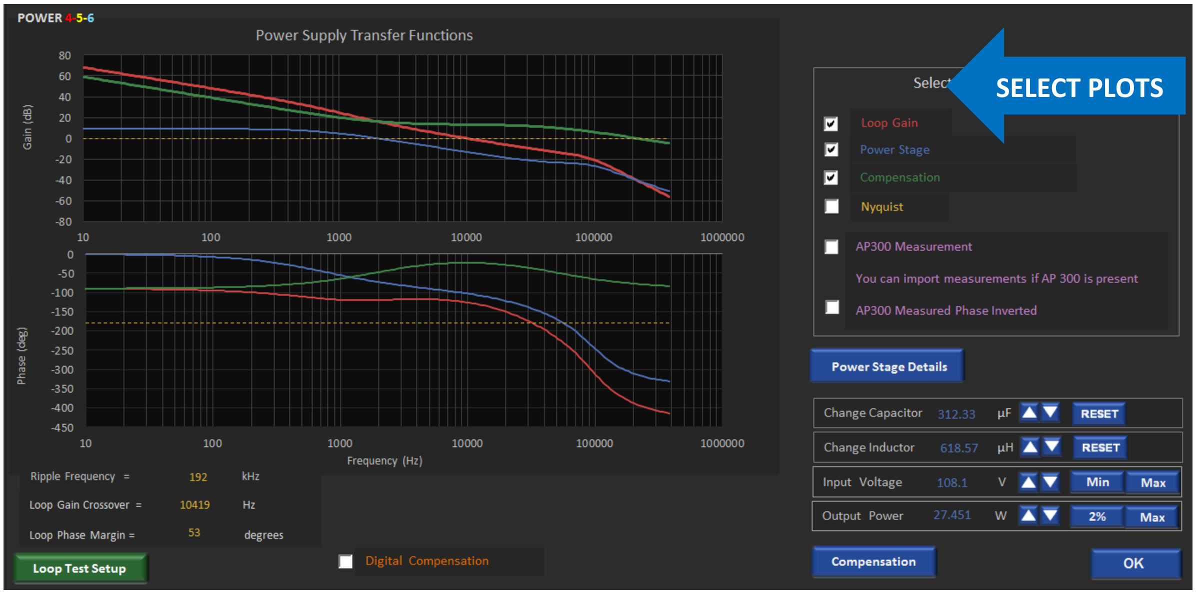


Fig. 3.2: Current-Mode Control Transfer Function Bode Plots in RidleyWorks™

Figure 3.2 shows the control transfer functions which are available in RidleyWorks™. You can select multiple plots to be shown all at the same time as shown in the box above. Measurements from the AP300 Frequency Response Analyzer can also be overlaid on the graph to compare with predictions.

You can do many things on these graphs, including moving the line and load up and down, and changing the values of the inductor and capacitor in the converter. As you change these values, you can see the immediate effect on the power stage, compensation and loop gain.

Note that when you change the inductor and capacitor values, each time you click on the button, the control loop is optimized for the new power stage and the transfer function plotted for the updated design. (400 cycles of simulation are also run, but this is fast enough that you won't even notice!)

RidleyWorks™ will automatically detect whether the converter is operating in CCM or DCM and provide the appropriate transfer function. If you wish to see details of the converter you can click on the **Power Stage Details** button and it will give you the poles and zeros.

The **Compensation** button is a recent feature of RidleyWorks™ that lets you interactively move the shape of the compensation values while looking at the shape of the loop at the same time. Figure 3.2 shows the transfer functions for current-mode control, the default control scheme chosen for all converters except the half-bridge.

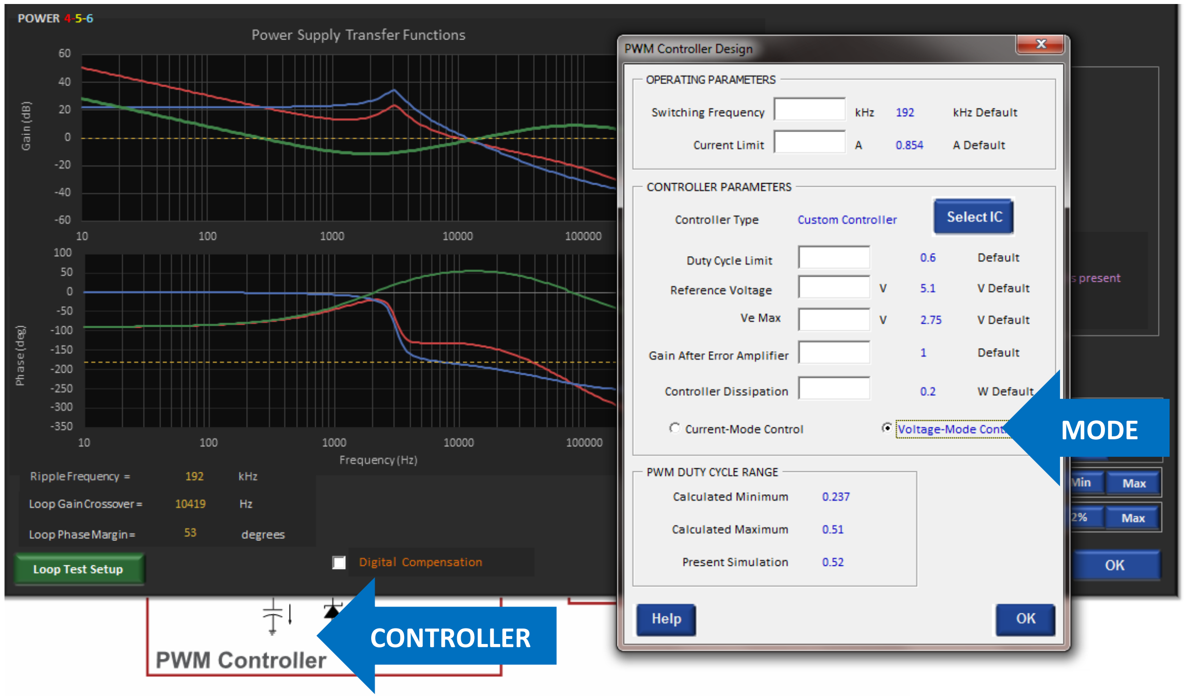


Fig. 3.3: Voltage-Mode Control Transfer Function Bode Plots in RidleyWorks™

If you click on the controller shown just below the graphs above, you can change your selection to voltage-mode control. Once you do this, the compensator will be re-optimized and the resulting transfer functions plotted. You will notice that in voltage-mode control, the gain of the power stage and the loop gain are directly affected by the input voltage.

3.3 Interactive Compensation Adjustment

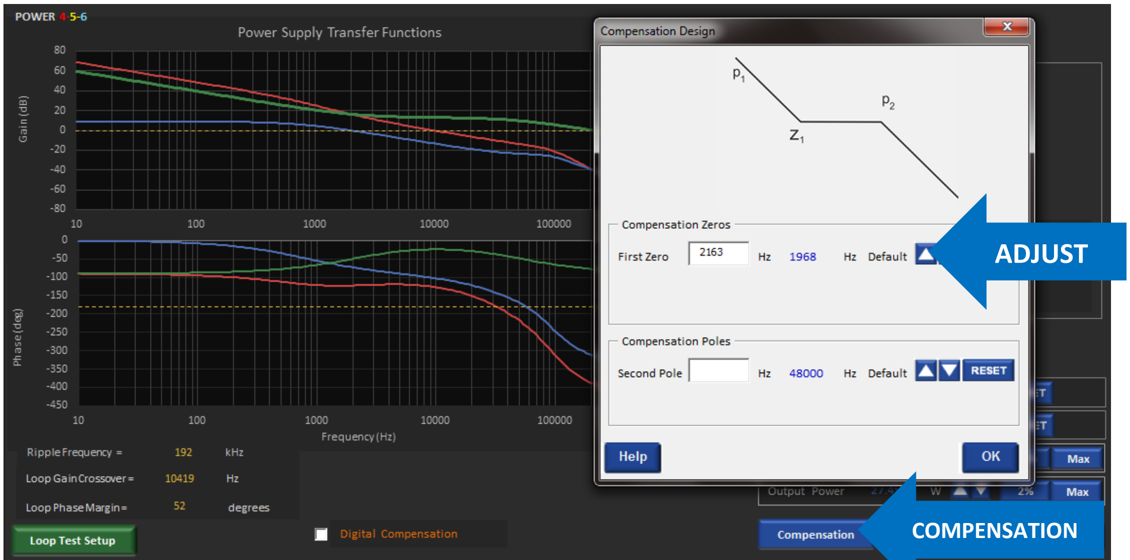


Fig. 3.4: Interactive Adjustment of Compensation Poles and Zeros with Transfer Functions

It is possible to look at the control transfer functions of RidleyWorks™ while adjusting the pole and zero locations of the compensation, as shown in the figure above. Each time you click the **Adjust** button the zero or pole will be moved, new compensation components selected, and the curves replotted.

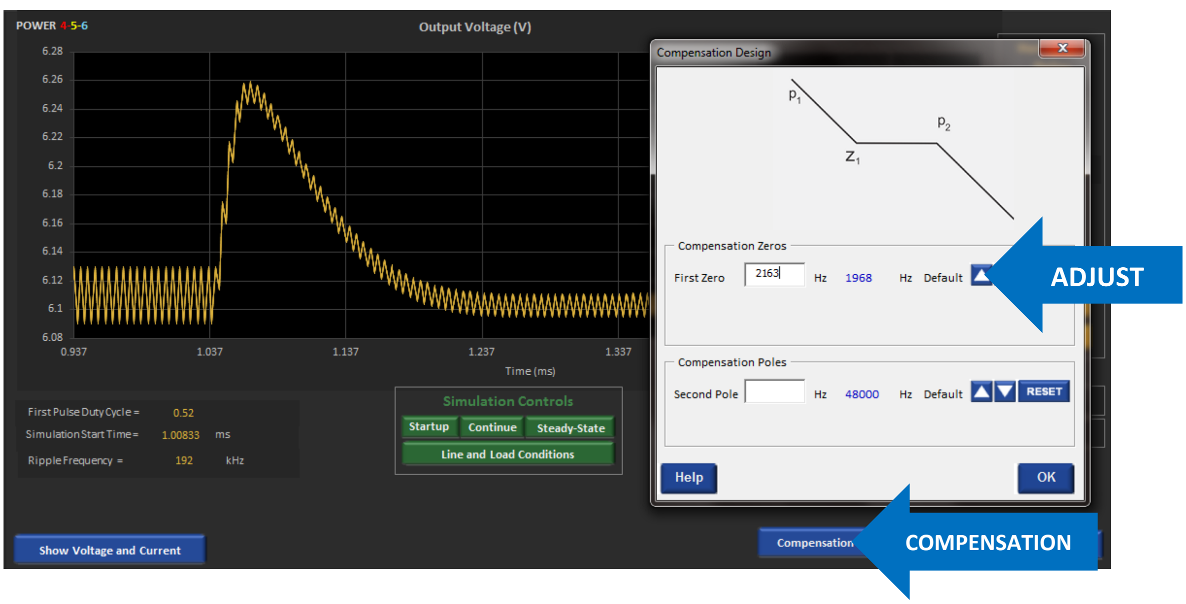


Fig. 3.5: Interactive Adjustment of Compensation Poles and Zeros with Simulation Waveforms

You can also interactively change the compensation parameters while looking at the simulation waveforms. This is a powerful feature with RidleyWorks™ and the simulation speed is essential for optimizing your control this way.

3.4 Voltage Feedforward Control

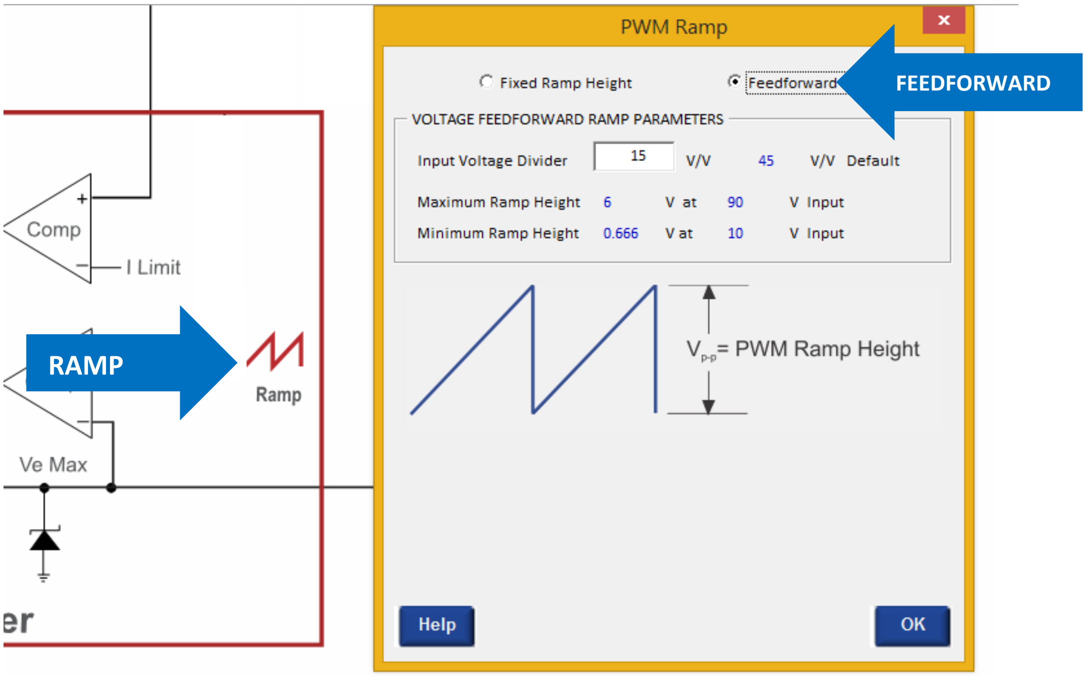


Fig. 3.5: Selecting Voltage-Mode with Feedforward

Starting with Release 9.60 of RidleyWorks™, it is possible to implement voltage-mode control with feedforward. The normal implementation of this technique in the control chip is to make the control ramp proportional to the input voltage, scaled by an input voltage divider constant, *k*.

$$V_{p-p} = \frac{V_{in}}{k}$$

When the input voltage is increased, the ramp size will increase, and there will be an immediate change in duty cycle. This can greatly improve the transient response with changes in input voltage. Normally it will be at least an order of magnitude better, especially for buck-derived converters.

In addition, the changing ramp will make sure that the loop gain of the system stays fixed for different input voltages. This can be very important for large ranges of input voltage, and compensation will remain optimal across the entire range. The converter will regulate much better, and step load response will be improved at low line.

4 Magnetics Designer

4.1 Turning on the Magnetics Designer

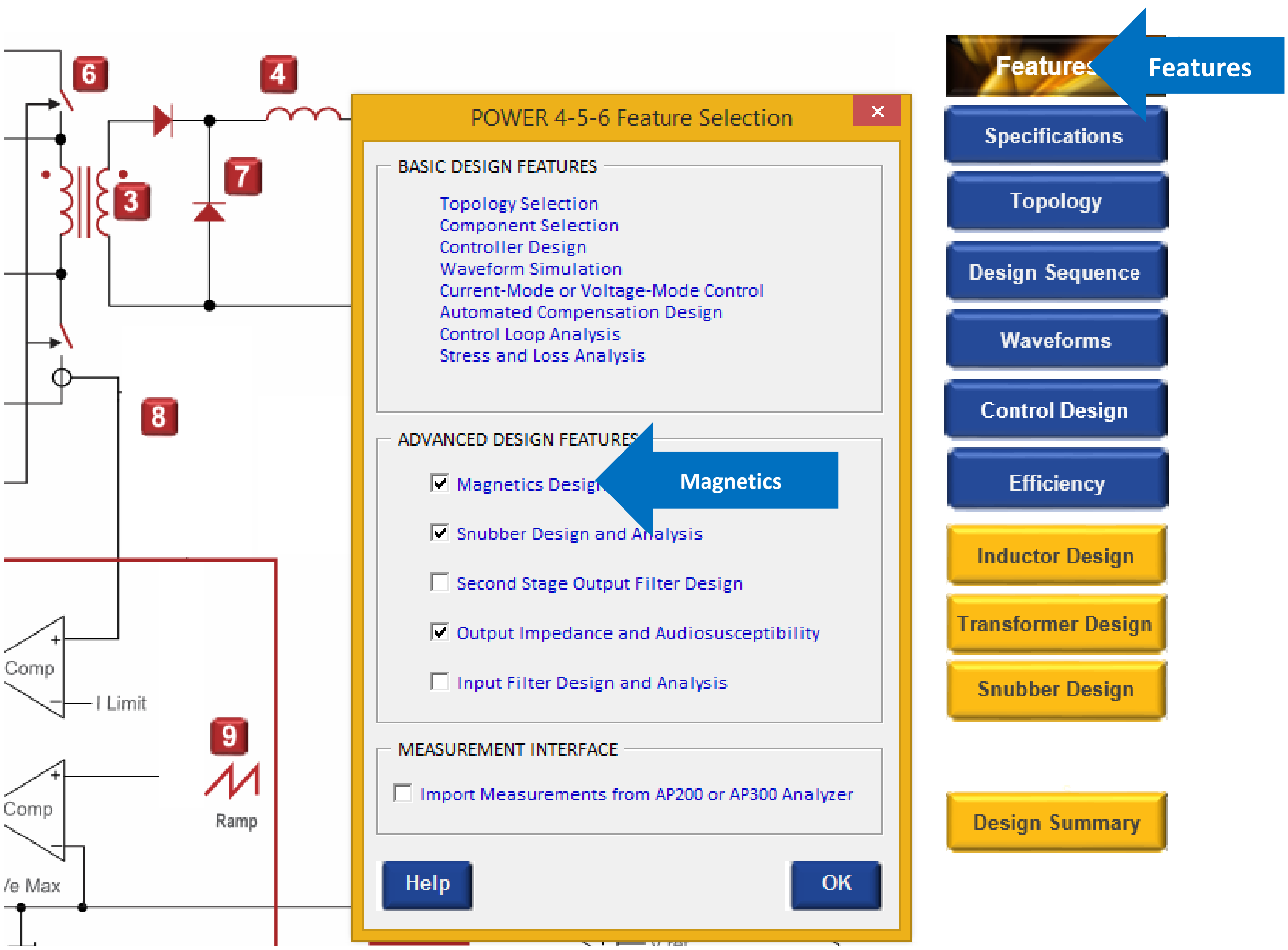


Fig. 4.1: Selecting the Magnetics Design Option Enables the Inductor and Transformer Designers

On the Power Stage design page, clicking on the Features button allows you to enable the magnetics design features of RidleyWorks™.

4.2 Inductor Design Page

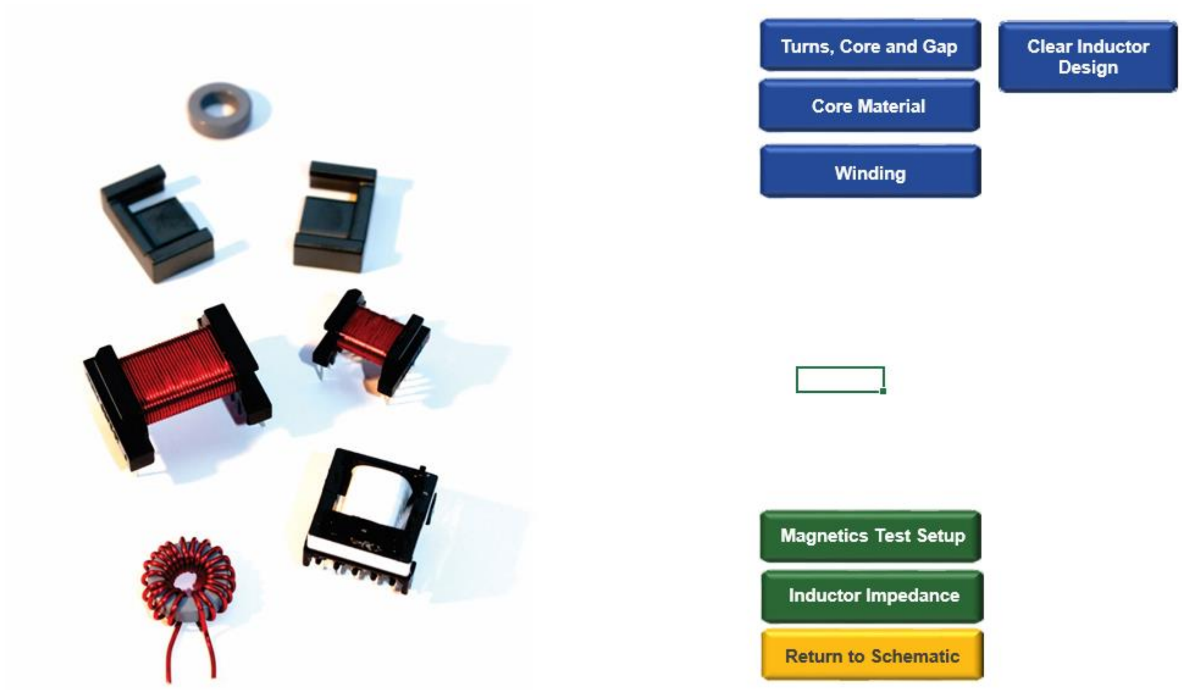


Fig. 4.2: Inductor Design Page Guides You Through The Inductor Details

Clicking the Inductor Design button on the Power Stage page will take you to the inductor design sheet in RidleyWorks™. On this page, pushing the blue buttons on the right will step you through a detailed design process. This will include core selection, material selection, winding design, proximity loss and many other details.

4.3 Choosing the Inductor Core Size

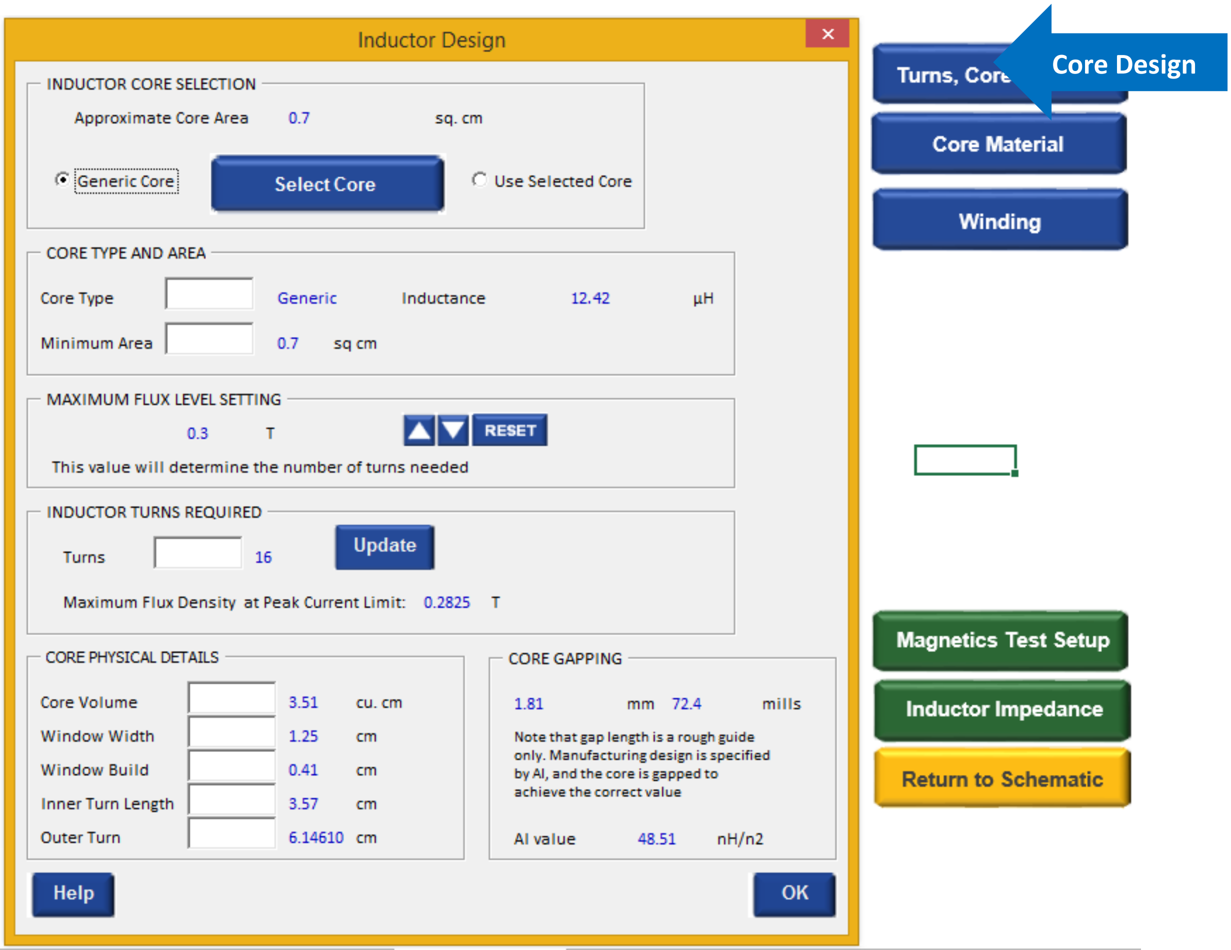


Fig. 4.3: Inductor Core and Turns Selection

Pushing the top button on the inductor design page will bring up the form for selecting the design parameters of the inductor. By default, a generic core will be selected with a recommended core area. This lets you choose any specific core that you or your company likes to use that has approximately that area. A larger core area will run a little cooler, and a smaller core size will have higher dissipation. Your actual selection will depend on your cooling situation, and your need for efficiency versus size.

If you click on the Select Core button, you will be presented with an array of standard cores to use, and you can also add your own favorite cores very easily to the program.

4.4 Choosing the Inductor Core Material

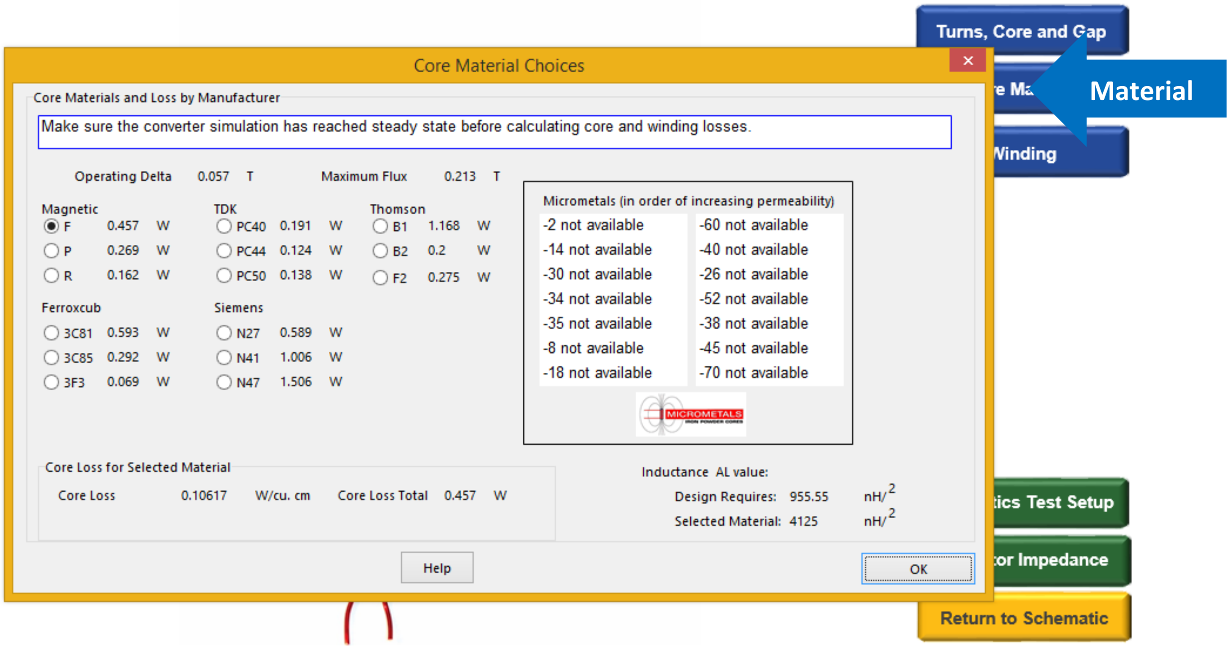


Fig. 4.4: Inductor Core Material Selection

You can use any core selection with a variety of core materials. RidleyWorks™ incorporates a unique core loss modeling techniques that accurately give the loss for different materials. Variable Steinmetz equation coefficients are used to produce a much more accurate core loss estimate than is available from the manufacturers. Details of the techniques used to calculate the loss are given in the Ridley Engineering Design Center (www. http://www.ridleyengineering.com/design-center.html) in paper **[A03] Modeling Ferrite Core Losses**.

If you are using a different core material to those shown, RidleyWorks™ gives you the proper frequency, flux level, and Delta B to be used with core loss curves.

4.5 Designing Inductor Windings

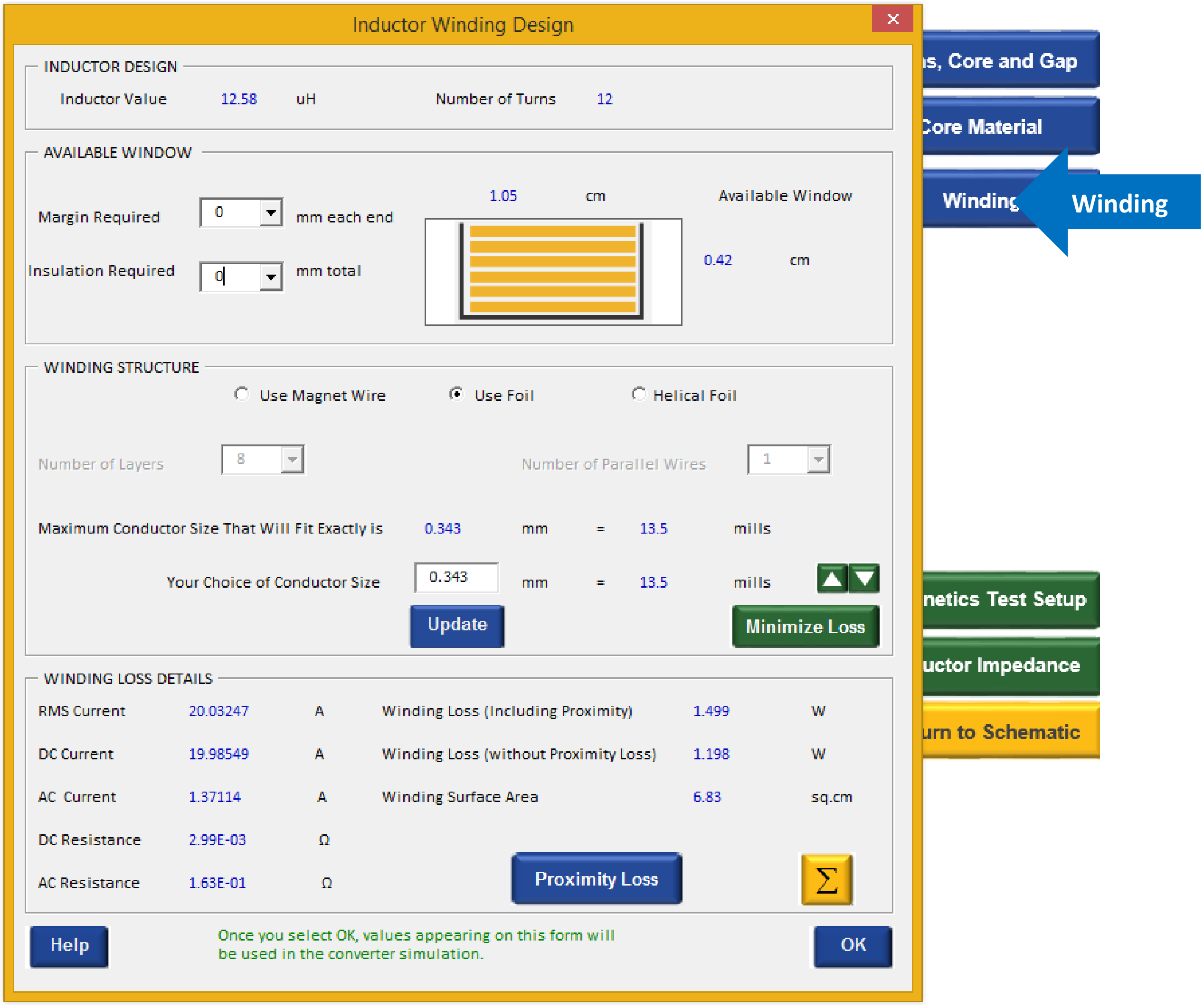


Fig. 4.5: Inductor Winding Design

Pushing the Winding button will show you the details of the inductor winging. You can build inductors with foil, helical windings, or with wire, and RidleyWorks™ will help you to optimize each of these. The foil winding thickness can be optimized with proper consideration for proximity losses, by clicking the Minimize Loss button.

Details of the sophisticated techniques used to calculate the proximity loss are given in the Ridley Engineering Design Center (www. http://www.ridleyengineering.com/design-center.html) in numerous papers on magnetics design and analysis.

4.6 Designing Transformers

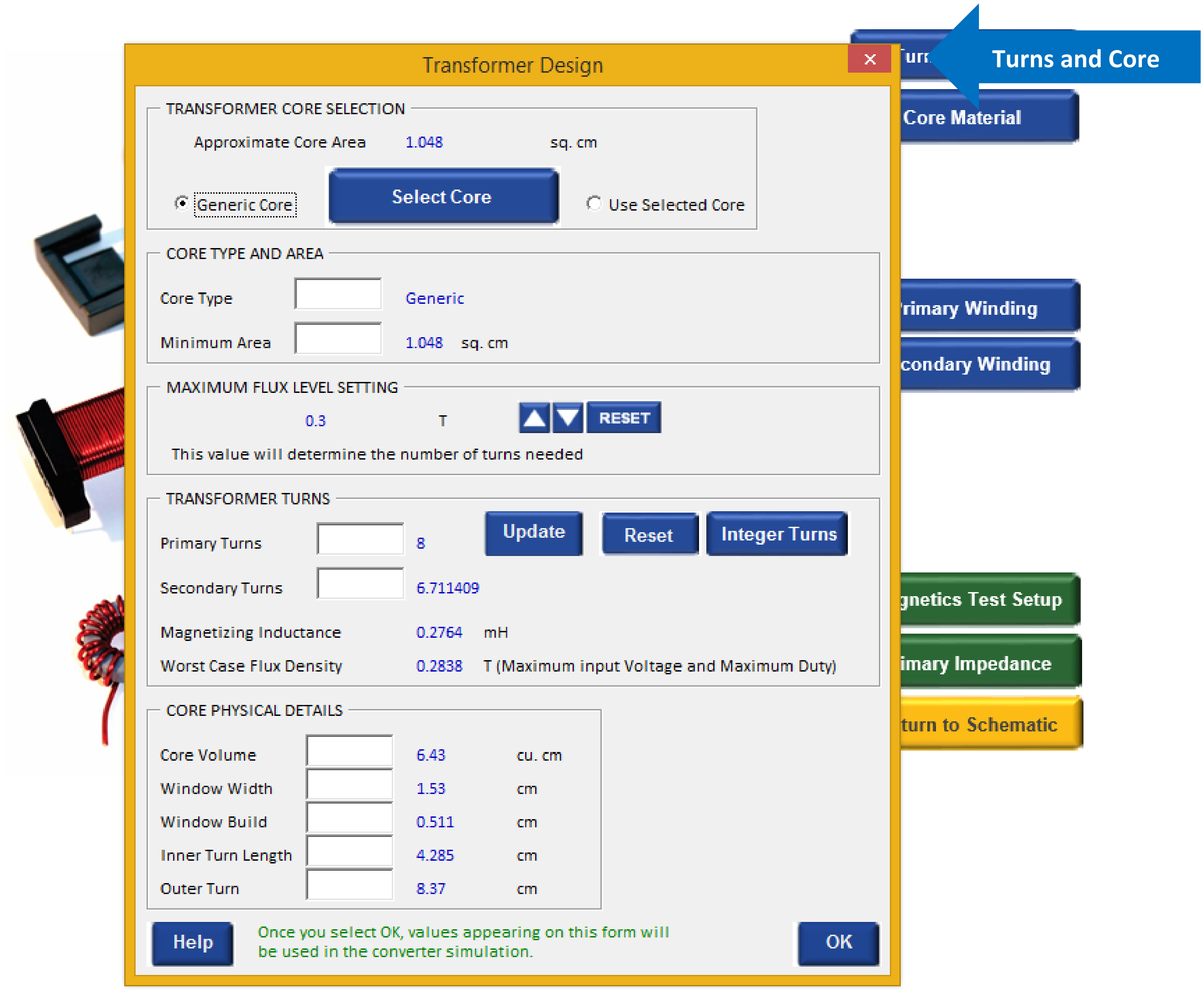


Fig. 4.6: Transformer Design Page

RidleyWorks™ has a powerful program for designing transformers, incorporating advanced core loss calculation, proximity loss analysis, core and winding selection, all in an easy-to-use package. The design program interfaces closely with simulation waveforms to provide fast, efficient, and reliable designs.

5 SPICELaunch™

5.1 Preparing an LTspice File

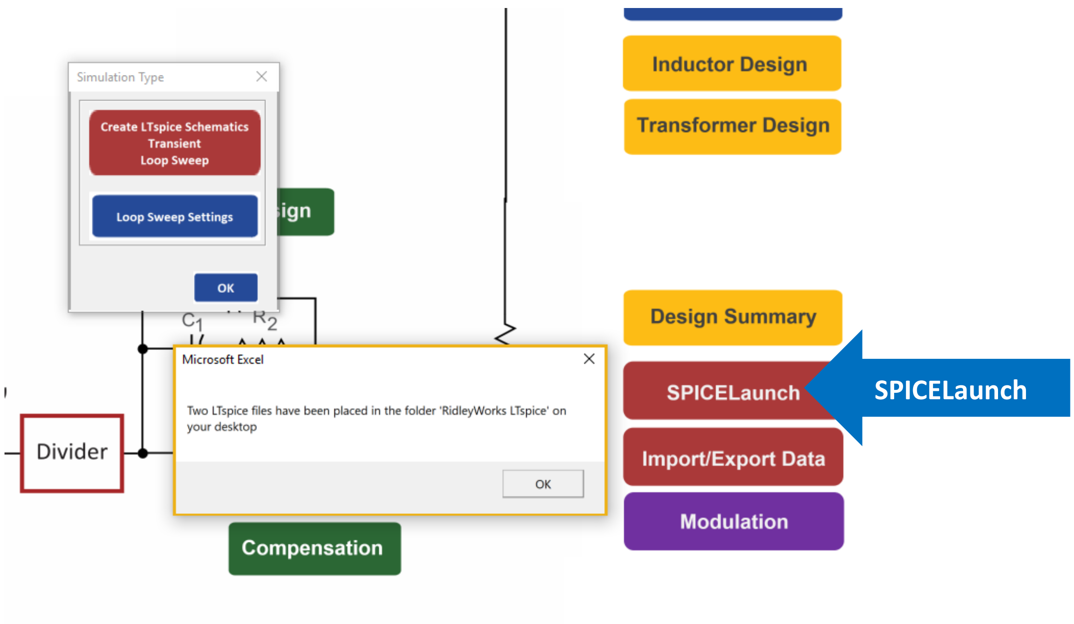
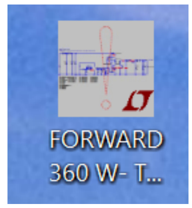


Fig. 5.1: Running SPICELaunch™

When you click on the green button, RidleyWorks™ will automatically create two LTspice file for you and place them in the folder **RidleyWorks™ LTspice** on your desktop. All the designed values are then ready to continue simulating and designing in the familiar LTspice environment.

5.2 Simulation Settings in LTspice

If you double click on the LTspice TRAN file that is the folder on your desktop, it will automatically open LTspice.



Before running a simulation, it is recommended that you set some parameters of LTspice for better simulation accuracy. Select Tools Control Panel Hacks! and set the check boxes as shown below.

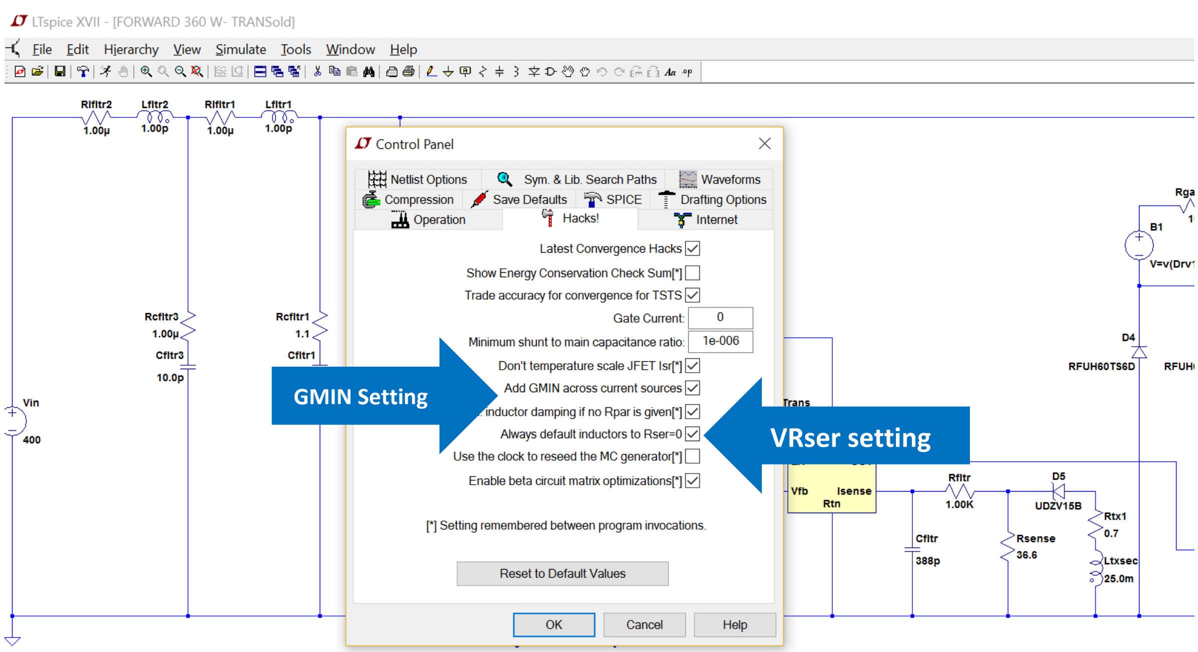


Fig. 5.2: Setting Up LTspice simulation parameters with Hacks!

LTspice, like all versions of spice, may sometimes struggle to converge during a simulation, and you may need to adjust other simulation parameters to help it along. This is one of the advantages of the RidleyWorks™ simulation – it never has convergence issues and simulations are almost instantaneous.

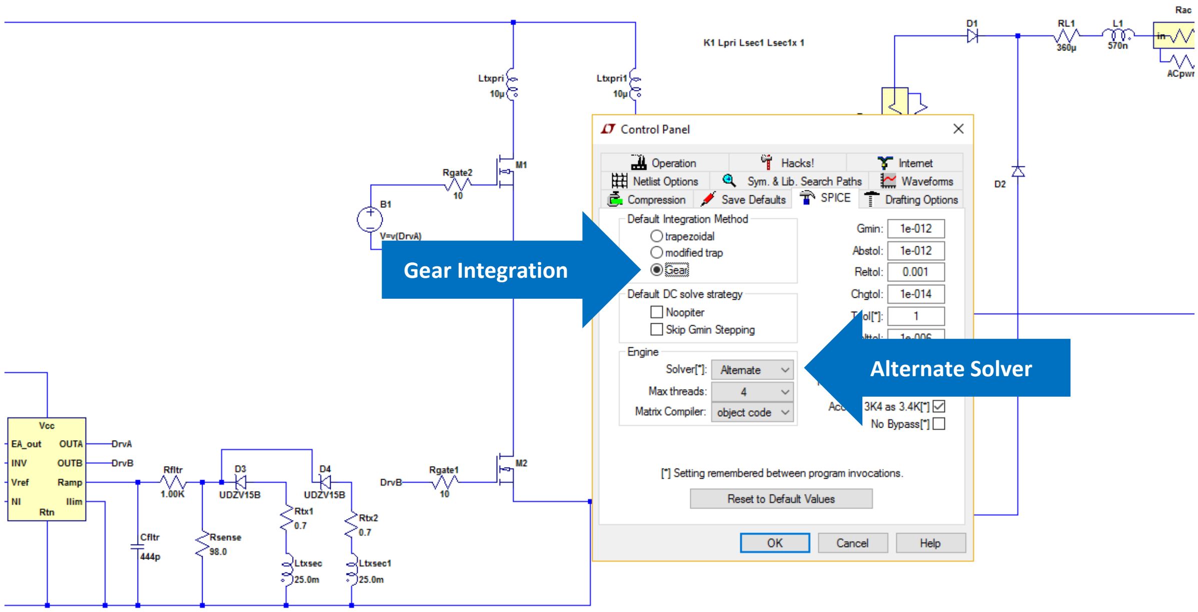


Fig. 5.3: Setting Up LTspice simulation parameters on SPICE panel

It is also recommended that you Solver Engine should be selected as Alternate. This will give greater simulation accuracy. The Normal setting will simulate faster which may be useful when generating the Bode plots inside LTspice.

These settings are not retained in LTspice each time you exit the program, so you will need to set them each time you come in.

5.3 Simulating Transients in LTspice

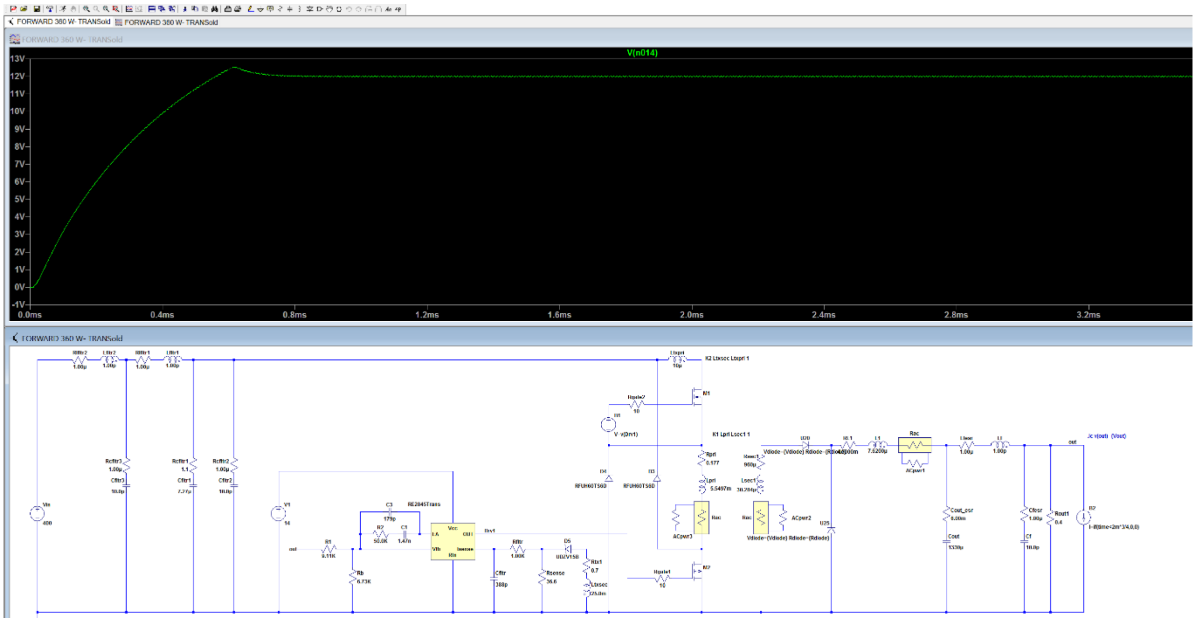


Fig. 5.3: Running LTspice Simulations

When you click on the running man icon, the spice simulation will start. You can then probe any waveform on the circuit. The simulation above is the output voltage during start-up of a circuit. Although the spice simulation may be fairly slow, you have already done all of the design of the control circuit and power parts in RidleyWorks™, and you can now use LTspice for the things it is good at. You can add any arbitrary circuits, any devices, and move your design much closer to the production schematic.

You will find that the combination of RidleyWorks™ and the rapid generation of the schematics for LTspice changes the way that you design. It should greatly speed up your process.

5.4 Generating Bode Plots in LTspice

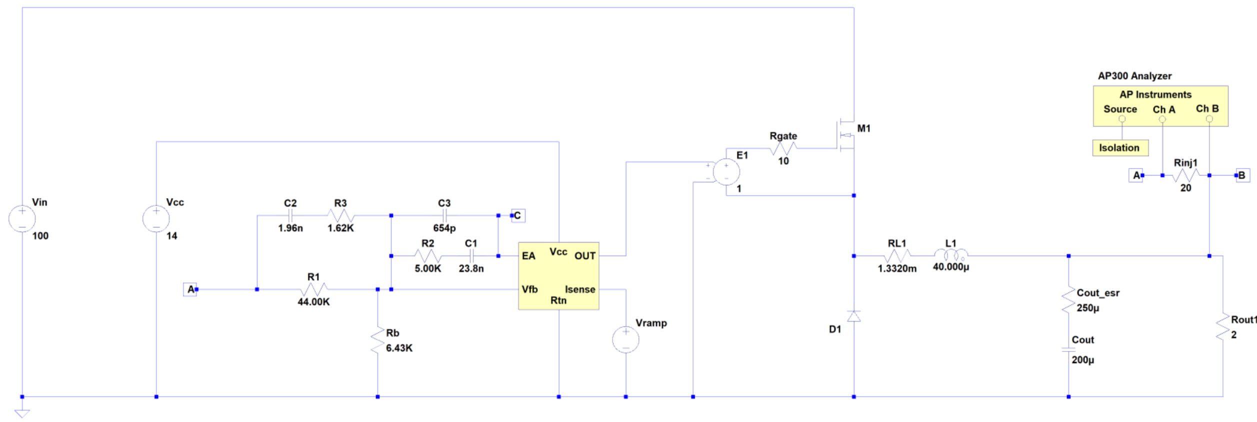


Fig. 5.4: LTspice Sweep Schematic for Bode Plots

A powerful new feature of RidleyWorks™ is the generation of schematics which can produce Bode plots *directly* from the time-domain schematic. There is *no need to simulate small-signal equivalent circuits* which are, by definition, approximations of the real circuit. For the first time, computers (in 2018) are fast enough that the intensive simulation needed for Bode plot generation can be done in a reasonable amount of time. This kind of work was only possible up until now with specialized high-speed simulation programs.

How fast can this be done? At the time of writing this manual, our record for simulation is just 24 seconds for a buck converter. This kind of speed is produced with the following features in place:

1. Automatic generation of a loop compensation that is ruggedly stable

2. Emulation of the features of the AP300 analyzer with frequency-dependent source, automatically configured to give good results.

3. Proper setup of simulation times for steady-state solution.

For the example buck schematic above, the bode generation is initiated by clicking on the running man icon. If you then click on **Point B** of the schematic, you can watch the waveforms being generated ready for measurement. This is done in a very similar way to the powerful AP300 analyzer.

Generation of the sweep schematic is a single button click in RidleyWorks™, and there is no need to change any settings from the default file that is generated. Figure 5.5 shows the repeated sweep waveforms generated in LTspice. It is very instructional to watch this procedure to enhance your understanding of how the AP300 frequency response analyzer works.

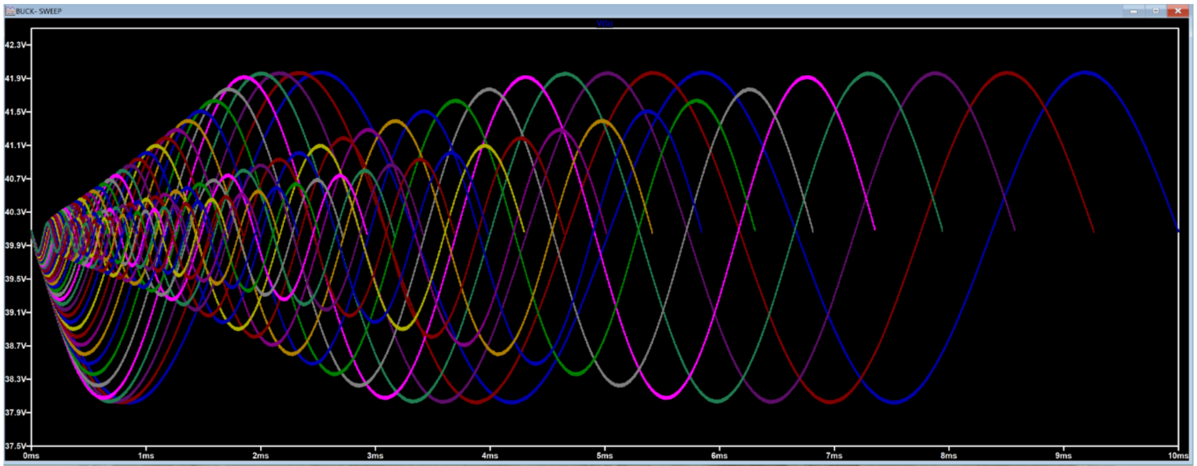


Fig. 5.5: LTspice Sweep Waveforms at Point B of the Circuit.

Once the sweeps shown above are done, and the data has been processed by LTspice, click on **View** then **Spice Error Log.** (If the Spice Error Log option is greyed out, LTspice has not yet finished processing the simulation data.) A file similar to that shown in Figure 5.6 will then appear:

```
Direct Newton iteration for .op point succeeded.
.step freq=300
.step freq=323.933
.step freq=349.774
.step freq=377.678
.step freq=407.807
.step freq=440.34
.step freq=475.468
.step freq=513.398
.step freq=554.355
.step freq=598.579
.step freq=646.33
.step freq=697.892
.step freq=753.566
.step freq=813.682
.step freq=878.593
.step freq=948.683
.step freq=1024.36
.step freq=1106.08
.step freq=1194.32
.step freq=1289.6
.step freq=1392.48
.step freq=1503.56
.step freq=1623.51
.step freq=1753.02
.step freq=1892.87
.step freq=2043.88
```

Fig. 5.6: LTspice Error Log

Right click in the space to the right of the numbers on the screen, and select the **option Plot .Step'd meas data**. Answer **Yes** to the question that pops up about complex data, and you will see Bode plot Axes appear. If you right click in the plot area, you can then add traces, and the Loop Gain, Power Stage Gain, and Compensation Gain are available as options.

Figure 5.6 shows the sweep for a buck power stage gain. Notice that approaching half the switching frequency, noise is apparent on the sweep. This noise characteristic will be very familiar to anyone who has used the AP300 on a switching power supply.

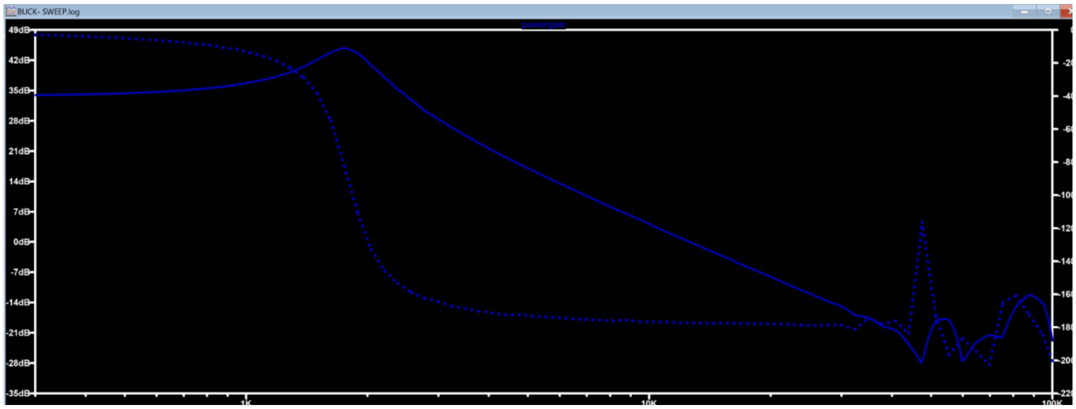


Fig. 5.6: LTspice Bode Plot of a Buck Power Stage Gain

Figure 5.7 shows the sweep for a buck power loop gain. Notice that the phase of this plot is reading phase *margin*, not phase. The cursors on the loop gain show the crossover frequency and the phase margin at this crossover.

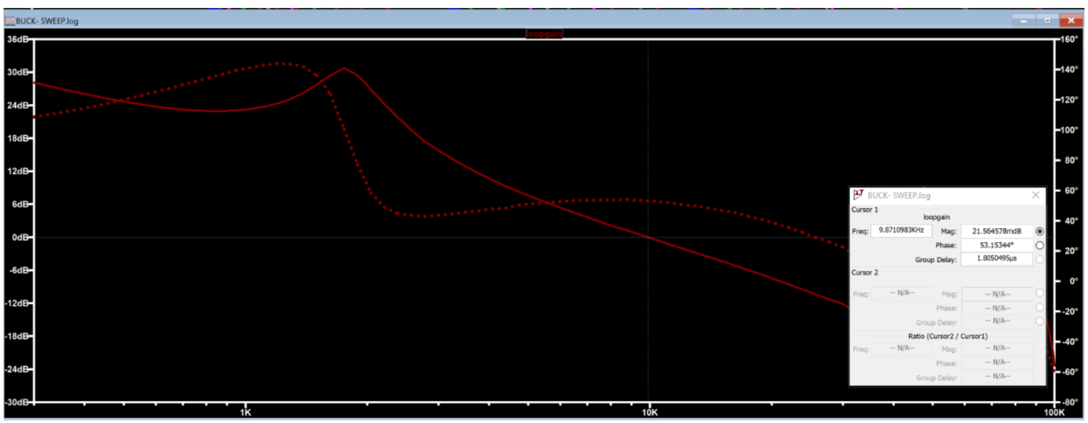


Fig. 5.7: LTspice Bode Plot of a Buck Loop Gain

6 Magnetics Winding Proximity Loss

One of the biggest sources of error in designing a power supply is underestimating the losses in inductor and transformer windings. To get a reasonable estimate of how much loss there will be, it is necessary to apply Dowell's equations, a set of highly complex formulae that is usually the domain of PhD students in power electronics. It is estimated that less than 1% of practicing engineers ever use these techniques in their design work.

Fortunately, RidleyWorks™ will do this for you. It does this in two ways – first by solving the Dowell's equation at the switching frequency to finding the increase in resistance. The winding current is then broken down into two parts – the dc current, and the ac current, which is the sum of all the harmonics. For a simple approximation, RidleyWorks™ assumes that all the ac current is at this frequency. This will give a low estimate of the proximity loss, but it does provide good and fast guidance for how to organize the winding layers and winding size.

Secondly, to get more accurate loss in the windings due to *all* of the current harmonics, RidleyWorks™ first does a sweep of the Dowell's equation solutions from 1 kHz to 10 MHz. It then generates a circuit network that produces the same impedance versus frequency as the Dowell's equations. This network is exported to an LTspice file where the proximity losses can be directly simulated in the time domain. This process is described in this chapter.

6.1 Estimating Proximity Losses in RidleyWorks™

The specifications for a 100 kHz two-switch forward converter are shown below in the Specifications entry form for RidleyWorks™. This is for a 20 V, 20 A isolated converter running from a high-voltage input.

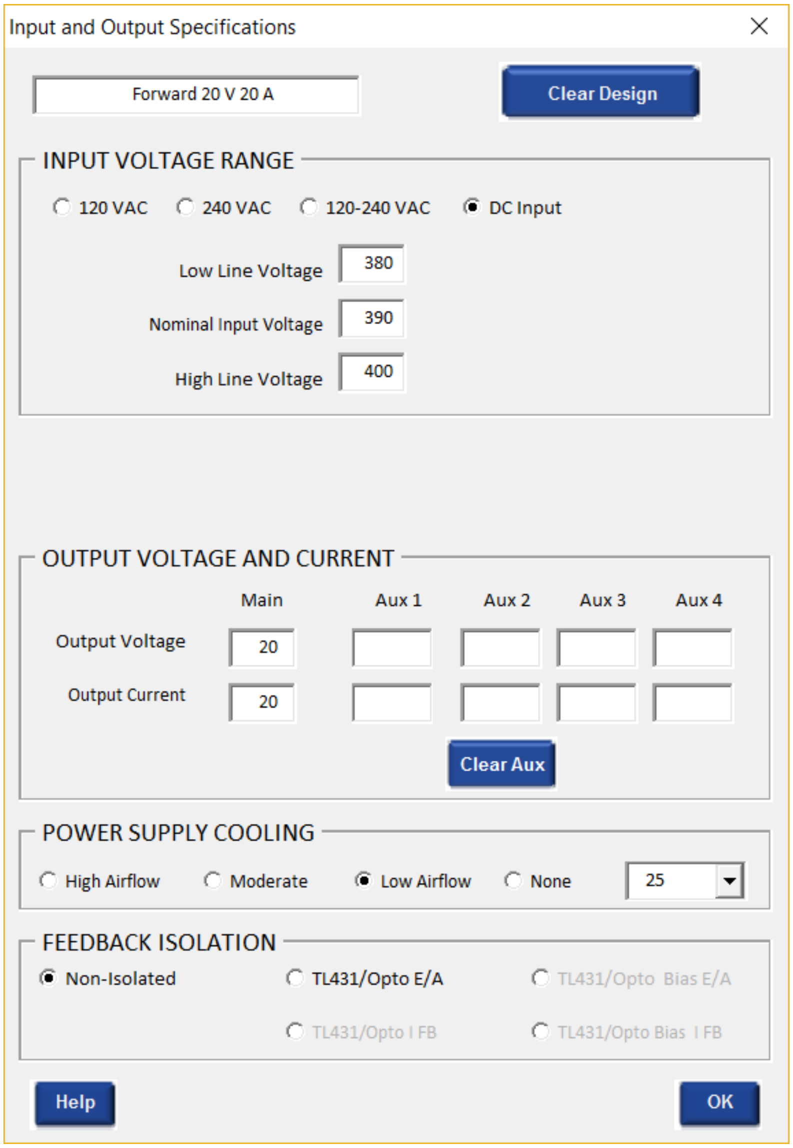


Fig. 6.1: Two-Switch Forward Specifications

Figure 6.2 shows the simulated primary current for the converter. The rms primary winding loss, using the dc value of the resistance of the winding is calculated to be 0.491 W. This is the value that most designers would use for estimating temperature rise, but we will soon see that it is much too low.

Fig. 6.2: Steady-State primary current from RidleyWorks™ Simulation

Figure 6.3 shows the important transformer parameters using and EC41 core. There are 62 primary turns, and 8 secondary turns.

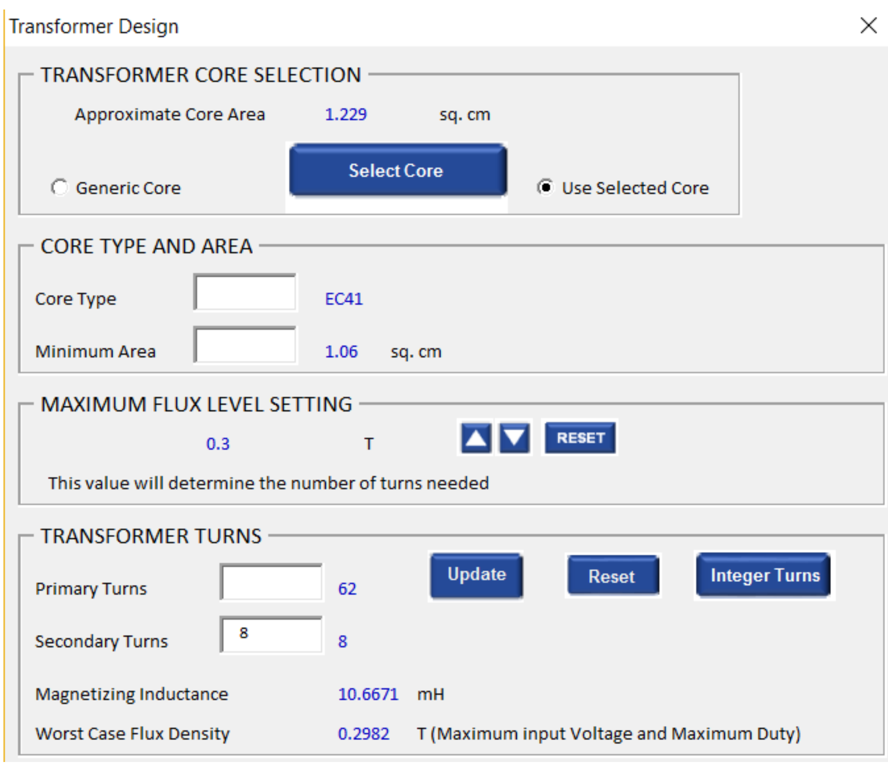


Fig. 6.3: Transformer parameters from RidleyWorks™.

Figure 6.4 shows the structure and analysis of the primary winding of the transformer. Two layers of 22 awg wire are used to give a dc resistance of 160 mOhm. When this is multiplied by the square of the rms current, we see 0.491 W of loss.

However, the ac resistance of the winding, calculated at 100 kHz, is much higher at 1.54 ohms, almost 10 times the dc resistance. RidleyWorks™ takes the rms of the ac current squared and multiplies by this number, adds to the dc current squared times the dc resistance, to get the total losses. You can see that they are much higher at 2.91 W. This is an increase of four times.

This more detailed and insightful information allows you to experiment with different numbers of layers, wire sizes, and parallel strands to see what gives the lowest loss combination. The **Minimize Loss** button automatically tries different layer counts to find the best solution for you.

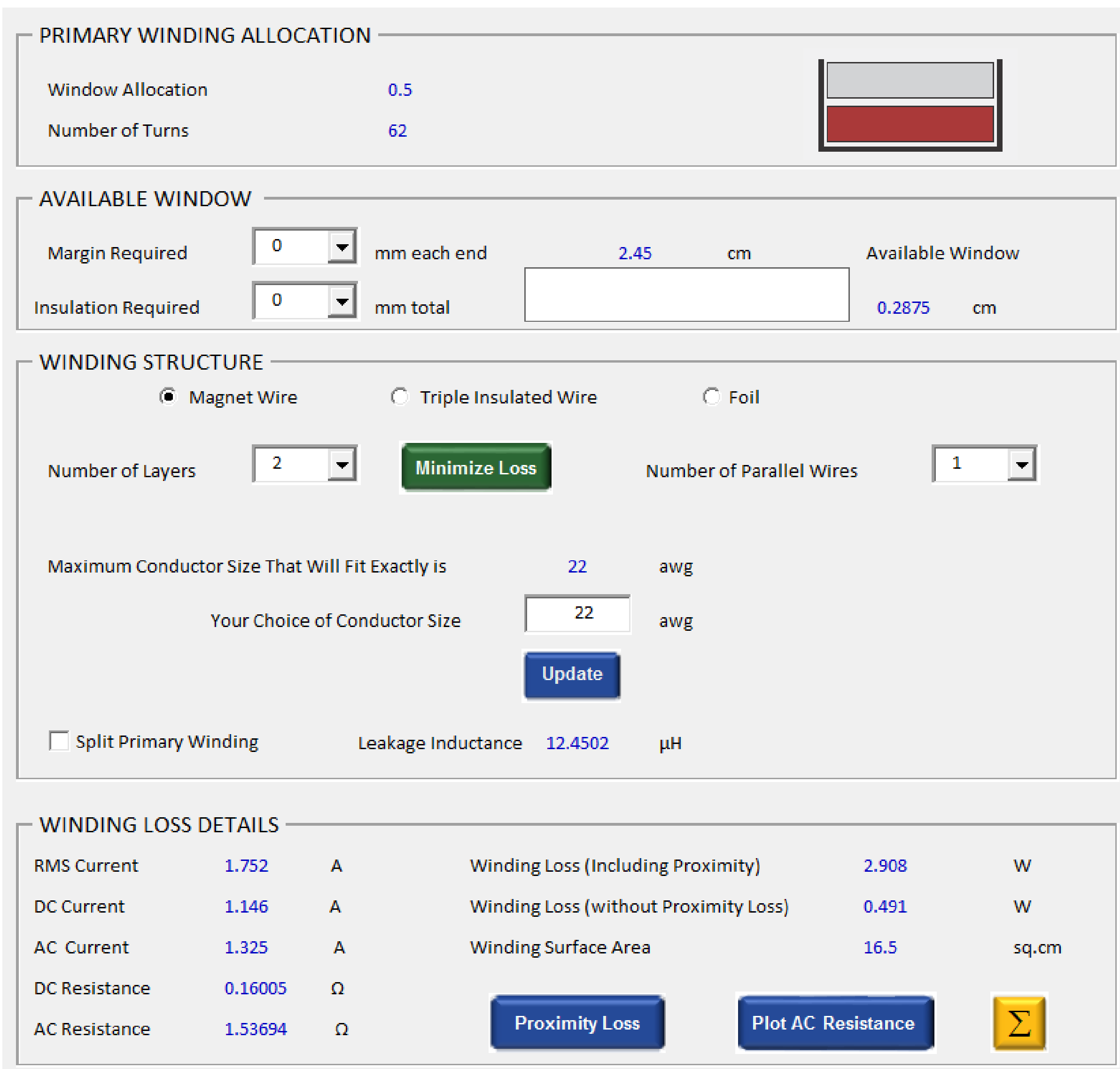
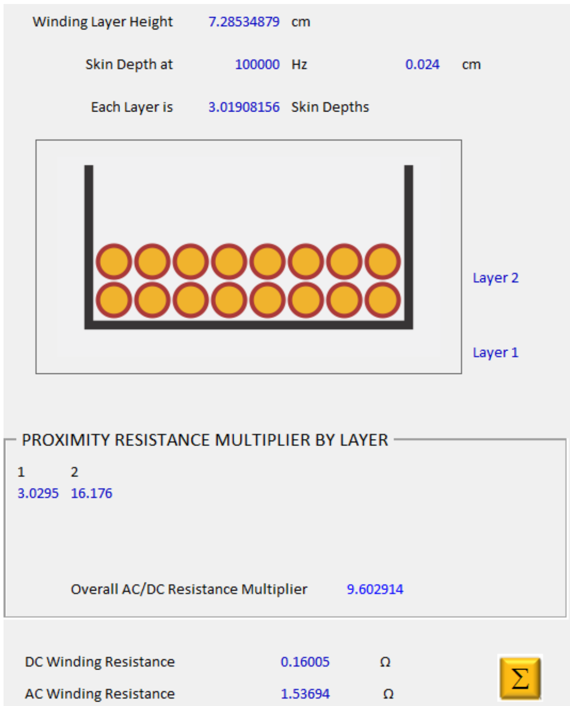


Fig. 6.4: Primary winding structure and analysis from RidleyWorks™

If you click on the blue **Proximity Loss** button, you can see a detailed breakdown of the resistance of the wire layer-by layer. The complexity of Dowell's equations shows why few engineers ever attempt this analysis. Fortunately, RidleyWorks™ automates the whole procedure.



Total power dissipation in a winding is given by:

$$P_d = b_w \sum_{i=1}^{n} l_i \frac{1}{h_i \eta_i \sigma} H_i^2 \left[\left(1+\alpha_i^2\right) G_{1_i} - 4\alpha_i G_{2_i} \right]$$

The H field is calculated from

$$H_i = \frac{N_i I_i}{b_w} \qquad b_w = \text{winding width}$$

Complex functions are needed to calculate the losses:

$$G_{1_i} = \Delta_i \frac{\sinh 2\Delta_i + \sin 2\Delta_i}{\cosh 2\Delta_i - \cos 2\Delta_i}$$

$$G_{2_i} = \Delta_i \frac{\sinh \Delta_i \cos \Delta_i + \cosh \Delta_i \sin \Delta_i}{\cosh 2\Delta_i - \cos 2\Delta_i}$$

The ratio of the winding layer height to skin depth is

$$\Delta_i = \frac{h_{cu_i}}{\delta} \qquad \text{skin depth } \delta = \sqrt{\frac{2}{\omega \mu_o \sigma \eta}}$$

$$\sigma = \text{conductivity} \qquad \mu_o = 4\pi \, x10^{-7} \qquad \eta = \text{porosity}$$

Fig. 6.5: Primary loss analysis by layer together with Dowell's equations published in 1966.

6.2 Advanced Proximity Losses with LTspice Circuit Modeling

Once you have defined the winding structure and are happy with the total dissipation, you can begin the process of LTspice model generation and simulation. When you click on the button like this

RidleyWorks™ will proceed to sweep the solutions to Dowell's equations from 1 kHz to 10 MHz and generate an equivalent circuit model to match the complex impedance.

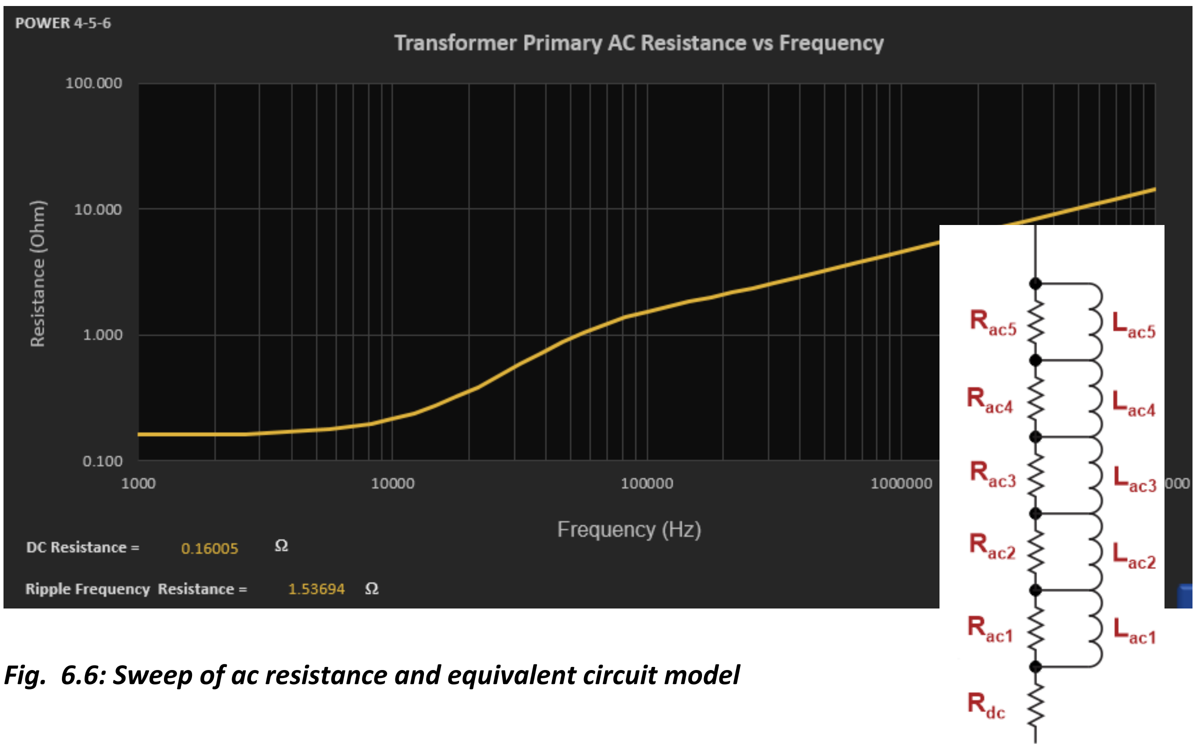


Fig. 6.6: Sweep of ac resistance and equivalent circuit model

This process must be followed for each of the magnetics windings to generate the equivalent circuit models to be used in LTspice. You can then click on the button below to export the complete circuit model.

6.3 Running LTspice for Proximity Loss

Figure 6.7 shows the two-switch forward schematic in LTspice. The yellow resistive elements are the ac proximity models for each of the windings.

Step 1 is to simulate the converter to steady-state, and plot the primary switch current **I(Lpri)** as shown below in Figure 6.7.

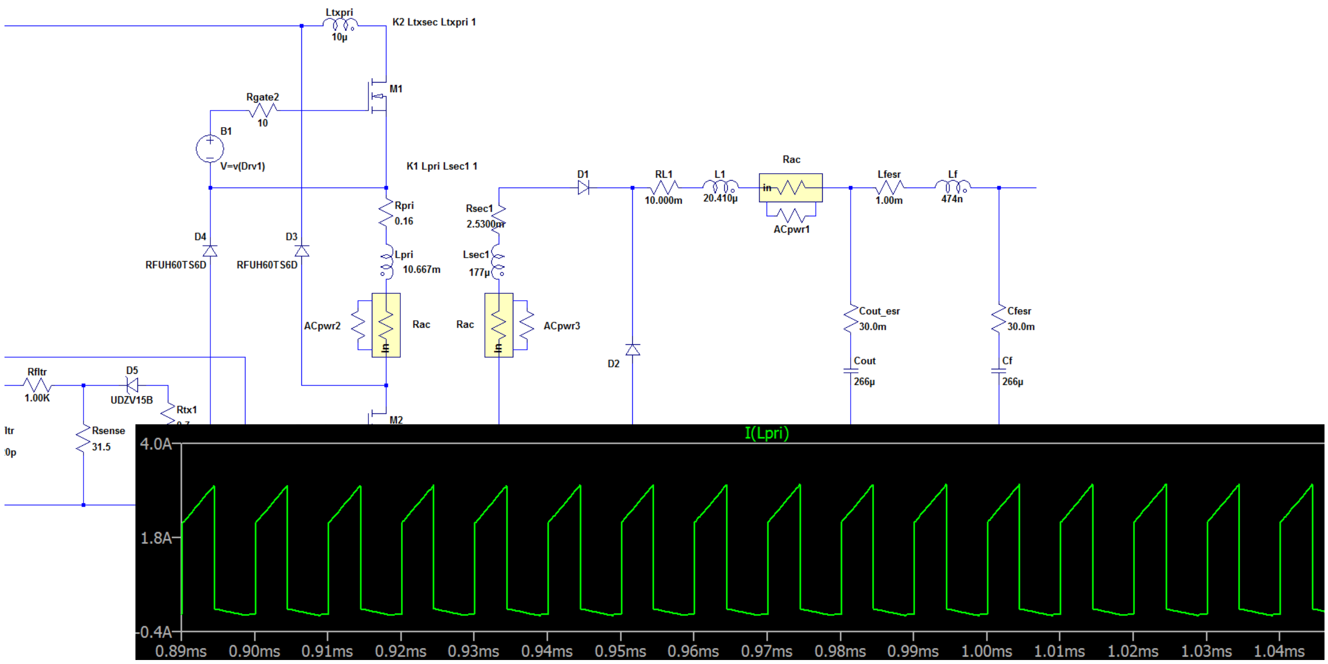


Fig. 6.7: Simulation of primary transformer current in LTspice.

You can plot the conventional dissipation in the primary (without proximity) by holding down the **ALT** key and clicking on **Rpri**. This results in the waveform shown in Figure 6.8. If you click on the name of the waveform in blue, while holding down the **Ctrl** key, it will show the average dissipation. You can see that this number agrees with the dissipation in RidleyWorks™ before proximity is added.

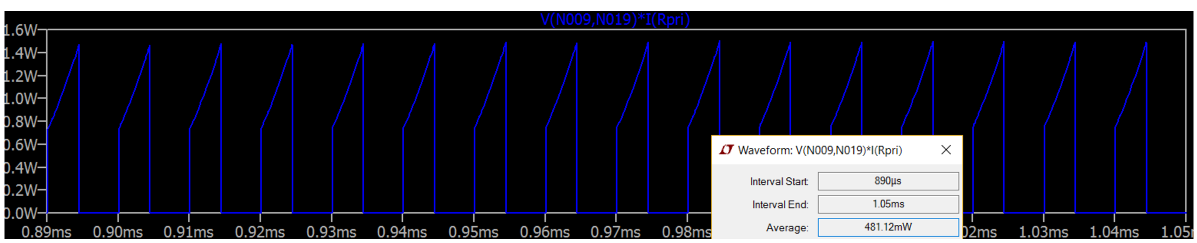


Fig. 6.8: Conventional dissipation in transformer primary (no proximity loss).

You can now plot the additional proximity loss dissipation in the primary by holding down the **ALT** key and clicking on the circuit element **ACpwr2**. This results in the waveform shown in Figure 6.9. If you click on the name of the waveform in green, while holding down the **Ctrl** key, it will show the average dissipation. The sum of the conventional dissipation and the ACpwr2 dissipation is the total winding loss.

You will probably see the total dissipation predicted by LTspice is higher than that predicted by RidleyWorks™. The LTspice number will be more accurate since it includes the dissipation in the resistors at higher harmonic frequencies. Depending on the topology and operating point, the difference may be considerable.

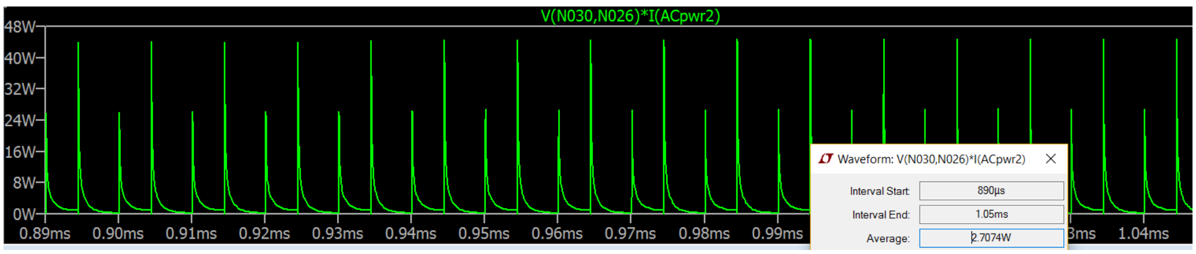


Fig. 6.9: Additional proximity loss dues to ac resistance model.

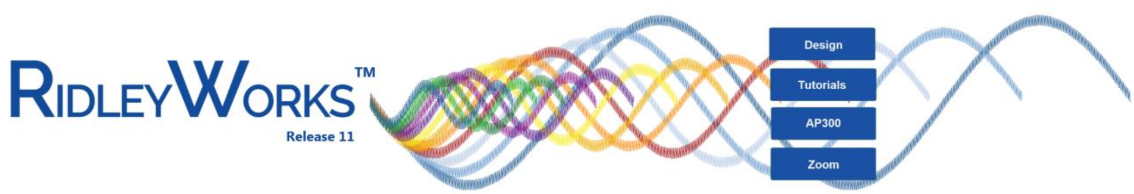
Once you have mastered this technique, you will be doing proximity loss calculations that are more advanced that just about anyone in the industry. Attempting to do this work without the aid of RidleyWorks™ is extremely time-consuming and difficult – you now have a powerful tool that gives you a huge design advantage.

7 Using RidleyWorks™ with an AP300 Analyzer

7.1 Launching RidleyWorks™

RidleyWorks™ has a powerful and user-friendly interface to the AP300 frequency response analyzer. This enables you to setup complex analyzer functions and settings with a single button click inside RidleyWorks™.

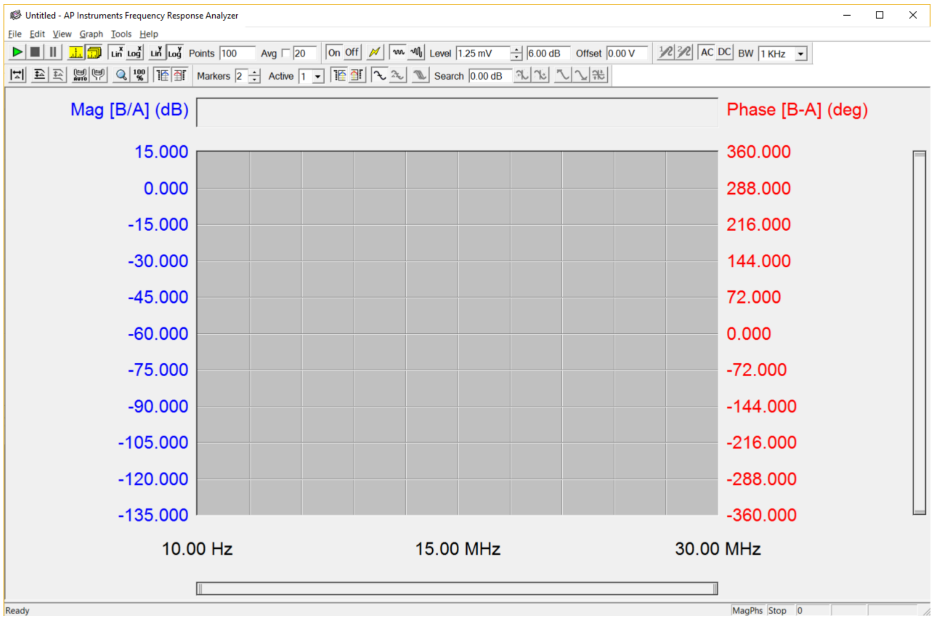
Open Excel on the computer, and load in the latest version of RidleyWorks™. You will then see this opening screen:



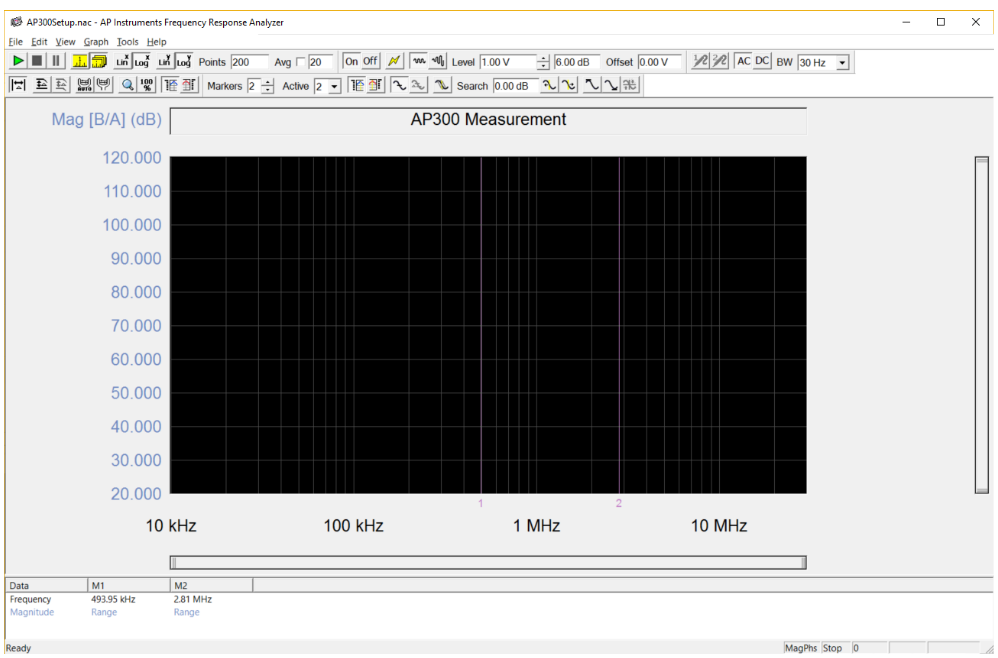
You will now want to launch the AP300 software and link the two together.

5.2 Launching the AP300 Analyzer Software

Power on the AP300 analyzer, and make sure it is connected with a USB cable to your computer. On the toolbar of the computer, you will see the icon for the APfra software which controls the AP300 analyzer. Click on this icon to launch the AP software. You will then see this opening screen:

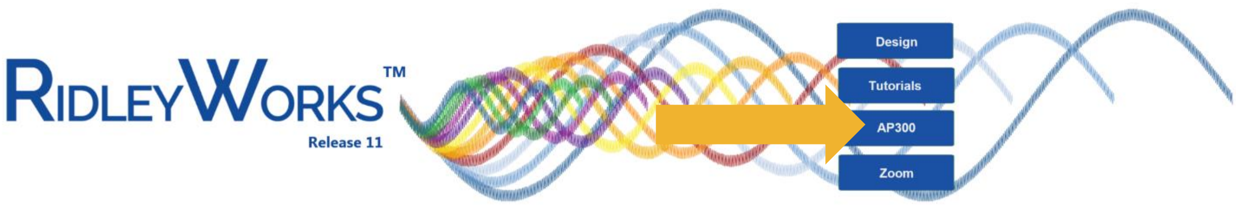


Click on File>Open Setup and select AP300Setup.nac to see this screen. Notice that the sweep is now logarithmic, and the stop frequency is 30 MHz with a drive signal of 1 V.

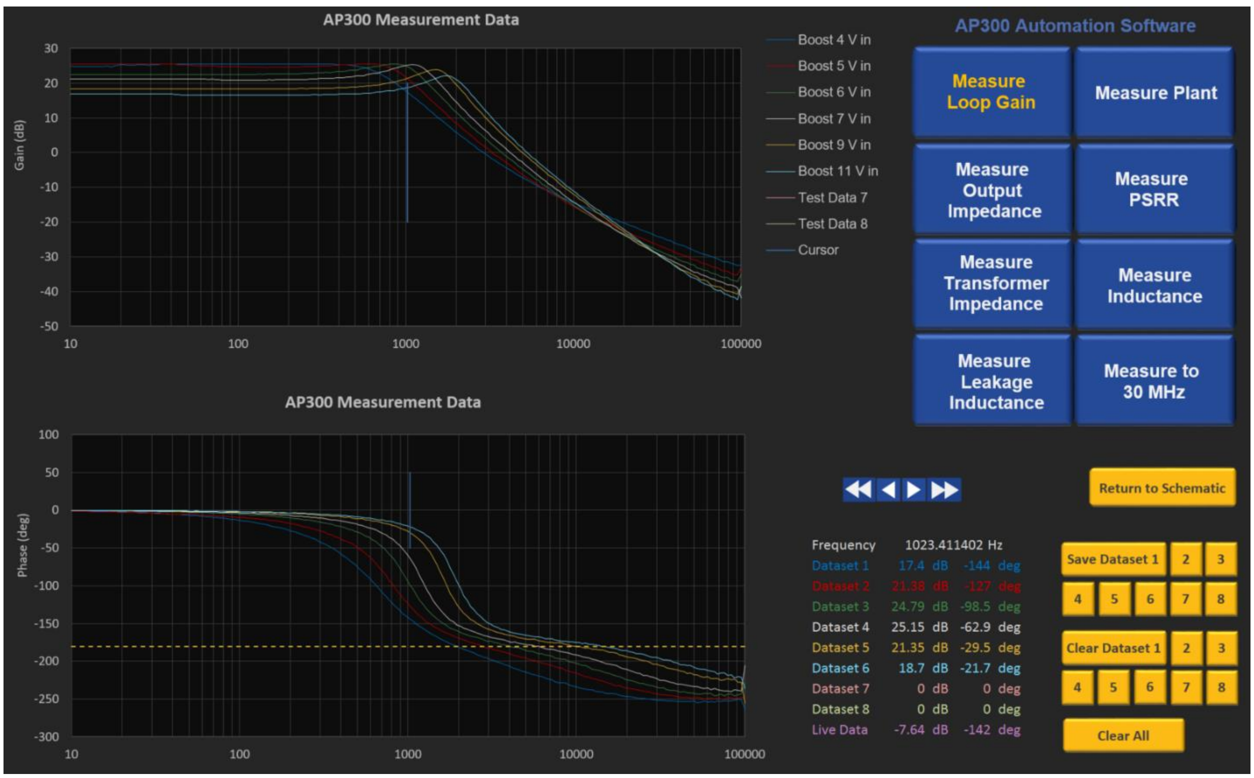


5.3 Connecting the AP300 to RidleyWorks™

Click on the button below to establish a live link between RidleyWorks™ and the AP300 analyzer. This may take a little time to complete.



Once the link is complete, RidleyWorks™ will connect to the page below.



This page provides a powerful interface for driving the AP300 and collecting multiple data sweeps. There are 8 preset settings on this page for magnetics measurements and control measurements, and we will use these extensively in the lab.

When you first come into RidleyWorks™ you will find a default set of control measurements for a boost converter transfer function as shown in the figure below. You can clear this data with the gold buttons and store up to 8 of your own traces as you collect them.

5.4 Opening a Word Notebook

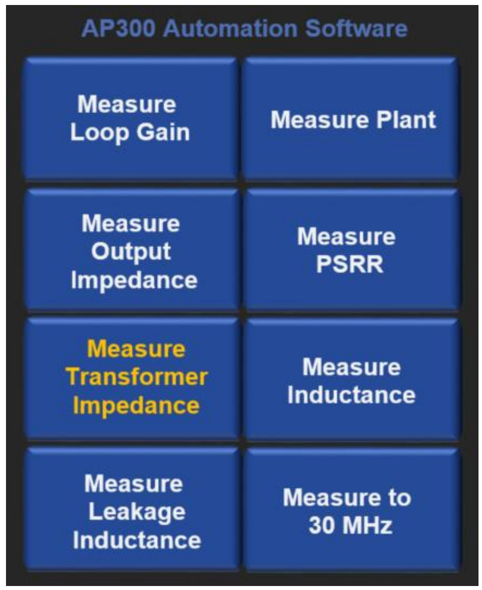
We recommend that you open a Word document to use as a lab notebook. When you see an interesting trace on your scope, or AP300 analyzer, use the command **ALT-PrtSc** to capture the screen graphic. You can then paste it into Word with **CTL-v.**

We have found this to be the fastest way to document intense test and debug under pressure of schedule. It also encourages you to write notes with the graphics in word as you go so you don't have to do documentation after your lab session.

AP300 Magnetics Measurements

5.5 Measuring Transformer Impedance

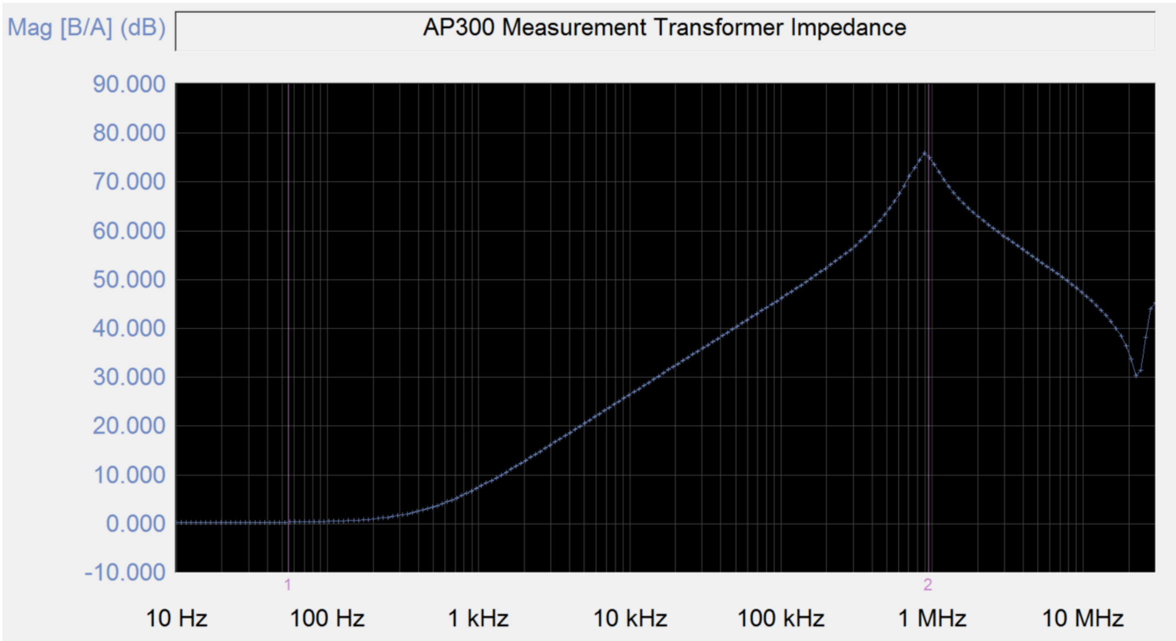
On the AP300 page of RidleyWorks™, click on the button to measure transformer impedance.



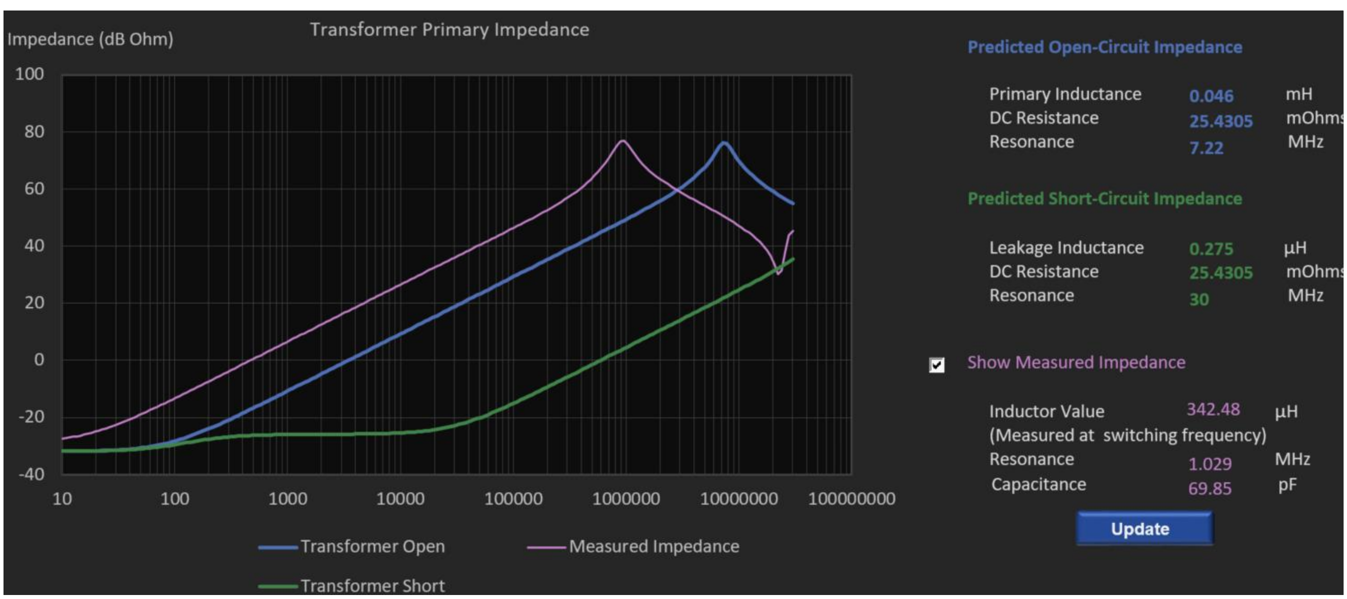
The hardware setup for this is shown below with the high-impedance test fixture.

Magnetics Testing

The AP300 analyzer screen will show the data as below. You can use markers inside the AP300 software to find the resonant peak of the device you are measuring.

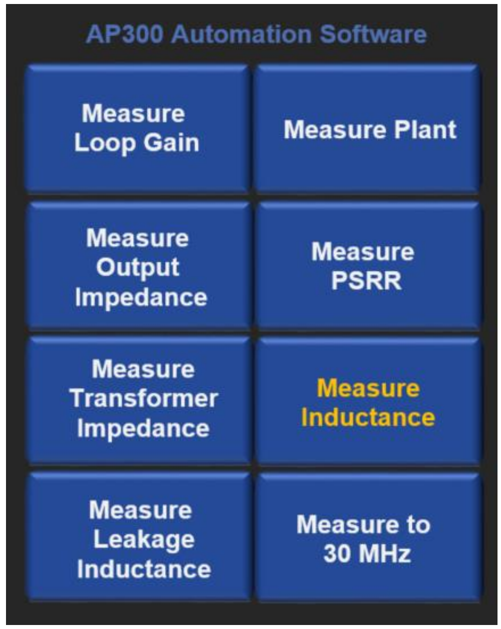


You can also look at the data as it is brought into RidleyWorks™ on the Transformer Design page. This has the advantage of showing both the impedance plot versus the predicted values, and RidleyWorks™ also extracts the circuit values of L and C for you.

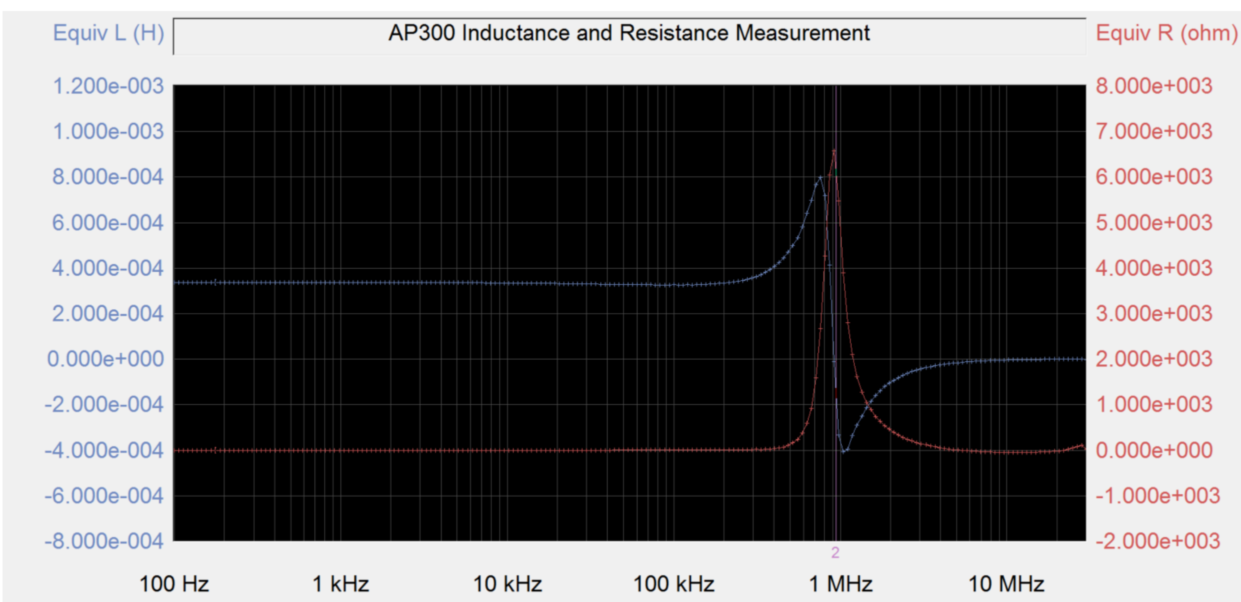


5.6 Measuring Inductance

You can measure the inductance versus frequency for the device you are testing. This can be useful when you have frequency-dependent inductor values. It is also useful for measuring winding resistance versus frequency.



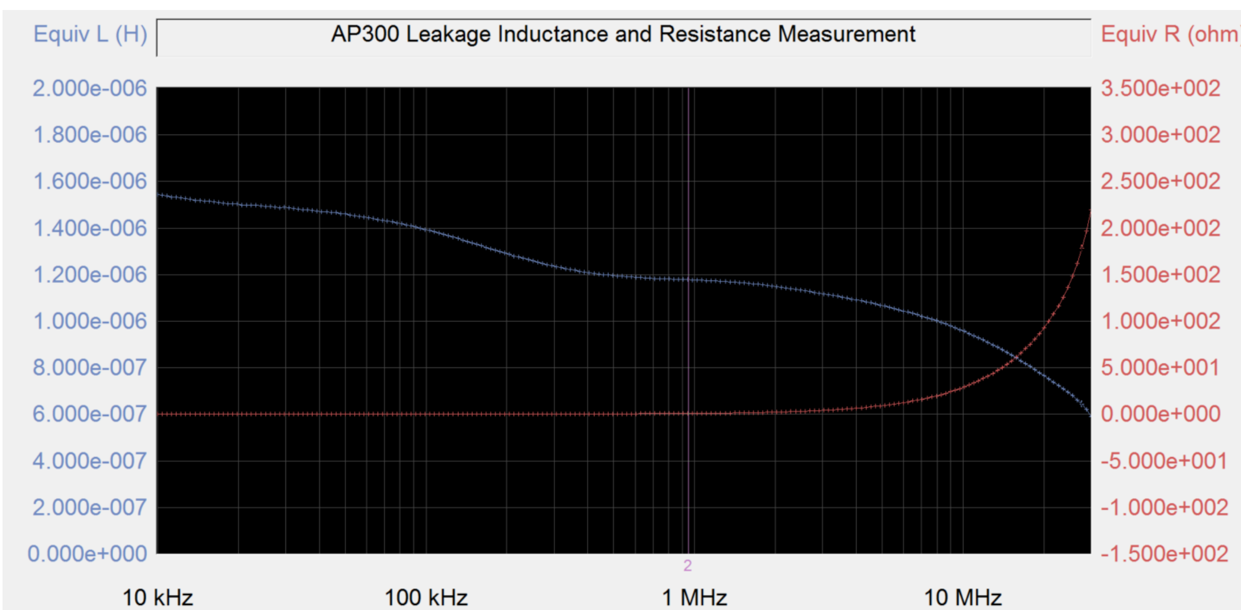
The data is presented as shown below in the AP300 software. You can use the cursor to read the values of R and L at different frequencies.



5.7 Measuring Leakage Inductance

Leakage inductance is made with a short circuit on the secondary windings of your transformer. The leakage inductance setting in RidleyWorks™ will sweep starting at 10 kHz and extract the L and R values of the transformer for you.

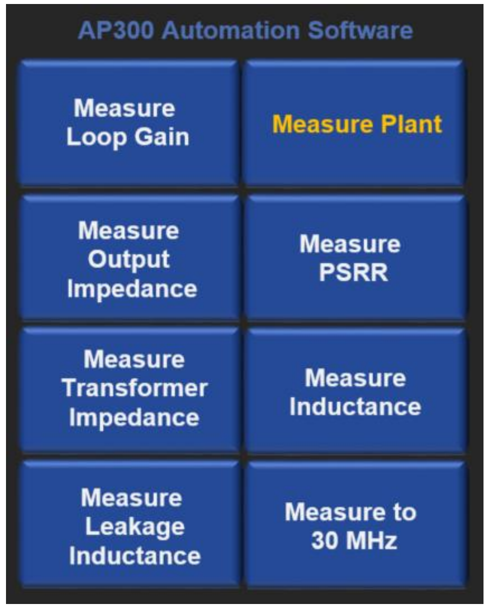
For many transformers you will see that the leakage inductance is a function of frequency. The frequency at which it starts to decrease in value indicates the effect of proximity loss in the windings.



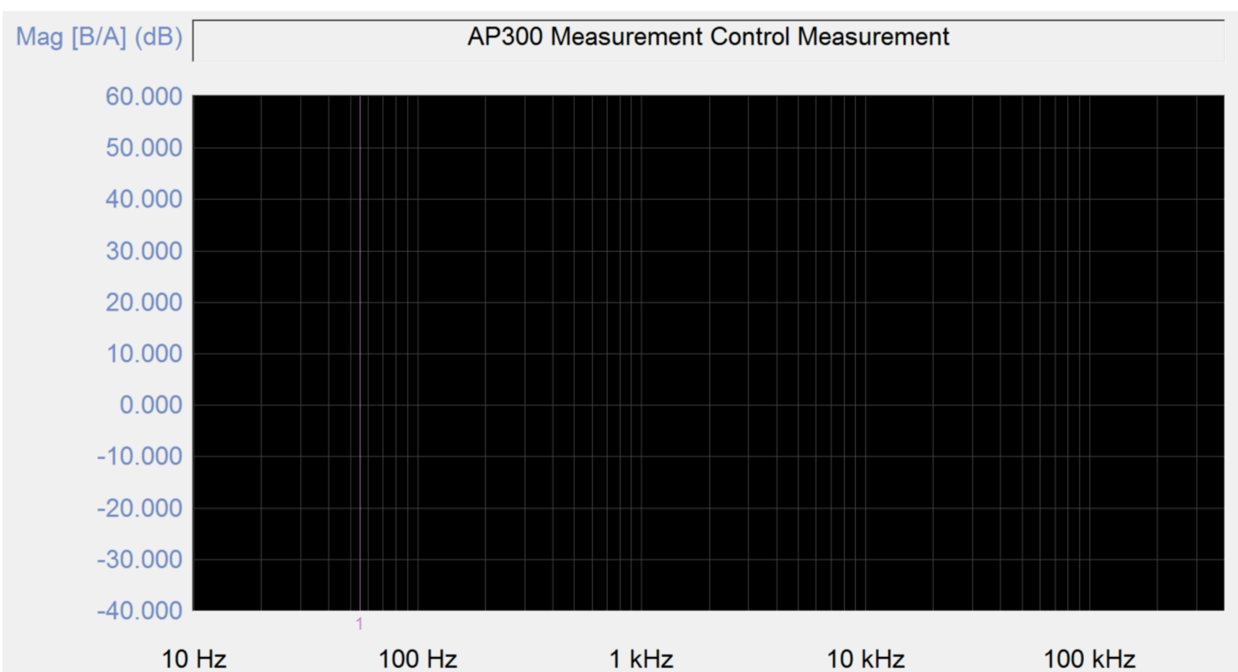
AP300 Control Measurements

7.8 Measuring Power Stage Transfer Functions

To measure open-loop transfer functions for a circuit, click the button below.

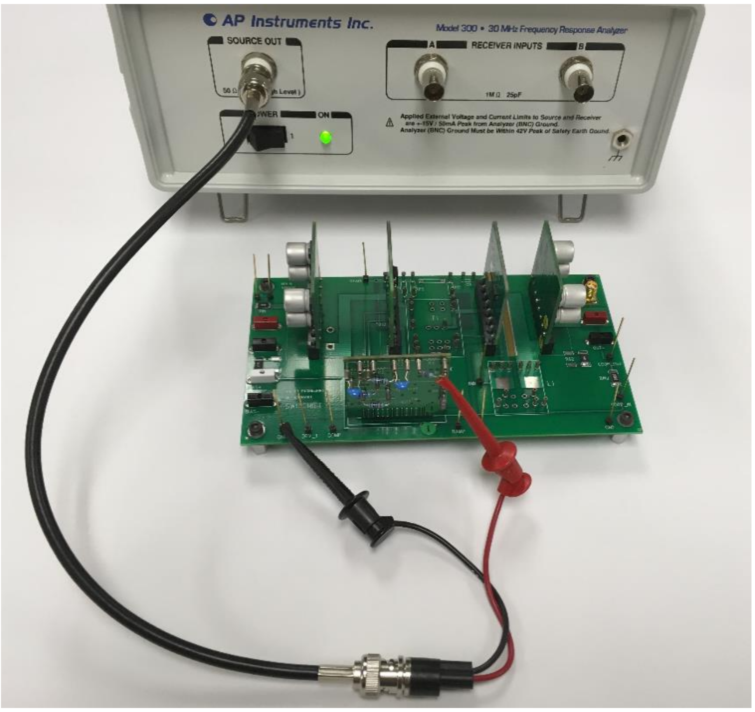


The analyzer sweep will now be set to twice the converter switching frequency as shown below.



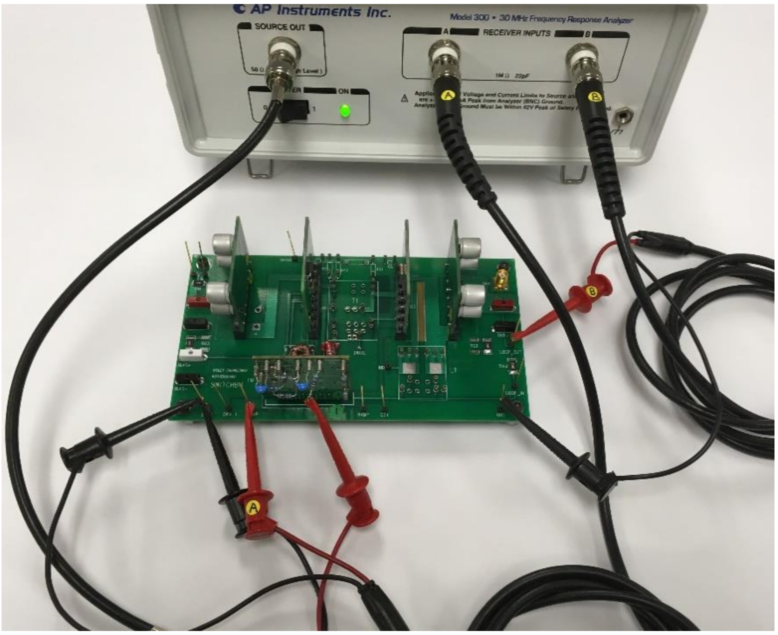
The injection setup is shown below on the hardware for the lab. Notice the 1 k resistor in series with the injection point right of the **C2** capacitor on the control board.

Control Injection



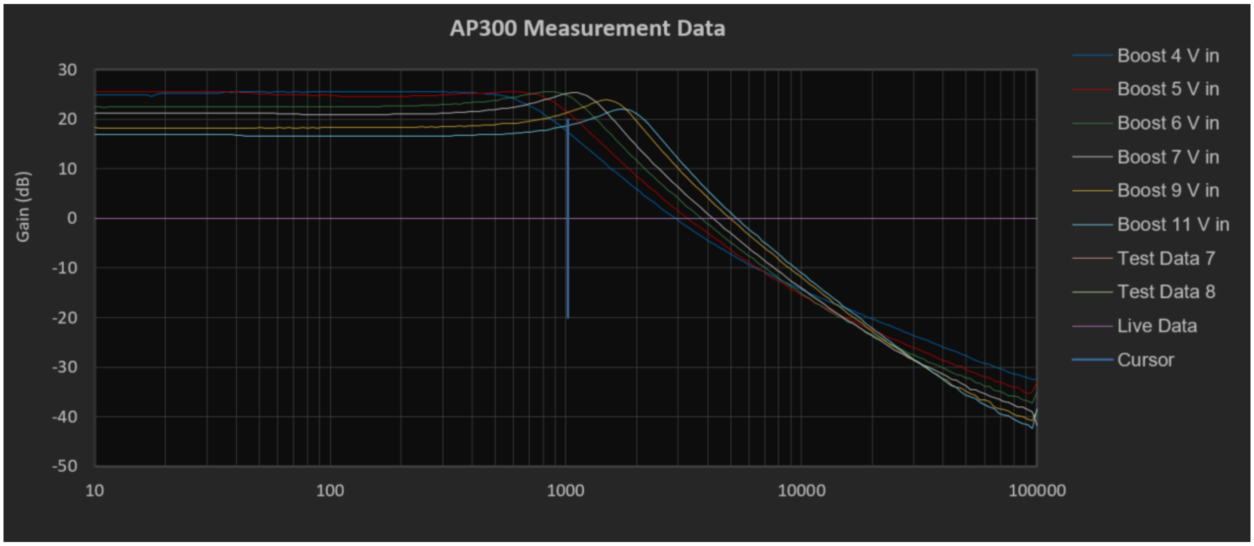
The picture below shows the connection of the A and B test channels from the AP300 analyzer, connected to measure the power stage transfer function.

Control Test Points

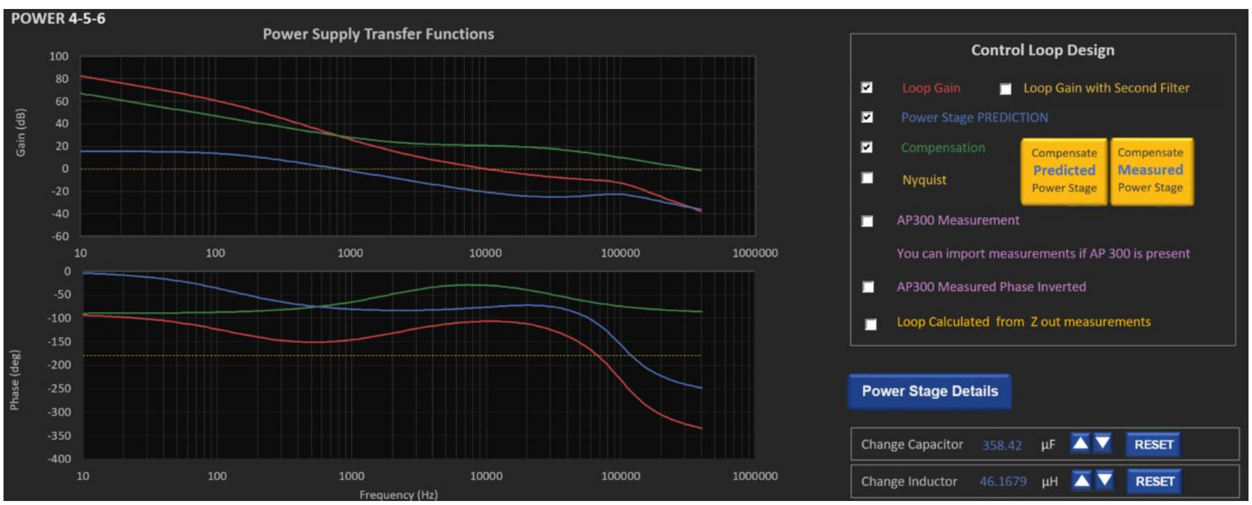


Channel A is connected to the **COMP** pin on the board this is the output of the PWM modulator error amplifier. Channel B is connected to the **LOOP_OUT** pin, which is the same node as the power supply output voltage.

There are several options for looking at the transfer function results. The can be seen directly in the AP300 software which will continually update the measurements. You can also see the measurements on the AP300 Measurement page of RidleyWorks™, and this page will allow you to save multiple sweeps with different operating conditions.



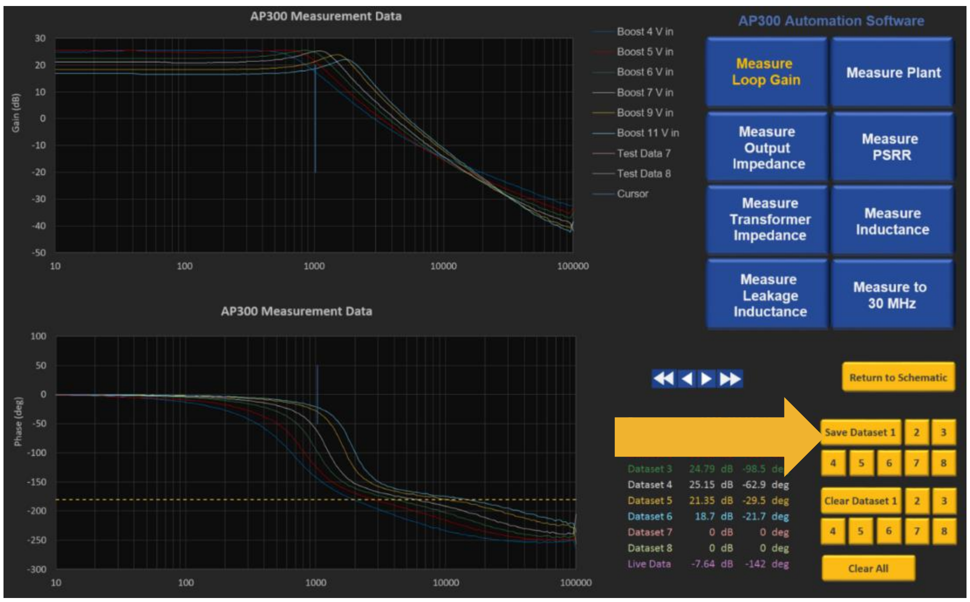
A third option is to view the measurements on the Power Stage page of RidleyWorks™ by clicking on the Loop button. With this option, you will be able to overlay measurements on top of the predictions of the power stage to validate your design better.



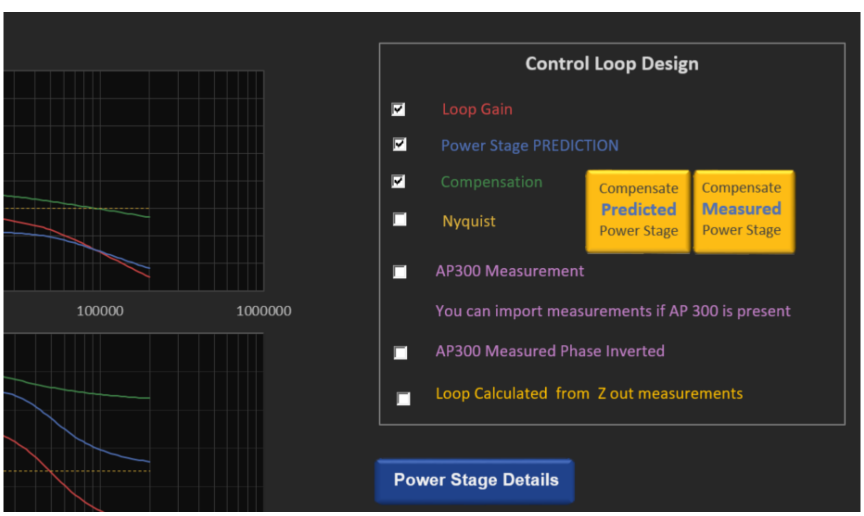
7.9 Designing a Compensator for a Power Stage Measurement

The default compensation design procedure in RidleyWorks™ is to select feedback components to work well with the predicted power stage measurements. You will sometimes run into cases where the measurements differ significantly from the predictions. RidleyWorks™ has the powerful option of taking your power stage measurements and designing a compensator to match. This is a two-step process.

First, go to the AP300 Measurements page after you have swept the power stage measurement. Click on the button below to save the measurement date in Dataset 1.



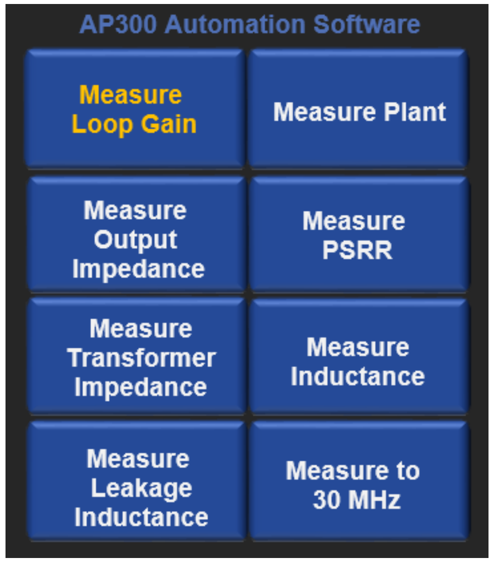
Then return to the power stage page and select the loop measurements screen.



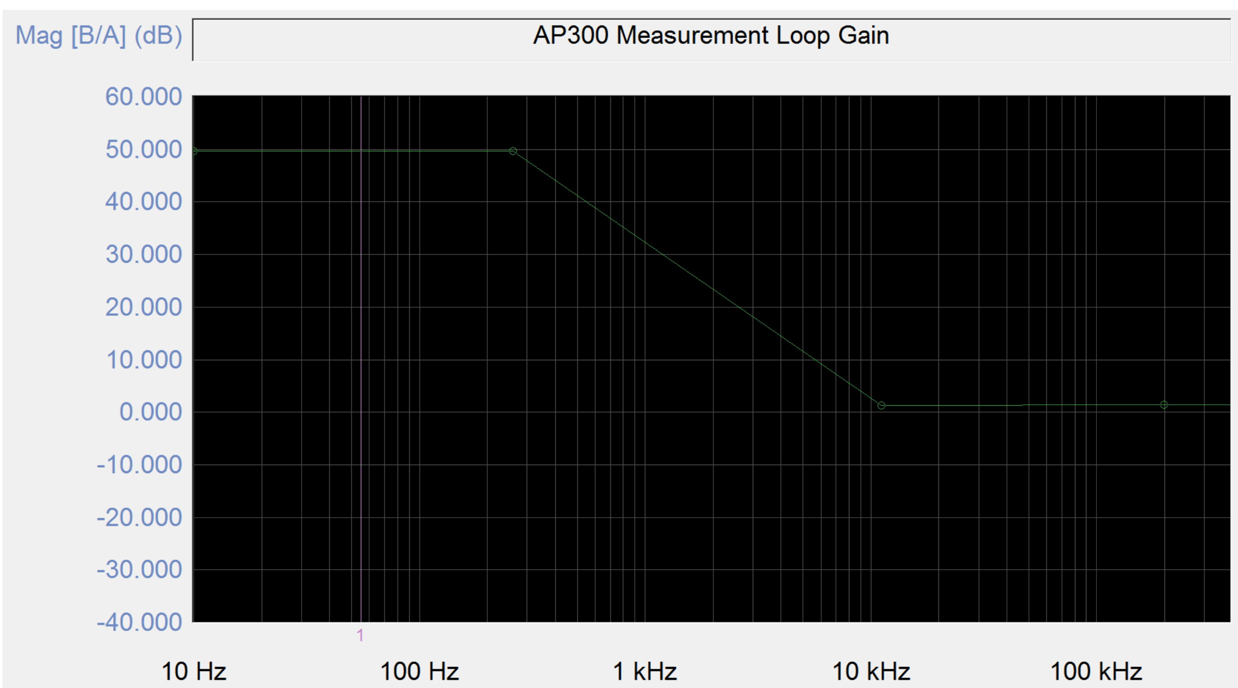
You will then see the measured power stage appear, and the resulting loop will be for the compensated measurement.

7.10 Measuring Loop Gains

To setup the AP300 analyzer for loop measurements, click on the button highlighted below.

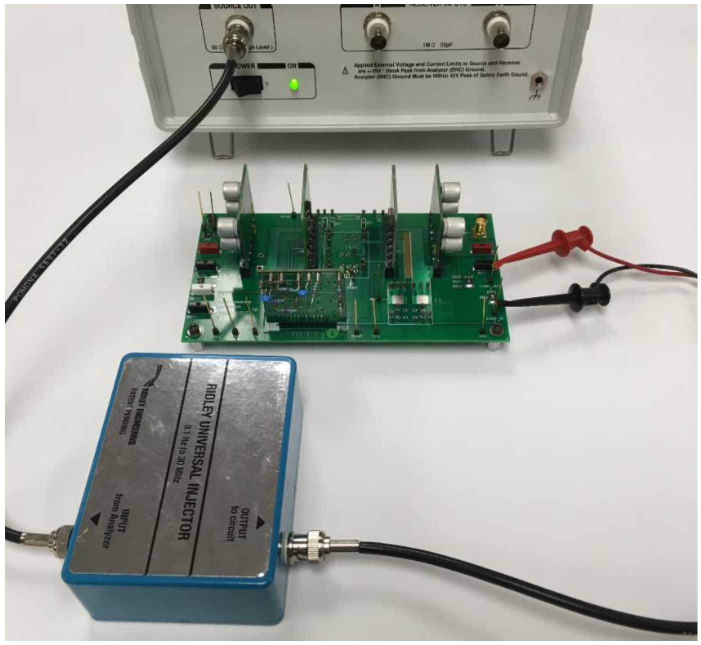


The analyzer will sweep from 10 Hz to twice the switching frequency. Notice the green curve on the graph below in the AP300 software. This sets the variable injection signal size versus frequency. The default settings will work well for typical power supply loops, but you can slide the curve up and down to adjust the signal for your test circuit as needed.



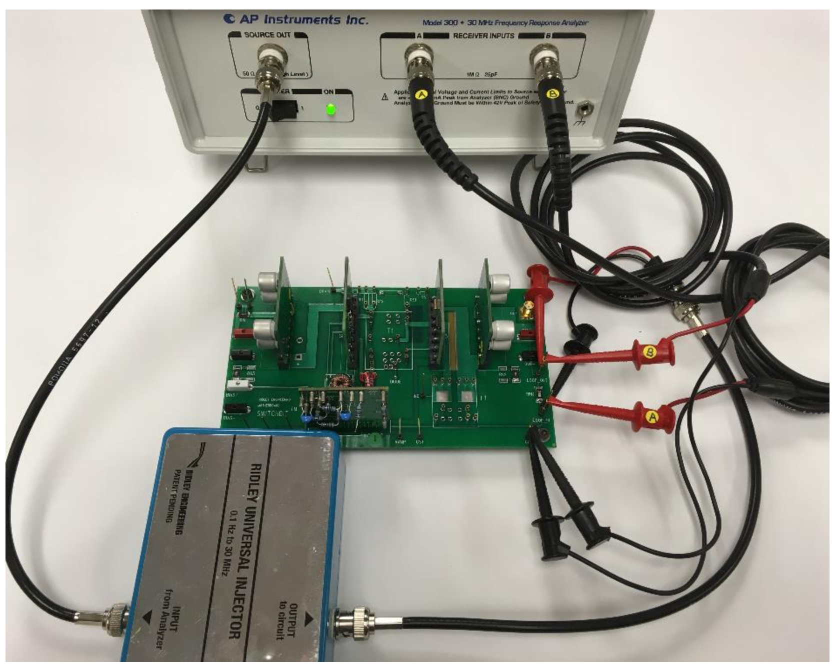
In the lab, the injection point for loop measurement differs from injection for the control-to-output measurement. An isolation transformer is needed to inject into the loop differentially. The injection leads are connected to the **LOOP_IN** and **LOOP_OUT** test points on the board.

Loop Injection



Below you can see the connection of the test leads from the AP300 analyzer. Channel A is connected from **GROUND** to **LOOP_IN.** Channel B is connected from **GROUND** to **LOOP_OUT.**

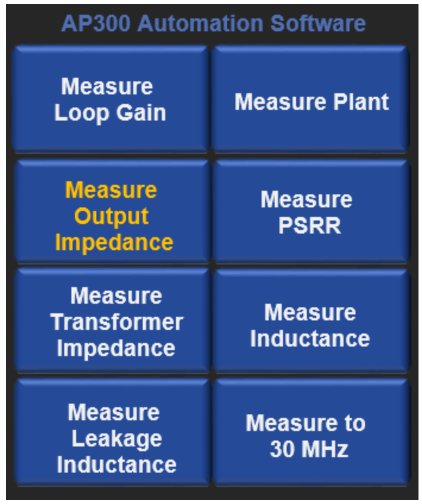
Loop Test Points



You can either use the AP300 software or the RidleyWorks™ software to see the resulting measurements, as with the control-to-output measurement.

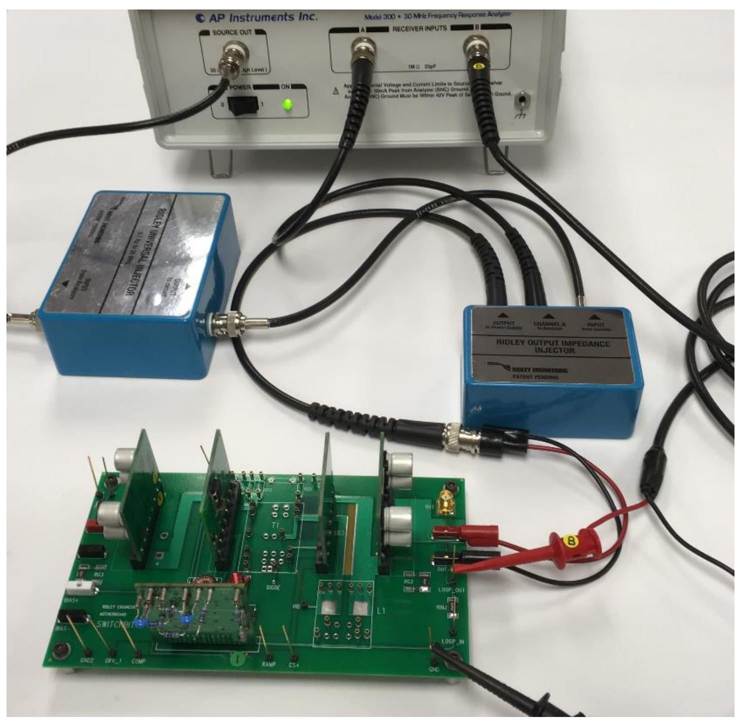
7.11 Measuring Output Impedance

To setup the AP300 analyzer for output impedance, click on the button highlighted below.



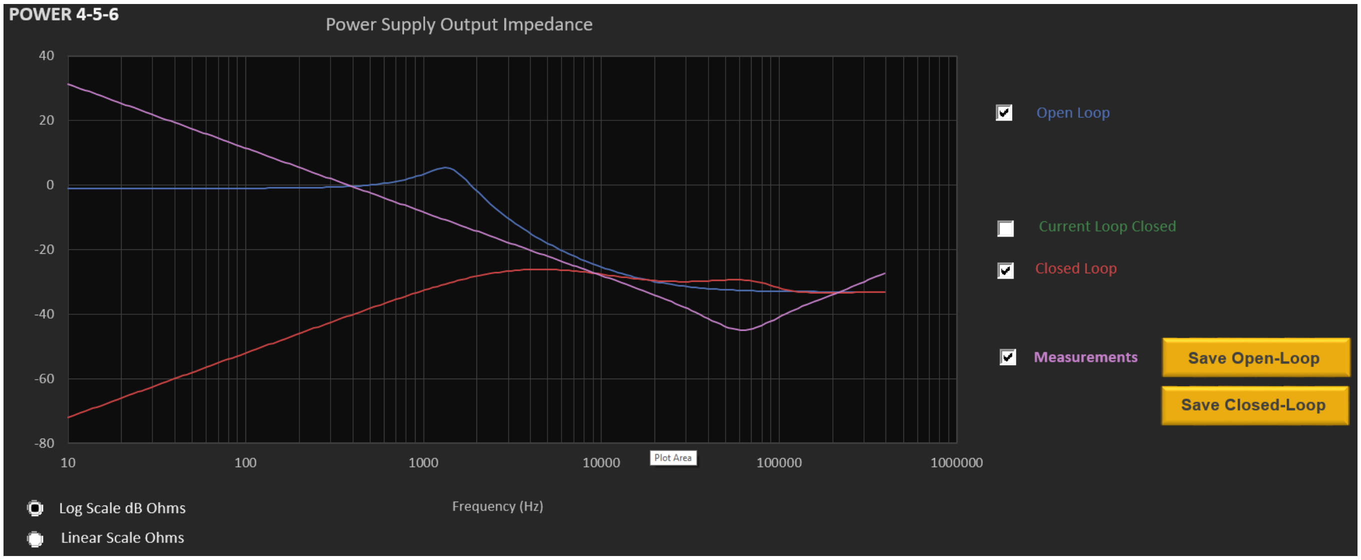
This will set the AP300 source to its maximum value to drive current into the output terminals of the power supply that you are testing.

Output Impedance Injection



The output impedance injector and the isolation transformer are needed in this setup. The injected signal is connected directly to the output of the power supply under test. The Channel B test lead is connecto to **GROUND** and **LOOP_OUT.**

The output impedance measurement can be viewed on the AP300 or by clicking on the Z Out button in RidleyWorks™.

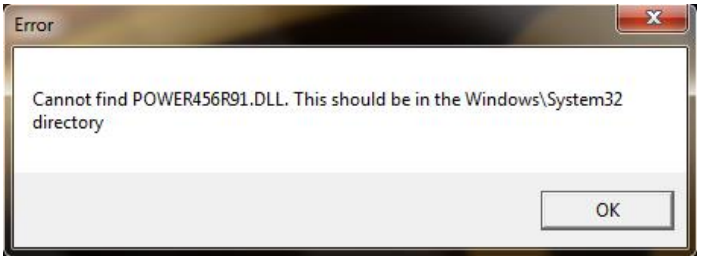


Notice the buttons to the right of the graphs that allow you to store the measurements of output impedance. An advanced feature of RidleyWorks™ is the ability to estimate the loop gain of the system from impedance measurement. This can be used if the loop of the system is inaccessible, but it is not as rugged a measurement as looking at the loop directly.

Appendix A Error Messages

Error Message	Page Number

Cannot find RIDLEYWORKS.DLL

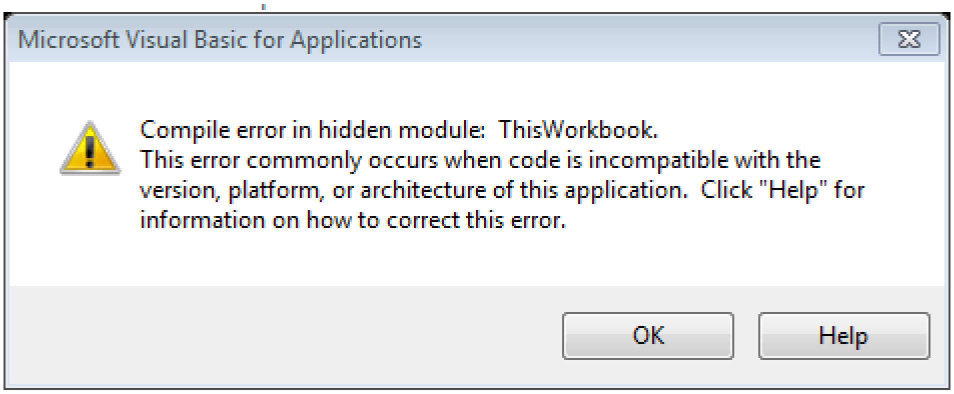


You will see this message if you try to run your RidleyWorks™ file from a directory other than the original installation directory. It's OK to save files to other directories, but when you want to run them, take them back to the original directory. Do NOT try moving the .dll files to the System32 directory, this will not solve the problem.

Newer operating environments looks elsewhere for the proper file. It you continue to get this message, please do the following:

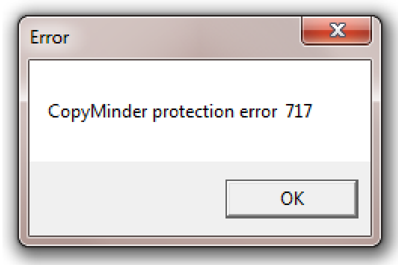
If any RidleyWorks™ client installation gets the error where 'RIDLEYWORKS™.dll' is not found. Copy it from C:\users*username*\documents\RIDLEYWORKS™\
To: C:\Windows\SysWOW64

Compile Error EXCEL 64-bit Installed Instead of 32-bit Excel



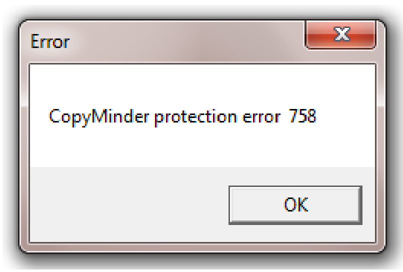
You will see this message if you have 64-bit version of Excel installed on your computer and you have a version of RidleyWorks™ prior to 1107. If you are on 64-bit Excel, please make sure you have the latest version of RidleyWorks™ downloaded.

Protection Error 717 Incorrect Passkey Entered



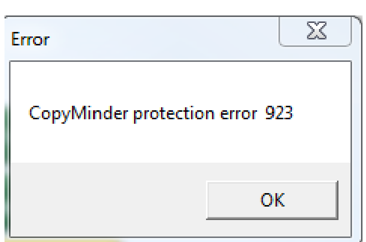
You will see this message if you enter an invalid passkey for the program. Check for the proper number, and contact Ridley Engineering if you cannot find it.

Protection Error 758 License Expired



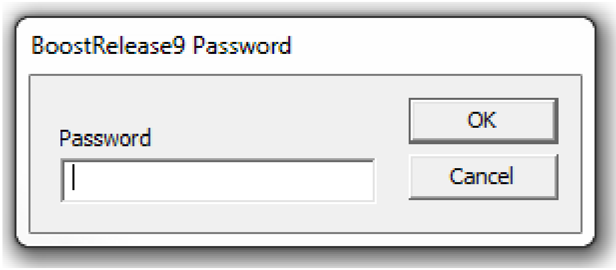
You will receive this error when your license has reached its expiration date. Contact us to verify the date or to renew your registration.

Protection Error 923 Installation Incomplete

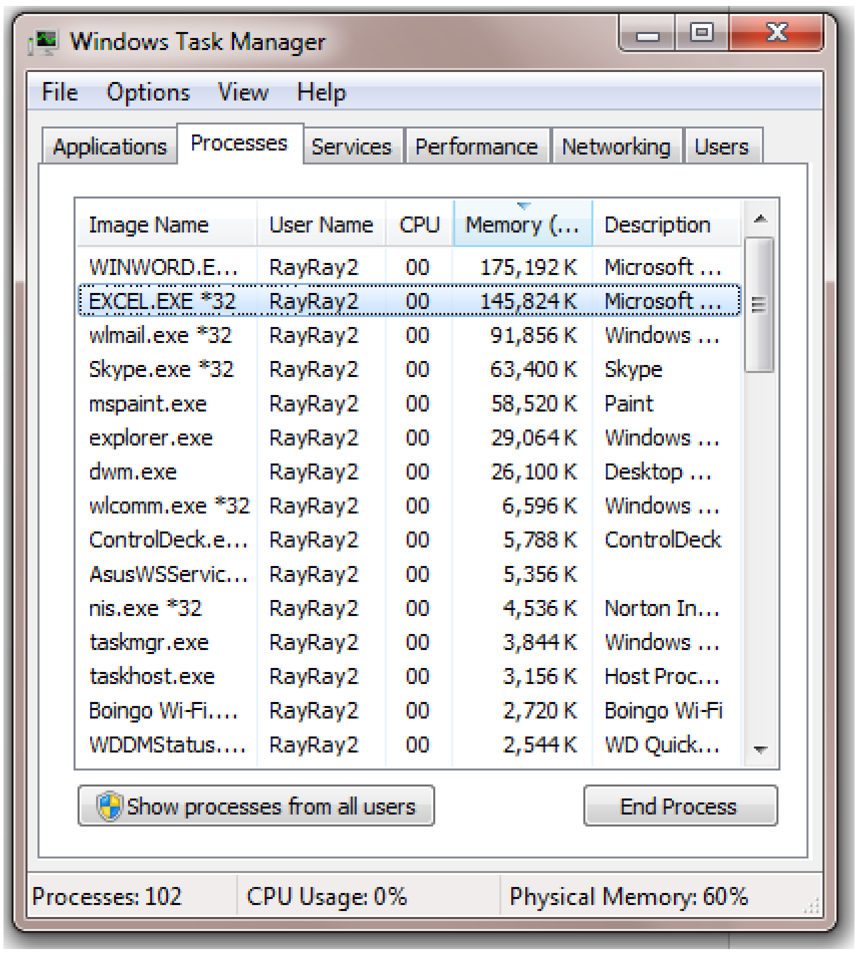


You will receive this error if the software installation did not finish generating all of the necessary files. Please go to Section 1.4, item number 2 of this manual to learn how to complete the installation.

Trouble Closing RidleyWorks™

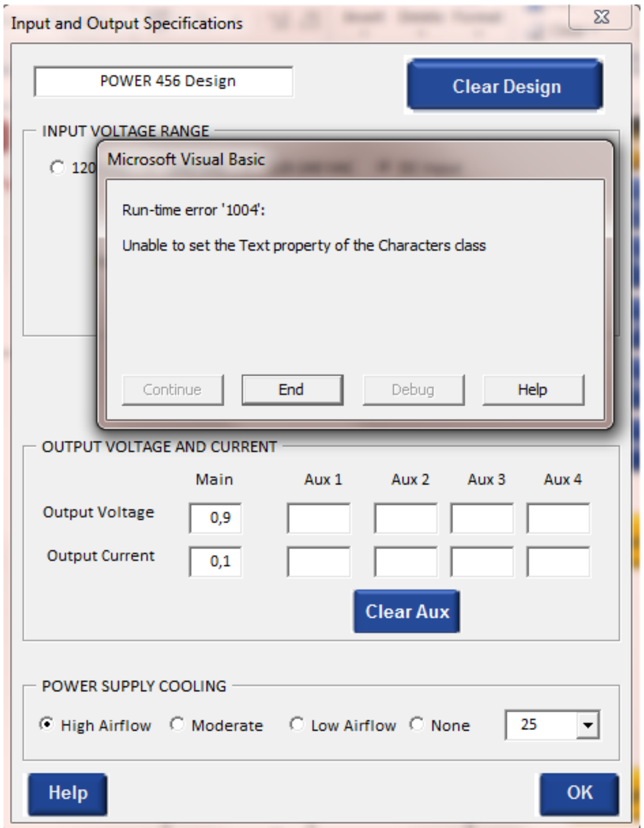


Very rarely, you may see this screen pop up when you try to close the program. Clicking OK or Cancel will not get rid of it. If this happens, type ctl-alt-delete and select Start Task Manager. Select Processes, highlight EXCEL.EXE*32, and click on End Process. This should close the program.



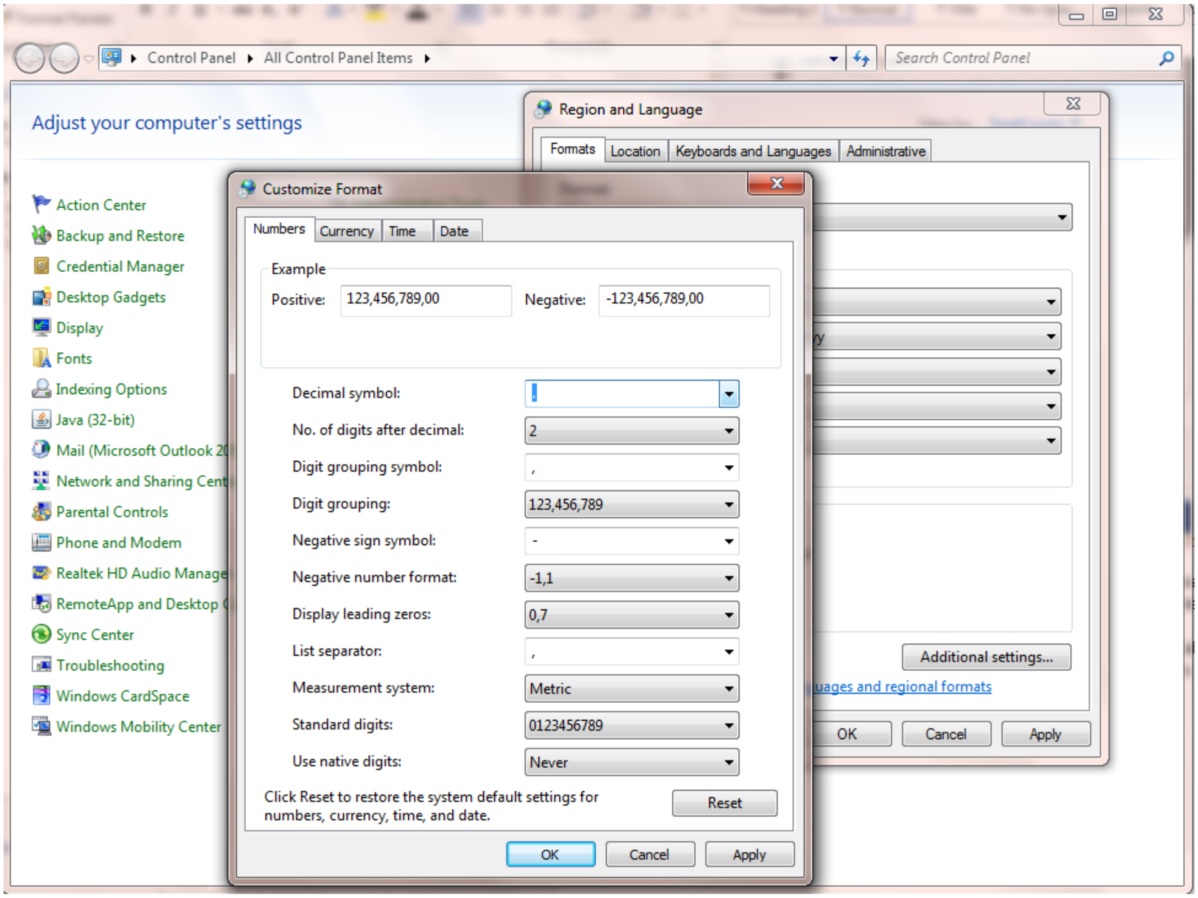
Run-Time Error 1004

This error will occur if you have an old version of Excel prior to 2013. Please upgrade to the latest version.

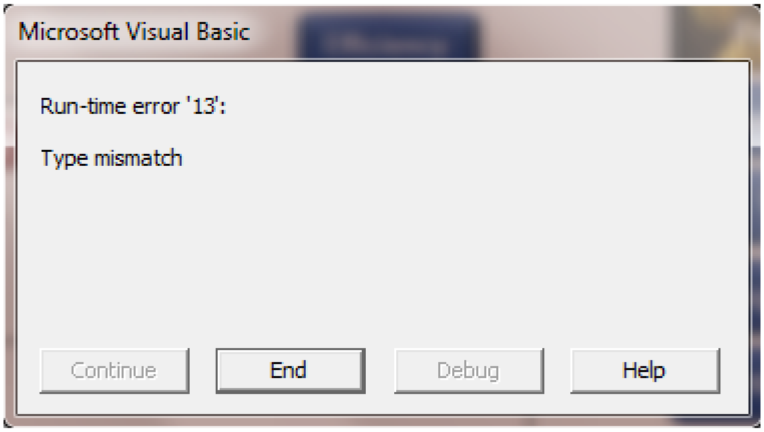


In some cases, the error will occur if you do not have the decimal separator character set to a period "." You can change the setting of the decimal separator in your Windows system as described below.

Click on Control Panel, Region and Language. Under the Format tab, click on Additional Settings, and you will be able to change the character to a period as shown.


Control Panel
All Control Panel Items
Search Control Panel
Adjust your computer's settings
Action Center
Backup and Restore
Credential Manager
Desktop Gadgets
Display
Fonts
Indexing Options
Java (32-bit)
Phone and Modem
Parental Controls
Sync Center
Troubleshooting
Windows CardSpace
Windows Mobility Center
Region and Language
Formats
Location
Keyboards and Languages
Administrative
Additional settings...
OK
Cancel
Apply
Customize Format
Numbers
Currency
Time
Date
Example
Positive:
123,456,789,00
Negative:
-123,456,789,00
Decimal symbol:
No. of digits after decimal:
2
Digit grouping symbol:
Digit grouping:
123,456,789
Negative sign symbol:
Negative number format:
-1,1
Display leading zeros:
0,7
List separator:
Measurement system:
Metric
Standard digits:
0123456789
Use native digits:
Never
Click Reset to restore the system default settings for numbers, currency, time, and date.
Reset
OK
Cancel
Apply

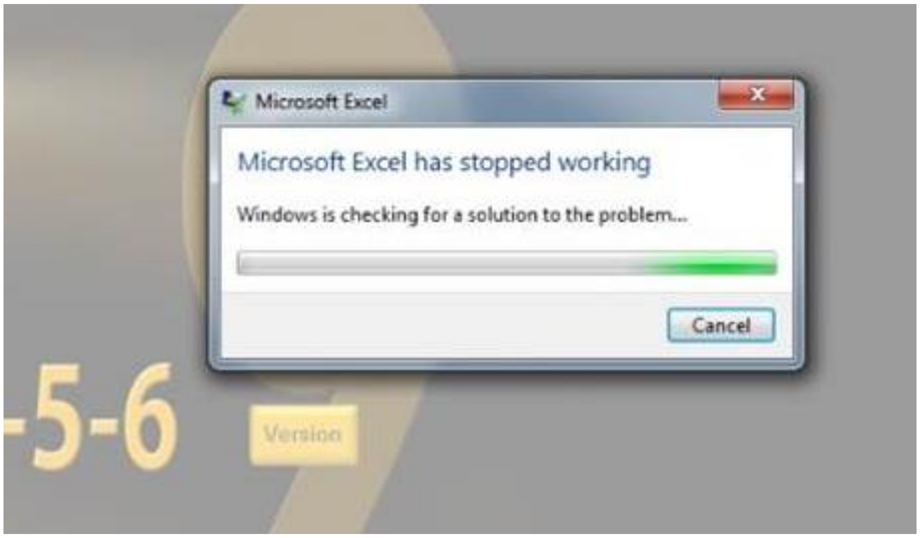
Data Entry Format Error – Run-Time Error 13



Most mistakes in data entry will be flagged by RidleyWorks™ and will give you an error message. However, if you see the message above, you may have the decimal separator set incorrectly in your system. This is changed as described in the above section.

If this does not fix the problem, you can solve it by clearing your design, but before you do that, if you save the file and send it by email to us, we can find the error. This will help us capture the few remaining data entry problems.

Microsoft Excel Stopped Working (EMET problem)



If you get the message that Excel has stopped working while verifying the license, it may be because your IT department has installed Microsoft EMET (Enhanced Mitigation Experience Toolkit). This will block access to the required website to verify the license code.

It is necessary to disable the following EMET options for RidleyWorks™ to register itself properly without triggering EMET to shut down the program.

Export Address Table Filtering
Simulate the execution flow

There is no security risk in implementing these changes.

Object Doesn't Support Property or Method

You may see messages such as this when you click on one of the buttons. Microsoft did some security updates recently, and it causes problems in excel. You can find it discussed at:

https://social.technet.microsoft.com/Forums/exchange/en-US/3f29c84b-97ad-46f7-9bc0-8648d69336ce/kb2553154-breaks-our-excel-macros?forum=officeitproprevious

fix is to simply delete the file MSForms.exd from any Temp subfolder in the user's profile. For instance:

```
C:\Users\[user.name]\AppData\Local\Temp\Excel8.0\MSForms.exd
C:\Users\[user.name]\AppData\Local\Temp\VBE\MSForms.exd
C:\Users\[user.name]\AppData\Local\Temp\Word8.0\MSForms.exd
```

You can search for any files ending in .exd and delete them while excel is closed. Then start excel again and it should work properly. Microsoft are aware of this issue and are trying to fix it, apparently.

More information is at http://stackoverflow.com/questions/27411399/microsoft-excel-activex-controls-disabled

Appendix B License Agreement

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Software License and Limited Warranty Statement

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