Getting Started with the MPLAB® Mindi™ Analog Simulator

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GETTING STARTED WITH THE MPLAB® MINDI™ ANALOG SIMULATOR

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Preface

NOTICE TO CUSTOMERS

All documentation becomes dated, and this manual is no exception. Microchip tools and documentation are constantly evolving to meet customer needs, so some actual dialogs and/or tool descriptions may differ from those in this document. Please refer to our website (www.microchip.com) to obtain the latest documentation available.

Documents are identified with a "DS" number. This number is located on the bottom of each page, in front of the page number. The numbering convention for the DS number is "DSXXXXXXXXA", where "XXXXXXXX" is the document number and "A" is the revision level of the document.

For the most up-to-date information on development tools, see the MPLAB® IDE online help. Select the Help menu, and then Topics, to open a list of available online help files.

INTRODUCTION

This chapter contains general information that will be useful to know before using the MPLAB® Mindi™ Analog Simulator. Items discussed in this chapter include:

- Document Layout
- Conventions Used in this Guide
- Recommended Resources
- The Microchip Website
- Product Change Notification Service
- Customer Support
- Document Revision History

DOCUMENT LAYOUT

This document describes how to use the MPLAB® Mindi™ Analog Simulator as a comprehensive tool for analog circuit design and analysis. The manual layout is as follows:

- Preface
- Introduction
- Running the MPLAB® Mindi™ Analog Simulator
- Running a Simulation
- Simulation Terms and Concepts
- Worldwide Sales and Service

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

<table>
<tr><th>Description</th><th>Represents</th><th>Examples</th></tr>
<tr><td colspan="3">Arial font:</td></tr>
<tr><td rowspan="2">Italic characters</td><td>Referenced books</td><td>MPLAB® IDE User’s Guide</td></tr>
<tr><td>Emphasized text</td><td>...is the only compiler...</td></tr>
<tr><td rowspan="3">Initial caps</td><td>A window</td><td>the Output window</td></tr>
<tr><td>A dialog</td><td>the Settings dialog</td></tr>
<tr><td>A menu selection</td><td>select Enable Programmer</td></tr>
<tr><td>Quotes</td><td>A field name in a window or dialog</td><td>“Save project before build”</td></tr>
<tr><td>Underlined, italic text with right angle bracket</td><td>A menu path</td><td><u>File>Save</u></td></tr>
<tr><td rowspan="2">Bold characters</td><td>A dialog button</td><td>Click OK</td></tr>
<tr><td>A tab</td><td>Click the Power tab</td></tr>
<tr><td>N‘Rnnnn</td><td>A number in verilog format, where N is the total number of digits, R is the radix and n is a digit.</td><td>4‘b0010, 2‘hF1</td></tr>
<tr><td>Text in angle brackets < ></td><td>A key on the keyboard</td><td>Press <Enter>, <F1></td></tr>
<tr><td colspan="3">Courier New font:</td></tr>
<tr><td rowspan="7">Plain Courier New</td><td>Sample source code</td><td><code>#define START</code></td></tr>
<tr><td>Filenames</td><td><code>autoexec.bat</code></td></tr>
<tr><td>File paths</td><td><code>c:\mcc18\h</code></td></tr>
<tr><td>Keywords</td><td><code>_asm, _endasm, static</code></td></tr>
<tr><td>Command-line options</td><td><code>-Opa+, -Opa-</code></td></tr>
<tr><td>Bit values</td><td><code>0, 1</code></td></tr>
<tr><td>Constants</td><td><code>0xFF, ‘A’</code></td></tr>
<tr><td>Italic Courier New</td><td>A variable argument</td><td>file.o, where file can be any valid filename</td></tr>
<tr><td>Square brackets [ ]</td><td>Optional arguments</td><td><code>mcc18 [options] file [options]</code></td></tr>
<tr><td>Curly brackets and pipe character: { | }</td><td>Choice of mutually exclusive arguments; an OR selection</td><td><code>errorlevel {0|1}</code></td></tr>
<tr><td rowspan="2">Ellipses...</td><td>Replaces repeated text</td><td><code>var_name [, var_name...]</code></td></tr>
<tr><td>Represents code supplied by user</td><td><code>void main (void)
{ ...
}</code></td></tr>
</table>

RECOMMENDED RESOURCES

- This user's guide provides information on how to use the MPLAB® Mindi™ Analog Simulator. For more in-depth, hands-on training, visit http://microchipdeveloper.com/mindi:hands-on-workbook.

THE MICROCHIP WEBSITE

Microchip provides online support via our website at www.microchip.com. This website is used as a means to make files and information easily available to customers. Accessible by using your favorite Internet browser, the website contains the following information:

- **Product Support** – Data sheets and errata, application notes and sample programs, design resources, user's guides and hardware support documents, latest software releases and archived software
- **General Technical Support** – Frequently Asked Questions (FAQs), technical support requests, online discussion groups, Microchip consultant program member listing
- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listings of Microchip sales offices, distributors and factory representatives

PRODUCT CHANGE NOTIFICATION SERVICE

Microchip's customer notification service helps keep customers current on Microchip products. Subscribers will receive e-mail notifications whenever there are changes, updates, revisions or errata related to a specified product family or development tool of interest.

To register, access the Microchip website at www.microchip.com, click **Product Change Notification** and follow the registration instructions.

CUSTOMER SUPPORT

Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support

Customers should contact their distributor, representative or field application engineer (FAE) for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document.

Technical support is available through the website at: http://www.microchip.com/support.

DOCUMENT REVISION HISTORY

Revision B (February 2019)

- Updated to current template.
- Divided the document into several chapters.
- Added new chapter – Simulation Terms and Concepts.
- Edited text for clarity.
- Updated figures throughout the document.

Revision A (January 2017)

- Initial release of this document.

Chapter 1. Introduction

1.1 WHAT IS THE MPLAB® MINDI™ ANALOG SIMULATOR?

The MPLAB® Mindi™ Analog Simulator is a comprehensive tool for analog circuit design and analysis. It contains two simulation engines: SIMetrix (SPICE) and SIMulation of Piecewise Linear Systems (SIMPLIS).

1.2 WHAT IS THIS USER'S GUIDE FOR?

This document is just a quick starting guide to help you use the MPLAB® Mindi™ Analog Simulator. It is not intended to replace the documentation and tutorials provided for the SIMetrix and SIMPLIS tools, which can be accessed from the **Help** menu in MPLAB® Mindi™.

Chapter 2. Running the MPLAB® Mindi™ Analog Simulator

2.1 STARTING THE MPLAB® MINDI™ SIMULATOR

To start the MPLAB® Mindi™ Analog Simulator, double-click the desktop shortcut after installation or select MPLAB® Mindi™ 8.20 from the Start Menu. A splash screen will display the MPLAB® Mindi™ Analog Simulator logo and brief licensing terms.

FIGURE 2-1: *MPLAB® Mindi™ Simulator Splash Screen.*

After clicking **OK** on the splash screen, the MPLAB® Mindi™ Analog Simulator graphical user interface (GUI) will load and display the Welcome page.

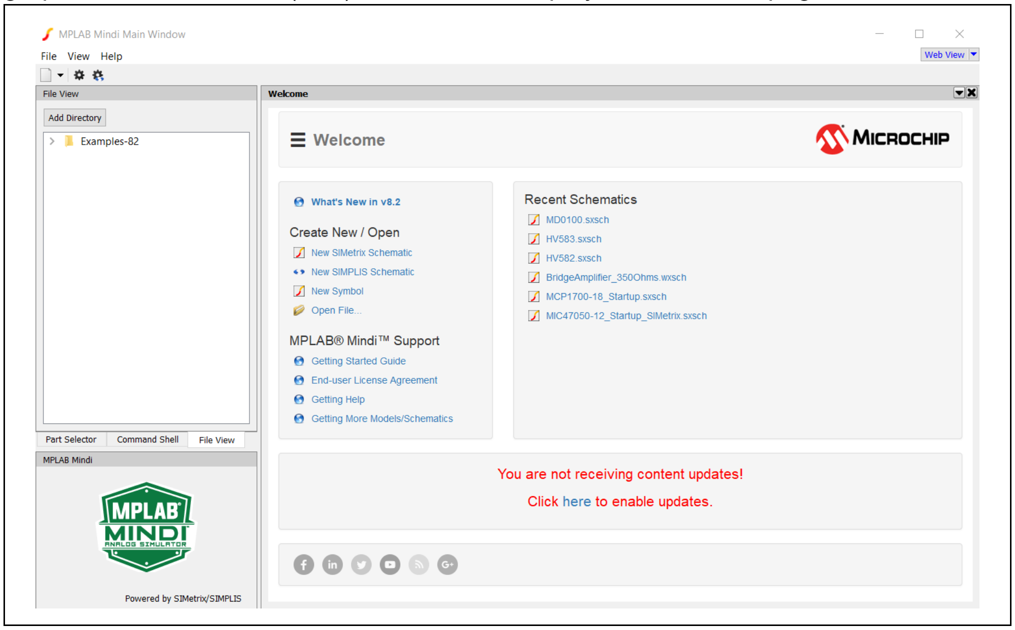


FIGURE 2-2: *MPLAB® Mindi™ Simulator Welcome Page.*

2.2 SETTING THE UPDATE SCHEDULE

We strongly recommend you to allow the MPLAB® Mindi™ Analog Simulator to check for regular updates automatically in order to ensure that the tool will always offer the latest patches, models and example application schematics.

To set the update schedule when opening the MPLAB® Mindi™ Analog Simulator for the first time, click “here” in the red text area.

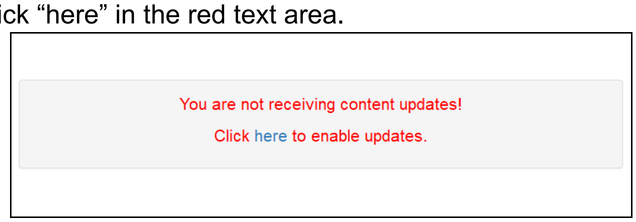


FIGURE 2-3: *MPLAB® Mindi™ Initial Update Settings Window.*

You can also set the desired update schedule later on. To do this, click <u>*Help>Check Updates Now*</u> and change the "Automatic Update Schedule" to Daily, Weekly, or Monthly.

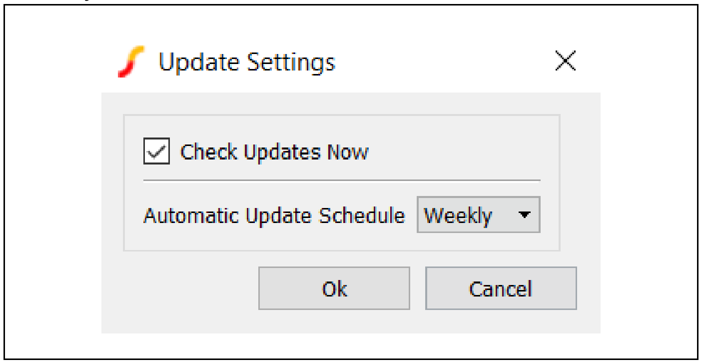


FIGURE 2-4: *MPLAB® Mindi™ Update Settings Window.*

2.3 PSPICE AND HSPICE COMPATIBILITY

With the release of version 8.2, the MPLAB®Mindi™ Analog Simulator implemented global PSpice and HSpice compatibility options for SIMetrix. You can set these options in <u>*Options>General>Miscellaneous>PSpice/HSpice compatibility level*</u>.

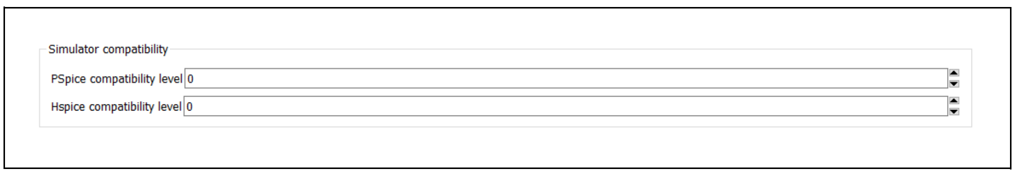


FIGURE 2-5: *MPLAB® Mindi™ Compatibility Options Menu.*

If the compatibility level is not set at the time of the simulation, SIMetrix will automatically use the default level, which is 2. Several simulation issues can be resolved by setting this option to 0. Also, this option can be set directly into the schematic by adding the line options initcondmode=0 below the analysis directives (.TRAN, .DC, .AC, etc.) but above the .simulator DEFAULT line in the schematic editor's command window. Also known as the F11 window, it can be displayed by pressing the <F11> key.

FIGURE 2-6: *MPLAB® Mindi™ Compatibility Options* - initcondmode.

The initcondmode directive sets the behavior of capacitors and inductors when given an initial condition parameter (IC) and may have these values:

- `0` - Berkeley SPICE compatible mode
- `1` - SIMPLIS compatible mode. Forces hard initial condition
- `2` - Spice compatible mode. Forces soft initial condition

2.4 WELCOME PAGE OVERVIEW AND NAVIGATION

The Welcome page has quick links for the following actions:

- By clicking the menu button ☰ you can browse application schematics by category using the searchable navigation tree;
- ***Create New/Open***: Open or create a new schematic or symbol for SIMPLIS or SIMetrix from scratch;
- ***MPLAB® Mindi™ Support***: Get help or more application schematics from Microchip;
- ***Recent Schematics***: Open recent schematics.

You can browse for the available example schematics in the navigation tree by going through the product categories. The navigation tree also has a search bar where you can search by IC part name as well as a a **Close** button in the top right corner.

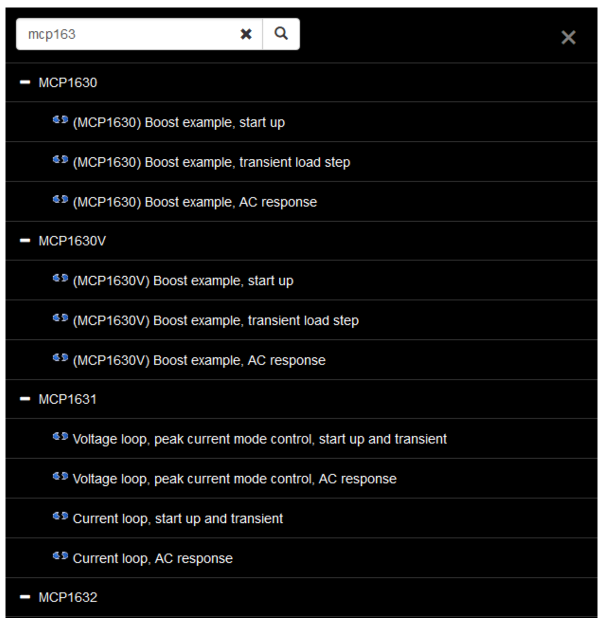


FIGURE 2-7: *MPLAB® Mindi™ - Navigation Menu.*

To search through the navigation tree, you can type a fragment or the whole IC part name and then press the <Enter> key or the **Search** button to display the results that match the search input.

To clear the search results, you can press the <Esc> key while the search input is focused or click the **x** button that will be displayed in the search input field.

If you press the <Esc> key twice while the search input is focused, the navigation tree will close. You can also close the navigation menu by clicking the **(Close) x** button in the top right corner.

Some navigation elements have a pop-up window that will display a brief description when the mouse hovers over that node.

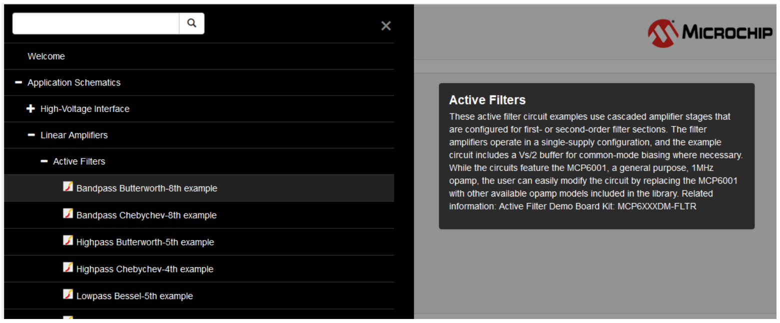


FIGURE 2-8: *MPLAB® Mindi™ Popup Window.*

The application schematics are preceded by icons that indicate which simulator engine is being used for that particular schematic.

You can also access the application schematics from the **File View** tab by navigating to the Microchip folder under SIMetrix or SIMPLIS.

SIMetrix files are marked with the icon, whereas SIMPLIS files are indicated by the icon.

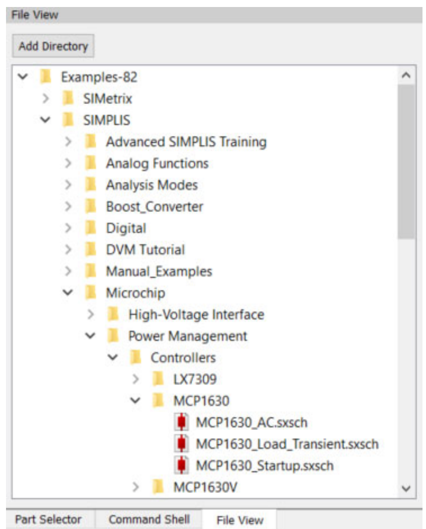


FIGURE 2-9: *MPLAB® Mindi™ Directory Structure - File View Tab.*

2.5 WORKING WITH THE PROVIDED APPLICATION SCHEMATICS

All application schematics are copied to your local documents folder when you run the simulator for the first time.

When modifying any of these schematics, we highly recommend you to save a copy of the file (using *File>Save Schematic As*) right after opening the schematic in order to avoid overwriting the default version.

If you overwrite your local default schematics by mistake, you can find copies of the provided schematics in the simulator installation folder, which is typically located at `C:\Program Files (x86)\MPLAB Mindi_820\support\examples`.

2.6 CREATING A NEW SCHEMATIC

You can create a new schematic from *File>New>SIMetrix/SIMPLIS Schematic*, or by using the Create New/Open quick link from the Welcome page. If you want to start from scratch, you can use Microchip's models from the *Place>From Microchip Library* menu.

The model list is organized according to product category, and only those models compatible with the currently selected simulator (SIMetrix or SIMPLIS) will be shown.

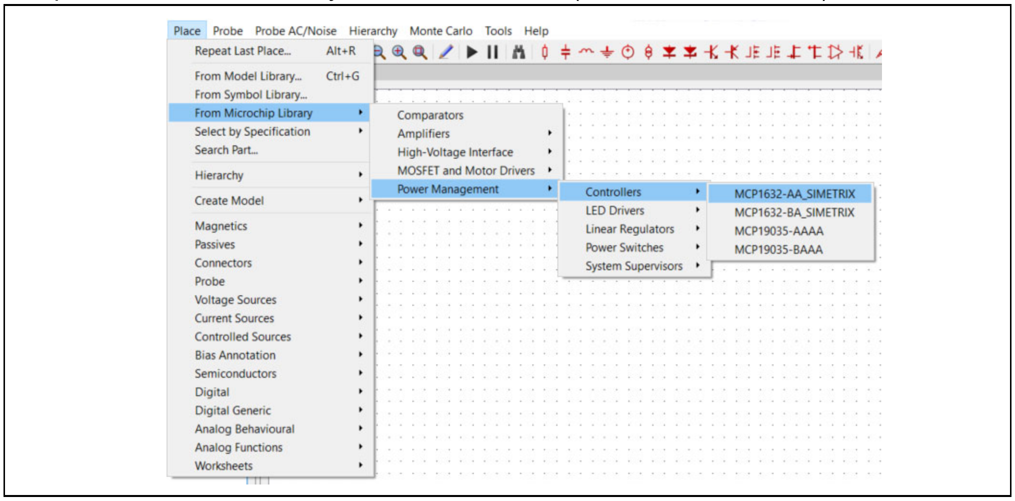
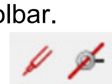


FIGURE 2-10: *MPLAB® Mindi™ - New Schematic Menu.*

Many common components or measuring devices can be selected from the toolbar at the top or from the Place menu.

For example you can choose fixed probes from the Place menu or interactive probes from the toolbar.

The probes  will ensure that waveforms will be displayed during simulation.

You can access all installed models from the *Place>From Model Library* menu, or by pressing the <Ctrl+G> key combination.

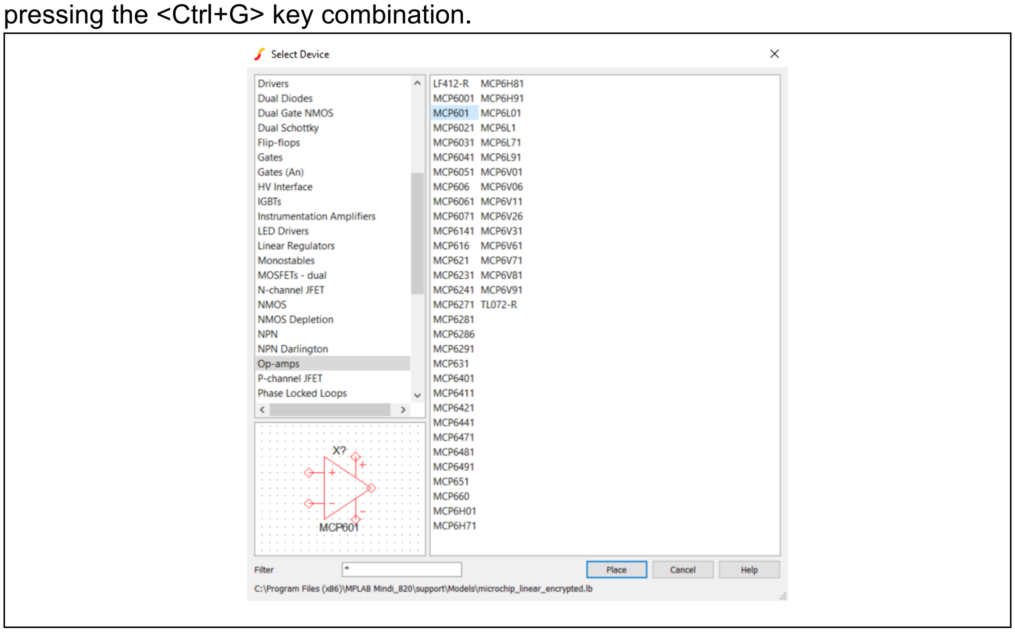


FIGURE 2-11: *MPLAB® Mindi™ - Model Library.*

2.7 THE DESIGN ANALYZER

The Design Analyzer is an integral part of the simulation environment of the MPLAB®Mindi™ Analog Simulator. It allows you to alter system requirements quickly, while observing key converter characteristics, such as loop stability via Bode plots. By employing input parameter range constrains, the Design Analyzer reduces circuit design time and design risk prior to simulation and hardware prototyping.

The Design Analyzer interface has two panels. The left panel contains parameters that can be modified by the user and suggested values based on the system requirements. The right panel contains the schematic of the part which is being analyzed, a closed-loop Bode plot, and estimated efficiency plots.

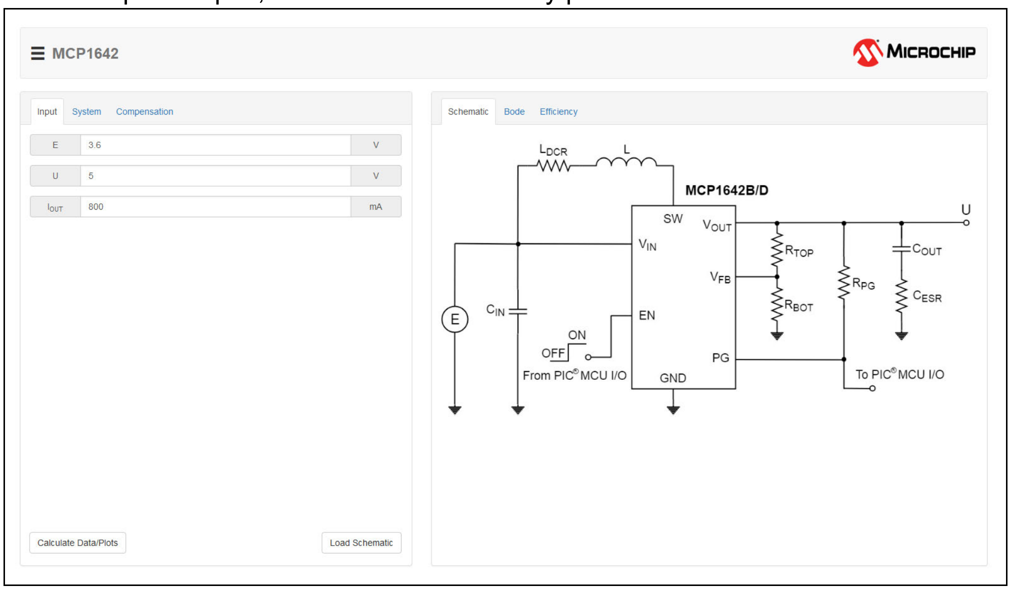


FIGURE 2-12: *MPLAB® Mindi™ Design Analyzer Panels.*

Some inputs can have specific validation criteria and suggested values attached to the left of the editable input.

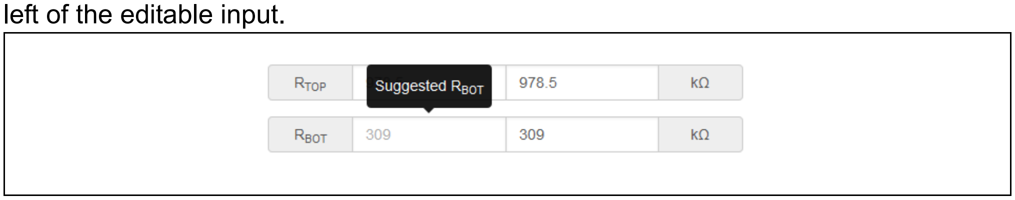


FIGURE 2-13: *MPLAB® Mindi™ Design Analyzer - Suggested Values.*

If the range validation of an input fails, an orange or red notification will pop up in the bottom right corner of the screen.

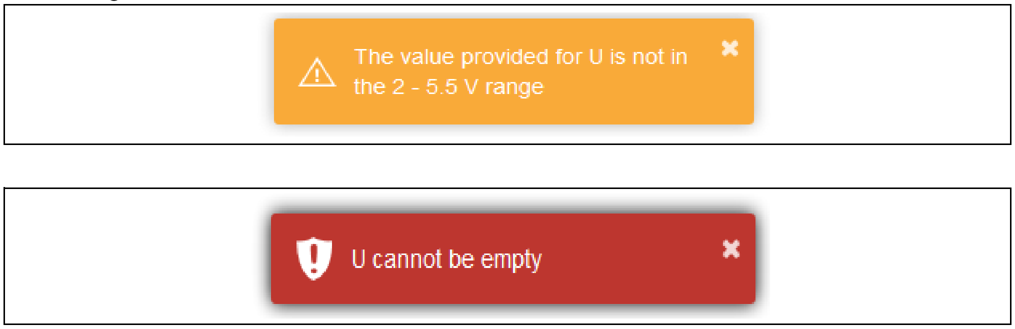
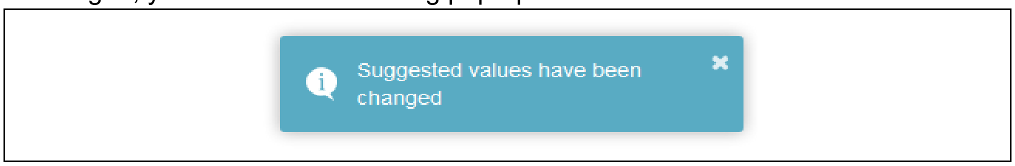
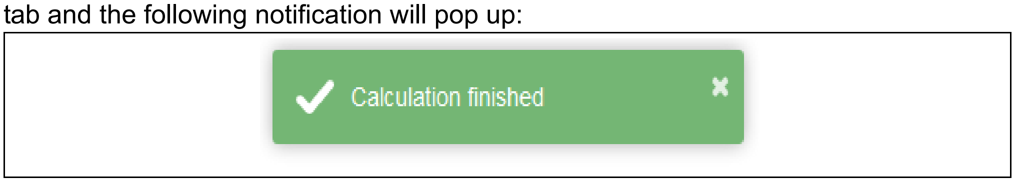


FIGURE 2-14: *MPLAB® Mindi™ Design Analyzer - Invalid Input Notifications.*

Some inputs take part in the calculation of the suggested values. If such an input value is changed, you will see the following pop-up notification:



After changing the values, if you click the bottom left **Calculate Data/Plots** button, the tool will calculate the Bode and estimated efficiency plots. The results output from each tab and the following notification will pop up:



Chapter 3. Running a Simulation

3.1 RUNNING A SIMULATION

After opening a Microchip application schematic, you can run the default analysis by pressing the <F9> key or by clicking Simulator>Run Schematic.

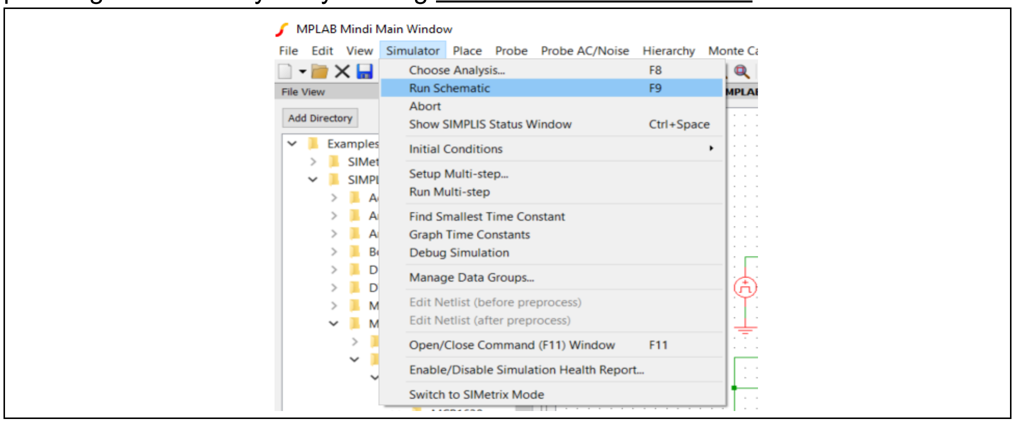


FIGURE 3-1: *MPLAB® Mindi™ - Running the Simulation*.

The default analysis type is highlighted in the application schematic's file name (for example `MCP1623_AC_Load_Transient`). To set its parameters you can open the Choose Analysis window under the Simulator tab or press the <F8> key.

If you want to run your own schematic, you must first choose the analysis type and its parameters.

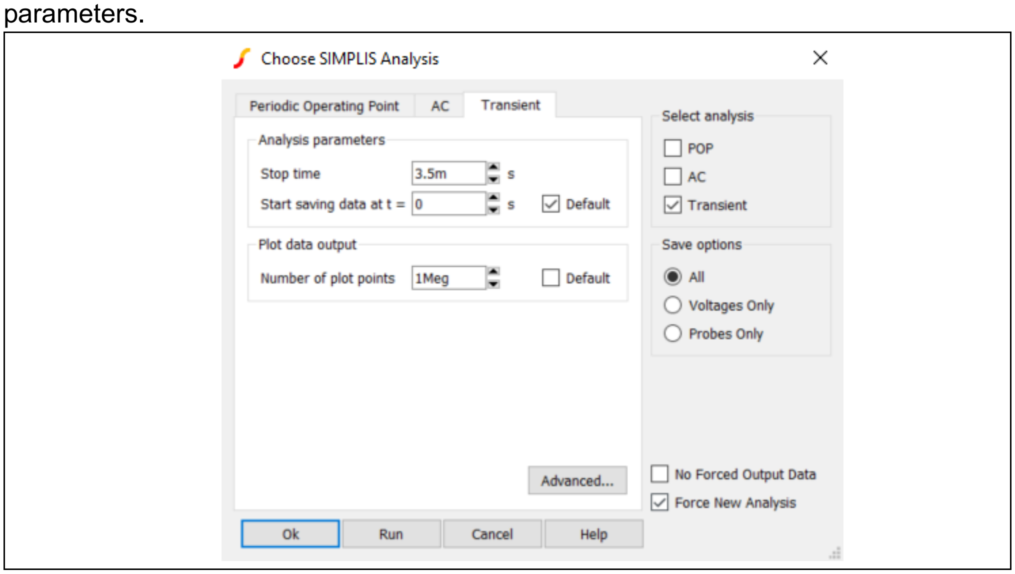


FIGURE 3-2: *MPLAB® Mindi™ - Custom Schematic.*

The analysis options for SIMPLIS and SIMetrix are different, and the models are generally not compatible from one tool to the other. If you try to run a SIMPLIS schematic using the SIMetrix tool (or vice versa), the MPLAB® Mindi™ Analog Simulator will issue a warning and highlight the incompatible components.

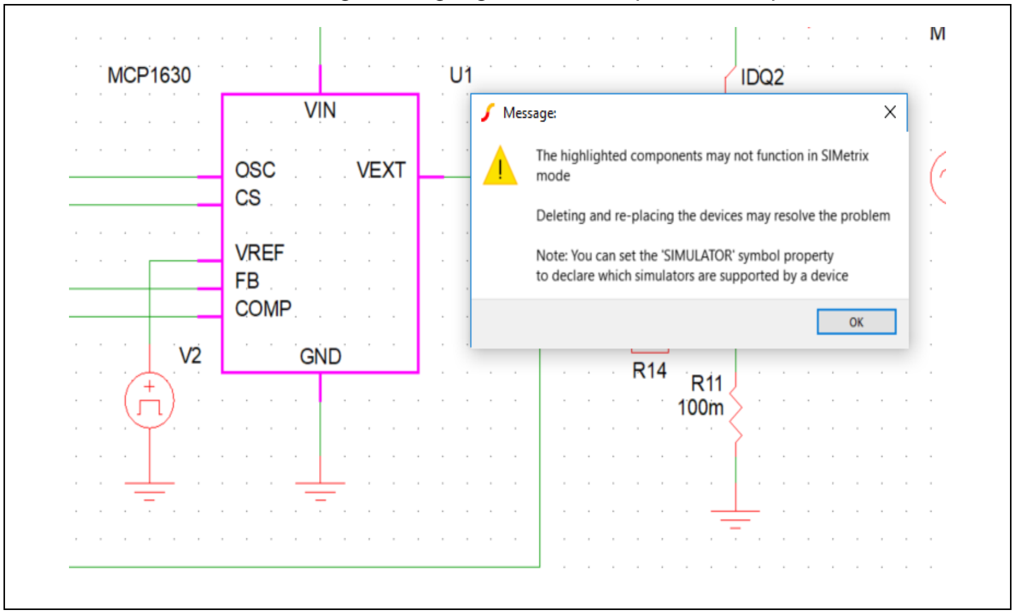


FIGURE 3-3: *MPLAB® Mindi™ - Incompatibility Warning.*

3.2 SIMULATION RESULTS

You can monitor the status of the simulation and analysis in the simulation status window, as shown below. During simulation, incremental waveform results will be displayed if they have been previously enabled. Please note that not all stimulus components or probes are functional with every simulation/analysis type. For each analysis type selected, it is important to add the proper probes and sources to the schematic.

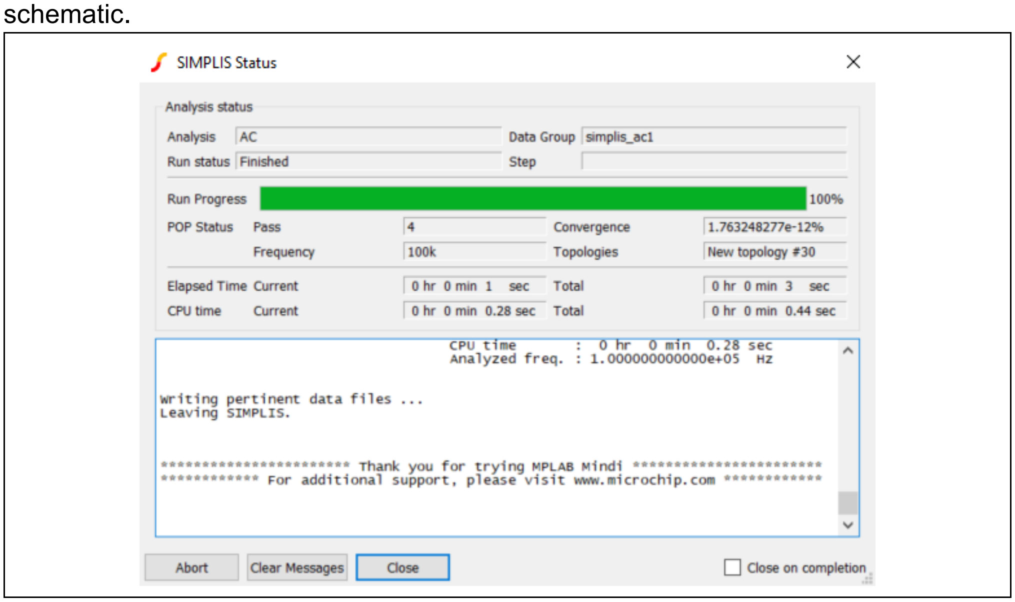


FIGURE 3-4: *MPLAB® Mindi™ - Simulation Status.*

The MPLAB® Mindi™ Analog Simulator can perform time domain (waveforms) and frequency domain (Bode plot) analyses. A time domain simulation shows multiple characteristics such as response time and overshoot.

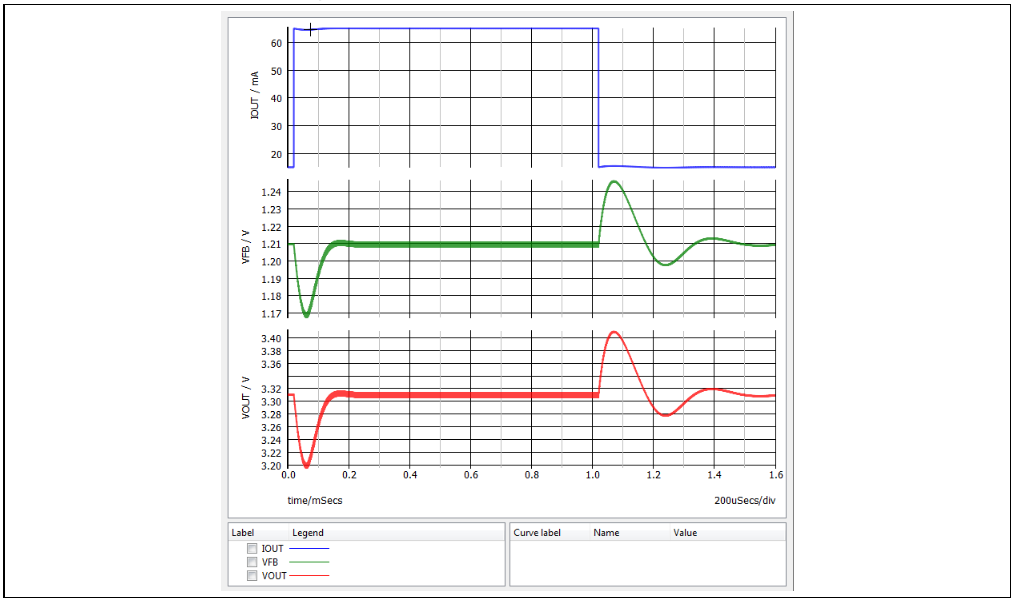


FIGURE 3-5: *MPLAB® Mindi™ - Time Domain Simulation.*

While the time domain analysis shows how a signal changes over time, the frequency domain analysis shows how the signal's energy is distributed over a range of frequencies.

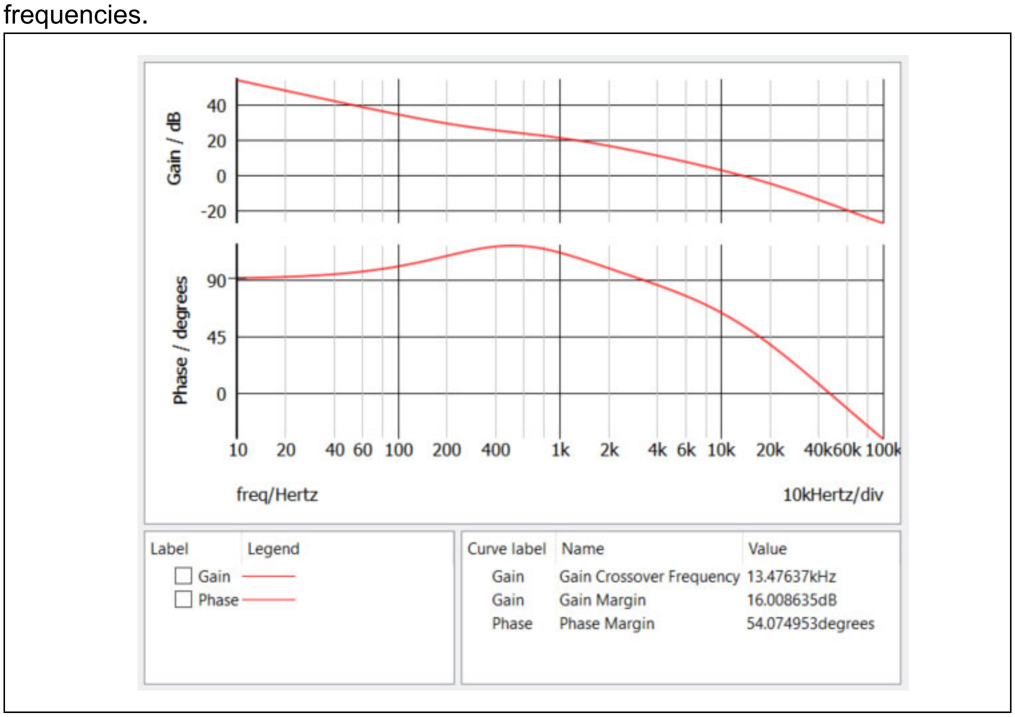


FIGURE 3-6: *MPLAB® Mindi™ - Frequency Domain Analysis.*

This frequency domain analysis produces the Bode plots. These plots include critical information regarding the circuit's closed-loop stability, such as gain and phase margins.

Chapter 4. Simulation Terms and Concepts

This chapter is a list of key terms and concepts used in describing and analyzing the characteristics of a circuit simulation. Please note that specific terms may vary slightly depending on the device that is being used.

4.1 START-UP FROM V_{IN}

Start-up from V_{IN} refers to the behavior of a device or circuit when first powered on. The assertion of the enable pin must be done before applying V_{IN}. The start-up time, in this case, is typically measured from the rising or the falling edge of the enable signal (depending on the required logic level) to 90% of the steady-state output value of the device, as shown in the waveform below.

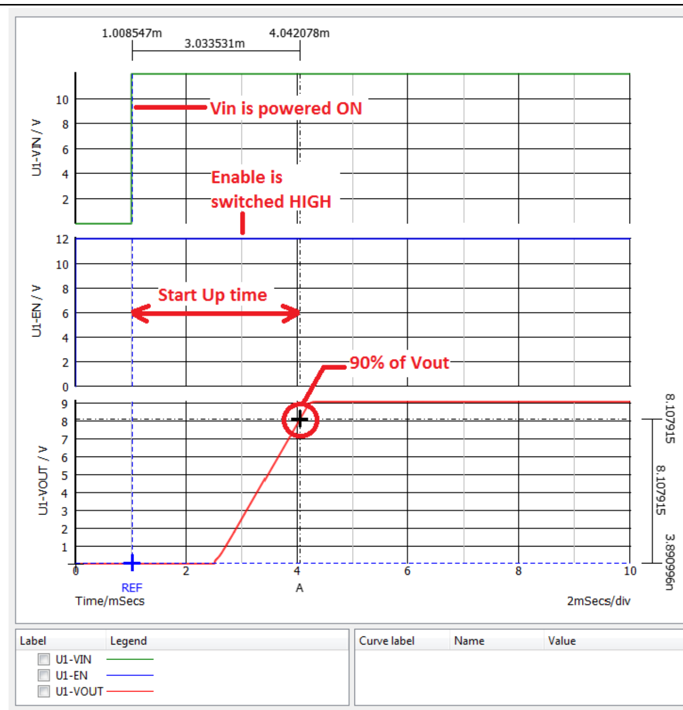


FIGURE 4-1: *Start-Up from V_{IN} Waveform.*

4.2 START-UP FROM ENABLE

Start-up from ENABLE is the response of a circuit or device when an enable signal is asserted. It is assumed that the system has been properly biased and any settling times have been met before the assertion of the enable signal. The start-up time, in this case, is typically measured from the rising or the falling edge of the enable signal (depending on the required logic level) to 90% of the steady-state output value of the device, as shown in the waveform below.

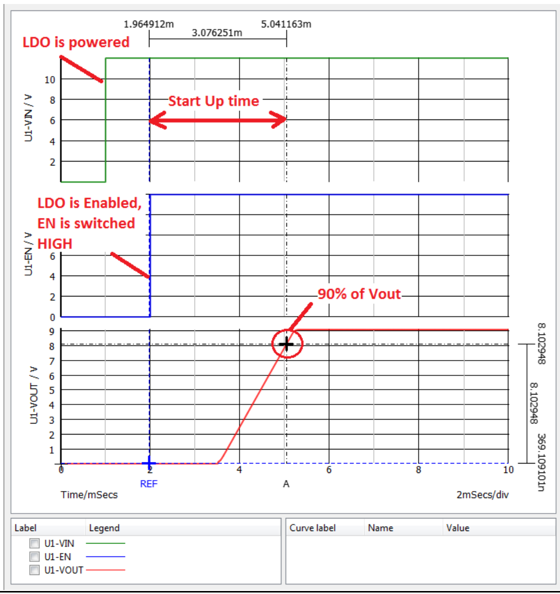


FIGURE 4-2: *Start-up from Enable Waveform.*

4.3 LOAD TRANSIENT RESPONSE

Load transient response describes the capability of a converter to maintain its output voltage during a change in the load. Typically, this is specified by the output voltage undershoot and overshoot during a load step, as shown below.

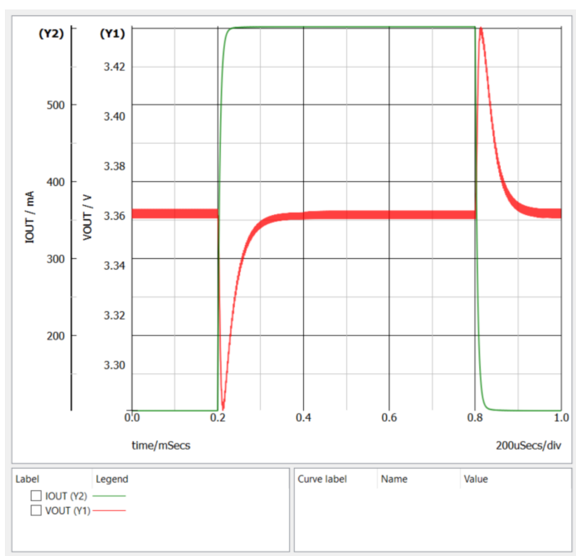


FIGURE 4-3: *Load Transient Response.*

4.4 POWER SUPPLY REJECTION RATIO (PSRR)

Power Supply Rejection Ratio (PSRR) describes the capability of an electronic circuit to suppress any power supply variations to its output signal. This capability is often expressed in decibels.

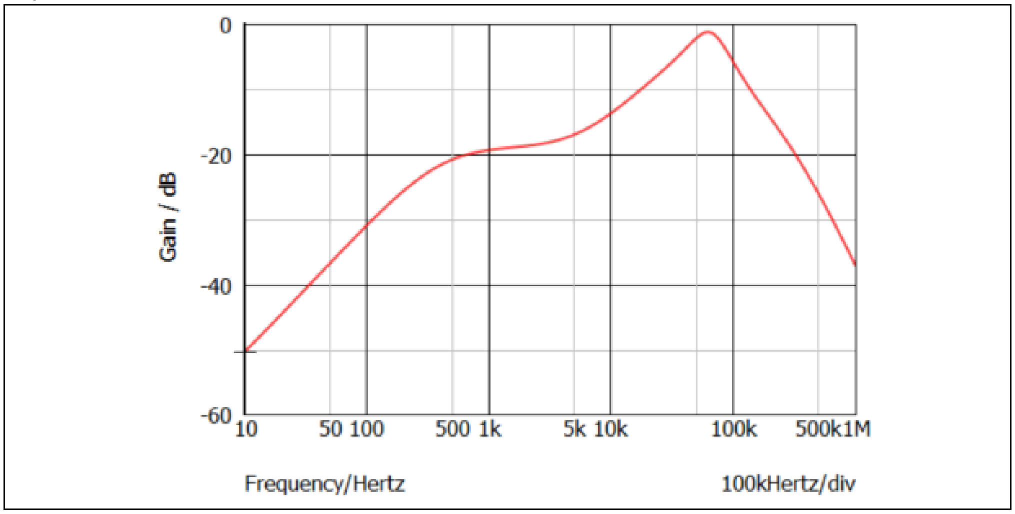


FIGURE 4-4: *Power Supply Rejection Ratio.*

4.5 CONTINUOUS AND DISCONTINUOUS CONDUCTION

In power supplies, the Continuous Conduction Mode (CCM) is the operating mode in which current flows through the inductor throughout the switching cycle.

In Discontinuous Conduction Mode (DCM), the inductor current falls to zero for some portion of the switching cycle. The first half of the figure below depicts CCM. After the load current drops in the second half, the converter transitions to DCM operation.

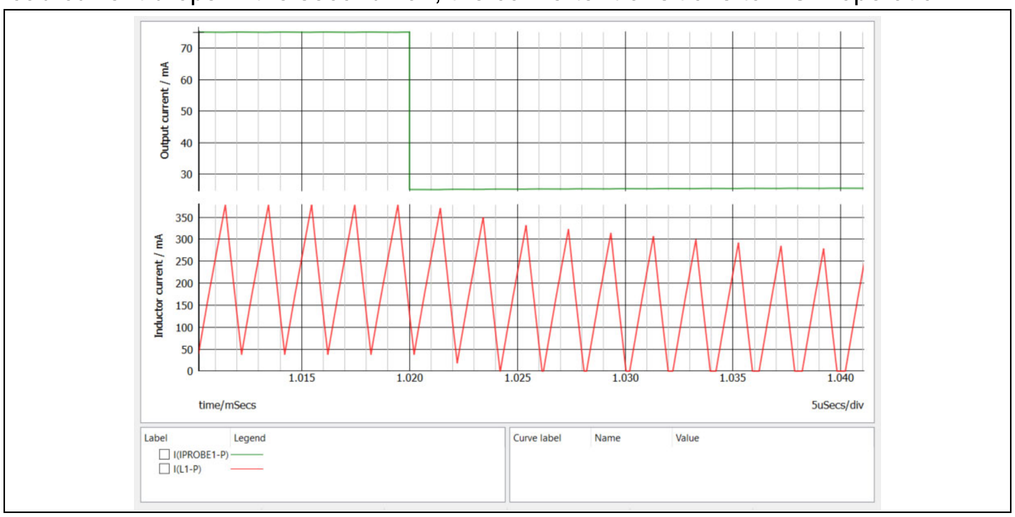


FIGURE 4-5: *Continuous and Discontinuous Conduction Modes.*

4.6 PULSE WIDTH AND PULSE FREQUENCY MODULATION

The Pulse Frequency Modulation (PFM) mode offers a higher efficiency over all load ranges. Devices run in PFM mode for light load conditions and for large input-to-output voltage ratios.

However, devices will switch into Pulse-Width Modulation (PWM) mode at higher load currents and lower input-to-output voltage ratios. PWM only operation is recommended for noise-sensitive applications in order to exhibit a much lower output voltage ripple.

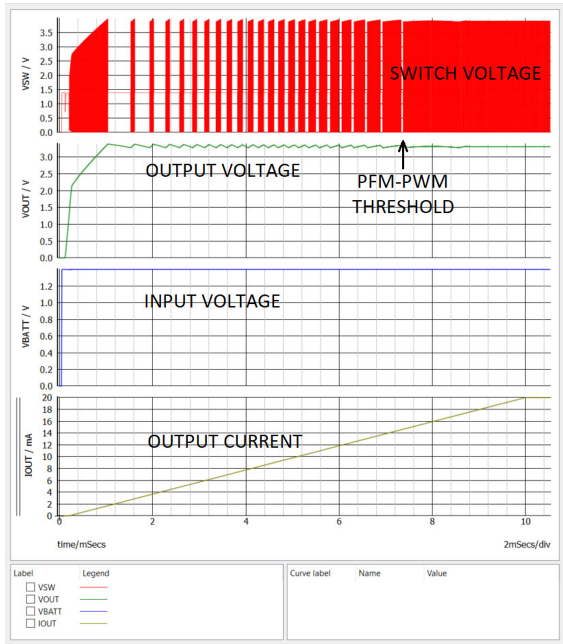


FIGURE 4-6: *Pulse Width Modulation and Pulse Frequency Modulation.*

4.7 HYPERLIGHT LOAD®

HyperLight Load (HLL) is a proprietary tool that controls load cycles through automatic switching between the ON and OFF modes. After the (constant) ON-time duration has expired, HLL turns the high side switch OFF until the output drops below the threshold. Once the output drops below the threshold a new cycle begins.

Using an NMOS low side switch instead of a diode allows for lower voltage drop across the switching device when it is on.

In discontinuous mode, HyperLight Load is used to regulate the output and to improve the efficiency of the regulators during light load currents by switching to the ON mode only when it is needed.

4.8 SOFT START

Soft start reduces the power supply input surge current at start-up by controlling the output voltage rise time. The input surge takes place while the output capacitor is being charged up. A slower output rise time will draw a lower input surge current.

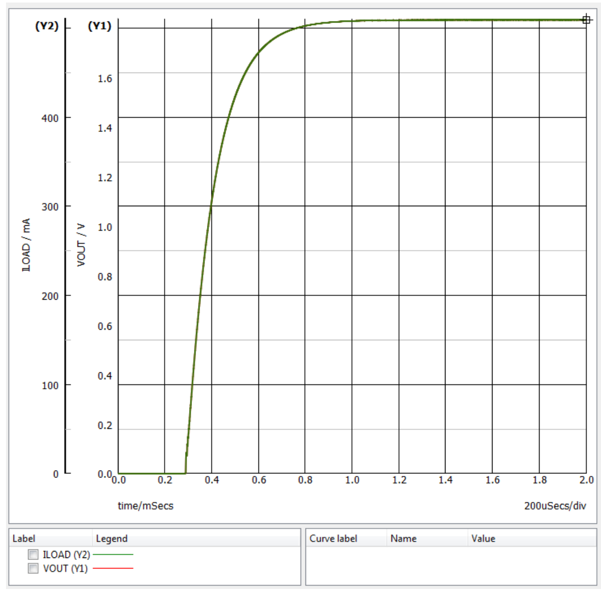


FIGURE 4-7: *Soft start.*

4.9 POWER GOOD

The Power Good (PG) output provides an indication of the output state of the device and is typically implemented as a comparator that trips when V_{OUT} is below 90% of regulation voltage.

The PG pin is generally an open-drain output that should be pulled up by the device that is measuring the PG state.

The PG delay time is measured from the point at which V_{OUT} reaches 90% of the regulation value and the rising edge of the PG output. The PG response time is measured from the point at which V_{OUT} drops below 90% of the regulation value to the falling edge of the PG output.

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