

**Demo Guide - Simulation**

# POWER 4-5-6

START ⇨

SCREEN SETUP ⇨



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<http://www.ridleyengineering.com>

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# 1 Introduction to POWER 4-5-6

POWER 4-5-6 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 **POWER 4-5-6**, Release 9 include:

- Power stage designer
- *Magnetics designer* (included in full version, not in Control and Simulation version.)
- 9 topologies most commonly used in the industry (plus rectifier options.) All topologies in one program allow you to compare quickly and easily
- Industry's *fastest cycle-by-cycle simulation* shows true large-signal performance
- *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
- Power stage loss and stress analysis for all major components
- Output impedance analysis
- Audiosusceptibility
- Second-stage LC filter analysis
- Snubber design and analysis
- Switching loss analysis for power FETs and IGBTs
- Control design and analysis on a single power stage schematic
- Toroid inductors with Micrometals parts.

POWER 4-5-6 is an Excel-based program with interactive controls, designed for rugged and reliable operation. All of the features listed above are offered using clear schematic presentation of circuits and designs with pop-up menus for easy data entry and analysis. Extensive on-line help is available at the click of a button.

There are three levels of application for this software. These levels are commensurate with experience and stage of your design to help you achieve the greatest value from POWER 4-5-6 without the burden of knowing the equations involved in arriving at the solution. We have defined these levels as follows:

### **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.

### **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 POWER 4-5-6, 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, POWER 4-5-6 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. Details are found on our web site:

<http://www.ridleyengineering.com>

## 1.1 Computer System Requirements (PC-Based)

To run POWER 4-5-6 effectively, any modern computer with at least Excel 2007 or later installed will work. The Power 4-5-6 code is extremely efficient, and it does not need a high-powered computer. It is also very compact, taking up only 15 MB of disk space.

Make sure you select the 32-bit version of Excel when installing. Microsoft installs this by default, and they do not recommend using the 64-bit version of Excel since it is missing many features and add-ins.

POWER 4-5-6 will work with Windows XP, Windows 7, or Windows 8.

## 1.2 Computer System Requirements (MAC-Based)

Microsoft Office is available to run on the MAC, but Excel does not work properly. You will be able to load POWER 4-5-6, but the formatting will not show everything as it is supposed to appear.

In order to use POWER 4-5-6 on the MAC, you will need to install a Windows partition and the normal PC-based version of Excel (32-bit).

## 1.3 POWER 4-5-6 Demo Software Download

The latest version of POWER 4-5-6 Demo is available for download at

<http://www.ridleyengineering.com/software.html>

The downloaded file is a zipped version of Excel, ready to run. You do not need any external programs such as Pspice, LTspice in order to run high-speed design and simulations. No connection to the internet is needed once your download is complete.

## 1.4 Loading Demo Workbook

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.



**Fig. 1.1: POWER 4-5-6 Guide Page**

The worksheets of POWER 4-5-6 are initially sized and formatted for an 1024x768 display. For other resolution options, click on the [Screen Setup](#) button, and select options 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.

## 1.6 On-Line Help Notes

POWER 4-5-6 has extensive on-line help inside the program. Click on any of the help buttons to access notes about a particular feature of POWER 4-5-6. A wealth of design information is contained in the program, together with power supply design tips.

## 1.7 Software Support

If you are having problems installing or running POWER 4-5-6, 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.

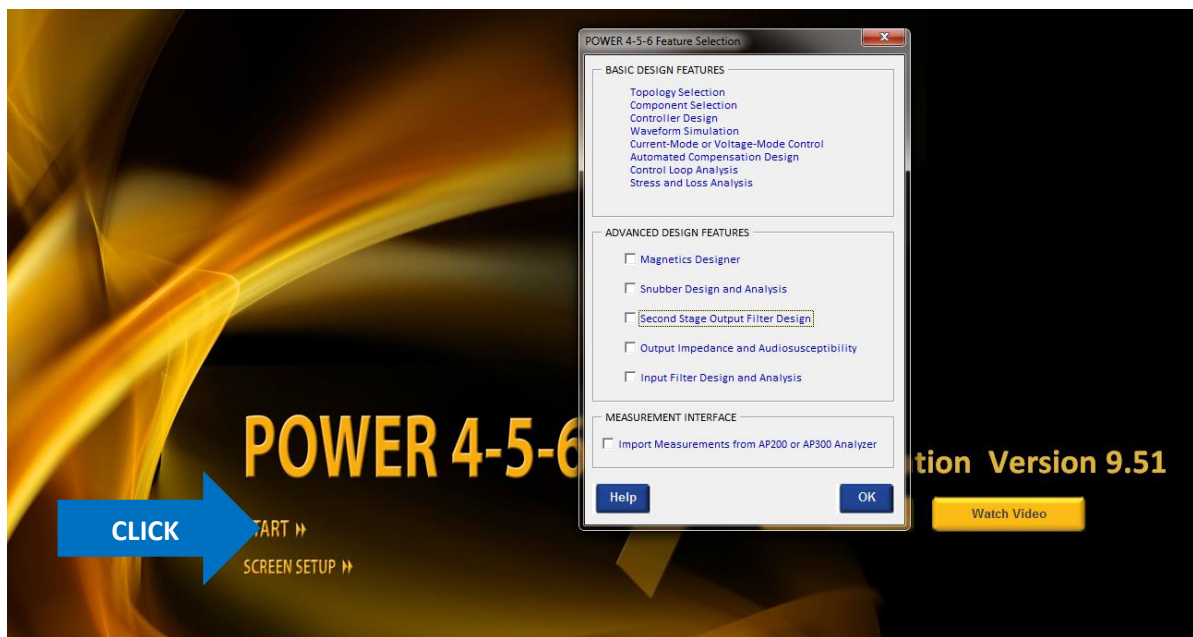
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## 2 Simulation with POWER 4-5-6

POWER 4-5-6 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 your first simulation, click on Start, and you will see a menu as shown below.



**Fig. 2.1: POWER 4-5-6 Guide Page with Start Menu**

POWER 4-5-6 has a wealth of features for design. 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.

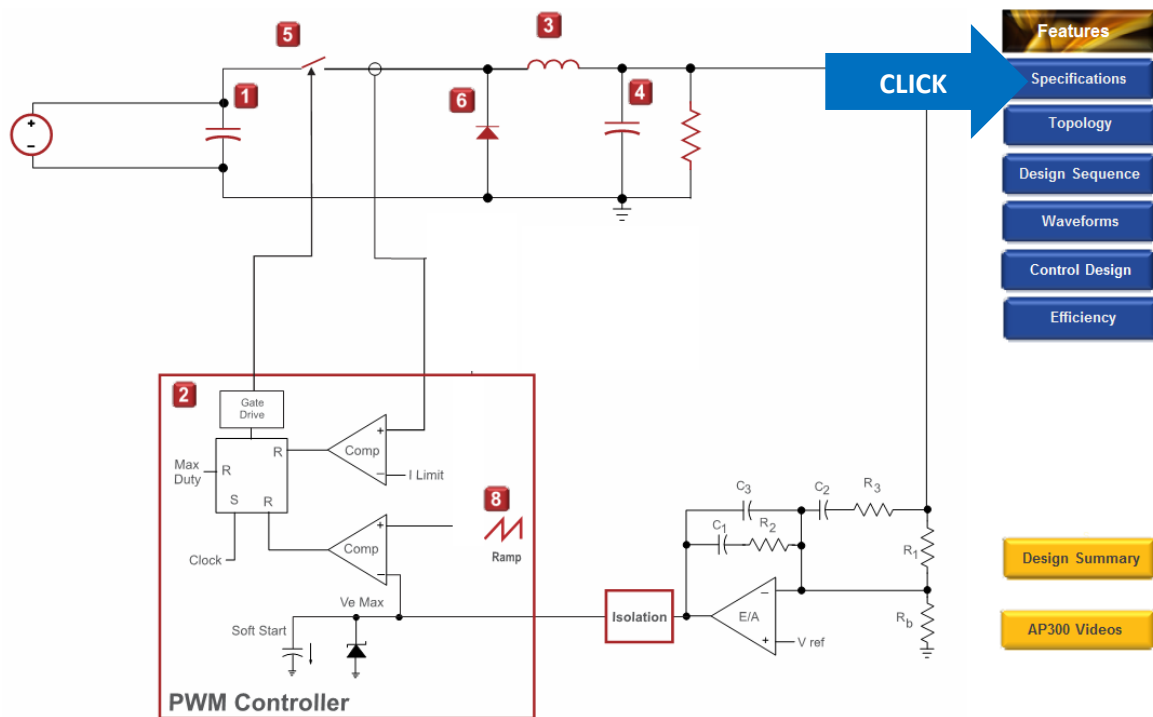
## 2.1 Entering Specifications and Topology

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 POWER 4-5-6 choose every parameter for you and you can expect a good working design.

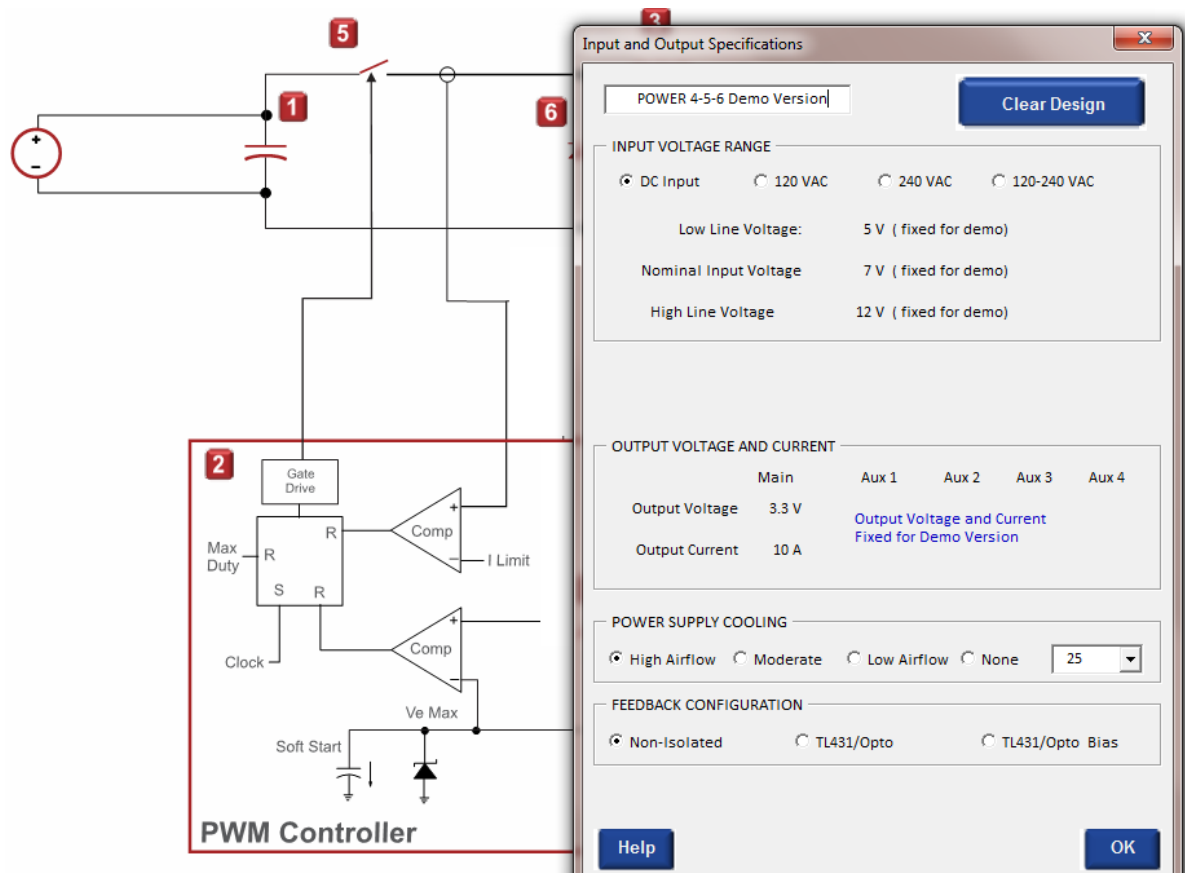
On the schematic page, you will see a power topology (a buck converter in the figure below), a controller with all the setting needed to implement most constant-frequency options, and a feedback compensator. Of course, the compensator and controller may all be in one chip, but you have full control of 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: POWER 4-5-6 Schematic Page**

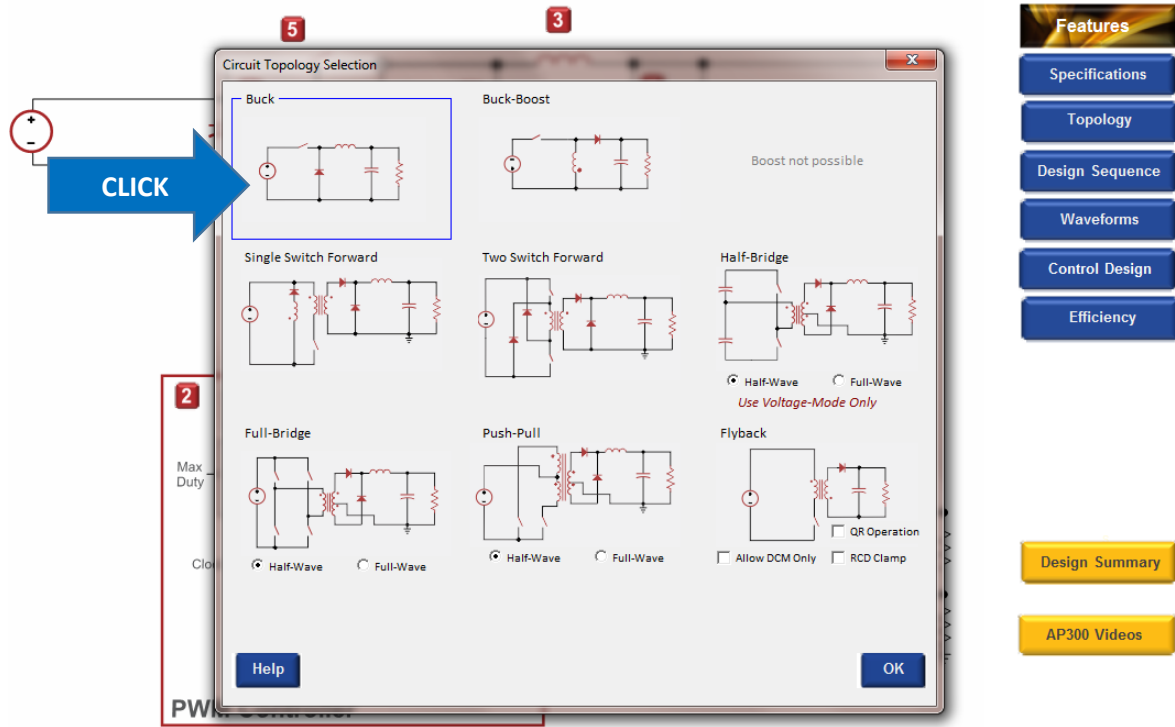


**Fig. 2.3: POWER 4-5-6 Specifications Entry Form**

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.

The output voltage is also fixed in POWER 4-5-6 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: POWER 4-5-6 Topology Choices**

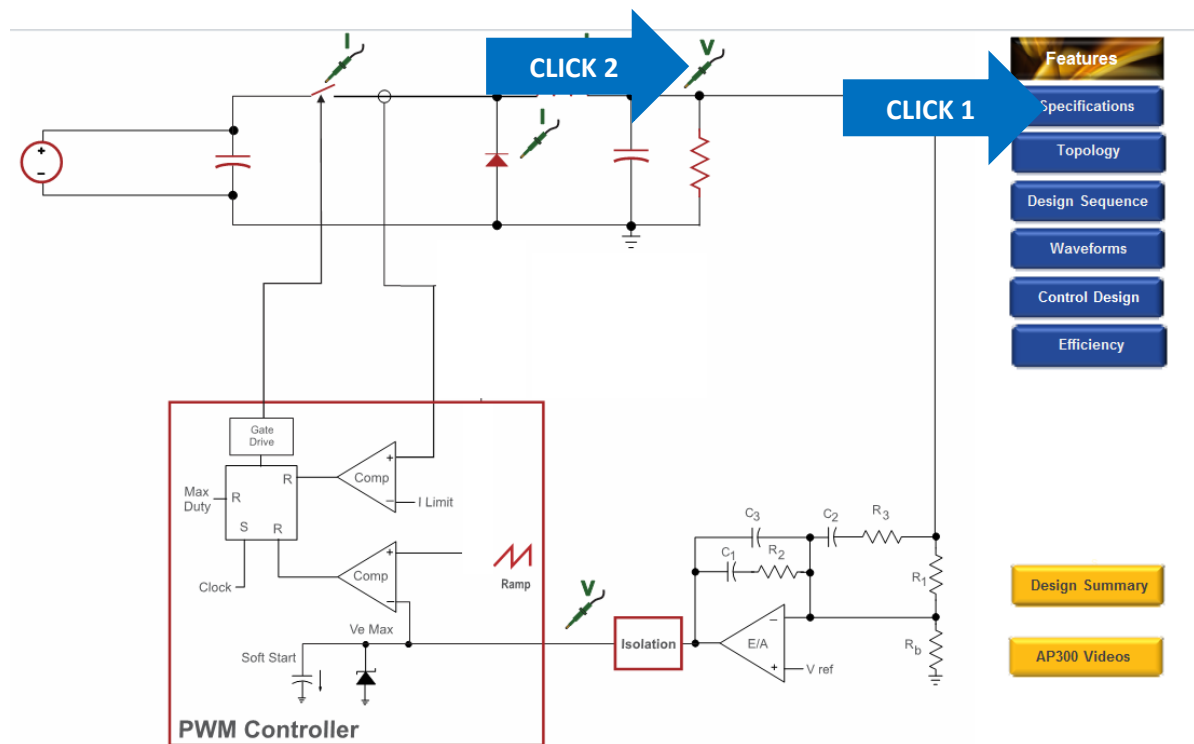
Figure 2.4 shows the set of topologies available for the input and output voltage specifications. Notice that the boost topology is not possible since the output voltage is lower than part of the input range of the converter.

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

Once you have done this, POWER 4-5-6 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 POWER 4-5-6 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: POWER 4-5-6 Waveform Choices**

Figure 2.5 shows the selection of voltages and currents that can be probed with POWER 4-5-6. The simulation algorithm inside POWER 4-5-6 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: POWER 4-5-6 Output Voltage Waveform**

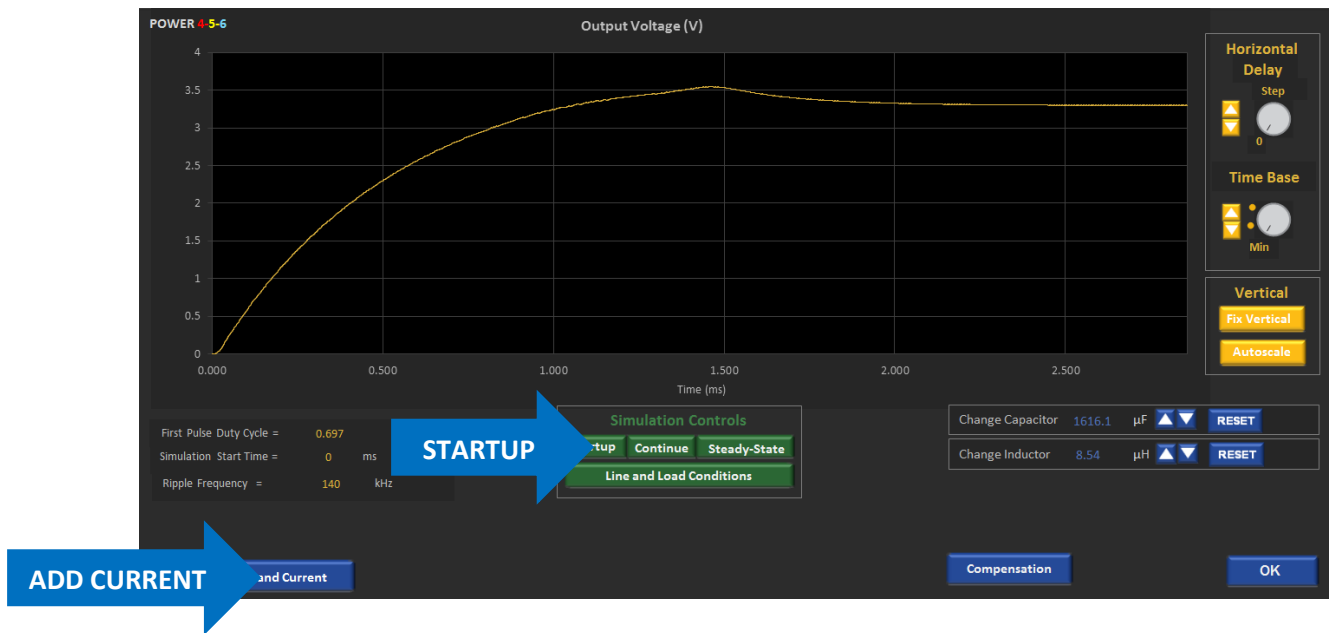
Figure 2.6 shows simulation of the output voltage for 400 cycles. To zoom in on this waveform, treat the controls of POWER 4-5-6 just like a scope. Turn the time-base dial clockwise to zoom in by clicking on the up arrow next to the dial, as shown below.



**Fig. 2.7: POWER 4-5-6 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



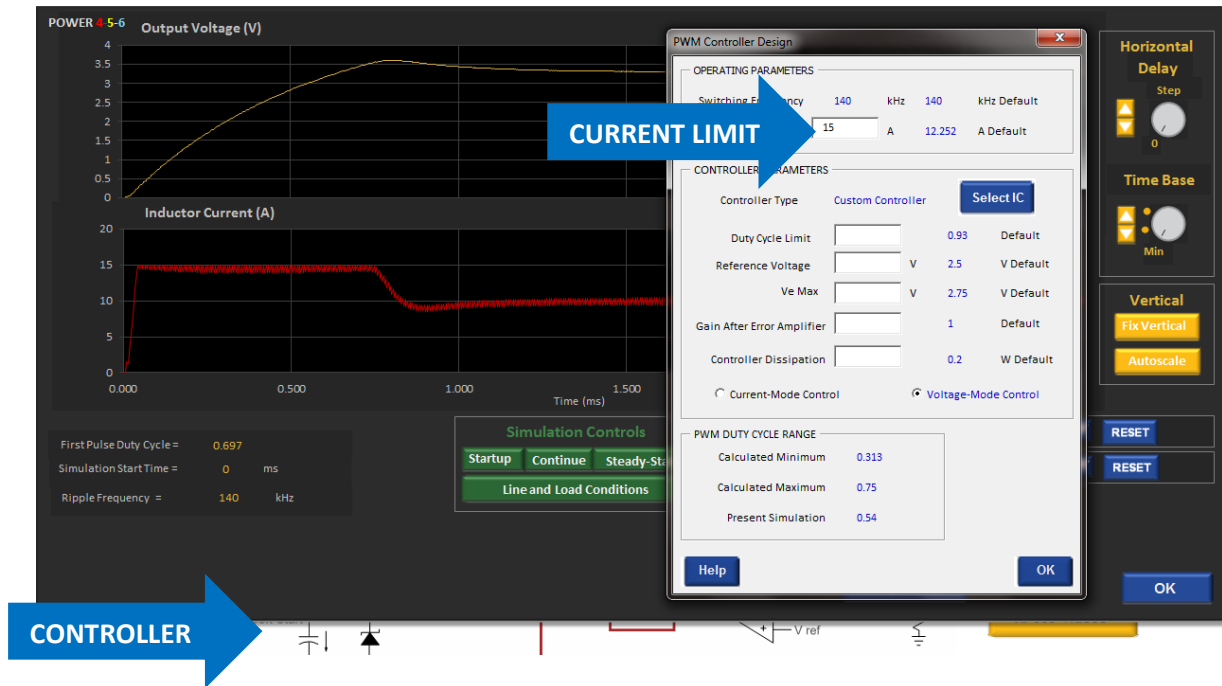
**Fig. 2.8: POWER 4-5-6 Start Up Simulation Voltage Waveform**

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: POWER 4-5-6 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.

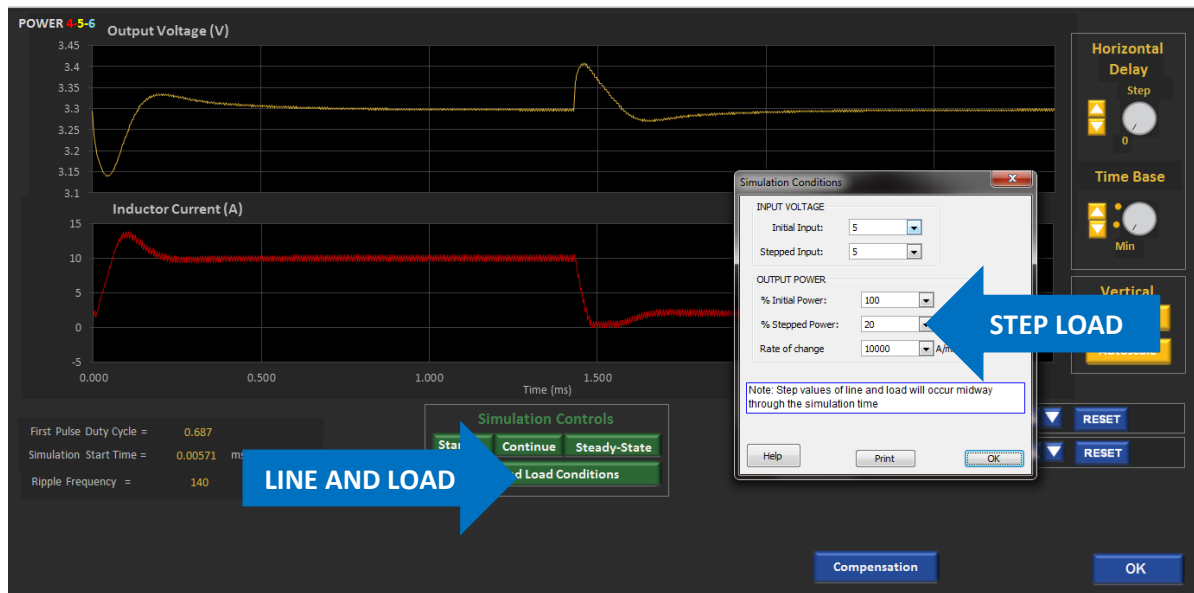


**Fig. 2.10: POWER 4-5-6 Start Up Simulation with Increased Current Limit**

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 on in the design cycle. POWER 4-5-6 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 Transient Simulation



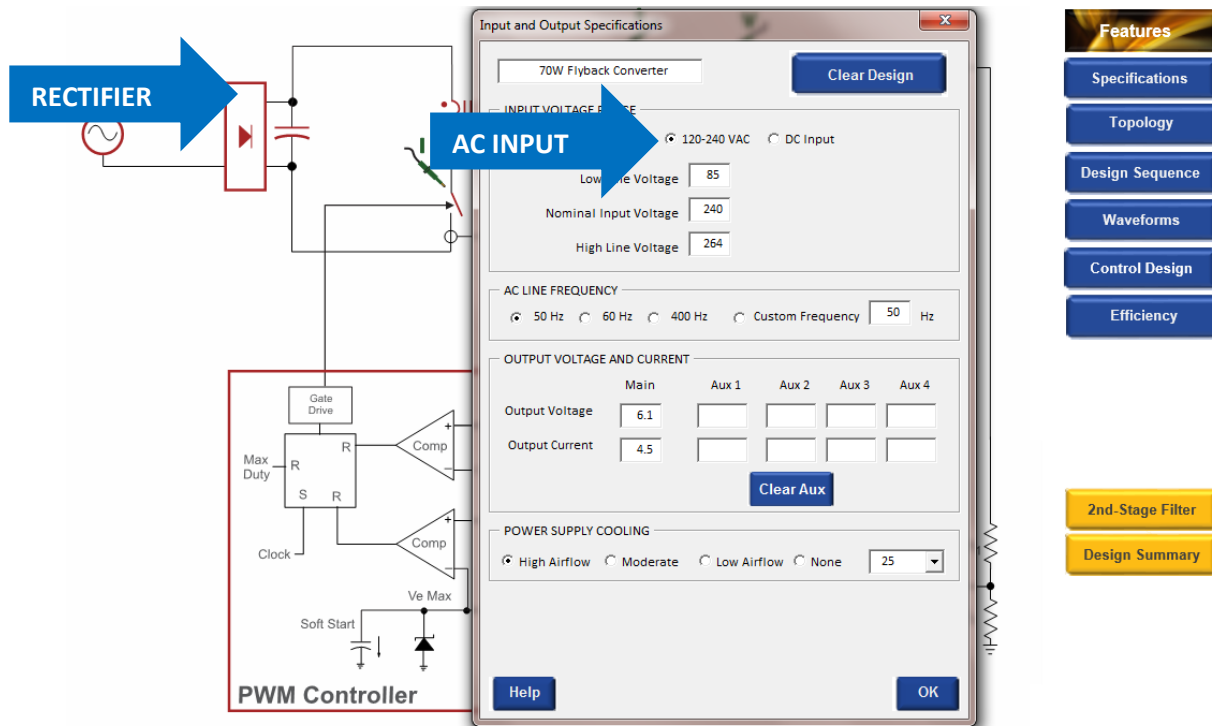
**Fig. 2.11: POWER 4-5-6 Step-Load Transient Simulation**

The line and load conditions can be set as shown above. Two values of load are shown, and 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%.

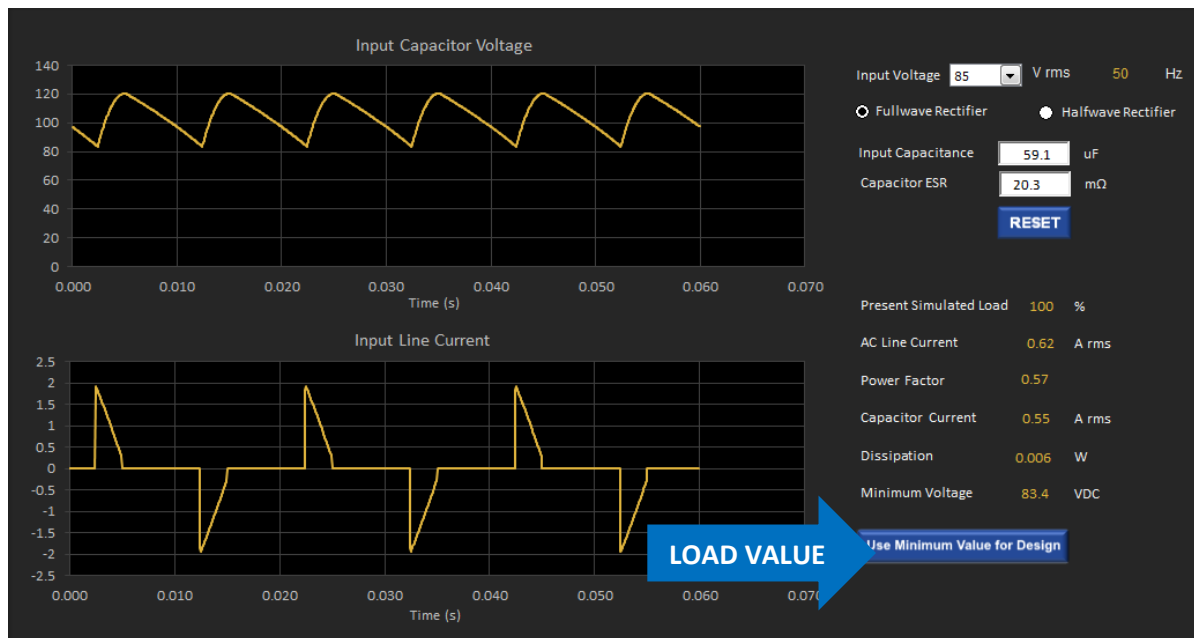
## 2.5 AC Input Simulation

With the full version of POWER 4-5-6 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. 2.12: Choosing AC Input on the Specifications Form (not available in Demo Version).**



**Fig. 2.13: 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 POWER 4-5-6 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 POWER 4-5-6 that will change the way that you do your designs and greatly speed up the process.

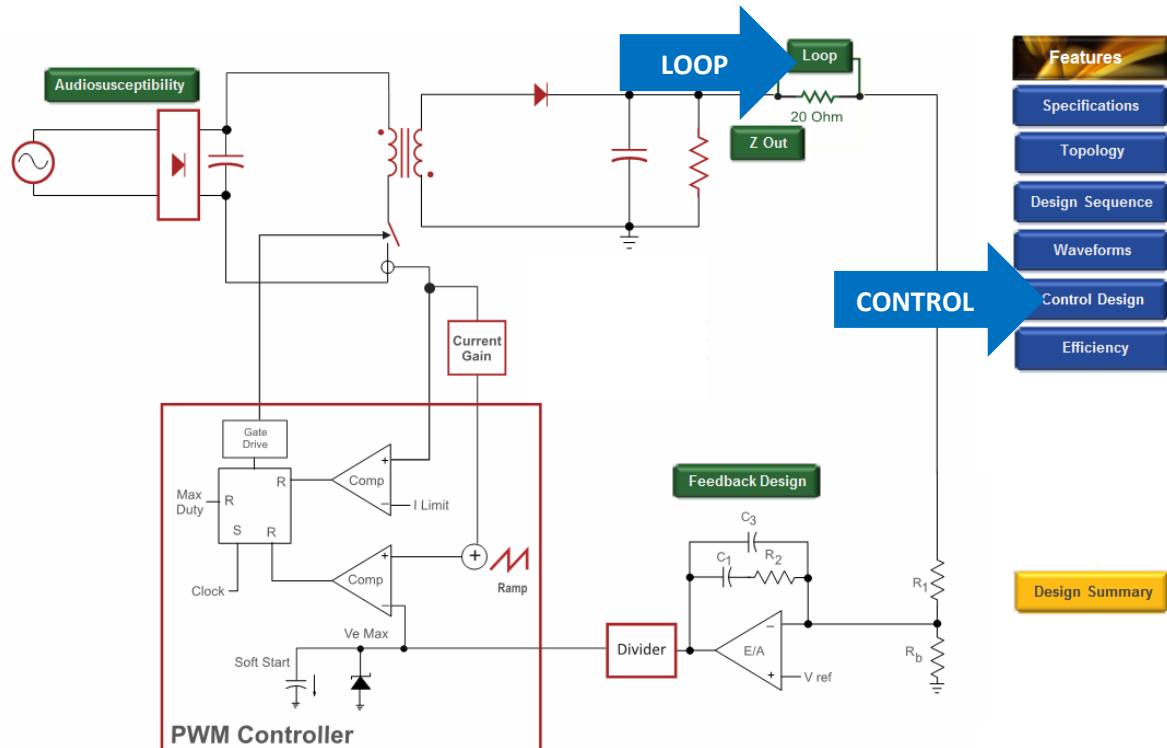
You are encouraged to try all these options in POWER 4-5-6. Let us know what you see, and tell us if there are additional features of that you would like to see included in the program in the future. Once you have a license for the software, all upgrades are free as long as your license is current.

# 3 Control Analysis Transfer Functions

POWER 4-5-6 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

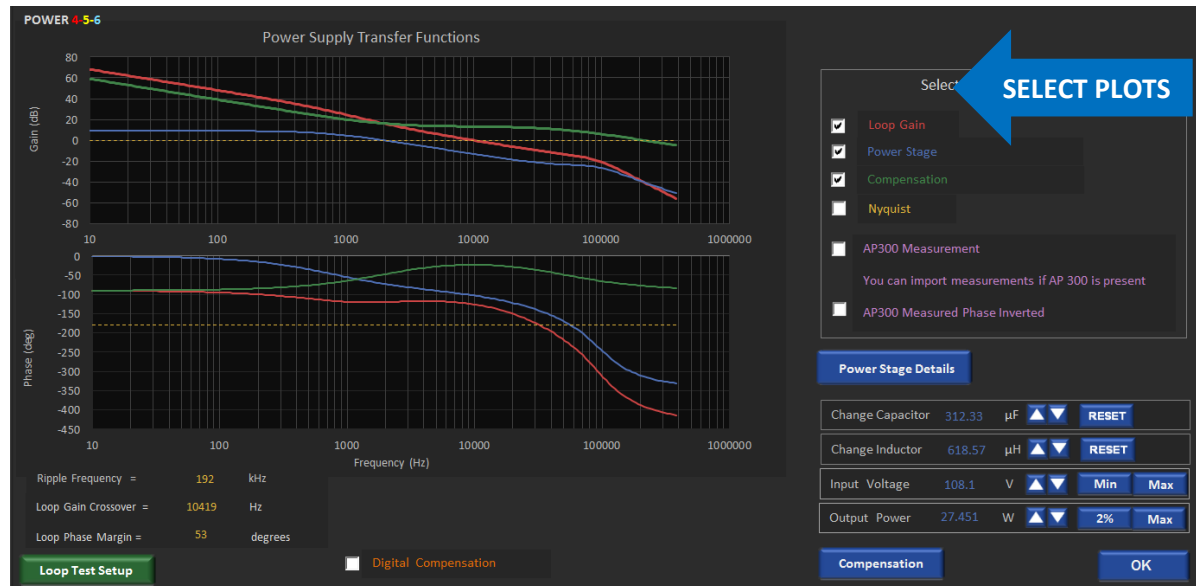
When you click on the **Control Design** blue button you will see the green options buttons below appear on the power stage schematic. (If you don't see the **Z Out** and the **Audiosusceptibility** buttons, make sure these features are checked when you click on the Features button.)



**Fig. 3.1: Control Design Options in POWER 4-5-6**

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 POWER 4-5-6**

Figure 3.2 shows the control transfer functions which are available in POWER 4-5-6. 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!)

POWER 4-5-6 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.

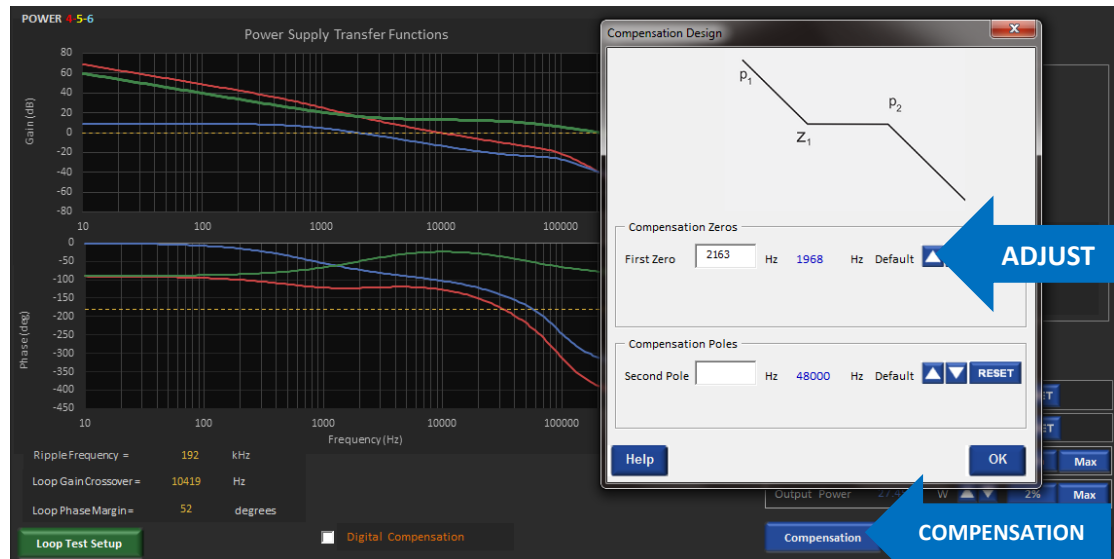
The [Compensation](#) button is a recent feature of POWER 4-5-6 that lets you interactively move the shape of the compensation values while looking at the shape of the loop at the same time. Figure 3.2 shows the transfer functions for current-mode control, the default control scheme chosen for all converters except the half-bridge.



**Fig. 3.3: Voltage-Mode Control Transfer Function Bode Plots in POWER 4-5-6**

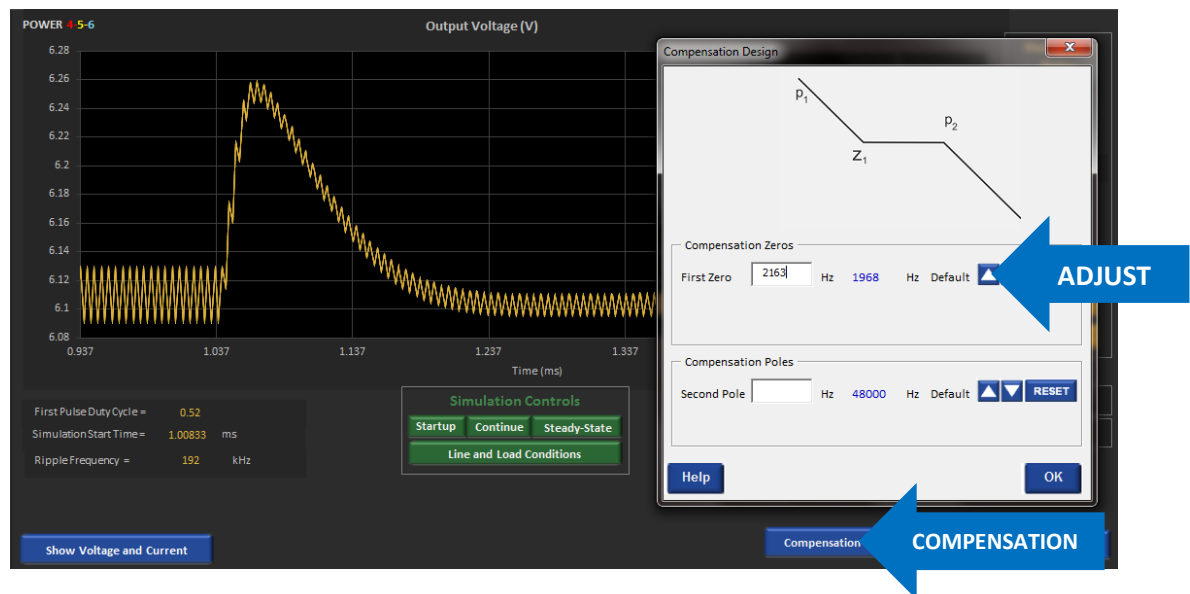
If you click on the controller shown just below the graphs above, you can change your selection to voltage-mode control. Once you do this, the compensator will be re-optimized and the resulting transfer functions plotted. You will notice that in voltage-mode control, the gain of the power stage and the 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 POWER 4-5-6 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**

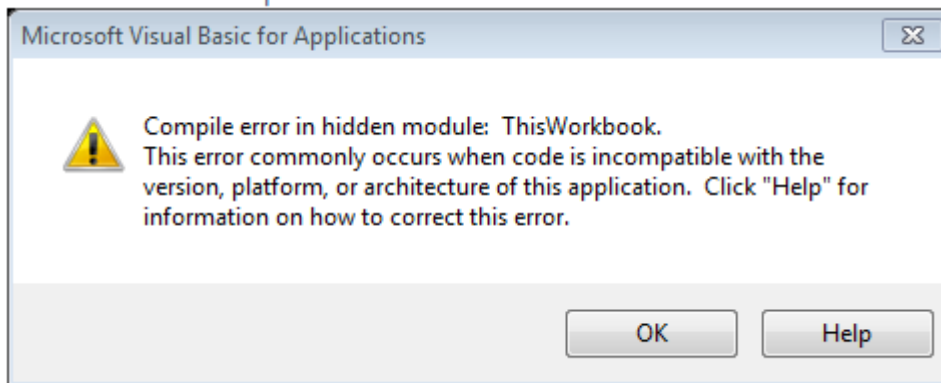
You can also interactively change the compensation parameters while looking at the simulation waveforms. This is a powerful feature with POWER 4-5-6 and the simulation speed is essential for optimizing your control this way.



## Appendix A    Error Messages

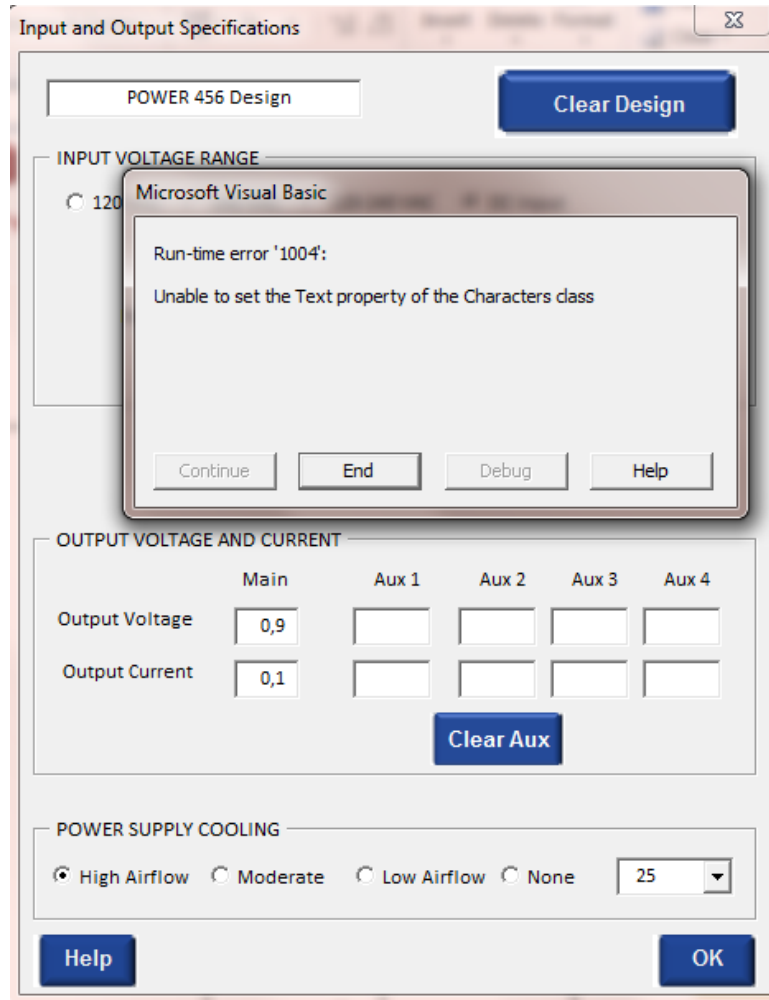
Error Message	Page Number
<b>Compile Error 64-bit EXCEL Installed Instead of 32-bit Excel</b>	<b>18</b>
<b>Decimal Separator Problem – Run-Time Error 1004</b>	<b>19</b>
<b>Data Entry Format Error – Run-Time Error 13</b>	<b>21</b>

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



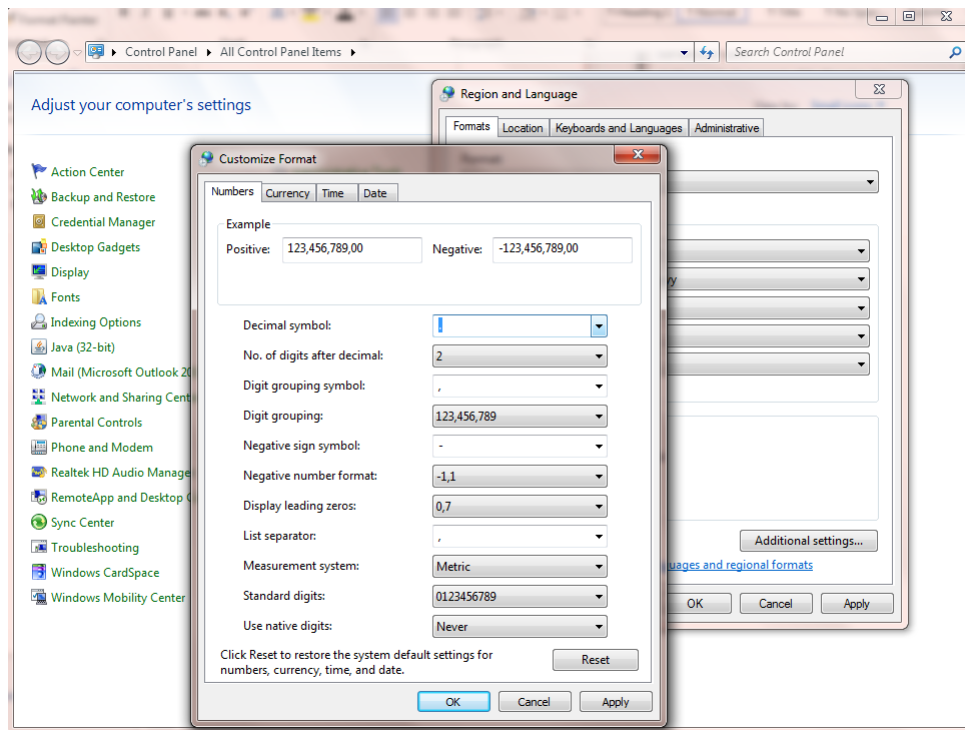
You will see this message if you have 64-bit version of Excel installed on your computer. This is not recommended by Microsoft since it is missing many features and add-ins. Please reinstall the 32-bit version of Excel (This is the default installation.)

## Decimal Separator Problem – Run-Time Error 1004

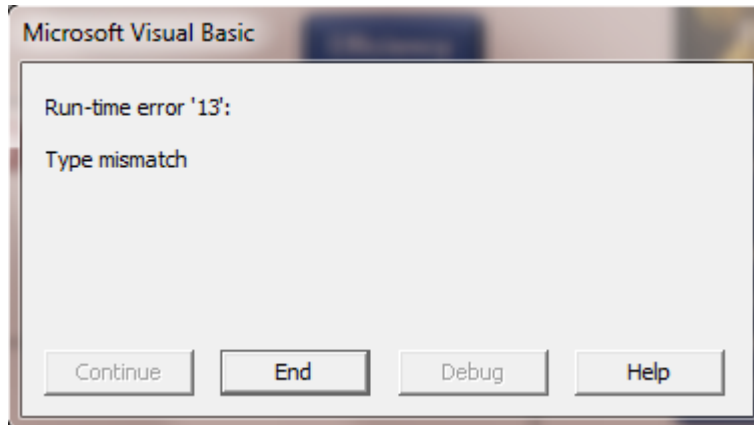


This error will occur if you do not have the decimal separator character set to a period “.” You can change the setting of the decimal separator in your Windows system as described below.

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.



### Data Entry Format Error – Run-Time Error 13



Most mistakes in data entry will be flagged by POWER 4-5-6 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.

# Appendix B License Agreement

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