# Mindi™ Amplifier Designer User's Guide

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**NOTES:**

# 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 web site (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 "DSXXXXXA", where "XXXXX" 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 on-line help. Select the Help menu, and then Topics to open a list of available on-line help files.**

## INTRODUCTION

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

- Document Layout
- Conventions Used in this Guide
- Recommended Reading
- The Microchip Web Site
- Customer Support
- Document Revision History

## DOCUMENT LAYOUT

This document describes how to use the Mindi™ Amplifier Designer & Simulator as a development tool to emulate and debug firmware on a target board. The manual layout is as follows:

- **Chapter 1. "Overview"** – this chapter provides an overview of the Mindi™ Amplifier Designer & Simulator.
- **Chapter 2. "Amplifier Circuit Design Tutorial"** – this chapter provides an amplifier circuit design example.
- **Chapter 3. "Input Requirements"** – this chapter discusses the desired parameters for the amplifier circuit.
- **Chapter 4. "Op Amp Selection"** – this chapter discusses the selection of op amps to be used in the amplifier circuit design.
- **Chapter 5. "Analyze"** – this chapter discusses the analysis of the amplifier and displays the amplifier circuit response.

 

## CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

**DOCUMENTATION CONVENTIONS**

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

 

## RECOMMENDED READING

This user's guide describes how to use Mindi™ Amplifier Designer & Simulator. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

- **AN 722, *"Operational Amplifier DC Specifications and Applications",* DS00722, Bonnie Baker, Microchip Technology Inc., 2000.**
- **AN 723, *"Operational Amplifier AC Specifications and Applications"*, DS00723, Bonnie Baker, Microchip Technology Inc., 2000.**
- **AN 682, *"Using Single Supply Operational Amplifiers in Embedded Systems",* DS00682, Bonnie Baker, Microchip Technology Inc., 2000.**
- **AN 884, *"Driving Capacitive Loads with Op Amps",* DS00884, Kumen Blake, Microchip Technology Inc., 2003.**
- **AN 990, *"Analog Sensor Conditioning Circuits - An Overview",* DS00990, Kumen Blake, Microchip Technology Inc., 2005.**

These application notes and others are listed in the design guide:

- ***"Signal Chain Design Guide",* DS21825.**

## THE MICROCHIP WEB SITE

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

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- 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 web site at: http://support.microchip.com.

## DOCUMENT REVISION HISTORY

### Revision B (April 2009)

- Updated the Tool's Name to Mindi™ Amplifier Designer & Simulator.
- Added Two Amplifier Circuits: Inverting Differentiator and Inverting Integrator.

### Revision A (November 2007)

- Initial Release of this Document.

# Chapter 1. Overview

## 1.1 INTRODUCTION

The Mindi™ Amplifier Designer & Simulator is an Application Circuit within the Mindi™ Circuit Designer & Simulator, which is available on the Microchip home page (http://www.microchip.com) under **"Analog Design & Sim. Tool"** or going directly to the Mindi home page (http://www.microchip.com/mindi). The Mindi™ Amplifier Designer & Simulator generates full schematic diagrams of the amplifier circuit with recommended component values and displays the signal responses in frequency and time domains.

The Mindi™ Amplifier Designer & Simulator allows the following designs:

- Inverting Amplifier
- Non-inverting Amplifier
- Voltage Follower
- Difference Amplifier
- Inverting Summing Amplifier
- Inverting Comparator
- Inverting Differentiator
- Inverting Integrator

Once the amplifier characteristics have been identified, the Mindi™ Amplifier Designer & Simulator can generate and simulate the schematic of the amplifier circuit. For maximum design flexibility, changes in resistor and capacitor values can be implemented to fit the demands of the application. The tool also generates a Design Summary of the designed amplifier, including Design Requirements, Application Schematic, Result Plot, and Bill of Materials (BOM). Users can directly download the schematic, BOM, and Mindi™ offline version. The op amps and evaluation boards also can be ordered from the Microchip web site at www.microchip.com.

## 1.2 ACCESSING MINDI™

The Mindi™ Circuit Designer & Simulator can be accessed on Microchip's Home Page (http://www.microchip.com) under **"Analog Design & Sim. Tool"** or by going directly to the Mindi™ Home web page (http://www.microchip.com/mindi).

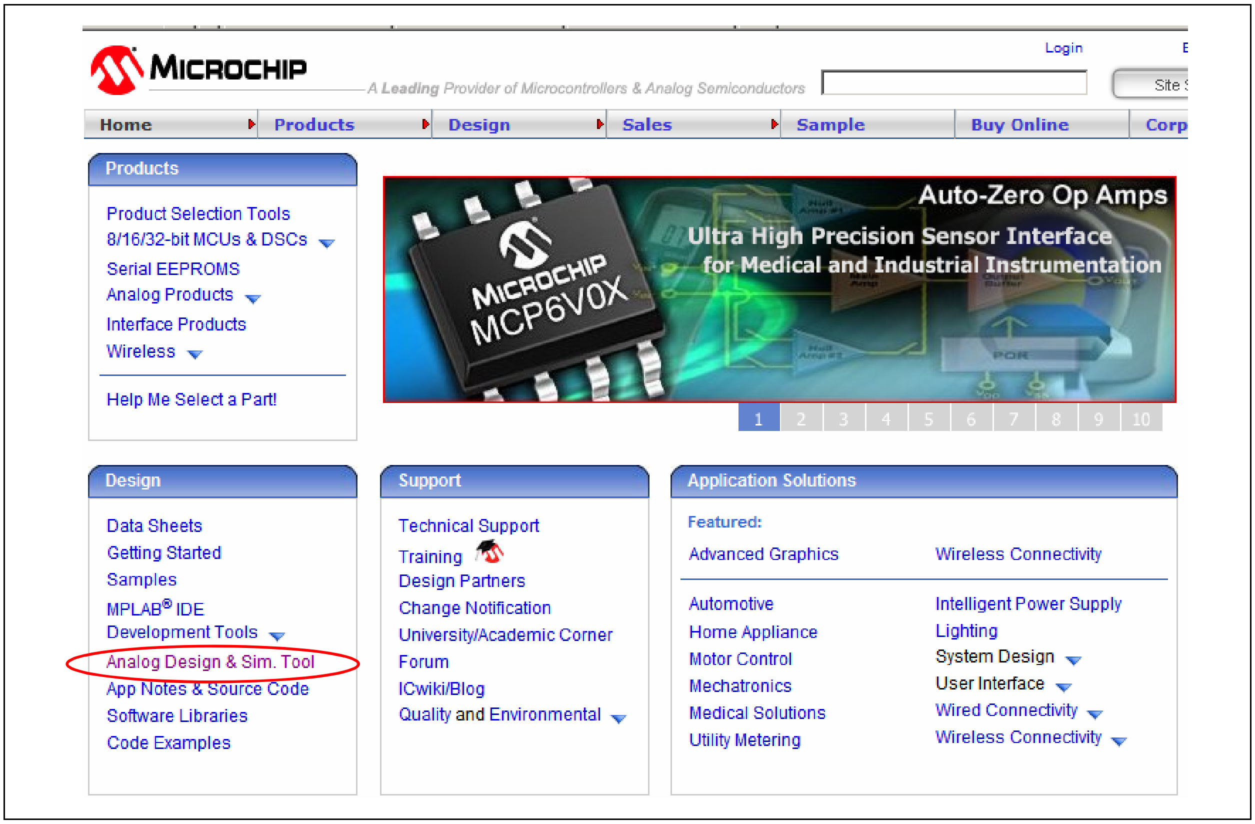



***FIGURE 1-1:*** *Mindi™ can be accessed on the Microchip Home Page.*

The Mindi™ Home Page is shown in Figure 1-2. To enter the Mindi™ Circuit Designer & Simulator, click the **Click Here to Start** button in the window.

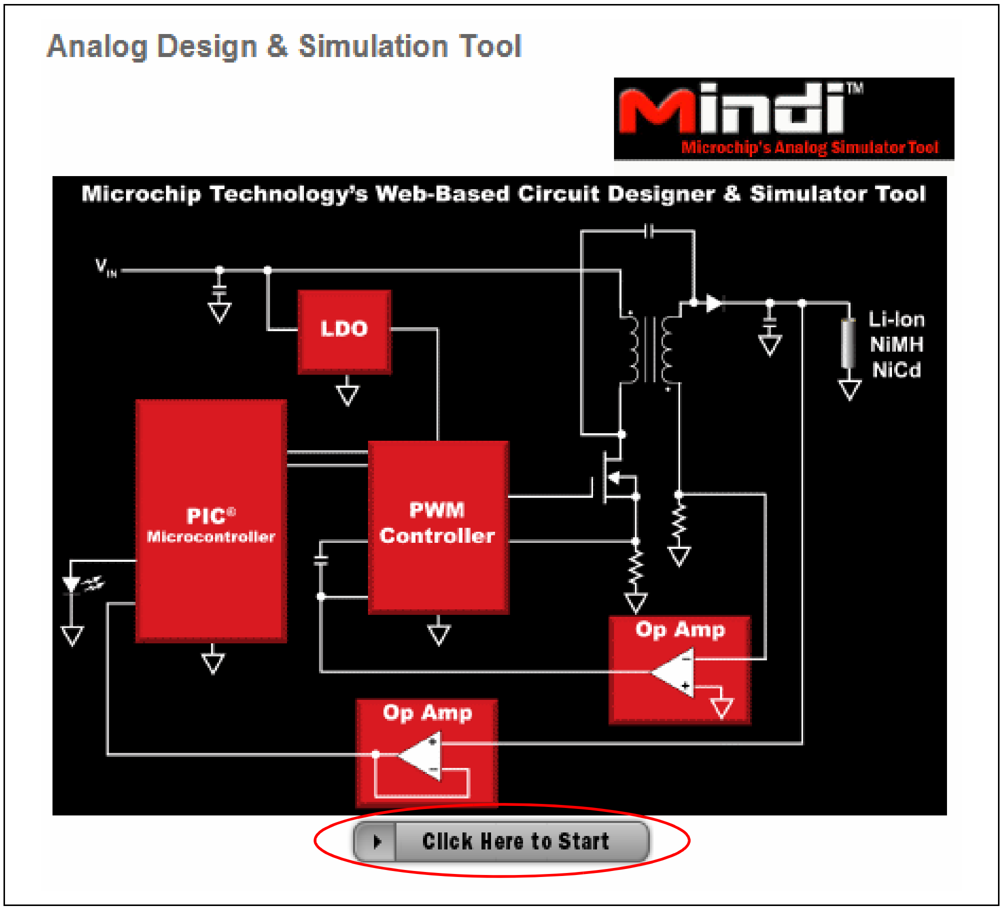



***FIGURE 1-2:*** *Bring up the Mindi™ Circuit Designer & Simulator on the Mindi™ Home Page.*

Once users log onto Mindi™, the Mindi™ home page is displayed, (as shown in Figure 1-3) indicating the application circuits that are available for design and simulation. The **Amplifiers** button is located in the upper-left corner of the web page. Click on it to enter the amplifier online design and simulation test environment.

The first time **Amplifiers** is accessed, users will be prompted to provide some basic registration information, as shown in Figure 1-4. Once registered, an account is created on the Host Server and users will be able to generate and analyze designs on the Mindi™ Circuit Designer & Simulator web page. Custom designs can also be saved to users' PC, where they can be accessed for future reference.

| | |
|---|---|
| **Note:** | If a Pop-Up Blocker is enabled on the users' browser, there may be a problem with the registration process. Please be sure to disable this feature when registering on Mindi™. On Internet Explorer, this is done by selecting the Pop-Up Blocker window under the **Tools** pull-down menu. |

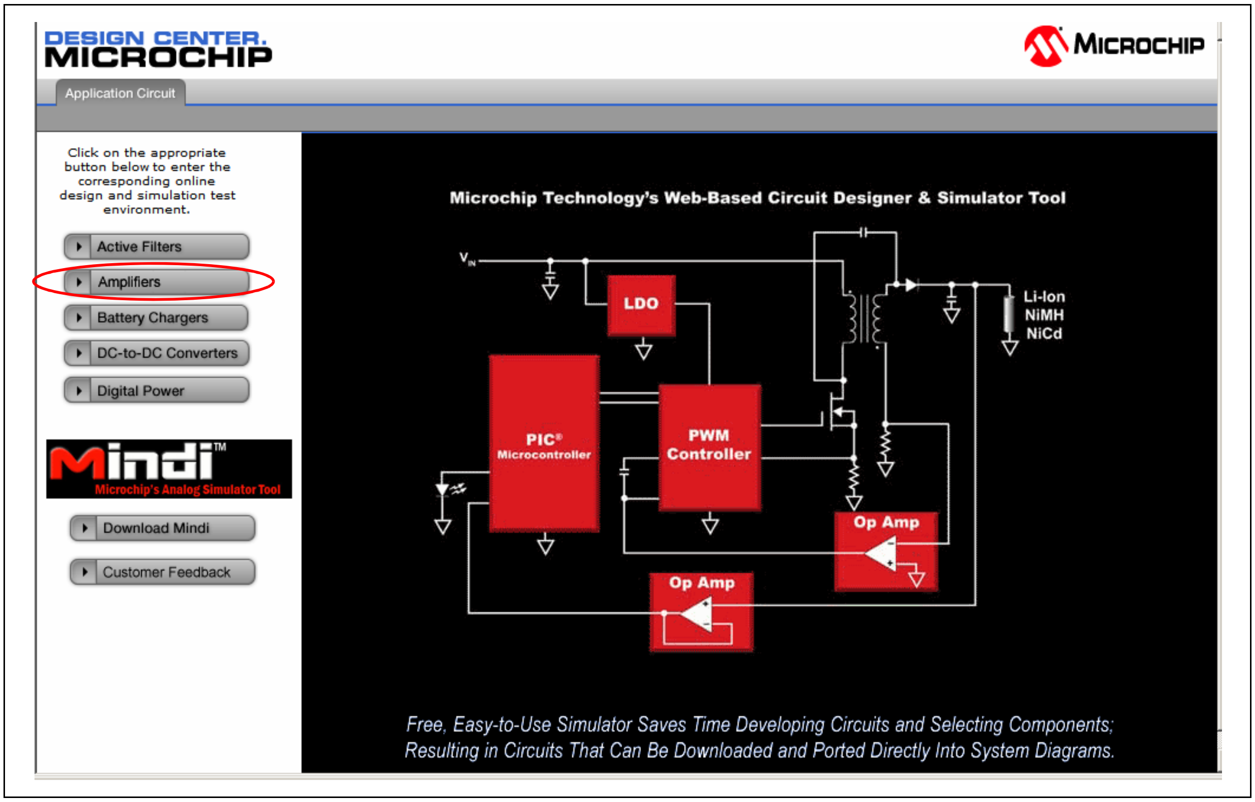



*FIGURE 1-3: Application Circuit.*

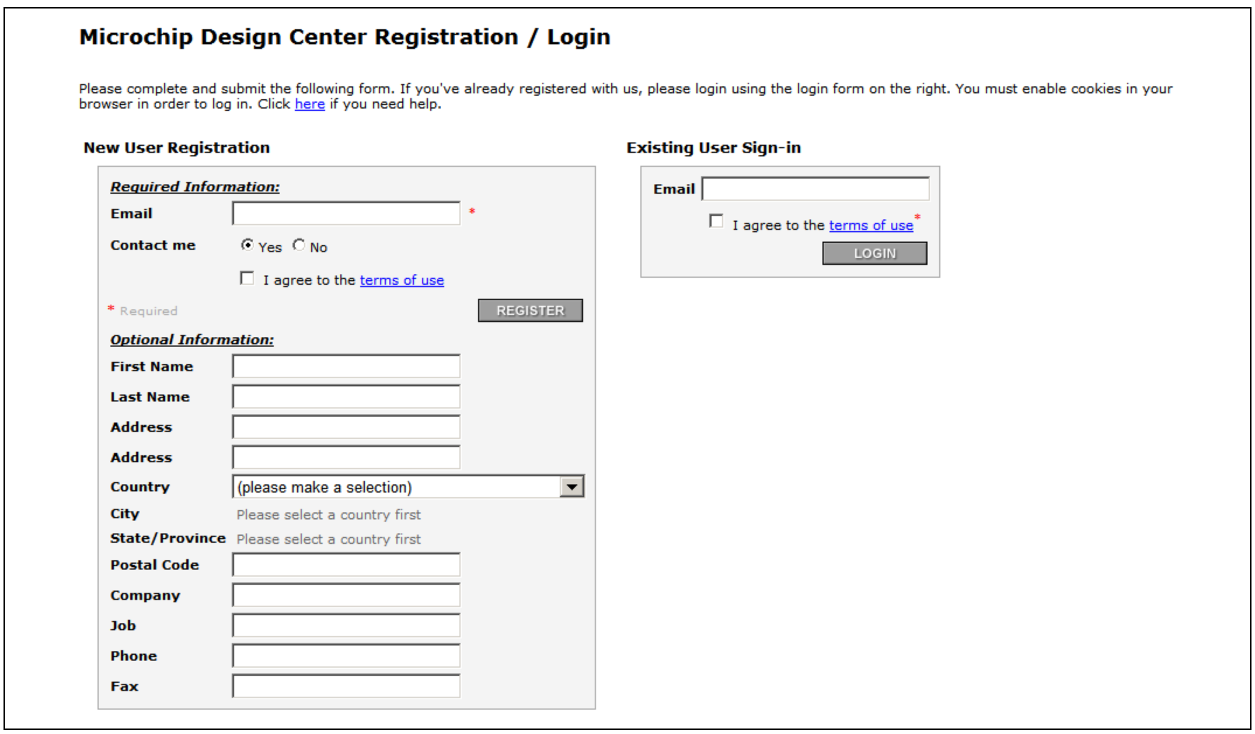



*FIGURE 1-4: New User Registration.*

## 1.3 AMPLIFIER DESIGN

The Mindi™ Amplifier Designer & Simulator has four amplifier design tabs which include **Application Circuit, Input Requirements, Op Amp Selection,** and **Analyze**, as shown on the Tab bar on the top of the tool page in Figure 1-5. These tabs allow the user to move through the design steps of specifying performance requirements. An overview of the Mindi™ Amplifier Designer & Simulator is given in the following sections.

### 1.3.1 Application Circuit Tab

The amplifier circuit design starts from the **Application Circuit** tab (see Figure 1-3). Select the **Amplifiers** button to enter the online simulation test environment.

### 1.3.2 Input Requirements Tab

Click the **Input Requirements** tab and set desired parameters for the amplifier circuit. (This tab is discussed in more detail in **Chapter 3. "Input Requirements"**.)

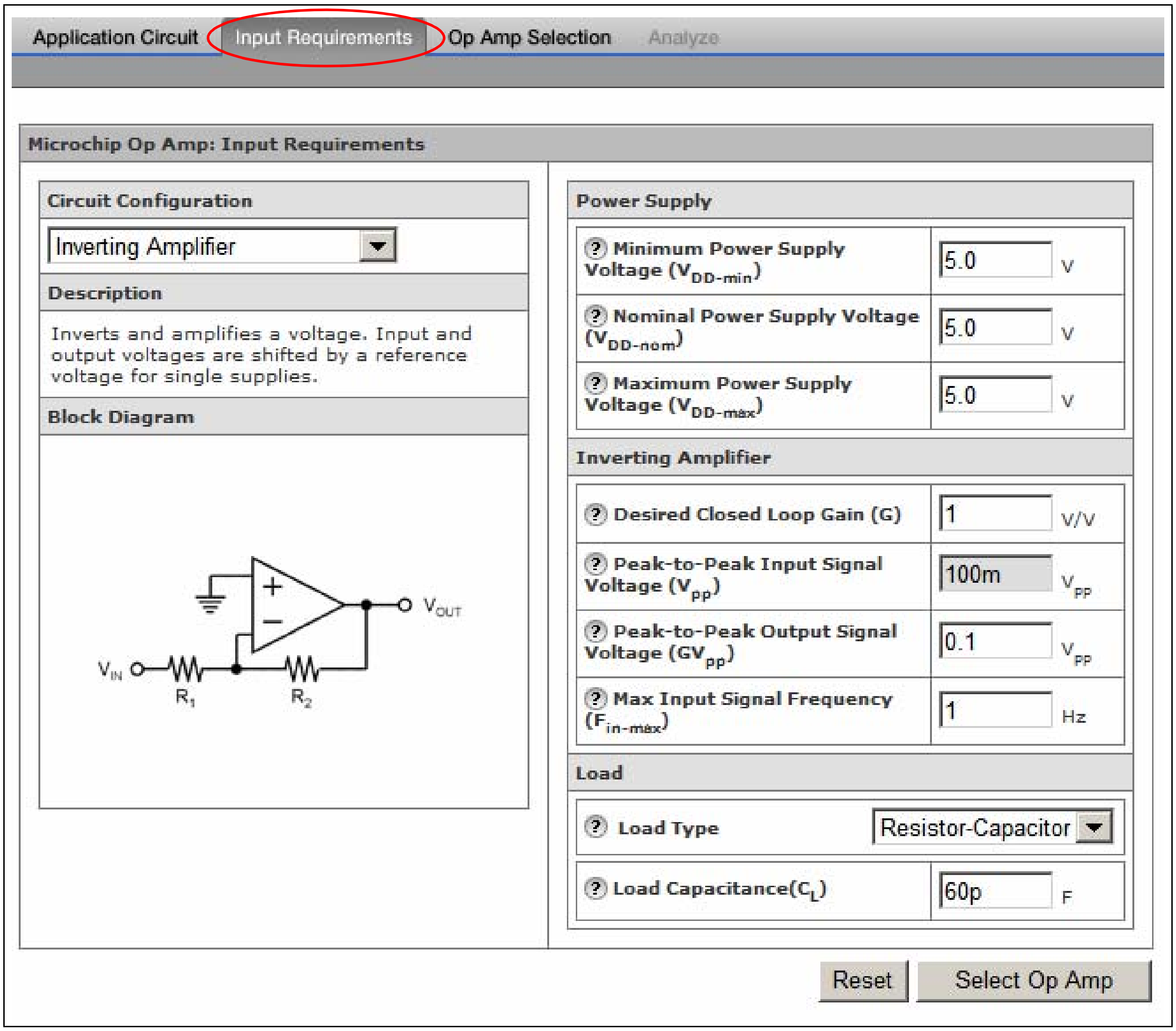
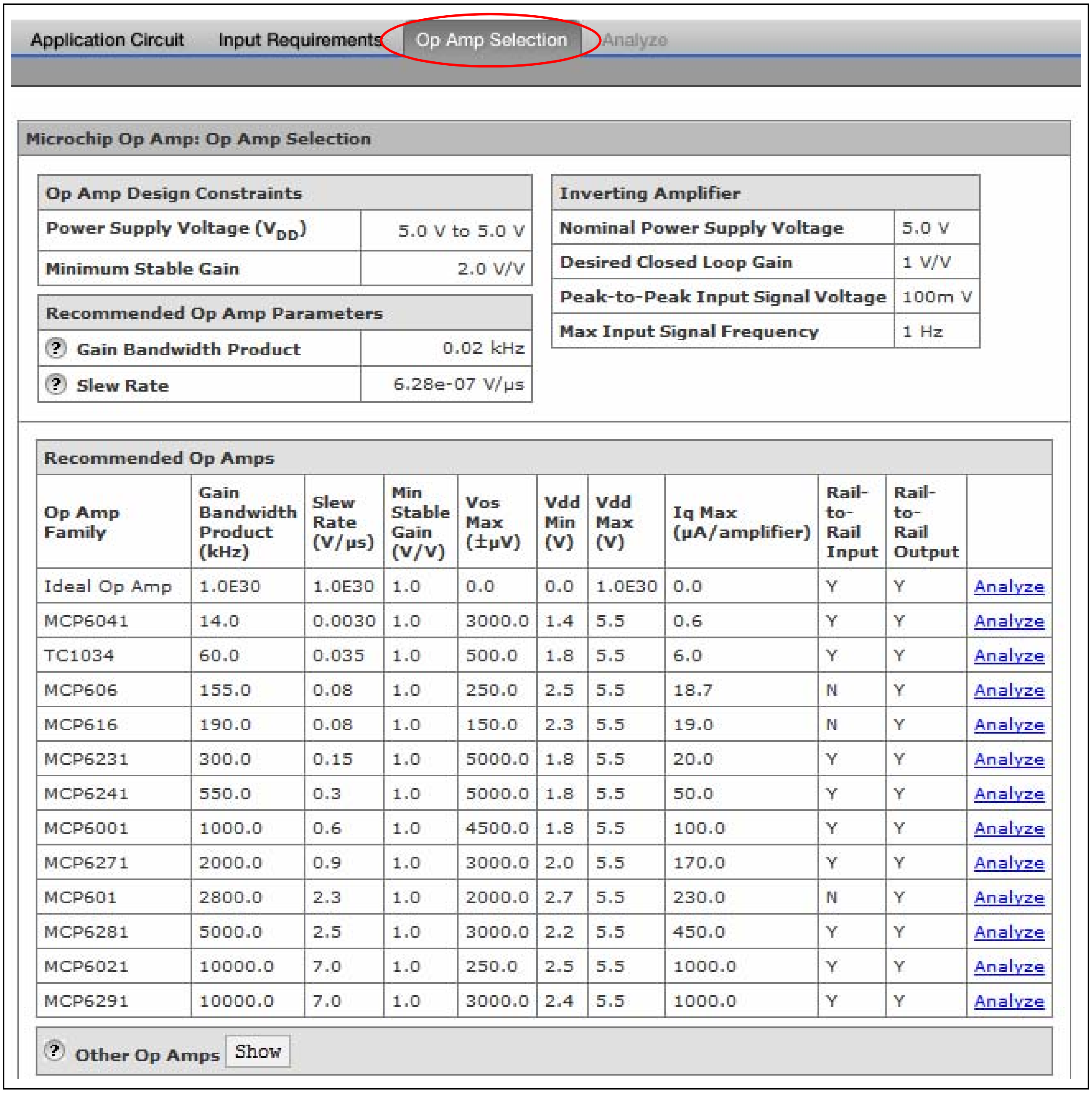



*FIGURE 1-5: Input Requirements.*

### 1.3.3 Op Amp Selection Tab

Click the **Op Amp Selection** tab, choose an op amp to be used in the amplifier circuit and click the corresponding **Analyze** link to start the next phase of the design. (This tab is discussed in more detail in **Chapter 4. "Op Amp Selection"**).




| Op Amp Design Constraints | |
|---|---|
| Power Supply Voltage ($V_{DD}$) | 5.0 V to 5.0 V |
| Minimum Stable Gain | 2.0 V/V |
| **Recommended Op Amp Parameters** | |
| Gain Bandwidth Product | 0.02 kHz |
| Slew Rate | 6.28e-07 V/µs |

| Inverting Amplifier | |
|---|---|
| Nominal Power Supply Voltage | 5.0 V |
| Desired Closed Loop Gain | 1 V/V |
| Peak-to-Peak Input Signal Voltage | 100m V |
| Max Input Signal Frequency | 1 Hz |

Recommended Op Amps

| Op Amp Family | Gain Bandwidth Product (kHz) | Slew Rate (V/µs) | Min Stable Gain (V/V) | Vos Max (±µV) | Vdd Min (V) | Vdd Max (V) | Iq Max (µA/amplifier) | Rail-to-Rail Input | Rail-to-Rail Output | |
|---|---|---|---|---|---|---|---|---|---|---|
| Ideal Op Amp | 1.0E30 | 1.0E30 | 1.0 | 0.0 | 0.0 | 1.0E30 | 0.0 | Y | Y | Analyze |
| MCP6041 | 14.0 | 0.0030 | 1.0 | 3000.0 | 1.4 | 5.5 | 0.6 | Y | Y | Analyze |
| TC1034 | 60.0 | 0.035 | 1.0 | 500.0 | 1.8 | 5.5 | 6.0 | Y | Y | Analyze |
| MCP606 | 155.0 | 0.08 | 1.0 | 250.0 | 2.5 | 5.5 | 18.7 | N | Y | Analyze |
| MCP616 | 190.0 | 0.08 | 1.0 | 150.0 | 2.3 | 5.5 | 19.0 | N | Y | Analyze |
| MCP6231 | 300.0 | 0.15 | 1.0 | 5000.0 | 1.8 | 5.5 | 20.0 | Y | Y | Analyze |
| MCP6241 | 550.0 | 0.3 | 1.0 | 5000.0 | 1.8 | 5.5 | 50.0 | Y | Y | Analyze |
| MCP6001 | 1000.0 | 0.6 | 1.0 | 4500.0 | 1.8 | 5.5 | 100.0 | Y | Y | Analyze |
| MCP6271 | 2000.0 | 0.9 | 1.0 | 3000.0 | 2.0 | 5.5 | 170.0 | Y | Y | Analyze |
| MCP601 | 2800.0 | 2.3 | 1.0 | 2000.0 | 2.7 | 5.5 | 230.0 | N | Y | Analyze |
| MCP6281 | 5000.0 | 2.5 | 1.0 | 3000.0 | 2.2 | 5.5 | 450.0 | Y | Y | Analyze |
| MCP6021 | 10000.0 | 7.0 | 1.0 | 250.0 | 2.5 | 5.5 | 1000.0 | Y | Y | Analyze |
| MCP6291 | 10000.0 | 7.0 | 1.0 | 3000.0 | 2.4 | 5.5 | 1000.0 | Y | Y | Analyze |



***FIGURE 1-6:*** *Op Amp Selection.*

### 1.3.4 Analyze Tab

There are four buttons associated with the Analyze tab:

- **Interactive Schematic**
- **Reset Design**
- **Design Summary**
- **Downloads, Samples and More**

The Mindi™ Amplifier Designer & Simulator generates the amplifier circuit schematic on this tab. For maximum design flexibility, changes in resistor and capacitor values can be implemented to fit the demands of the application. To run a simulation, choose a mode from the Select drop-down menu and click the **Run** button to simulate the schematic. Once the simulation is complete, waveforms will be available via the Waveforms drop-down menu. A single-page design summary can be generated by clicking **Design Summary** button. Moreover, the schematic, amplifier SPICE model and Mindi™ offline version can be downloaded. (This tab is discussed in more detail in **Chapter 5. “Analyze”**).

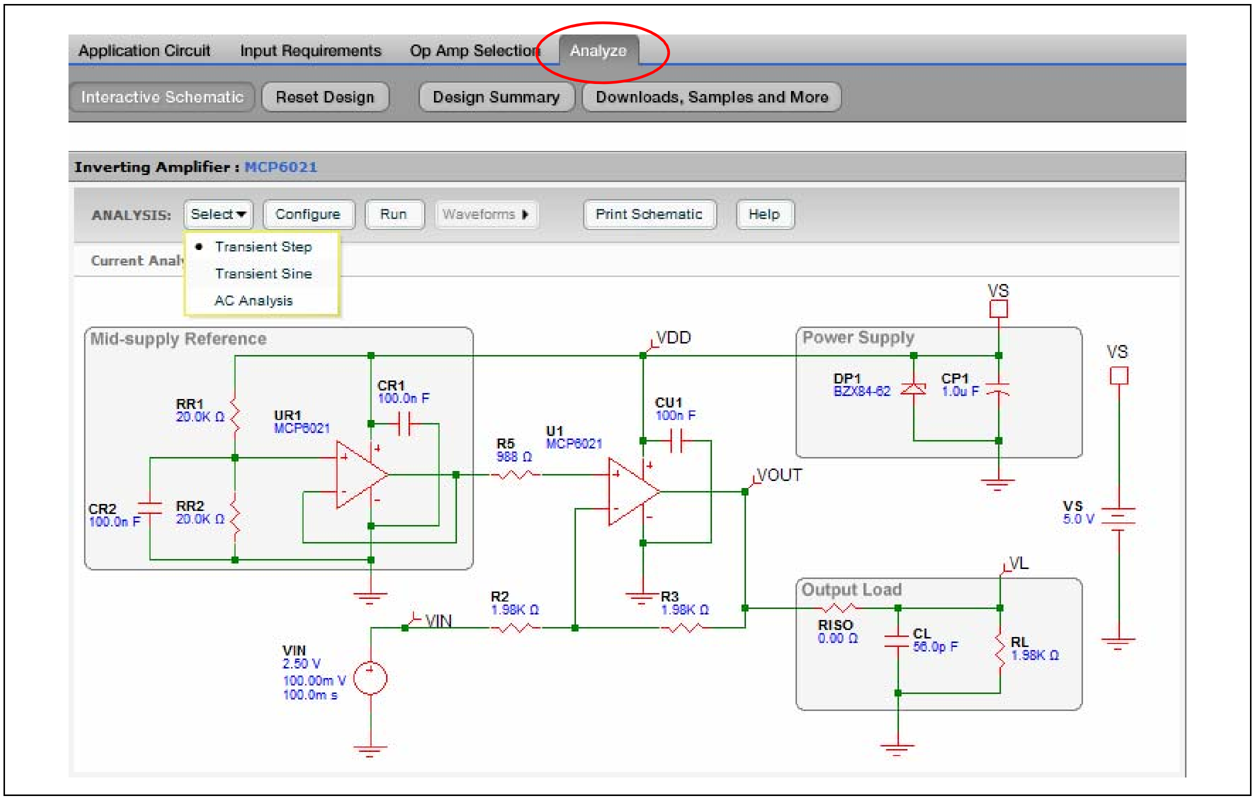



*FIGURE 1-7: Analyze.*

**NOTES:**

# Chapter 2. Amplifier Circuit Design Tutorial

## 2.1 INTRODUCTION

This chapter steps users through the design of an example amplifier circuit.

## 2.2 AMPLIFIER DESIGN EXAMPLE

Design a non-inverting amplifier with the following requirements:

- Closed Loop Gain = +2 V/V
- Power Supply Voltage = 5.0V
- Load Type: Resistor-Capacitor
- Load Capacitance = 60 pF

The block diagram of a non-inverting amplifier is shown in Figure 2-1.

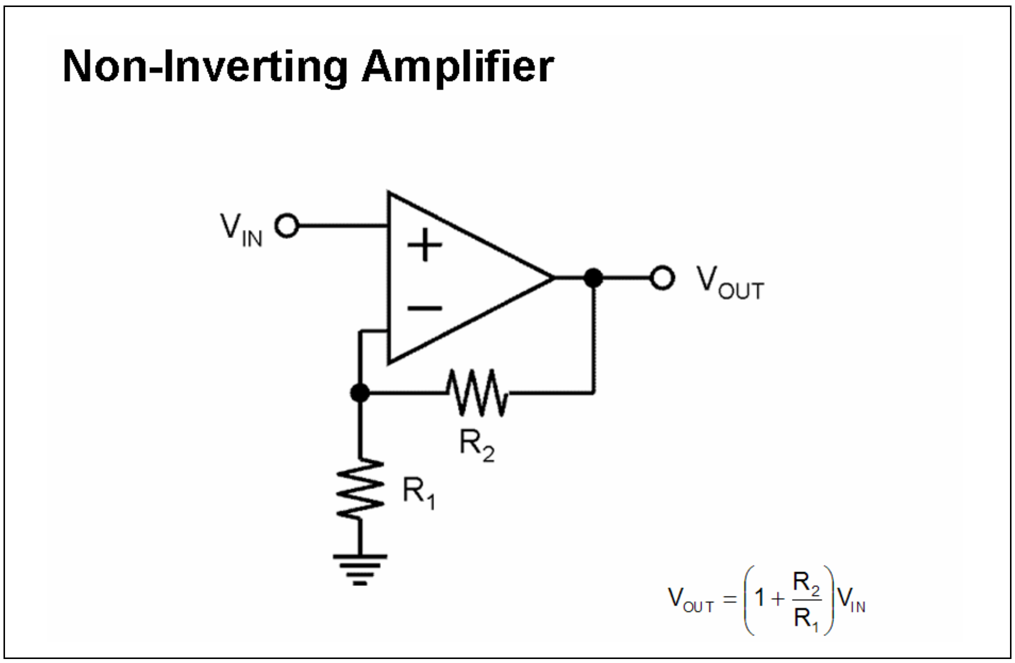



***FIGURE 2-1:*** *Block Diagram for a Non-Inverting Amplifier.*

1. To access the Mindi™ Amplifier Designer & Simulator, refer to **Section 1.2 "Accessing Mindi™"** for more detail (especially Figure 1-3).
2. Set Desired Parameters

Click the **Circuit Configuration** drop-down menu and choose **Non-Inverting Amplifier**.

The Power Supply dialog enables users to specify the minimum power supply ($V_{DD-min}$), nominal power supply voltage ($V_{DD-nom}$), and maximum power supply voltage ($V_{DD-max}$). Enter **5.0** in these text boxes.

The Non-Inverting Amplifier dialog enables users to specify the desired closed loop gain (G), Peak-to-Peak Output Signal Voltage ($GV_{PP}$), and Max Input Signal Frequency ($F_{in-max}$). Enter **2** in the text box of desired closed loop gain. Use default values for the other text boxes.

The Load dialog enables users to specify the load type. Click the **Load Type** drop-down menu and choose Resistor-Capacitor. Enter **60p** in the Load Capacitance text box.

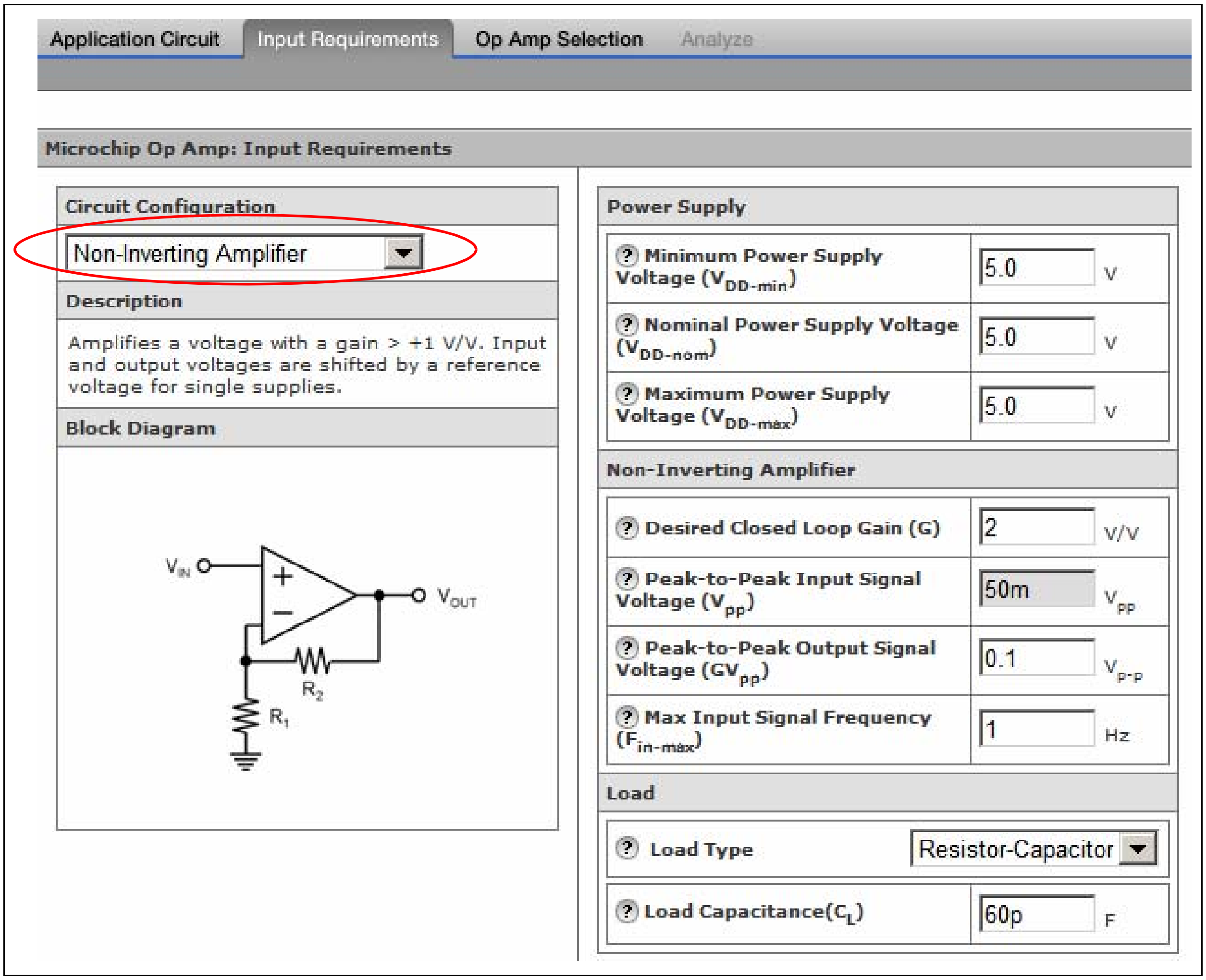
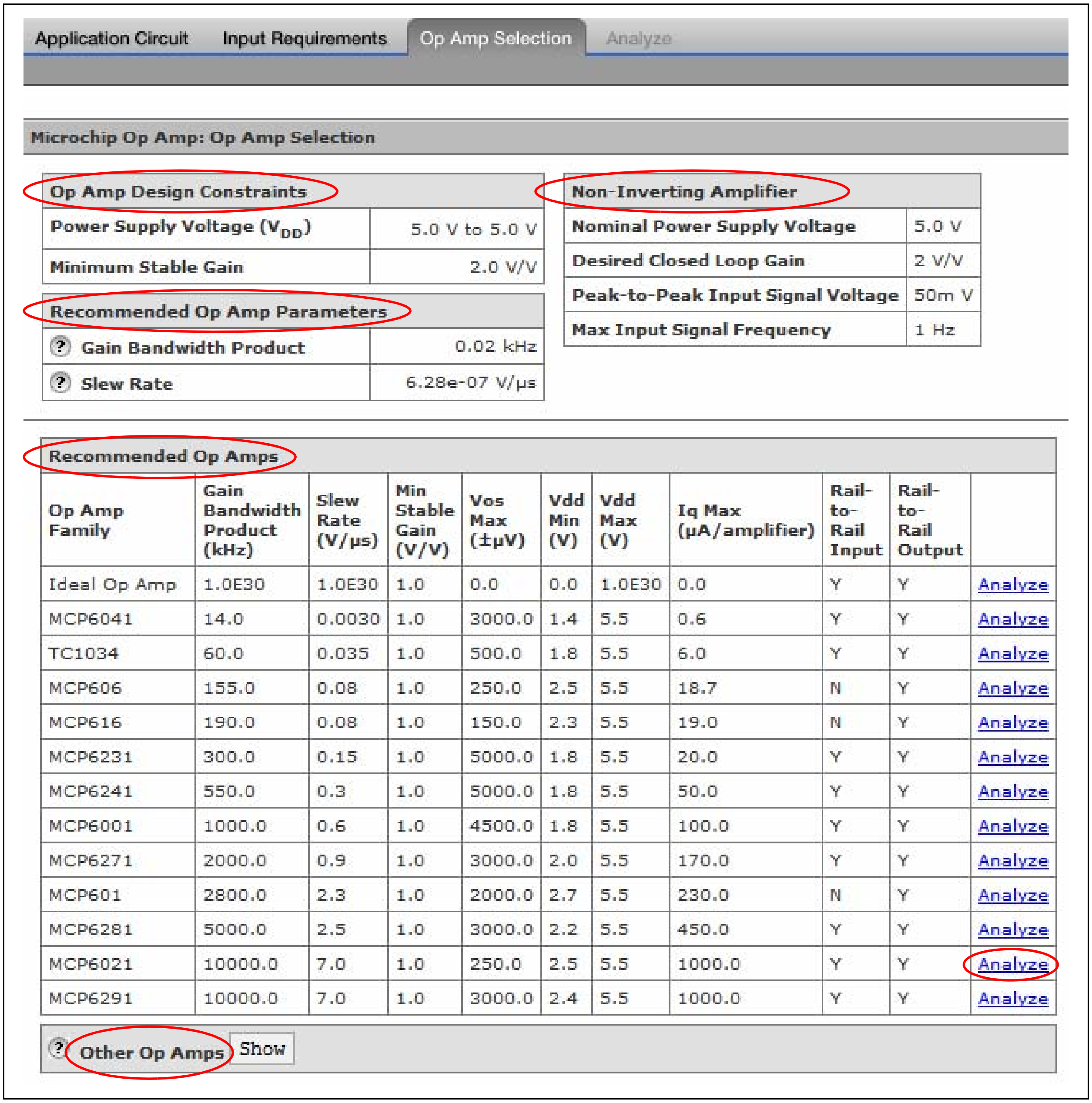



*FIGURE 2-2: Input Requirements.*

3. Select Op Amp

The Non-Inverting Amplifier table lists key amplifier design information as a reminder. The Recommended Op Amps table lists those op amps that come close to the recommended op amp specifications. For this tutorial, select **MCP6021** by clicking the corresponding Analyze link.



Application Circuit | Input Requirements | Op Amp Selection | Analyze

Microchip Op Amp: Op Amp Selection

| Op Amp Design Constraints | |
|---|---|
| Power Supply Voltage ($V_{DD}$) | 5.0 V to 5.0 V |
| Minimum Stable Gain | 2.0 V/V |
| **Recommended Op Amp Parameters** | |
| Gain Bandwidth Product | 0.02 kHz |
| Slew Rate | 6.28e-07 V/µs |

| Non-Inverting Amplifier | |
|---|---|
| Nominal Power Supply Voltage | 5.0 V |
| Desired Closed Loop Gain | 2 V/V |
| Peak-to-Peak Input Signal Voltage | 50m V |
| Max Input Signal Frequency | 1 Hz |

Recommended Op Amps

| Op Amp Family | Gain Bandwidth Product (kHz) | Slew Rate (V/µs) | Min Stable Gain (V/V) | Vos Max (±µV) | Vdd Min (V) | Vdd Max (V) | Iq Max (µA/amplifier) | Rail-to-Rail Input | Rail-to-Rail Output | |
|---|---|---|---|---|---|---|---|---|---|---|
| Ideal Op Amp | 1.0E30 | 1.0E30 | 1.0 | 0.0 | 0.0 | 1.0E30 | 0.0 | Y | Y | Analyze |
| MCP6041 | 14.0 | 0.0030 | 1.0 | 3000.0 | 1.4 | 5.5 | 0.6 | Y | Y | Analyze |
| TC1034 | 60.0 | 0.035 | 1.0 | 500.0 | 1.8 | 5.5 | 6.0 | Y | Y | Analyze |
| MCP606 | 155.0 | 0.08 | 1.0 | 250.0 | 2.5 | 5.5 | 18.7 | N | Y | Analyze |
| MCP616 | 190.0 | 0.08 | 1.0 | 150.0 | 2.3 | 5.5 | 19.0 | N | Y | Analyze |
| MCP6231 | 300.0 | 0.15 | 1.0 | 5000.0 | 1.8 | 5.5 | 20.0 | Y | Y | Analyze |
| MCP6241 | 550.0 | 0.3 | 1.0 | 5000.0 | 1.8 | 5.5 | 50.0 | Y | Y | Analyze |
| MCP6001 | 1000.0 | 0.6 | 1.0 | 4500.0 | 1.8 | 5.5 | 100.0 | Y | Y | Analyze |
| MCP6271 | 2000.0 | 0.9 | 1.0 | 3000.0 | 2.0 | 5.5 | 170.0 | Y | Y | Analyze |
| MCP601 | 2800.0 | 2.3 | 1.0 | 2000.0 | 2.7 | 5.5 | 230.0 | N | Y | Analyze |
| MCP6281 | 5000.0 | 2.5 | 1.0 | 3000.0 | 2.2 | 5.5 | 450.0 | Y | Y | Analyze |
| MCP6021 | 10000.0 | 7.0 | 1.0 | 250.0 | 2.5 | 5.5 | 1000.0 | Y | Y | Analyze |
| MCP6291 | 10000.0 | 7.0 | 1.0 | 3000.0 | 2.4 | 5.5 | 1000.0 | Y | Y | Analyze |

Other Op Amps  Show

***FIGURE 2-3:*** *Op Amp Selection.*

4. Analyze

The Mindi™ Amplifier Designer & Simulator automatically generates the full schematic diagram of the amplifier circuit with recommended component values. There are three types of analysis in the Select drop-down menu: Transient Step, Transient Sine, and AC Analysis.

First, choose **AC Analysis**. Then, click the **Configure** button to set up the AC simulation condition. This pull-down menu allows the user to set up the start frequency, stop frequency, and resolution. Finally, click the **Run** button to simulate the schematic. Once the simulation is completed, the AC response will be available via the Waveforms drop-down menu. Similarly, the Transient Step and the Sine Analysis can be completed and the transient responses will also be available via the Waveforms drop-down menu. Moreover, a design summary can be generated by clicking the **Design Summmary** button (see Figures 2-4 to Figure 2-14).

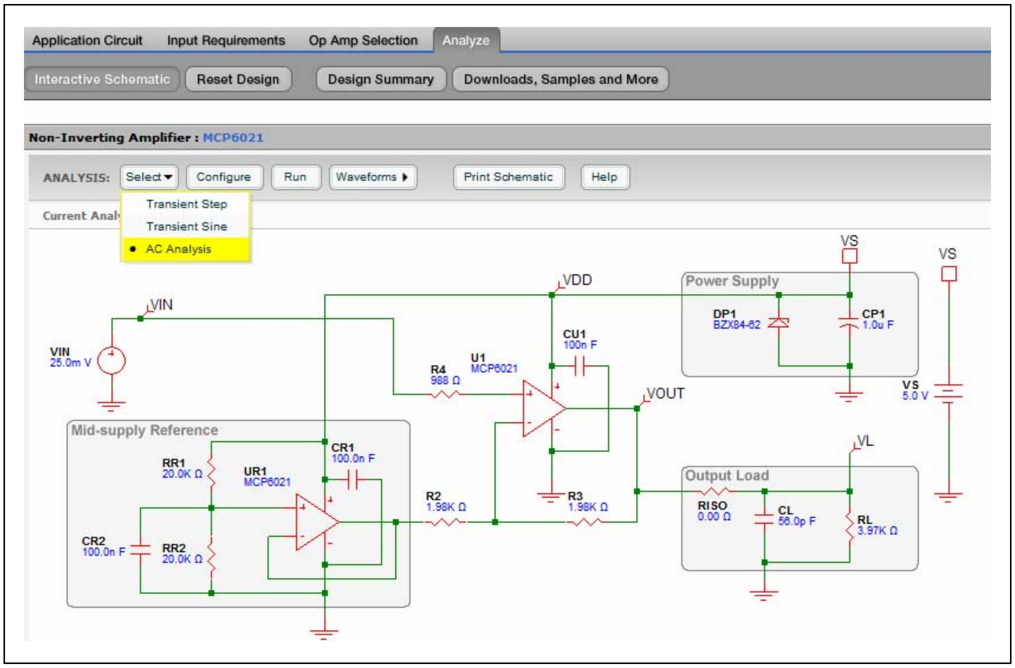



***FIGURE 2-4:*** *AC Analysis.*

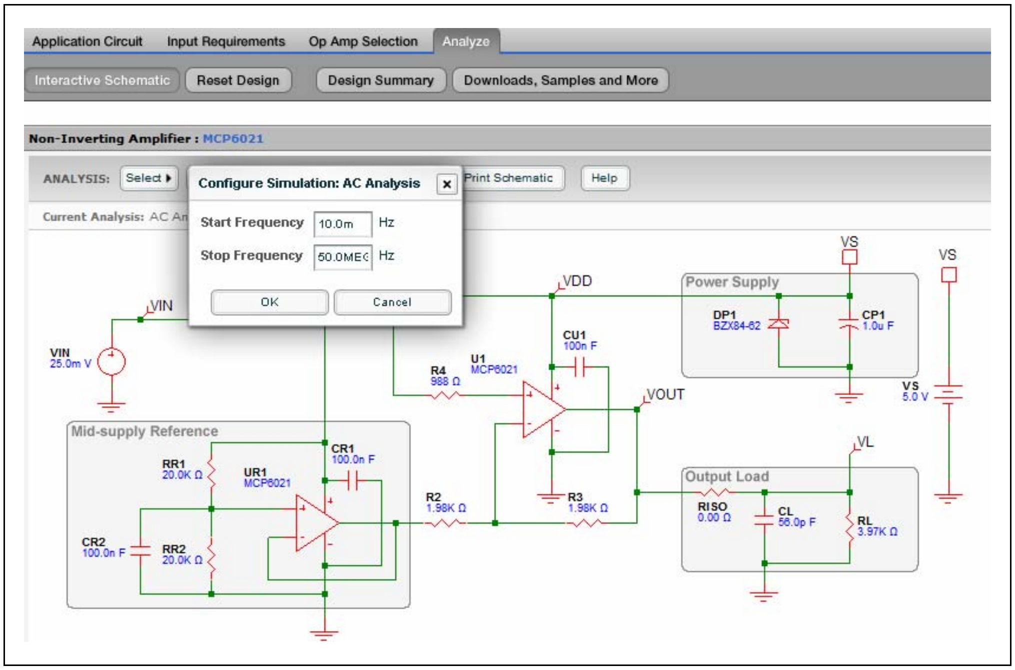



*FIGURE 2-5: Configure the Simulation.*

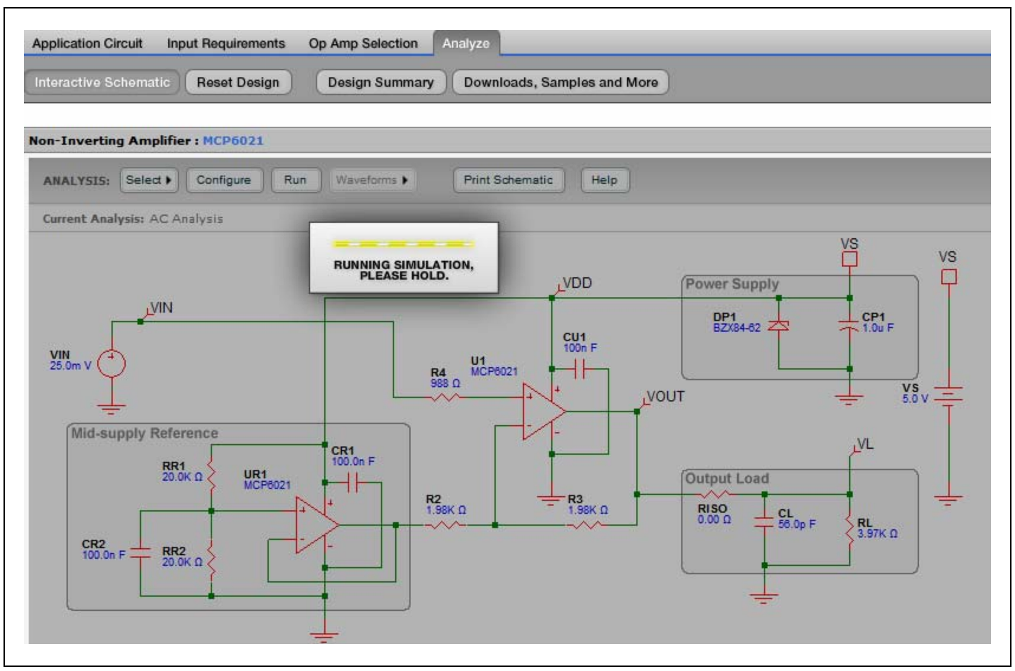



*FIGURE 2-6: Running the Simulation.*

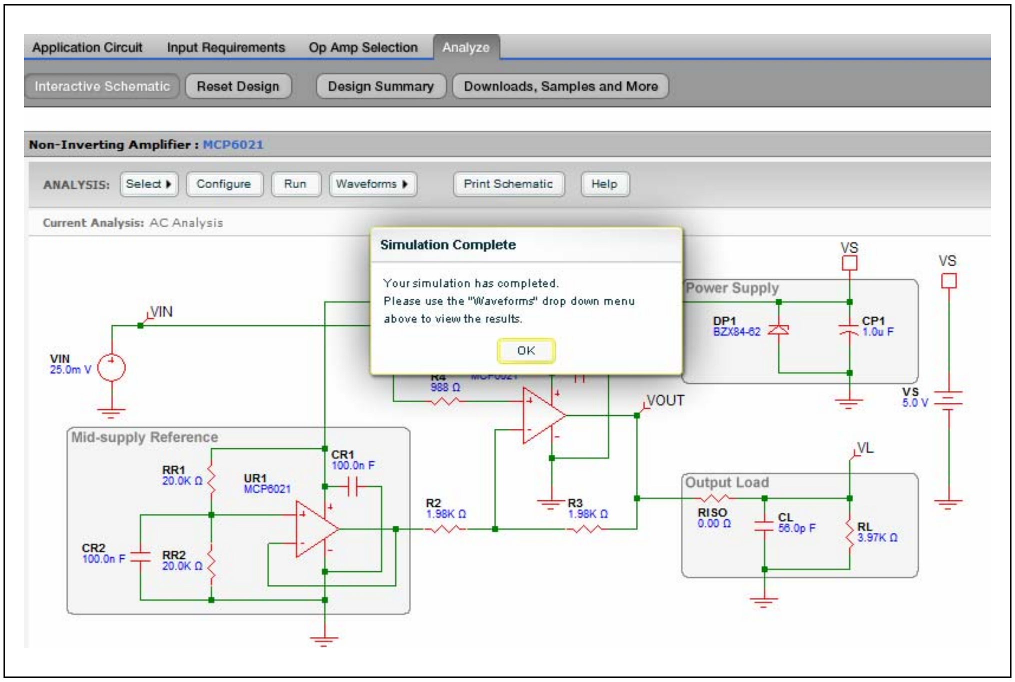



*FIGURE 2-7:* *Simulation Complete.*

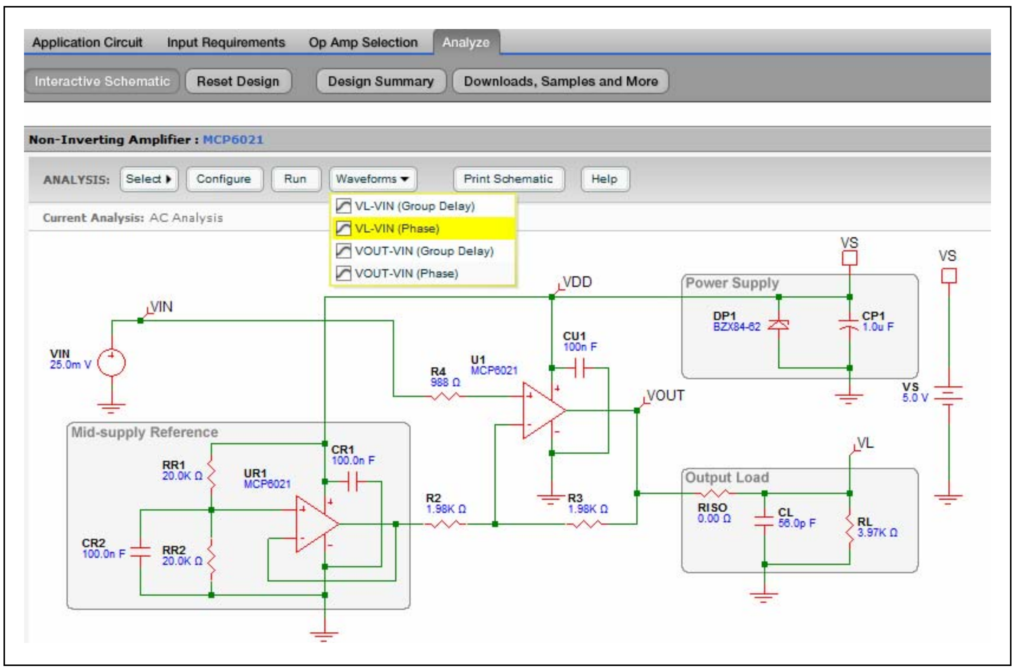



*FIGURE 2-8:* *View the Waveform.*

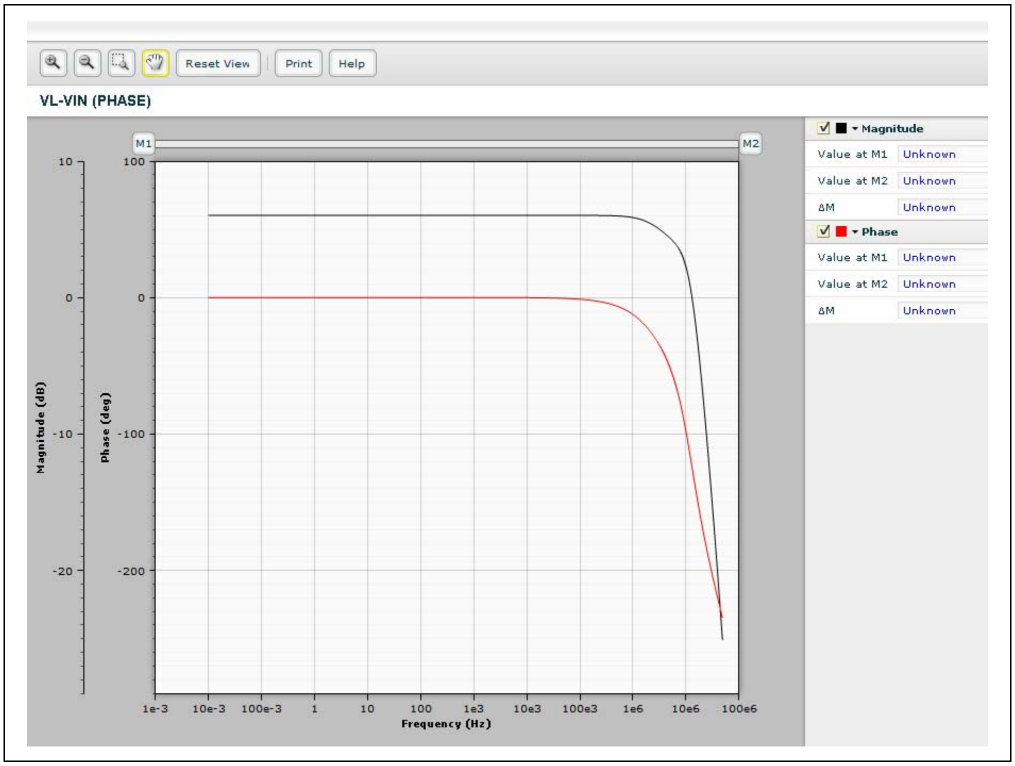



***FIGURE 2-9:*** *AC Response: Magnitude-Phase.*

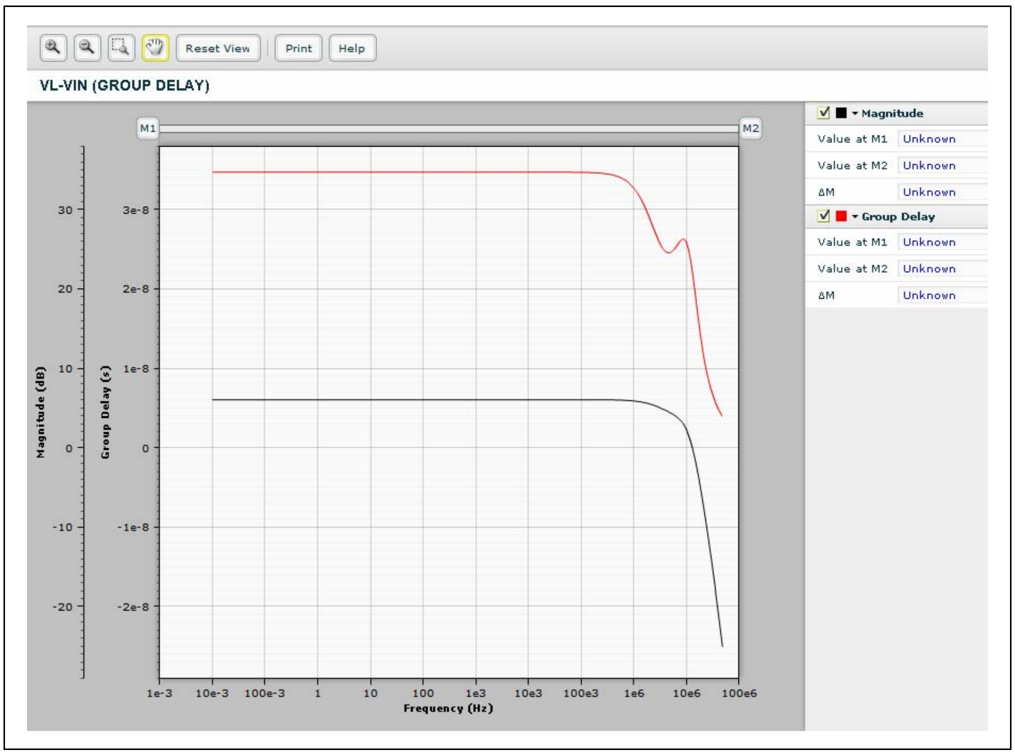



***FIGURE 2-10:*** *AC Response: Magnitude-Group Delay.*

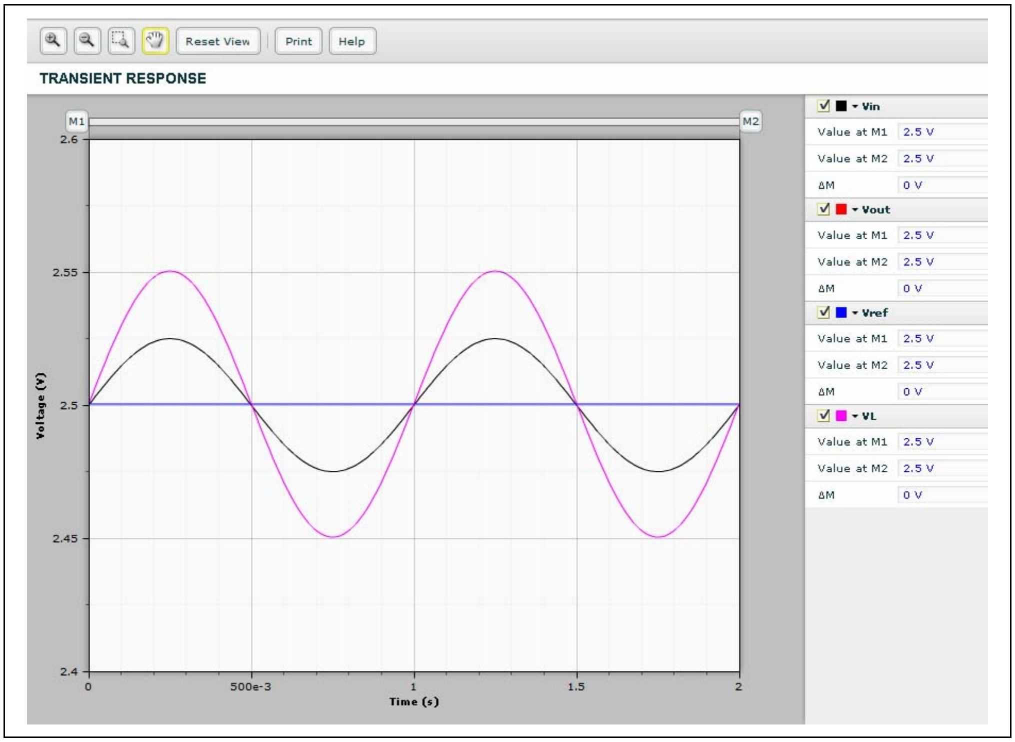



***FIGURE 2-11:*** *Transient Sine Response.*

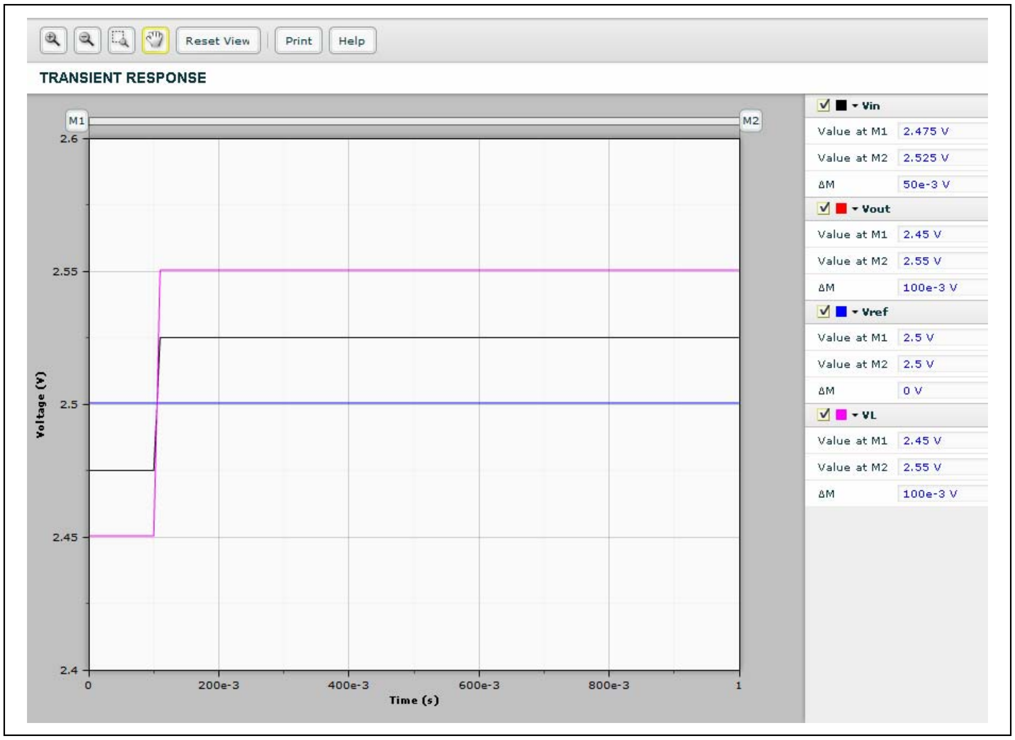



***FIGURE 2-12:*** *Transient Step Response.*

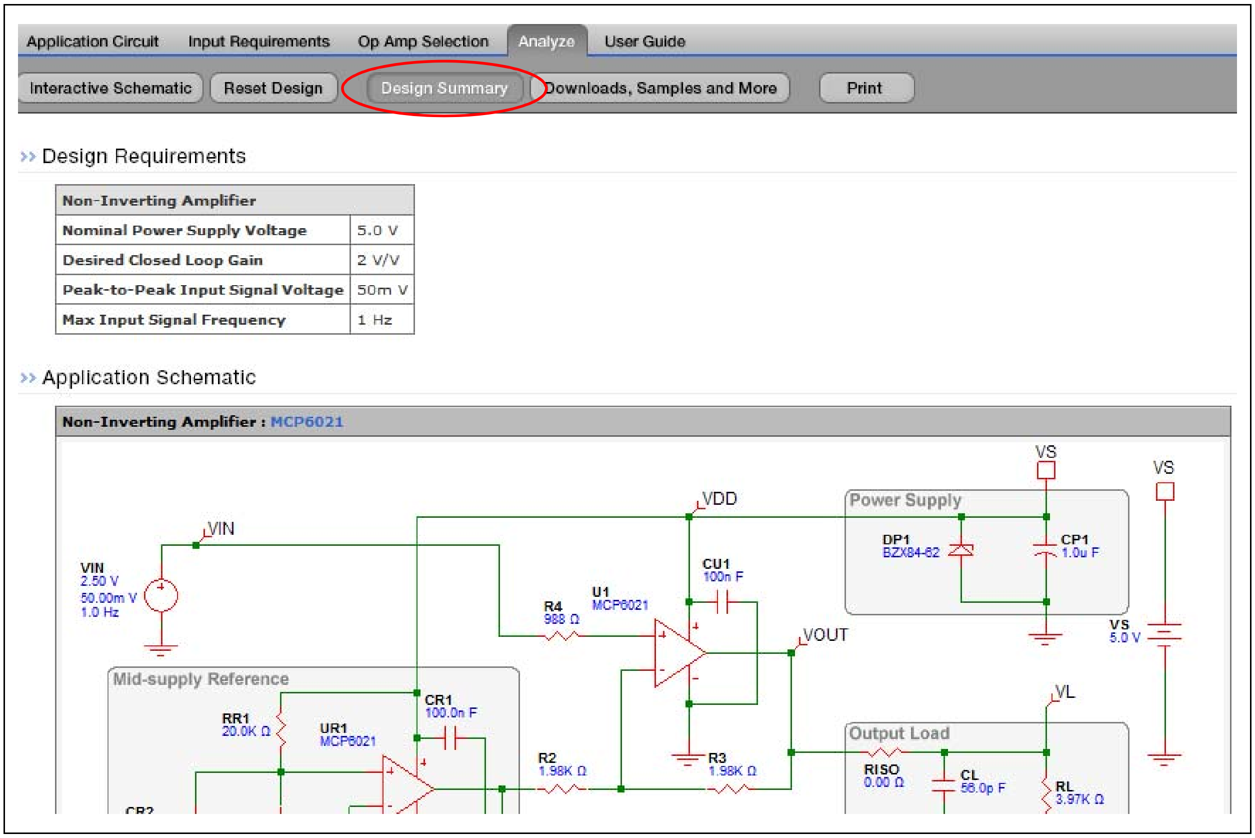



*FIGURE 2-13:* *Design Summary.*

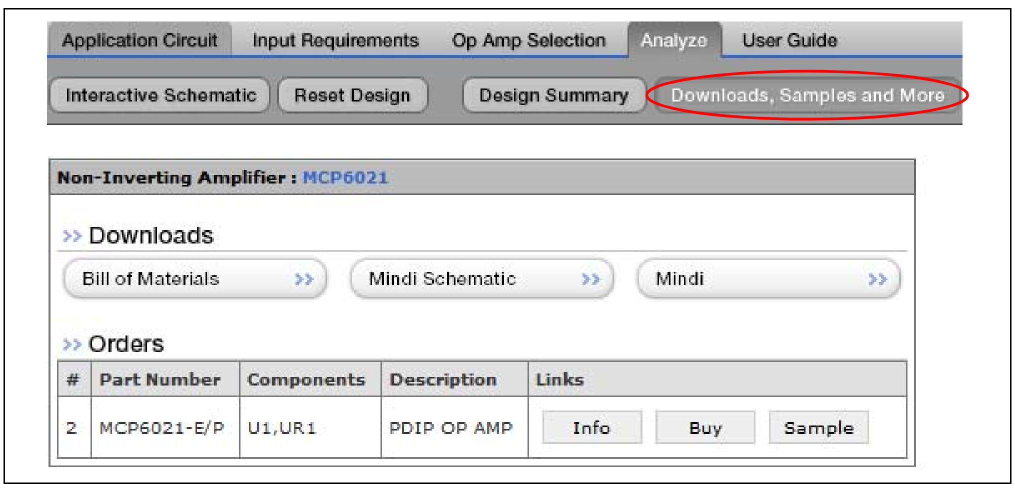



*FIGURE 2-14:* *Downloads, Samples and More.*

**NOTES:**

# Chapter 3. Input Requirements

## 3.1 INTRODUCTION

This chapter discusses the Mindi™ **Input Requirements** tab in greater detail. The **Input Requirements** tab is shown in Figure 1-5 in Section 1.3.2.

## 3.2 CIRCUIT CONFIGURATION

The Circuit Configuration drop-down menu enables the user to specify the amplifier circuit type as: Inverting Amplifier, Non-Inverting Amplifier, Voltage Follower, Difference Amplifier, Inverting Summing Amplifier, Inverting Comparator, Inverting Differentiator and Inverting Integrator.

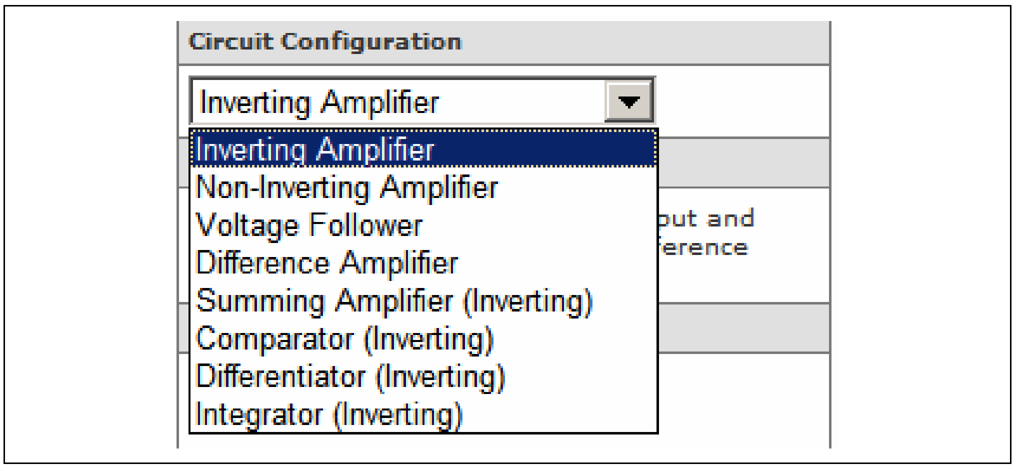



***FIGURE 3-1:*** *Circuit Configuration.*

## 3.3 DESCRIPTION AND BLOCK DIAGRAM

The Description table below the Circuit Configuration pull-down menu describes the specified amplifier circuit; the corresponding Block Diagram is also displayed.

1. Move the mouse over the block diagram and click on it to enlarge it, as indicated in Figure 3-2 through Figure 3-17.

- Inverting Amplifier
  - Description: Inverts and amplifies a voltage.

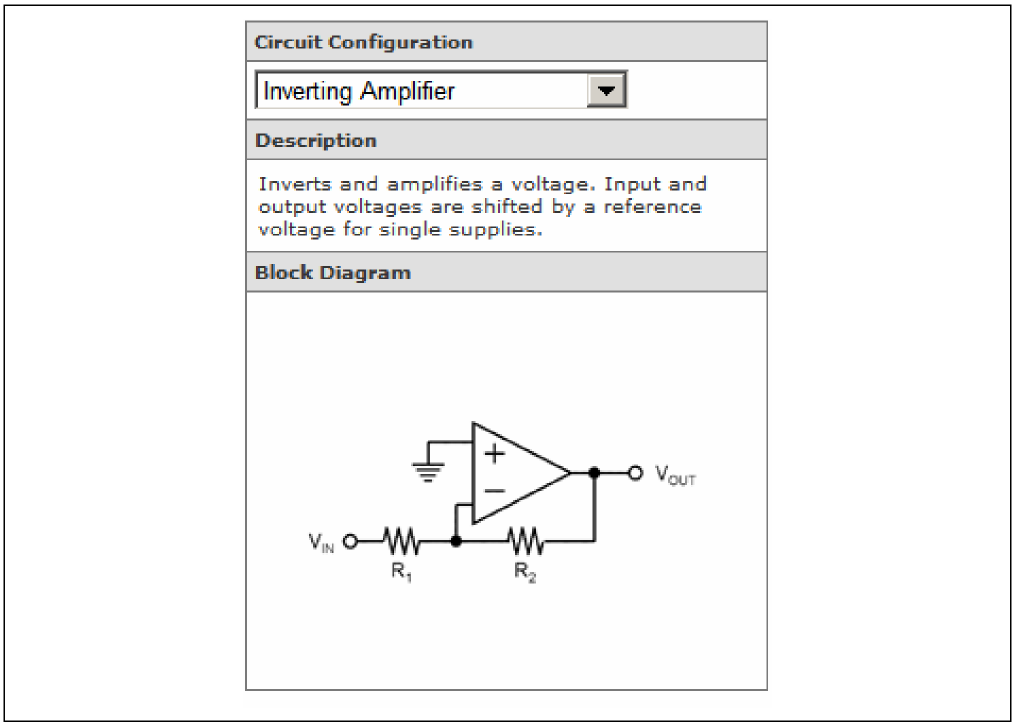



***FIGURE 3-2:*** *Inverting Amplifier.*

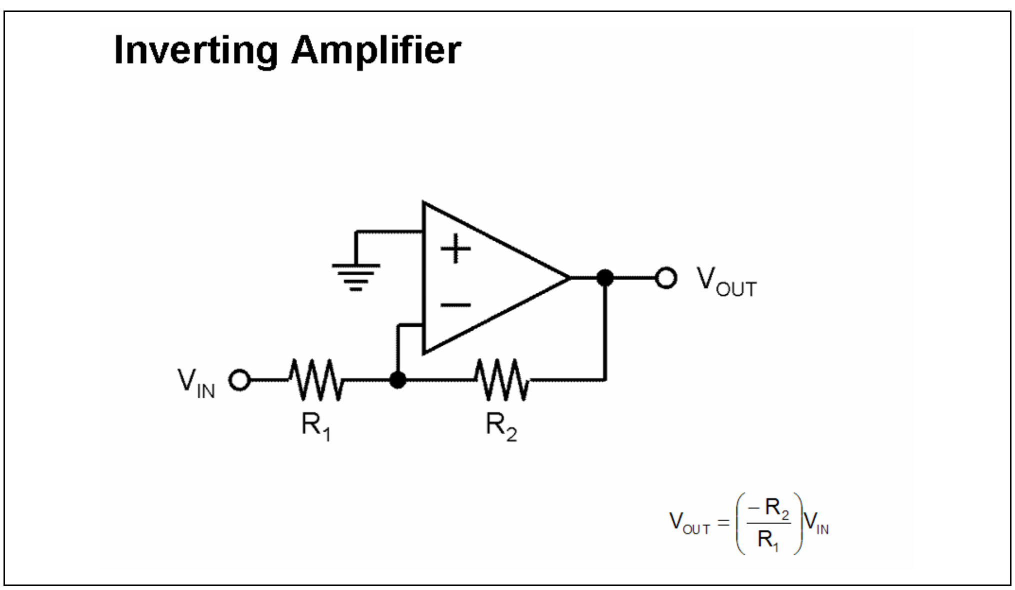



***FIGURE 3-3:*** *Enlarged Inverting Amplifier Block Diagram.*

- Non-Inverting Amplifier
  - Description: Amplifies a voltage with a gain > +1 V/V.

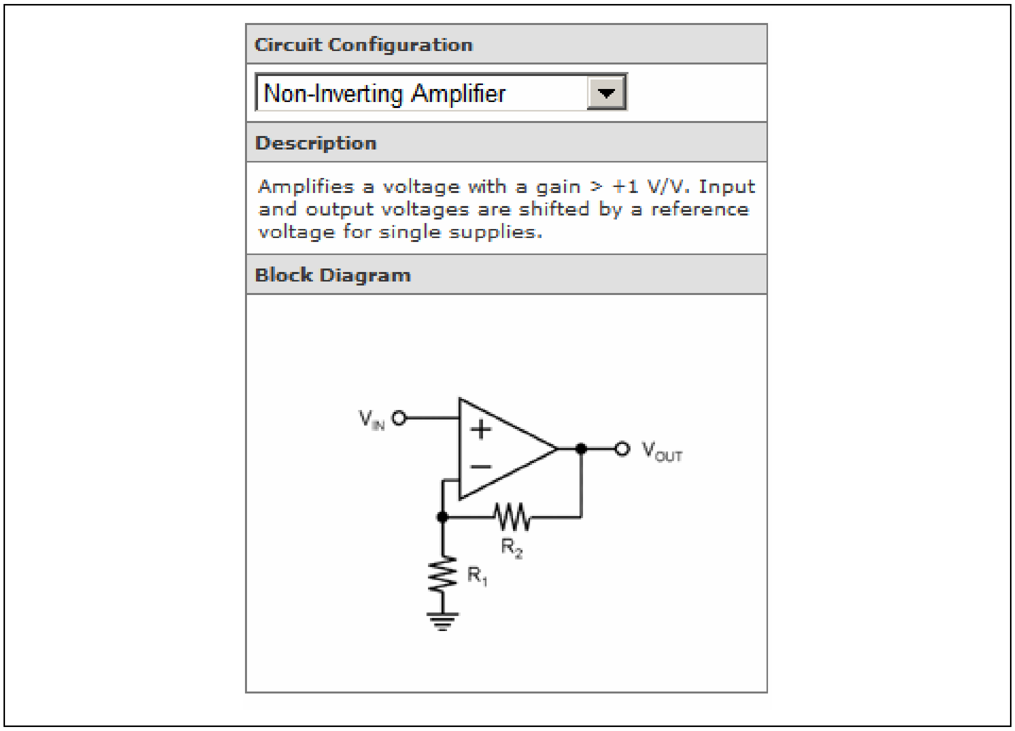



***FIGURE 3-4:*** *Non-Inverting Amplifier.*

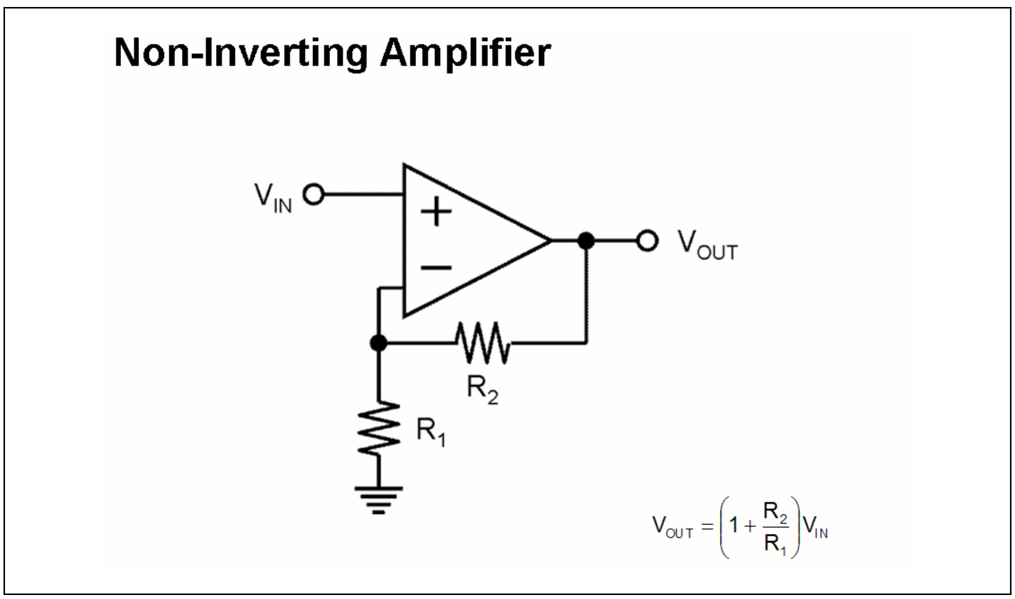



***FIGURE 3-5:*** *Enlarged Non-Inverting Amplifier Block Diagram.*

- Voltage Follower
  - Description: Known as a Unity Gain Buffer and as a Voltage Follower. Amplifies a voltage with a gain of +1 V/V.

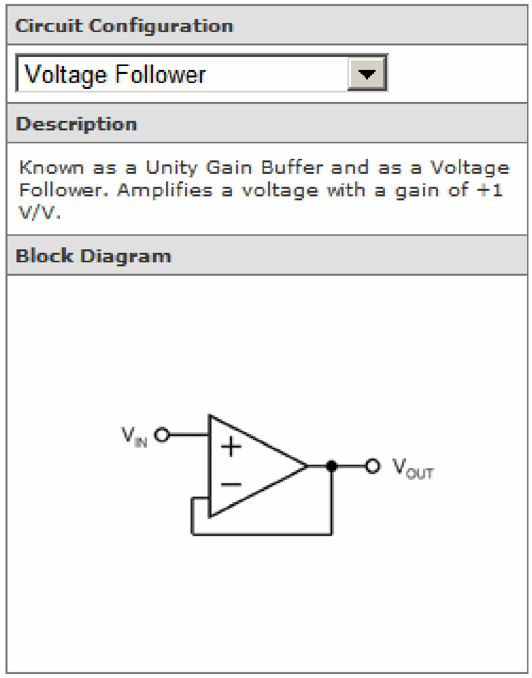



***FIGURE 3-6:*** *Voltage Follower.*

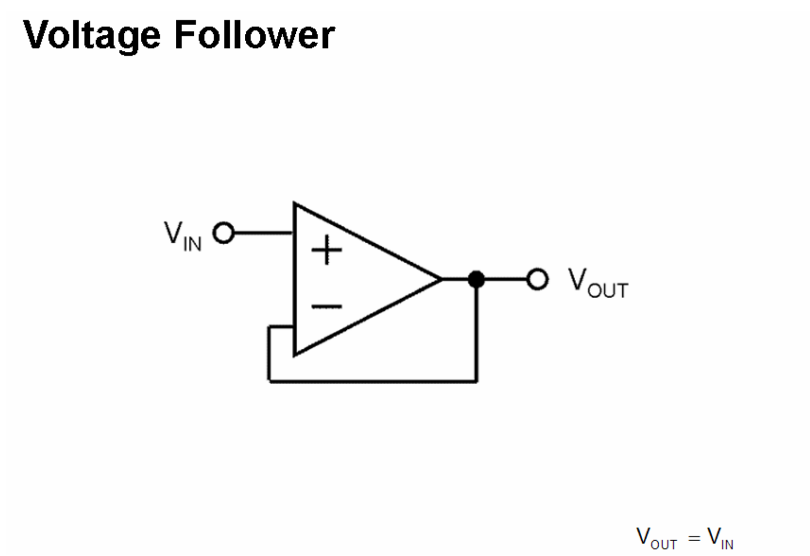



***FIGURE 3-7:*** *Enlarged Voltage Follower Block Diagram.*

- Difference Amplifier
  - Description: Amplifies the difference between two voltages, while rejecting the common mode (average) input voltage.

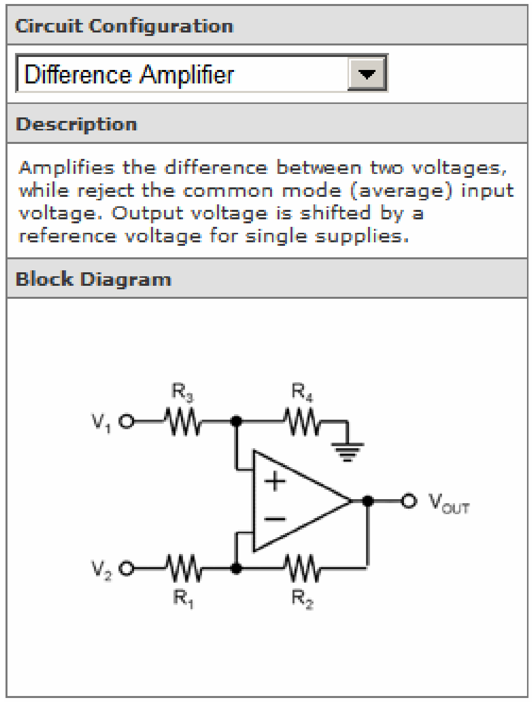



***FIGURE 3-8:*** *Difference Amplifier.*

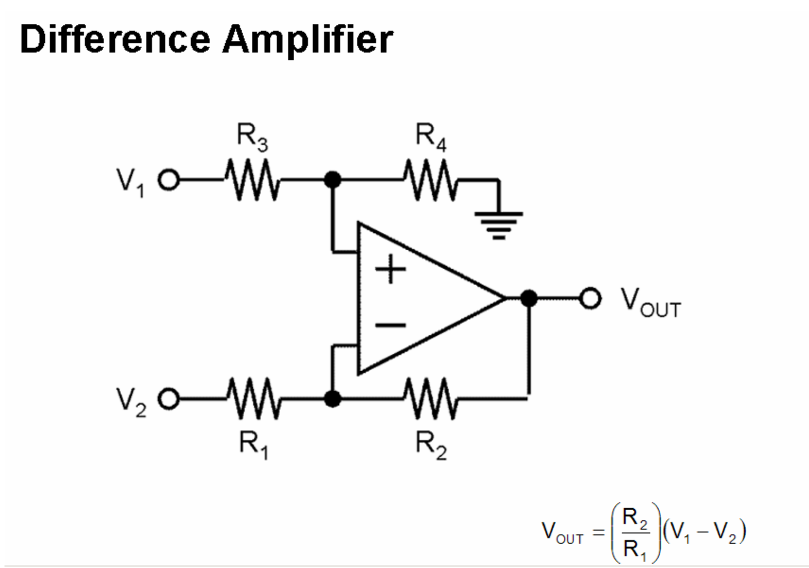



***FIGURE 3-9:*** *Enlarged Difference Amplifier Block Diagram.*

- Summing Amplifier (Inverting)
  - Description: Amplifies two or more input voltages with an inverting gain.

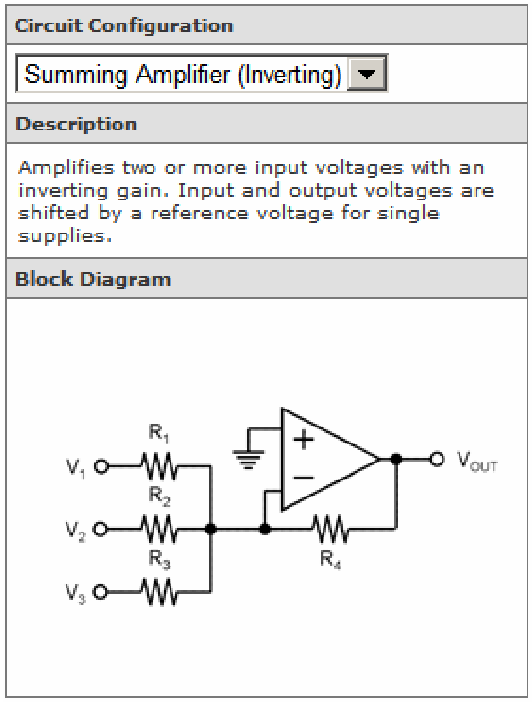



***FIGURE 3-10:*** *Inverting Summing Amplifier.*

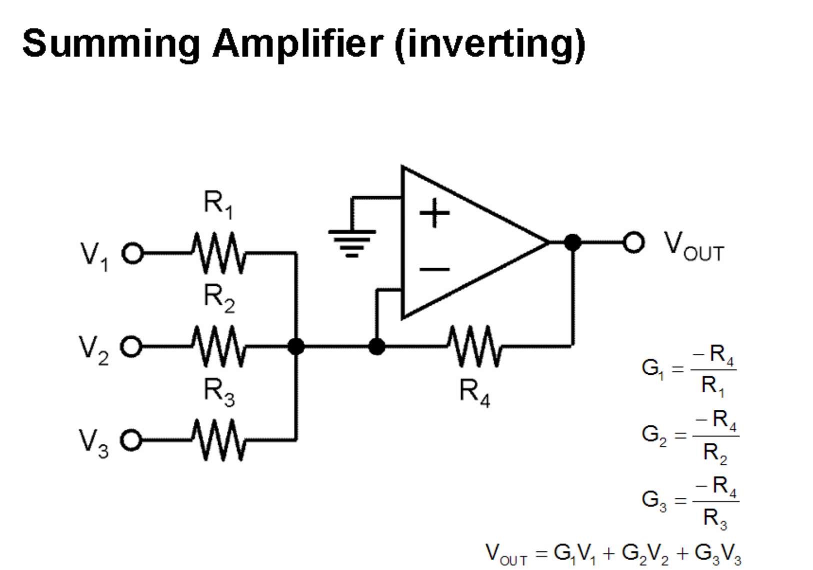



***FIGURE 3-11:*** *Enlarged Inverting Summing Amplifier Block Diagram.*

- Comparator (Inverting)
  - Description: Compares the difference between two voltages and forces the output to one of two digital states. The comparison includes a user selected amount of hysteresis.

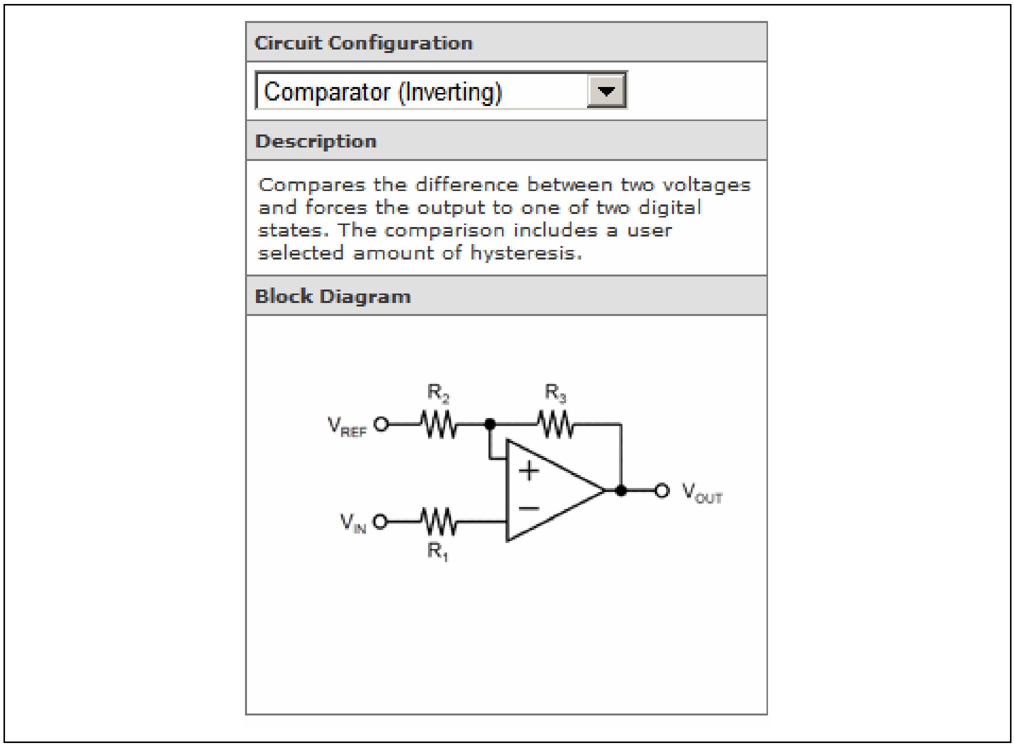



***FIGURE 3-12:*** *Inverting Comparator.*

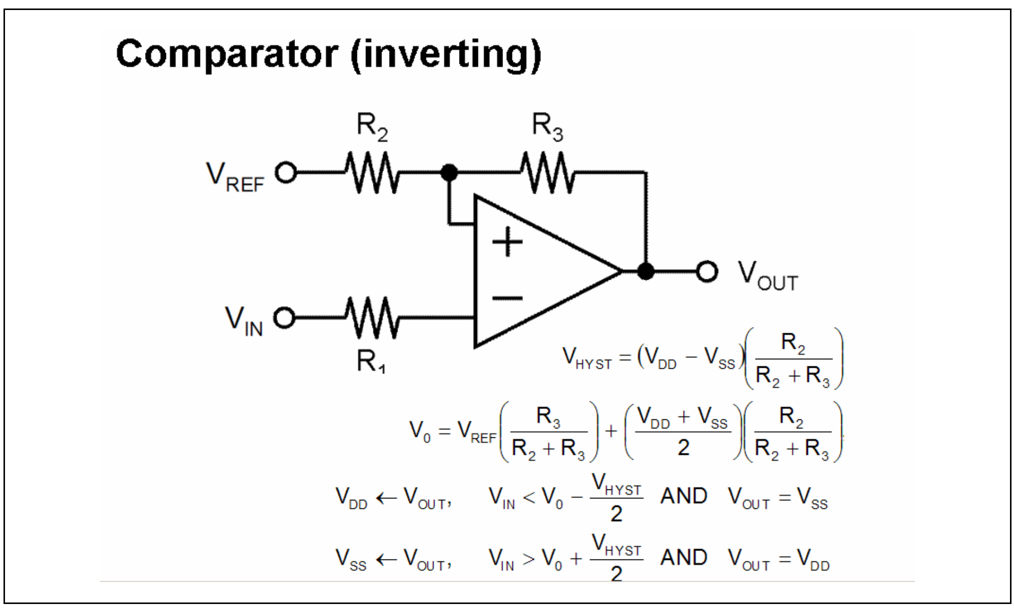



***FIGURE 3-13:*** *Enlarged Inverting Comparator Block Diagram.*

- Inverting Differentiator
  - Description: Output voltage is proportional to the negative derivative of the input voltage.

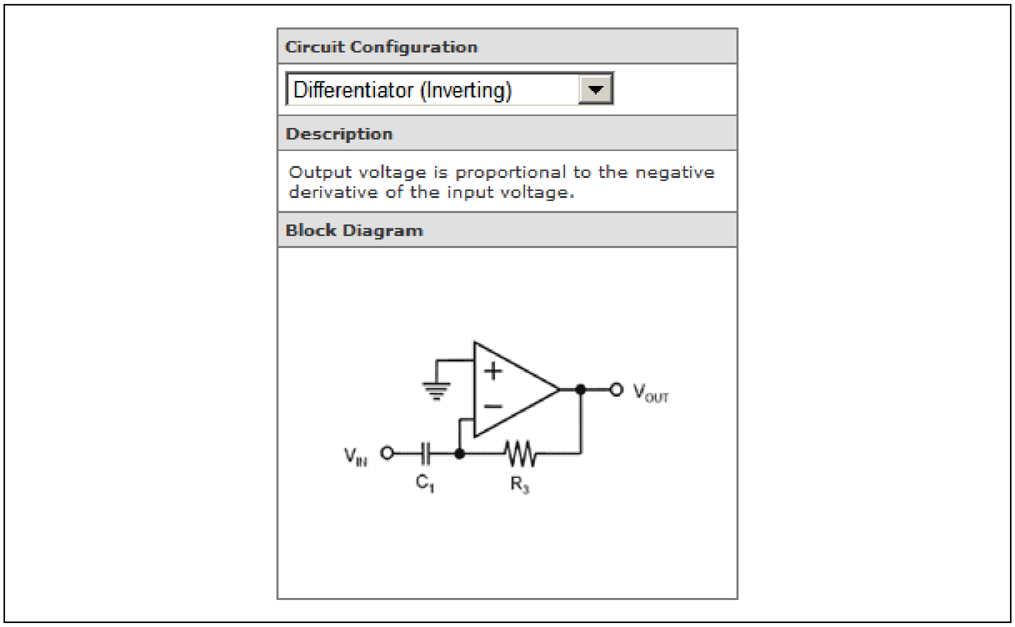



*FIGURE 3-14: Inverting Differentiator.*

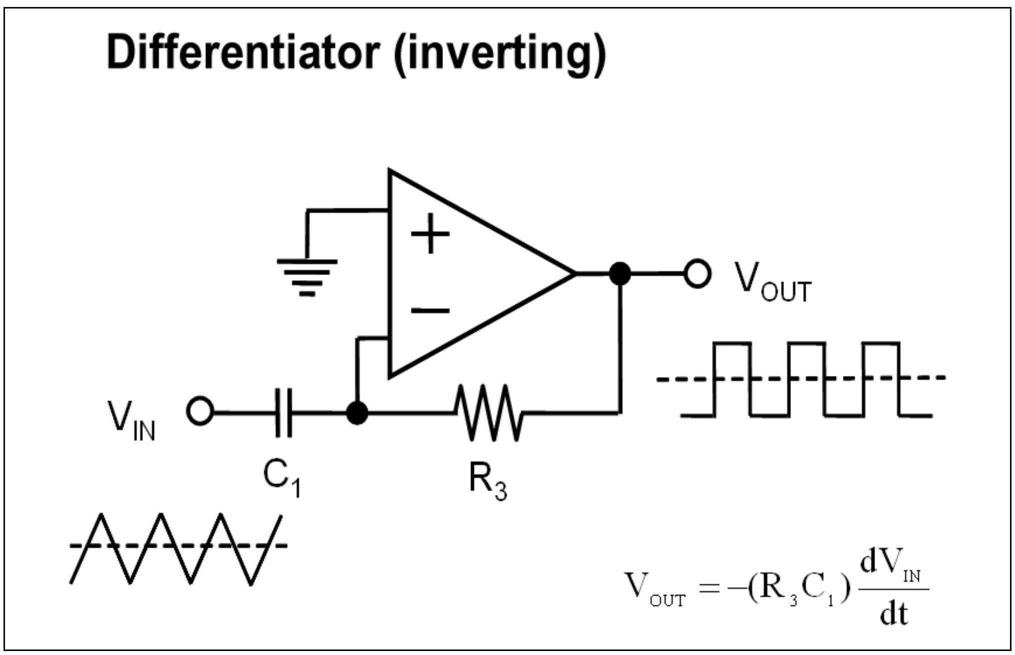



*FIGURE 3-15: Enlarged Inverting Differentiator Block Diagram.*

- Inverting Integrator
  - Description: Output voltage is proportional to the negative integral of the input voltage.

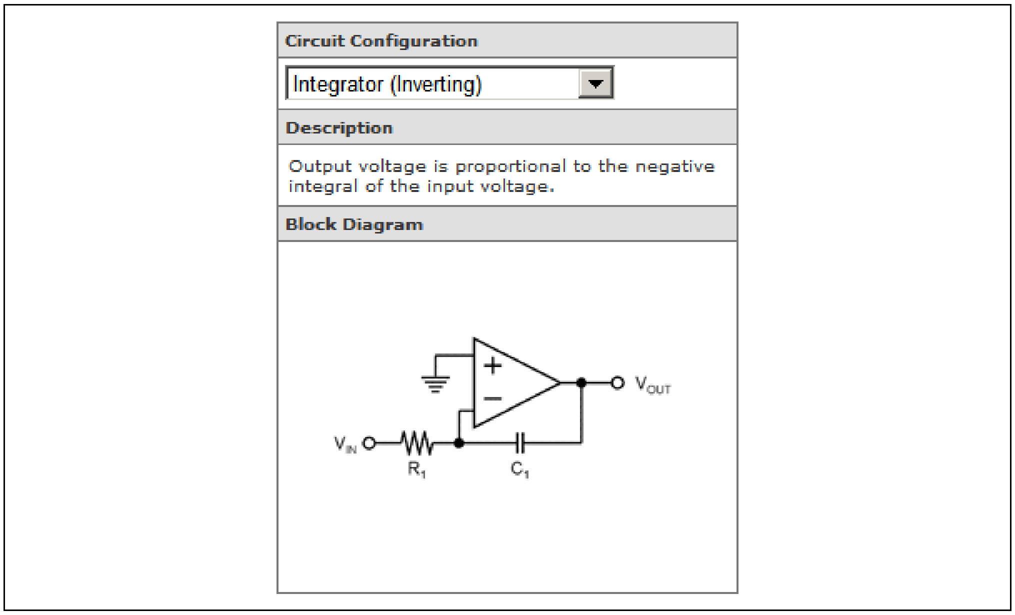



***FIGURE 3-16:*** *Inverting Integrator.*

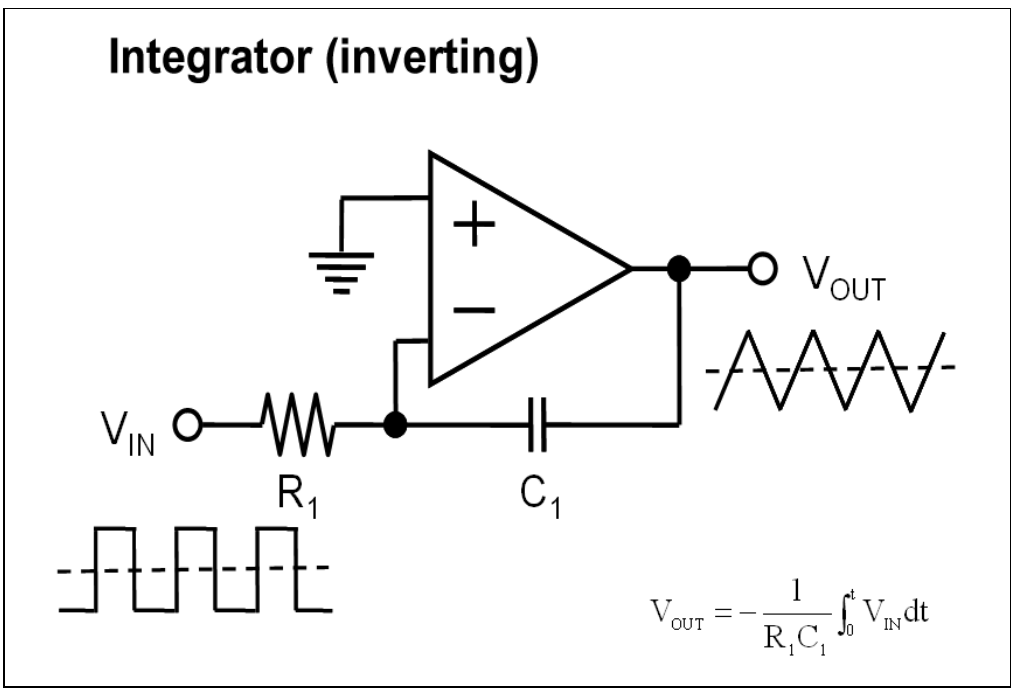



***FIGURE 3-17:*** *Enlarged Inverting Integrator Block Diagram.*

## 3.4 POWER SUPPLY

The "Power Supply" text boxes allow users to modify the power supply requirement of the amplifier circuit. The allowable range of power supply is 1.4V to 5.5V.

1. Move the mouse over the text and view the ranges, as indicated in Figure 3-18 through Figure 3-21.

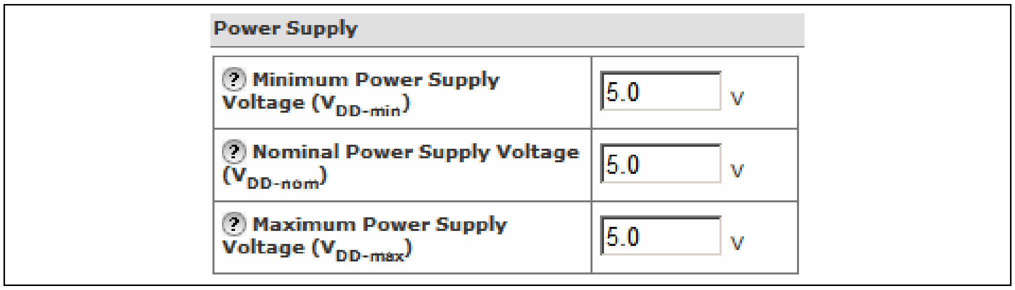



***FIGURE 3-18:*** *Power Supply Text Boxes.*

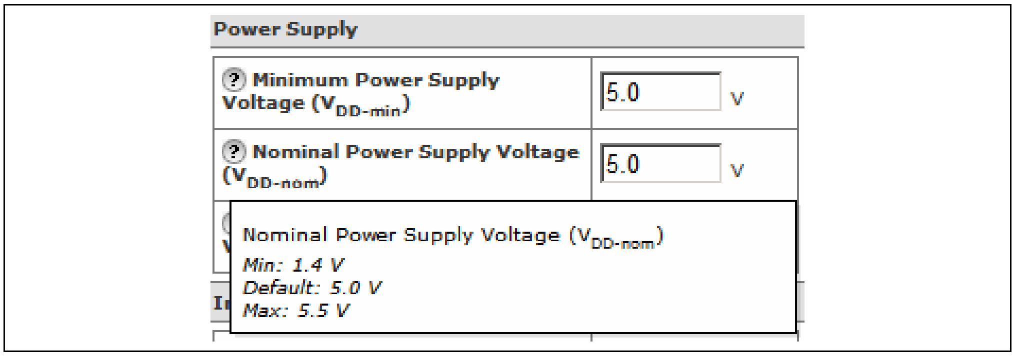



***FIGURE 3-19:*** *Nominal Power Supply Voltage.*

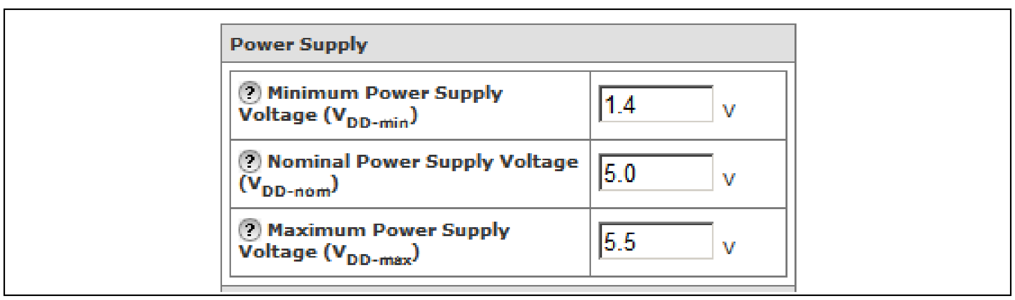



***FIGURE 3-20:*** *Minimum Power Supply Voltage.*

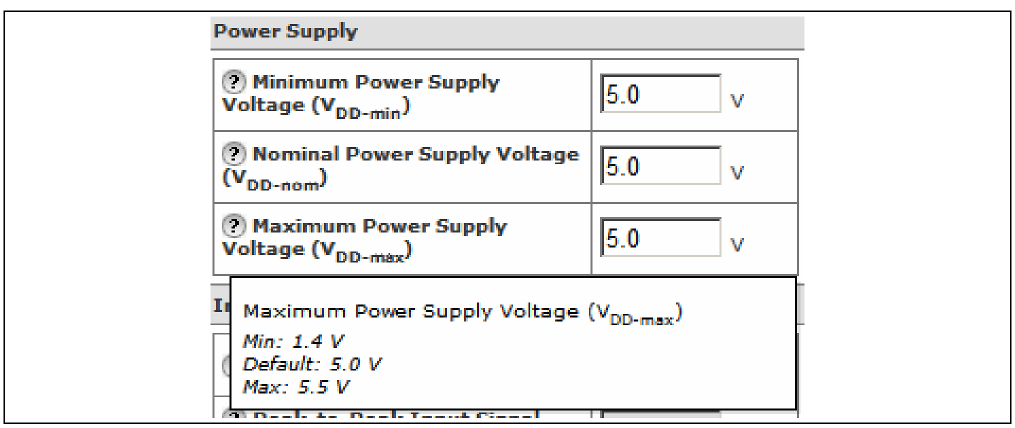



***FIGURE 3-21:*** *Maximum Power Supply Voltage.*

## 3.5 LOAD

The Load Type drop-down menu specifies six load types: Resistor-Capacitor, ADC, PIC, Coax, Twisted Pair, and Ribbon Cable. The corresponding characteristics text boxes allow users to modify the load parameters, as indicated in Figure 3-18 through Figure 3-21.

### 3.5.1 Resistor-Capacitor

The allowable range of Load Capacitance is 0F to 1 μF.

1. Move the mouse over the text and the range will be shown.

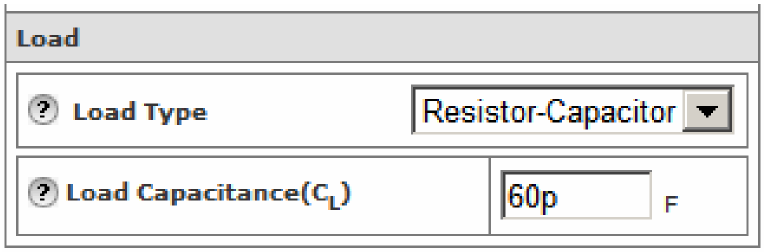



***FIGURE 3-22:*** *Load Type: Resistor-Capacitor.*

### 3.5.2 ADC, PIC

The allowable range of Load Capacitance is 0F to 1 μF. The allowable range of Load Resistance is 100Ω to 10 MΩ.

1. Move the mouse over the text and the range will be shown.

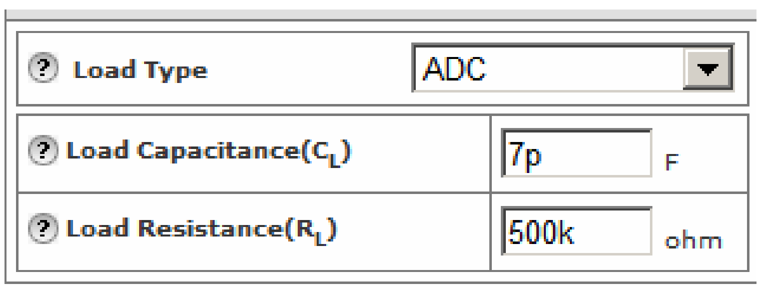



***FIGURE 3-23:*** *Load Type: ADC.*

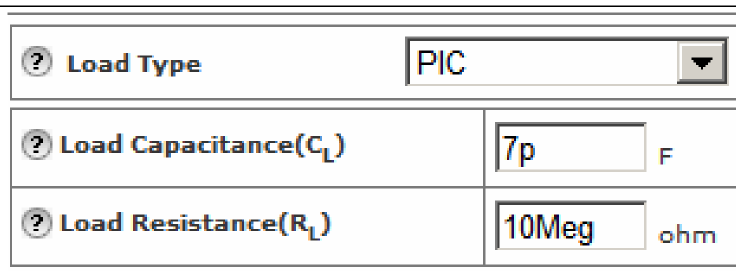



***FIGURE 3-24:*** *Load Type: PIC.*

### 3.5.3 Coax, Twisted Pair, and Ribbon Cable

The allowable range of Length is 10 mm to 1 km. The allowable range of Capacitance per Length is 1 pF/m to 1 nF/m.

1. Move the mouse over the text and the range will be shown.

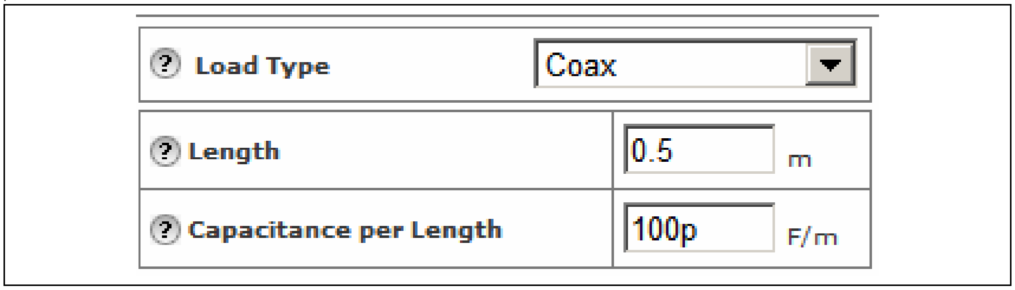



*FIGURE 3-25:* *Load Type: Coax.*

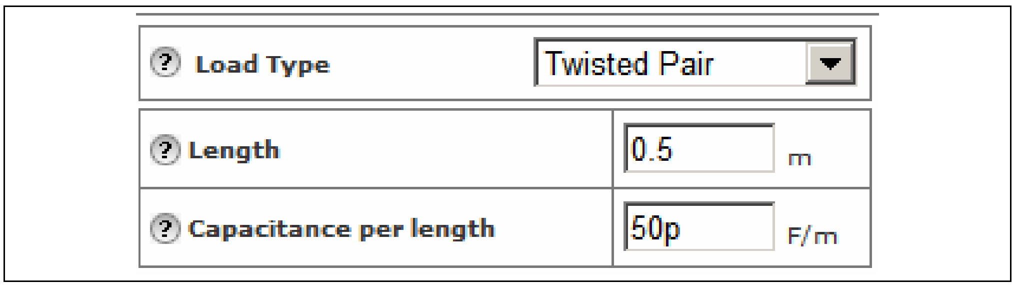



*FIGURE 3-26:* *Load Type: Twisted Pair.*

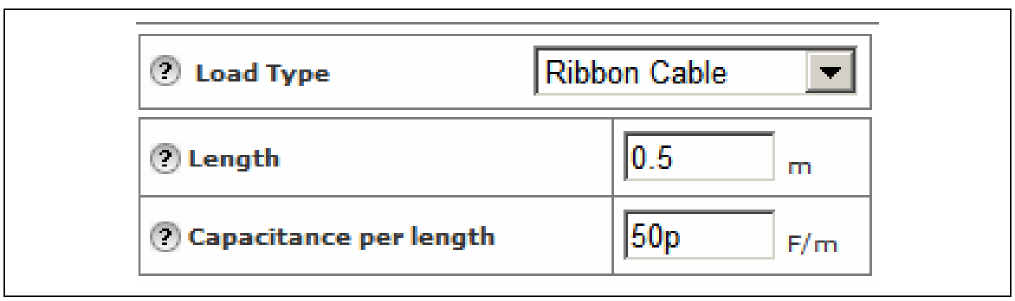



*FIGURE 3-27:* *Load Type: Ribbon Cable.*

## 3.6 AMPLIFIER CHARACTERISTICS

The Amplifier Characteristics text boxes allow users to specify the Desired Closed Loop Gain, Peak-to-Peak Output Signal Voltage, Maximum Input Signal Frequency, etc, as shown in Figure 3-28 through Figure 3-37.

1. The allowable range of Desired Closed Loop Gain is 0.1 V/V to 10 kV/V.
2. The allowable range of Peak-to-Peak Output Signal Voltage is 1 $mV_{pp}$ to 5.5 $V_{pp}$.

> **Note:** The Mindi™ Amplifier Designer & Simulator will automatically calculate the Peak-to-Peak Input Signal Voltage according to the Peak-to-Peak Output Signal Voltage specified by users.

3. The allowable range of Max Input Signal Frequency is 1 Hz to 1 MHz.

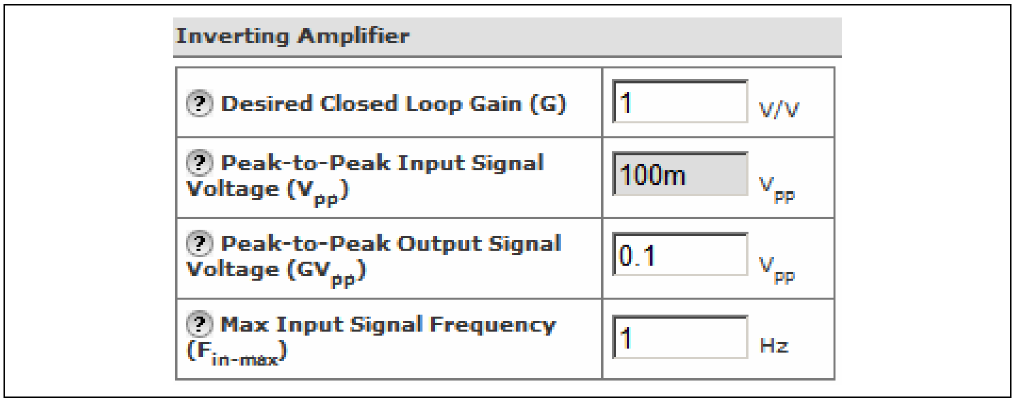



***FIGURE 3-28:*** *Inverting Amplifier.*

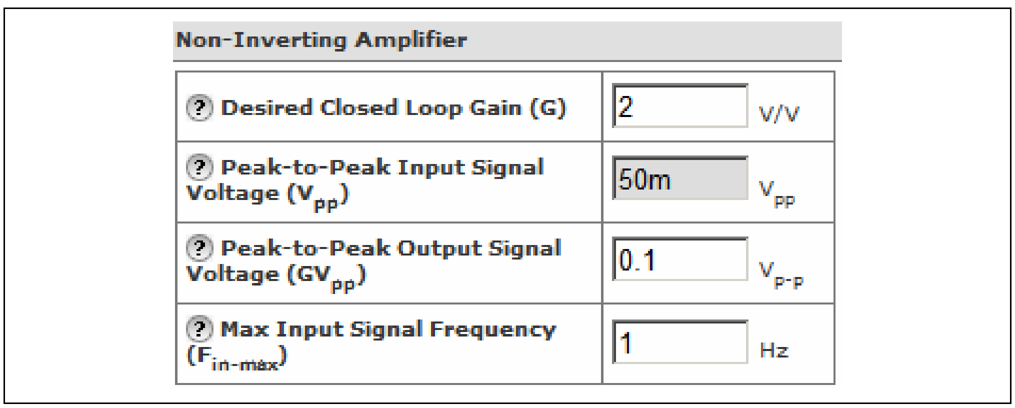



***FIGURE 3-29:*** *Non-Inverting Amplifier.*

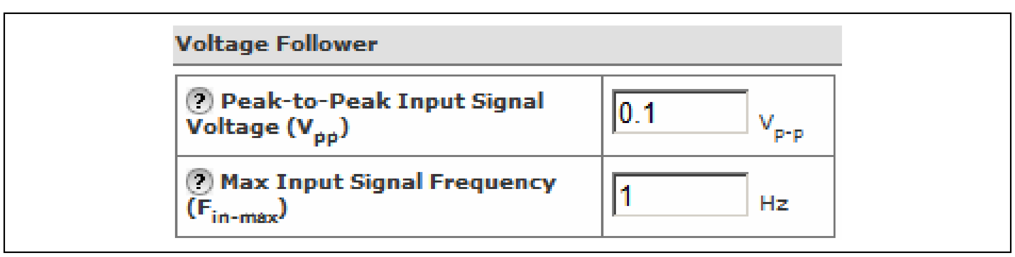



***FIGURE 3-30:*** *Voltage Follower.*

| Difference Amplifier | |
|---|---|
| Desired Closed Loop Gain (G) | 1 V/V |
| Peak-to-Peak Input Signal Voltage ($V_{pp}$) | 100m $V_{PP}$ |
| Peak-to-Peak Output Signal Voltage ($GV_{pp}$) | 0.1 $V_{PP}$ |
| Max Input Signal Frequency ($F_{in-max}$) | 1 Hz |

***FIGURE 3-31:*** *Difference Amplifier.*

| Summing Amplifier (Inverting) | |
|---|---|
| Number of Input Voltages | 2 |
| Desired Gain for $V_1$ (G1) | 1 V/V |
| Desired Gain for $V_2$ (G2) | 1 V/V |
| Peak-to-Peak Input Signal Voltage ($V_{pp}$) | 50m $V_{PP}$ |
| Peak-to-Peak Output Signal Voltage ($GV_{pp}$) | 0.1 $V_{P-P}$ |
| Max Input Signal Frequency ($F_{in-max}$) | 1 Hz |

***FIGURE 3-32:*** *Summing Amplifier (Inverting).*

| Comparator (Inverting) | |
|---|---|
| Input Hysteresis ($V_{hyst}$) | 10m V |
| Center Trip Point ($V_0$) | 2.5 V |
| Rise Time ($t_r$) | 100u s |

***FIGURE 3-33:*** *Comparator (Inverting).*

| Differentiator (Inverting) | |
|---|---|
| Max Slope Magnitude of Input Signal ($D_{in-max}$) | 100 V/s |
| Peak-to-Peak Output Signal Voltage ($V_{out-pp}$) | 5 $V_{P-P}$ |
| Output Signal Rise Time (Tr) INFO | 785u s |

***FIGURE 3-34:*** *Differentiator (Inverting).*

4. Click the **INFO** button to view the advanced summary.

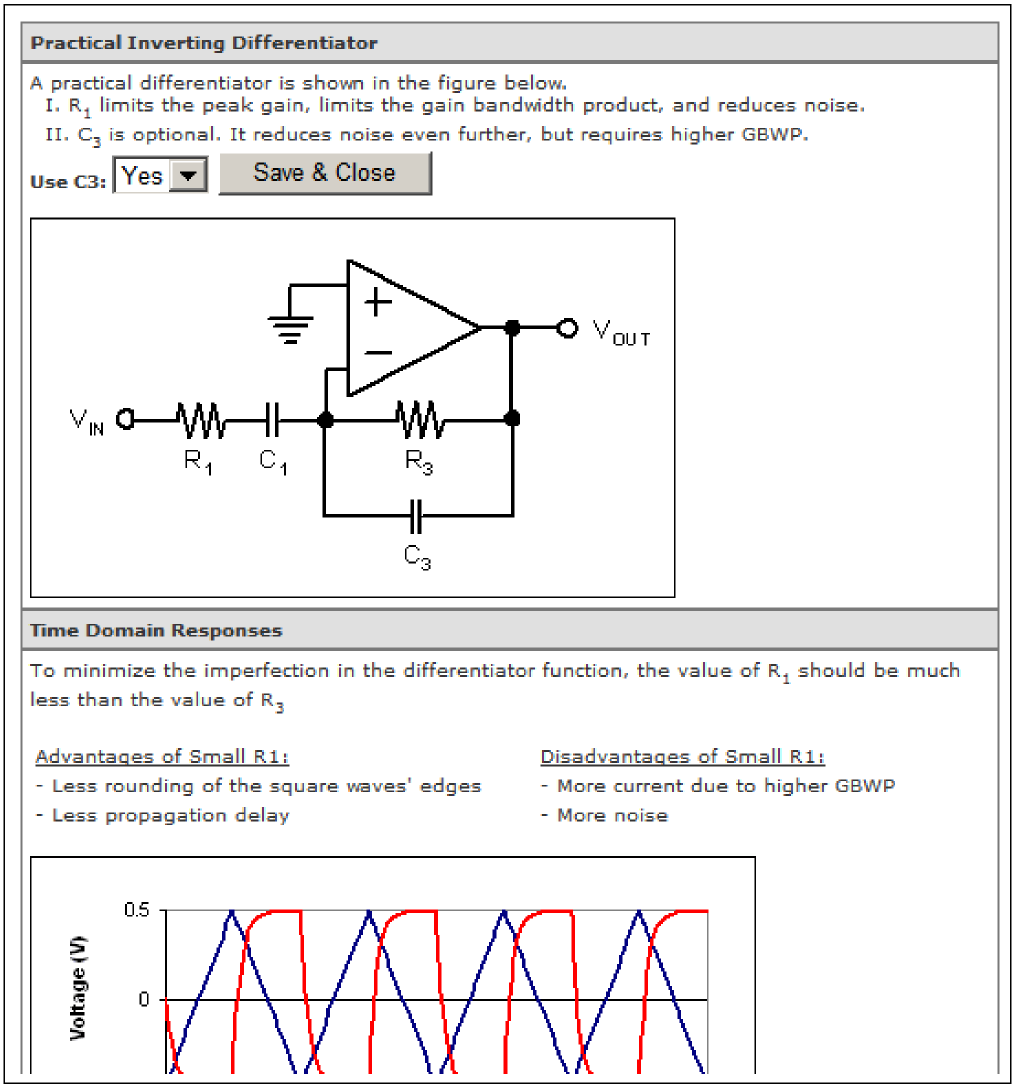



***FIGURE 3-35:*** *Viewing Advanced Summary.*

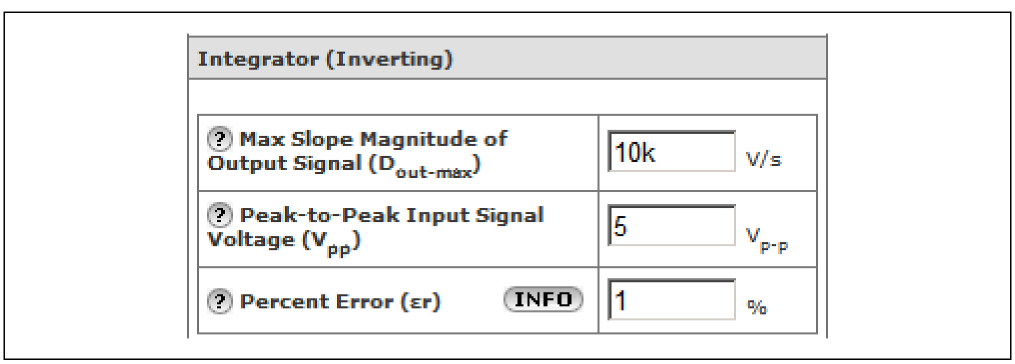



***FIGURE 3-36:*** *Integrator (Inverting).*

5. Click **INFO** button to view the advanced summary.

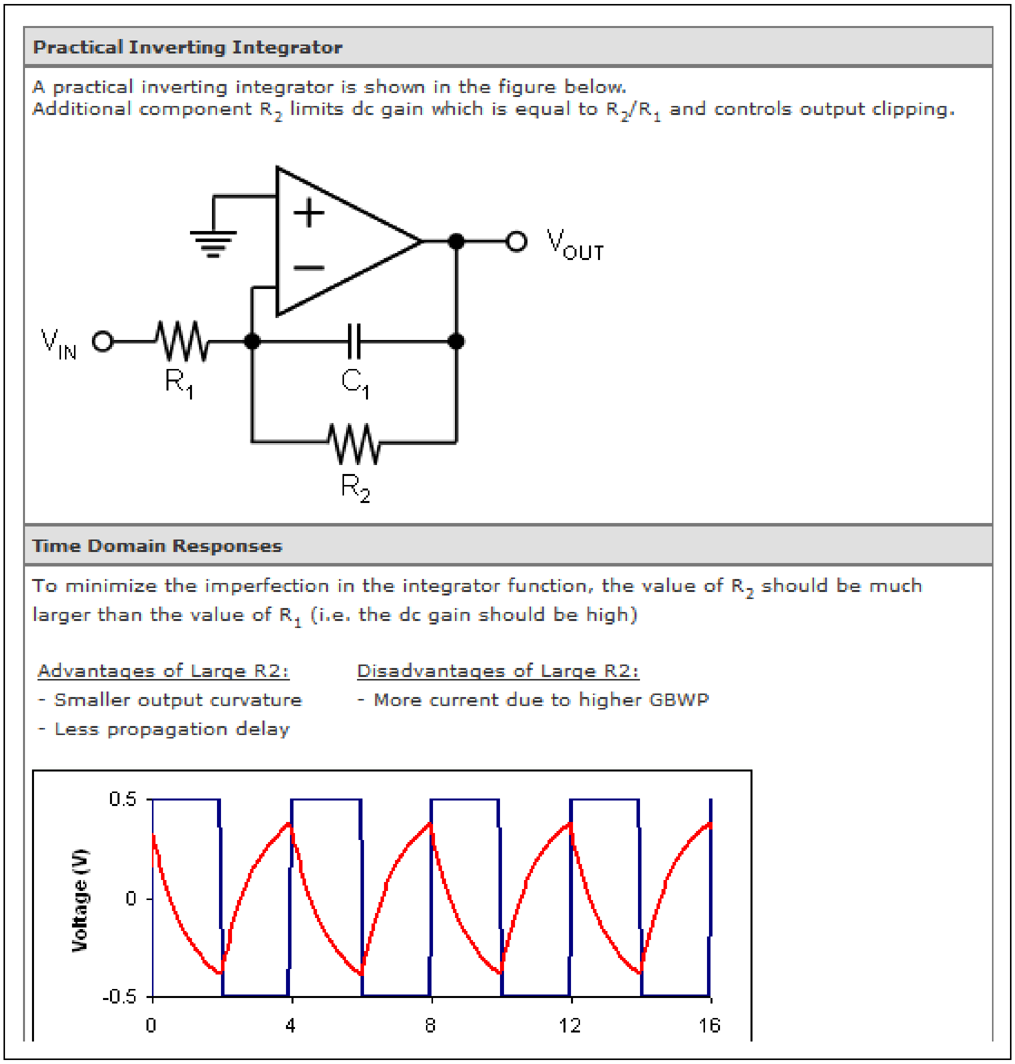



***FIGURE 3-37:*** *Viewing Advanced Summary.*

6. After setting the desired specifications for the input requirments, click the **Op Amp Selection** tab to select the op amp to be used in this amplifier.

# Chapter 4. Op Amp Selection

## 4.1 INTRODUCTION

This chapter discusses the Mindi **Op Amp Selection** tab in greater detail. The **Op Amp Selection** tab is shown in Figure 1-6 in Section 1.3.4. This tab allows the user to specify which Microchip op amp is used in the amplifier circuit.

## 4.2 RECOMMENDED OP AMPS

Four table  are provided in this tab as indicated in Figure 4-1.

1. The Amplifier Characteristics table lists the key amplifier design information as a reference.
2. The Op Amp Design Constraints and Recommended Op Amp Parameters tables show the recommended op amp specifications for the amplifier design.
3. The Recommended Op Amps table lists those op amps that come close to the recommended op amp specifications. The ideal op amp list at the top is included for comparing simulation results to textbook amplifier responses.
4. The Other Op Amps table lists other op amps that are not as close to the recommended op amp specifications. Click the Show button to display these op amps; the op amps and parameters that do not meet recommendations are indicated in red.

## 4.3 OP AMP PARAMETERS

The following parameters and their definitions will help the designer choose the correct op amp.

1. **Gain Bandwidth Product:**

   The product of op amp open-loop gain times the frequency at any point where the amplifier response is attenuating at a rate of -20 dB/decade of frequency.

2. **Slew Rate:**

   The maximum rate of change at the output of an op amp. Basically, it shows how fast the output can "follow" the input.

3. **Minimum Stable Gain:**

   The minimum gain at which an op amp can be set while still remaining stable. Most op amps are unity gain stable ($G \geq +1$ V/V). A few op amps need to be set at higher gains to remain stable (e.g., $G \geq +10$ V/V for the MCP6141).

4. **Power Supply Voltage:**

   The acceptable supply voltage that allows the linear operation of an op amp.

5. **Quiescent Current ($I_q$):**

   The amount of current consumed by the op amp when it is not performing any work (idle).

6. **Rail-to-Rail Input/Output:**

   The op amp will operate correctly when its input/output is closely driven to either power rail under defined operating conditions. (N means *No* and Y means *Yes*).

**Microchip Op Amp: Op Amp Selection**

| Op Amp Design Constraints | |
|---|---|
| Power Supply Voltage ($V_{DD}$) | 5.0 V to 5.0 V |
| Minimum Stable Gain | 2.0 V/V |

| Recommended Op Amp Parameters | |
|---|---|
| Gain Bandwidth Product | 0.02 kHz |
| Slew Rate | 6.28e-07 V/µs |

| Non-Inverting Amplifier | |
|---|---|
| Nominal Power Supply Voltage | 5.0 V |
| Desired Closed Loop Gain | 2 V/V |
| Peak-to-Peak Input Signal Voltage | 50m V |
| Max Input Signal Frequency | 1 Hz |

**Recommended Op Amps**

| Op Amp Family | Gain Bandwidth Product (kHz) | Slew Rate (V/µs) | Min Stable Gain (V/V) | Vos Max (±µV) | Vdd Min (V) | Vdd Max (V) | Iq Max (µA/amplifier) | Rail-to-Rail Input | Rail-to-Rail Output | |
|---|---|---|---|---|---|---|---|---|---|---|
| Ideal Op Amp | 1.0E30 | 1.0E30 | 1.0 | 0.0 | 0.0 | 1.0E30 | 0.0 | Y | Y | Analyze |
| MCP6041 | 14.0 | 0.0030 | 1.0 | 3000.0 | 1.4 | 5.5 | 0.6 | Y | Y | Analyze |
| TC1034 | 60.0 | 0.035 | 1.0 | 500.0 | 1.8 | 5.5 | 6.0 | Y | Y | Analyze |
| MCP606 | 155.0 | 0.08 | 1.0 | 250.0 | 2.5 | 5.5 | 18.7 | N | Y | Analyze |
| MCP616 | 190.0 | 0.08 | 1.0 | 150.0 | 2.3 | 5.5 | 19.0 | N | Y | Analyze |
| MCP6231 | 300.0 | 0.15 | 1.0 | 5000.0 | 1.8 | 5.5 | 20.0 | Y | Y | Analyze |
| MCP6241 | 550.0 | 0.3 | 1.0 | 5000.0 | 1.8 | 5.5 | 50.0 | Y | Y | Analyze |
| MCP6001 | 1000.0 | 0.6 | 1.0 | 4500.0 | 1.8 | 5.5 | 100.0 | Y | Y | Analyze |
| MCP6271 | 2000.0 | 0.9 | 1.0 | 3000.0 | 2.0 | 5.5 | 170.0 | Y | Y | Analyze |
| MCP601 | 2800.0 | 2.3 | 1.0 | 2000.0 | 2.7 | 5.5 | 230.0 | N | Y | Analyze |
| MCP6281 | 5000.0 | 2.5 | 1.0 | 3000.0 | 2.2 | 5.5 | 450.0 | Y | Y | Analyze |
| MCP6021 | 10000.0 | 7.0 | 1.0 | 250.0 | 2.5 | 5.5 | 1000.0 | Y | Y | Analyze |
| MCP6291 | 10000.0 | 7.0 | 1.0 | 3000.0 | 2.4 | 5.5 | 1000.0 | Y | Y | Analyze |

**Other Op Amps** Hide

| Op Amp Family | Gain Bandwidth Product (kHz) | Slew Rate (V/µs) | Min Stable Gain (V/V) | Vos Max (±µV) | Vdd Min (V) | Vdd Max (V) | Iq Max (µA/amplifier) | Rail-to-Rail Input | Rail-to-Rail Output | |
|---|---|---|---|---|---|---|---|---|---|---|
| MCP6141 | 100.0 | 0.024 | 10.0 | 3000.0 | 1.4 | 5.5 | 0.6 | Y | Y | Analyze |

***FIGURE 4-1:*** *Op Amp Selection.*

1. Once the op amp has been selected, click the corresponding Analyze link and the Mindi™ Amplifier Designer & Simulator will generate and simulate the schematic of the amplifier circuit.

# Chapter 5. Analyze

## 5.1 INTRODUCTION

This chapter discusses the Mindi **Analyze** tab in greater detail. The **Analyze** tab is shown in Figure 1-7 in **Section 1.3.4**. This tab includes four buttons which selects the following views: **Interactive Schematic**, **Reset Design**, **Design Summary** and **Downloads**, **Samples and More**.

## 5.2 INTERACTIVE SCHEMATIC

### 5.2.1 Schematic Viewer

The Mindi™ Amplifier Designer & Simulator automatically generates the full schematic view of the amplifier circuit with recommended component values based on the Input Requirements. Various simulation operations can also be selected in order to analyze and evaluate the performance of the amplifier circuit. In addition, the individual components of the schematic can be modified, allowing users to further evaluate the design solution. Detailed help on using the Schematic Viewer can be accessed via the **Help** button.

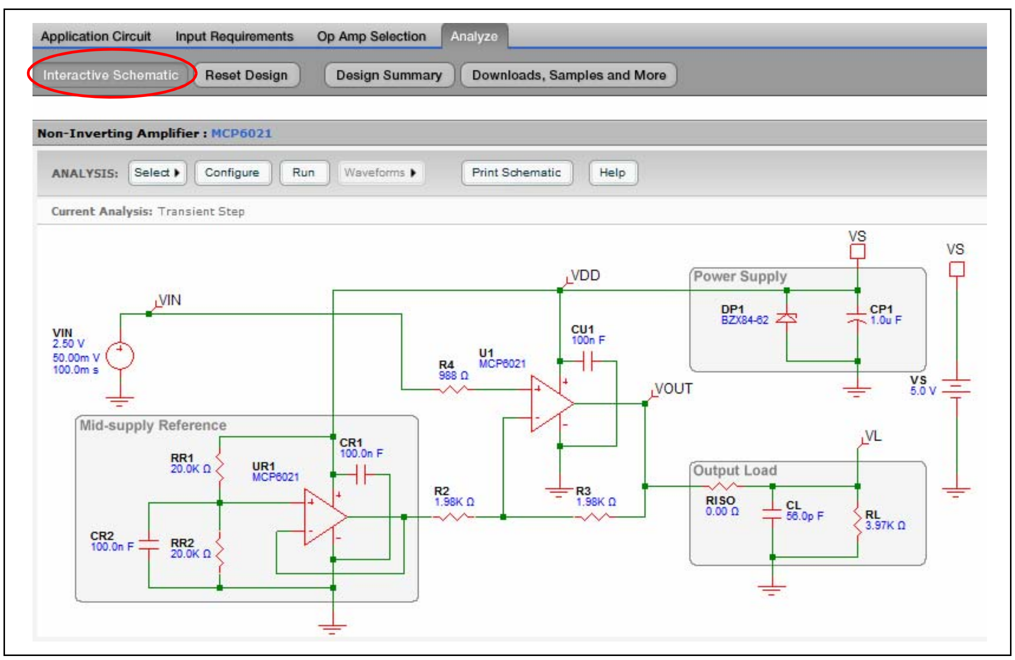



***FIGURE 5-1:*** *Schematic Viewer.*

### 5.2.2 Edit Component Value

The value of a component (resistor or capacitor) can be changed from its default value calculated by the Mindi™ Amplifier Designer & Simulator. Changing the component value only affects the component that is selected. To adjust a component value, click on the component to access its attributes window, as shown in Figure 5-2 through Figure 5-5.

- **Database** Tab: Contains recommended parts to use with this circuit. Users can click on the header of any column to sort the database by that column. Column widths can also be adjusted by dragging the boundary between columns.
- **Custom** Tab: Enter custom parameter for this component.

The allowable range of capacitance is from 1.0 pF to 10 µF.

The allowable range of resistance is from 0Ω to 1.0 GΩ.

| | |
|---|---|
| **Note 1:** | 0Ω , 1.0 GΩ, 1.0 pF, and 10 µF are intended for simulation purposes and are not practical in real applications. |
| **2:** | To remove parts from the schematic for simulation purposes, use 1.0 GΩ for shunt resistors, 0Ω for series resistor, use 1.0 pF for shunt capacitors and 10 µF for series capacitors. |

| | |
|---|---|
| **Note:** | It is the user's responsibility to ensure the proper circuit behavior when the component values are changed. |

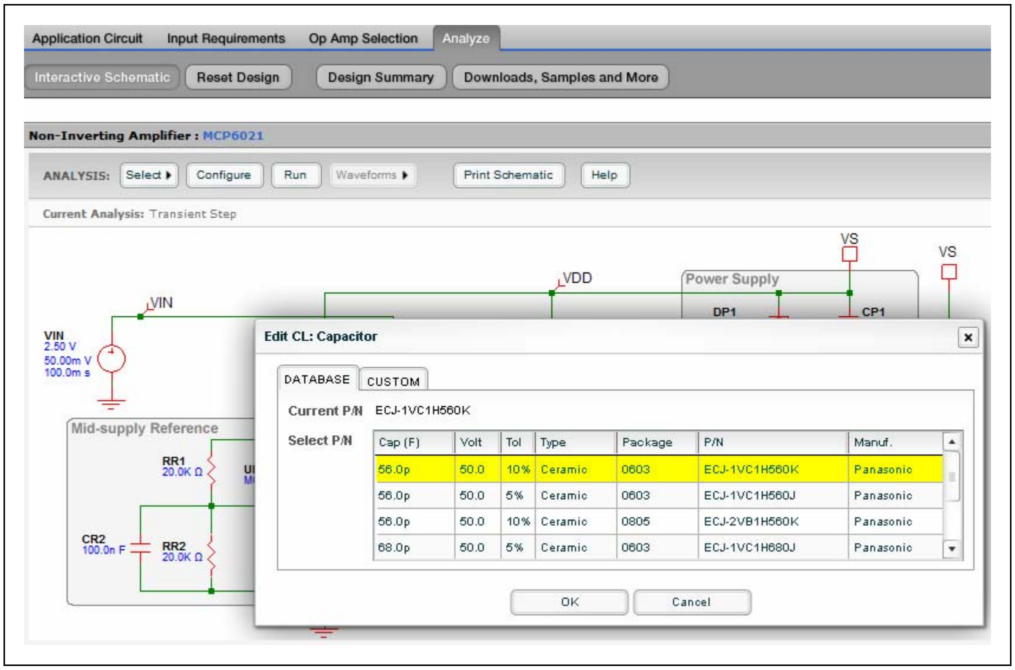



*FIGURE 5-2:* *Edit Capacitor: Database Tab.*

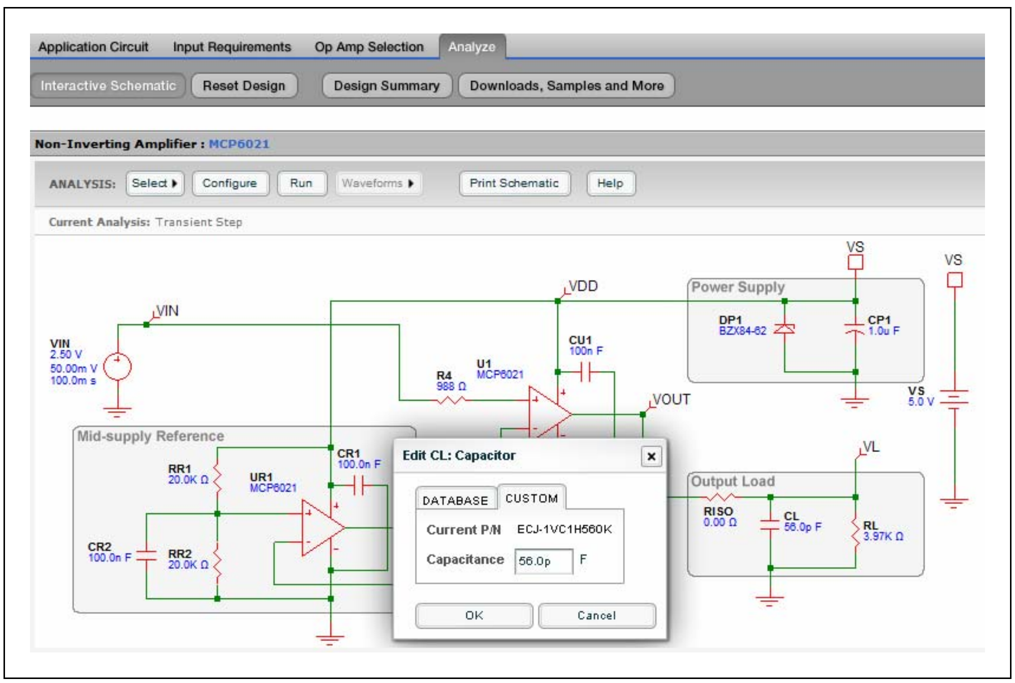



*FIGURE 5-3:* *Edit Capacitor: Custom Tab.*

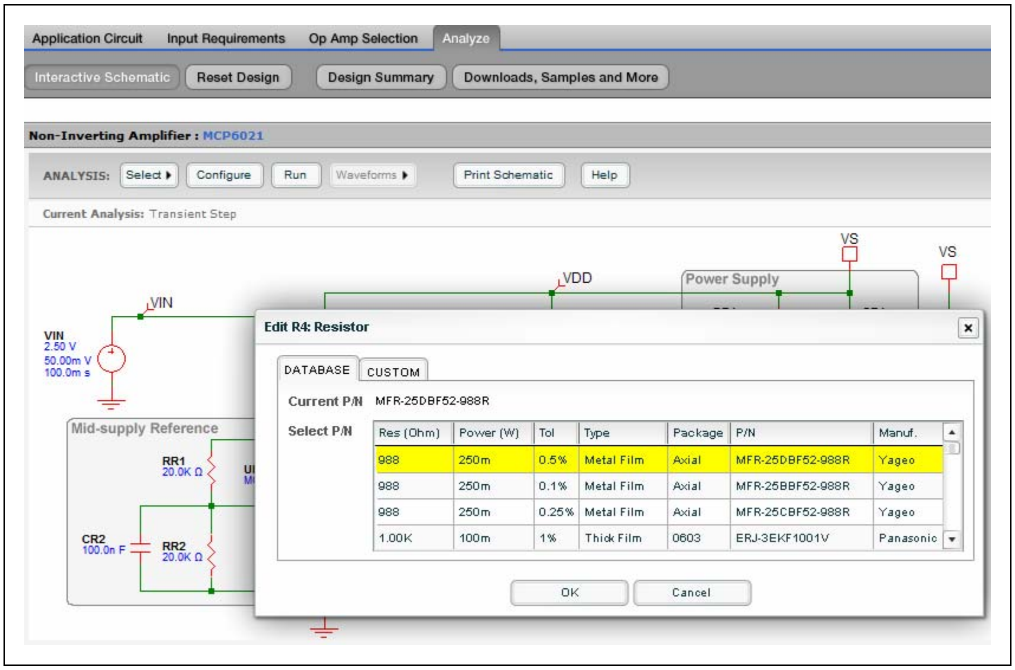



**FIGURE 5-4:** *Edit Resistor: Database Tab.*

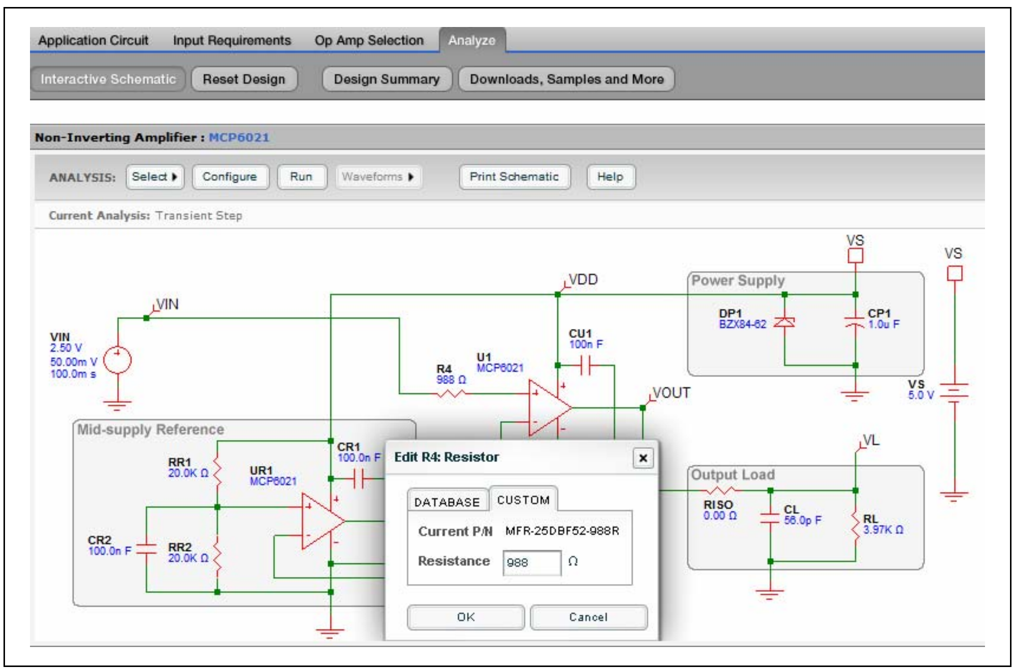



**FIGURE 5-5:** *Edit Resistor: Custom Tab.*

### 5.2.3 Edit Op Amp

The type of op amp can also be changed. Changing the type of op amp only affects the op amp that is selected as shown in Figure 5-6.

1. To change the op amp, move the mouse over the appropriate op amp, then left-click the mouse. The attributes window will appear. Select the type of op amp and click **OK**.

| **Note:** | It is the user's responsibility to ensure the proper circuit behavior when the op amp is changed. |
|---|---|

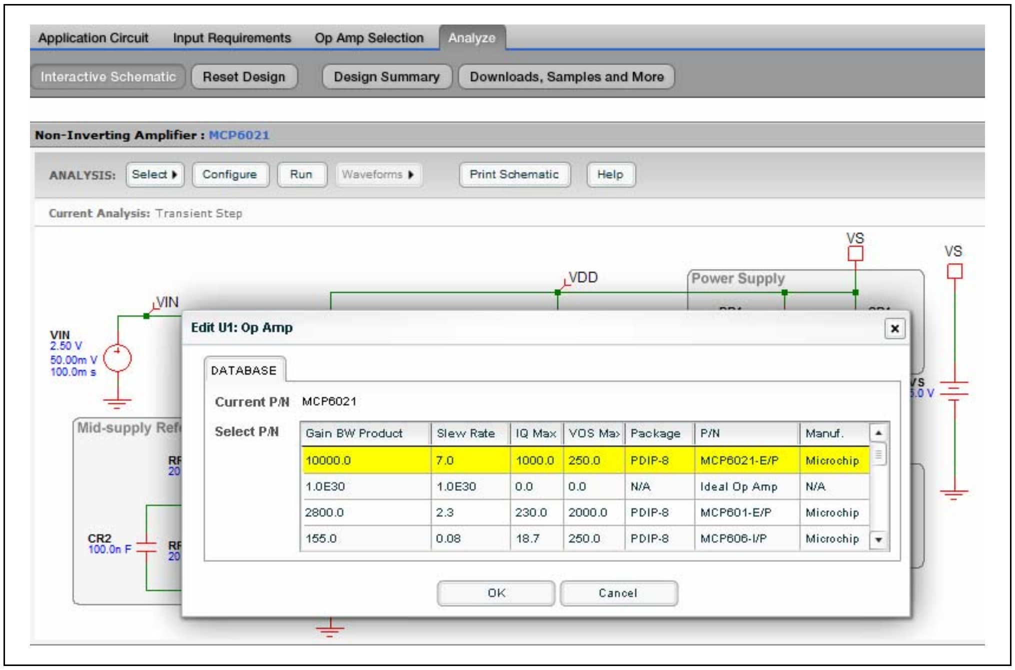



***FIGURE 5-6:*** *Edit Op Amp.*

### 5.2.4 Select Analysis

Three types of analysis may be selected in the Select drop-down menu: Transient Step, Transient Sine, and AC Analysis.

- Transient Analysis or time-domain analysis most closely simulates the phenomena seen in the real circuit by means of an oscilloscope. A simulation consists usually of a time sweep starting at t = 0. There are two types of Transient Analysis: Transient Step and Transient Sine
- AC Analysis or frequency-domain analysis is used mainly in connection with amplifiers when the frequency response is needed. The AC simulation is usually based on a sweep over a range of frequencies. In the real world, this kind of measurement would be made with a network analyzer (the source power would be small enough to not excite any non-linearities, such as slew rate)

#### 5.2.4.1 AC ANALYSIS

AC Analysis can be chosen from the Select drop-down menu.

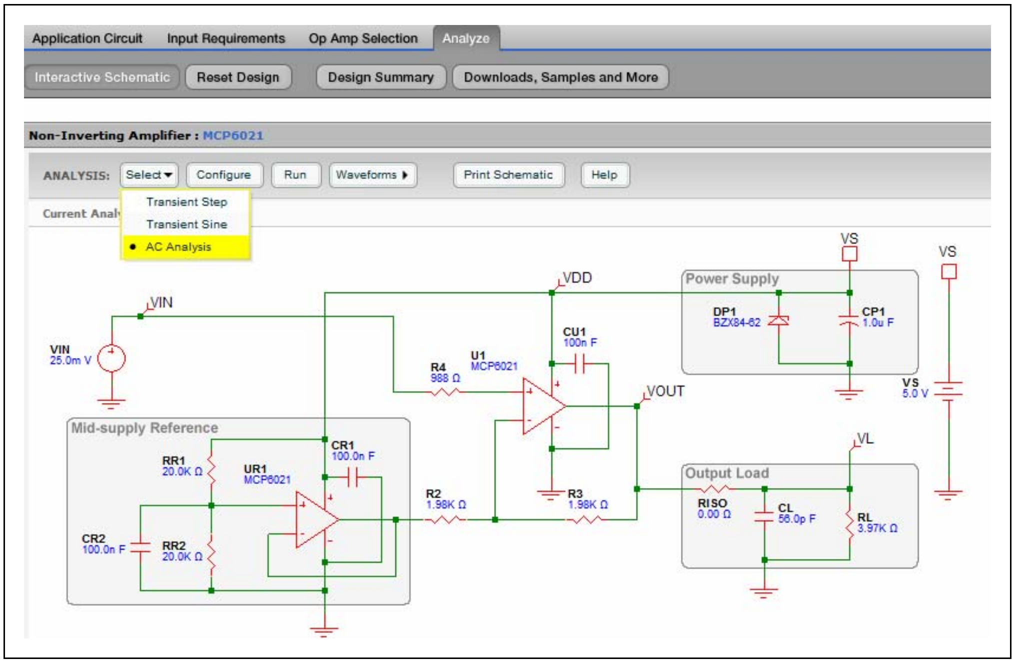



*FIGURE 5-7: Select AC Analysis.*

5.2.4.2 CONFIGURE SIMULATION

The “Configure Simulation: AC Analysis” text boxes allow users to set up the start frequency and the stop frequency.

- The allowable range of start and stop frequencies: 0.001 Hz to 1 GHz.

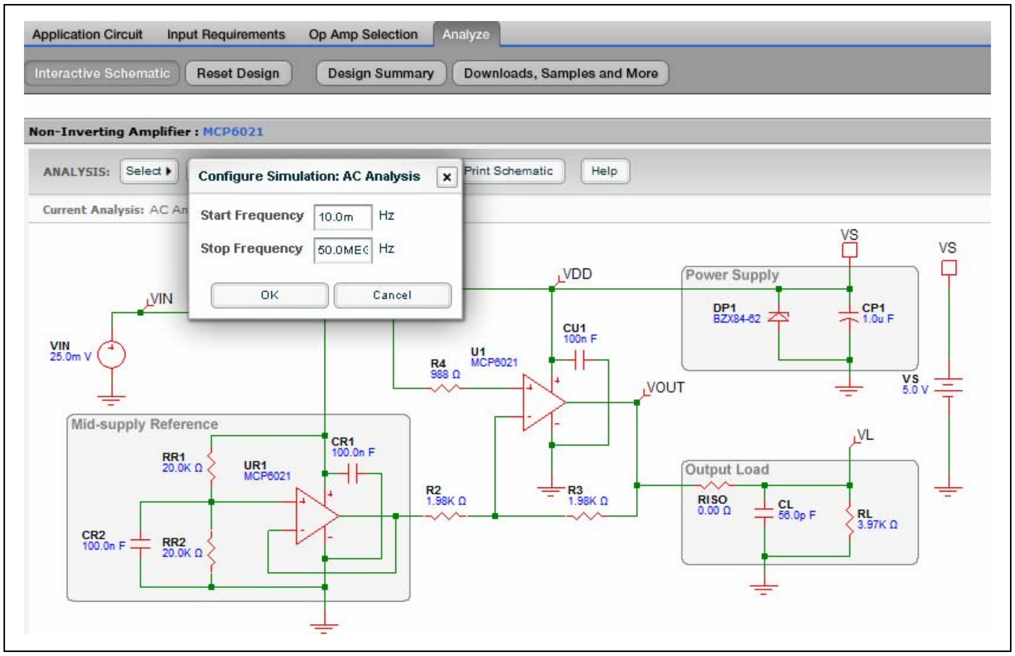



***FIGURE 5-8:*** *Configure Simulation: AC Analysis.*

5.2.4.3 RUN SIMULATION

1. Click the **Run** button to start the simulation. The Simulation Complete message box appears when the simulation is complete.
2. Click the **OK** button to view the waveforms. (See Figure 5-9 and Figure 5-10).

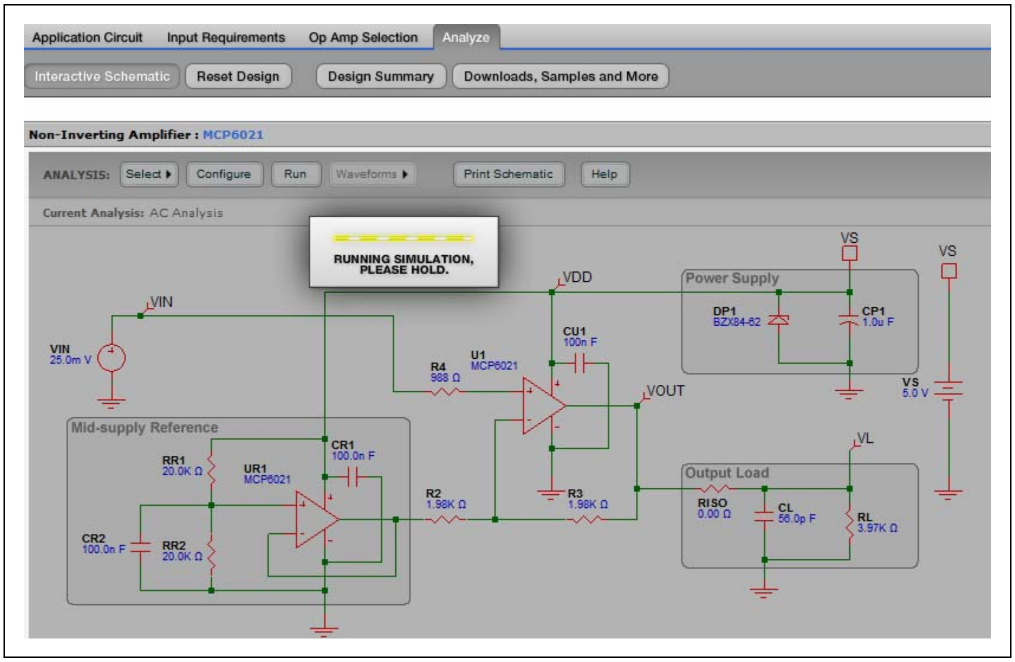



***FIGURE 5-9:*** *Run Simulation.*

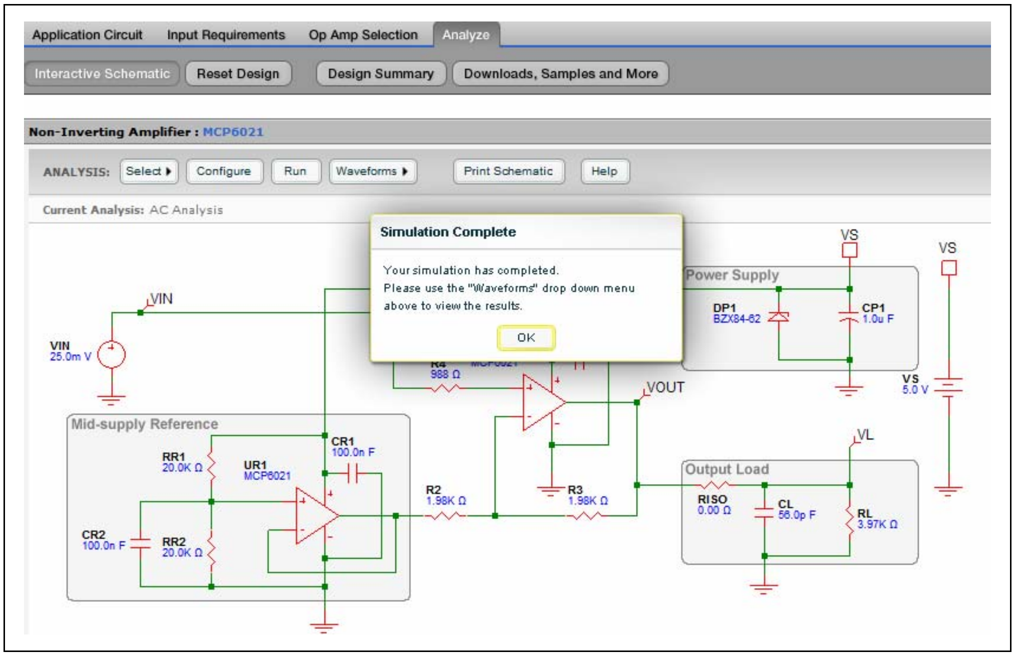



***FIGURE 5-10:*** *Simulation Complete.*

5.2.4.4 VIEW WAVEFORMS

The Waveforms drop-down menu includes two types of waveforms:

- Magnitude - Phase
  - $V_L$ - $V_{IN}$ (Phase)
  - $V_{OUT}$ - $V_{IN}$ (Phase)
- Magnitude - Group Delay
  - $V_L$ - $V_{IN}$ (Group Delay)
  - $V_{OUT}$ - $V_{IN}$ (Group Delay)

**Note 1:** Magnitude means the magnitude response of the amplifier circuit's transfer function, which is the overall amplifier gain.

**2:** Phase means the phase response of the amplifier circuit's transfer function, which is the overall amplifier phase shift.

**3:** Group Delay is a measure based on the frequency domain response of the amplifier circuit. It focuses on the relative time delay among sine waves of nearly equal frequency.

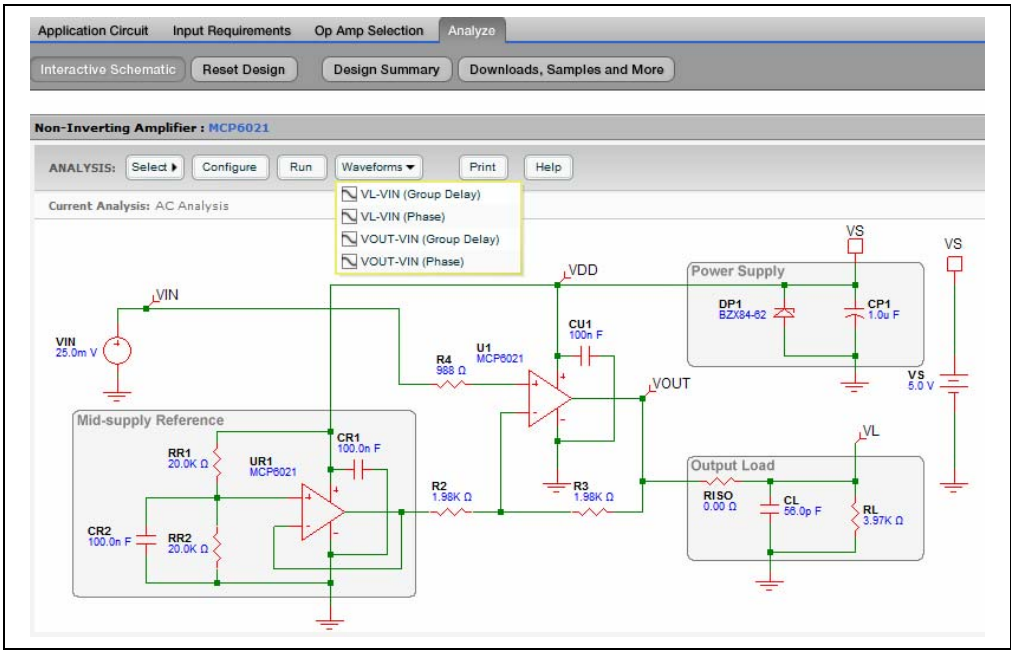



***FIGURE 5-11:*** *View Waveforms.*

5.2.4.4.1 Magnitude - Phase

Magnitude - Phase can be chosen in the View Waveforms drop-down menu. The y-axes display the magnitude and phase responses of the overall amplifier transfer function. The x-axis displays the frequency.

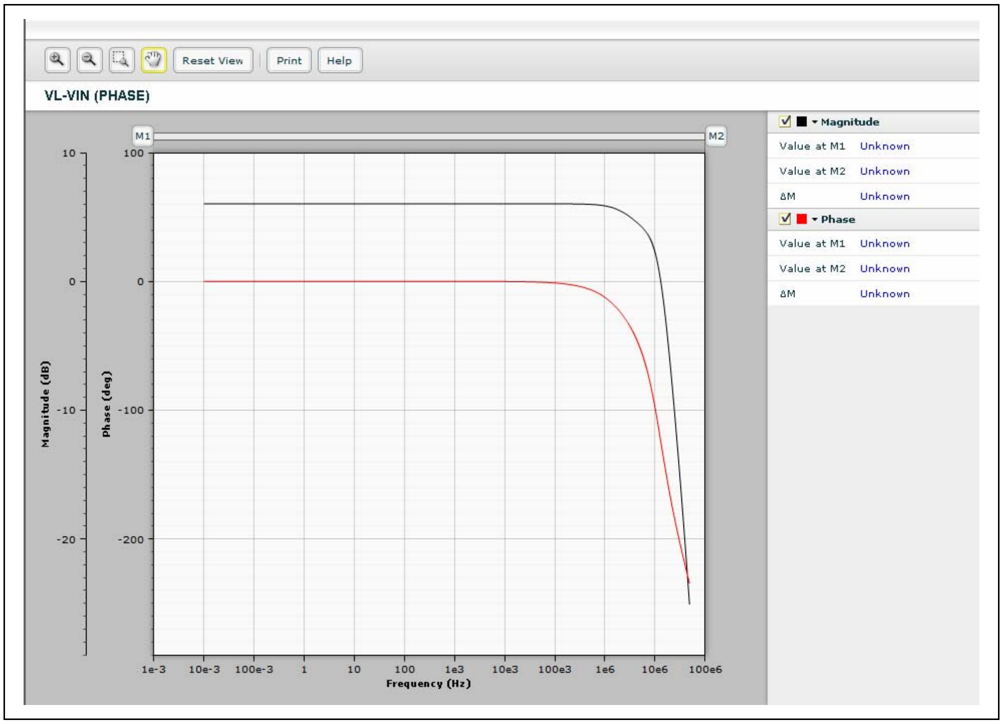



***FIGURE 5-12:*** *Magnitude - Phase Waveform.*

M1 or M2 can be moved horizontally to a desired frequency value. Or, double click M1 or M2 and a dialog box will appear; you can input a frequency value to force the marker to that value. (See Figure 5-13). After the frequency value are set for M1 and M2, the values of magnitude and phase will be updated.

Also worth noting are the buttons in the upper left hand corner of the window (Zoom In, Zoom Out, Magnifier, Hand Tool, Reset View, and Print) that allow the waveform view to be changed or printed.

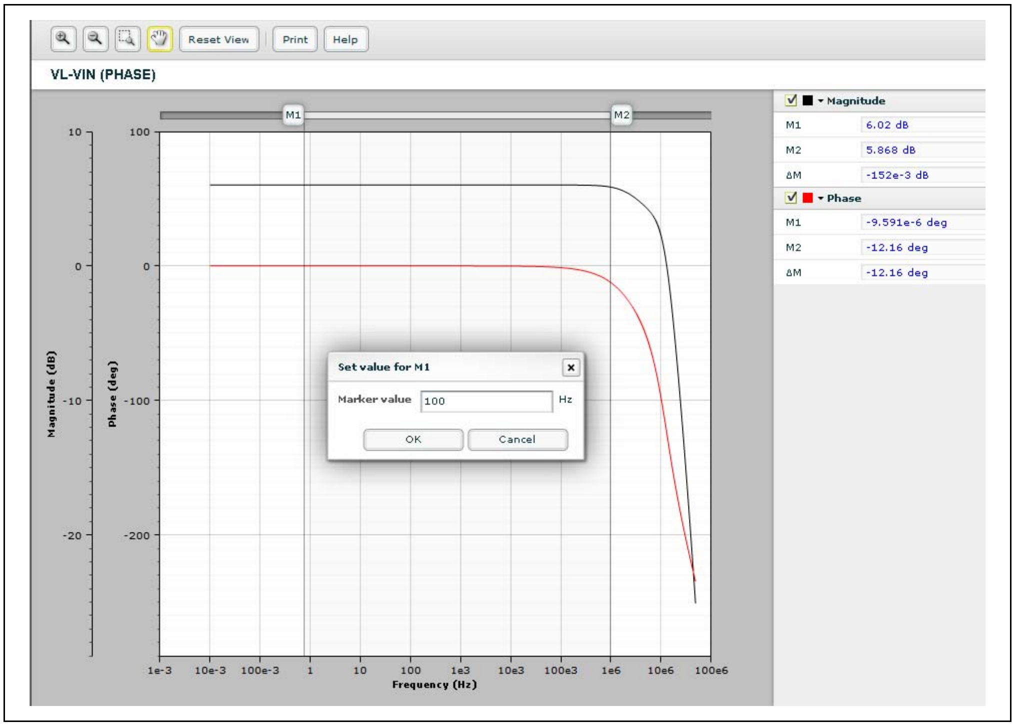



**FIGURE 5-13:** *Set Value for Markers.*

#### 5.2.4.4.2 Magnitude - Group Delay

Magnitude - Group Delay can be chosen in the Waveforms drop-down menu. The y-axes display the magnitude of overall amplifier transfer function and the group delay. The x-axis displays the frequency.

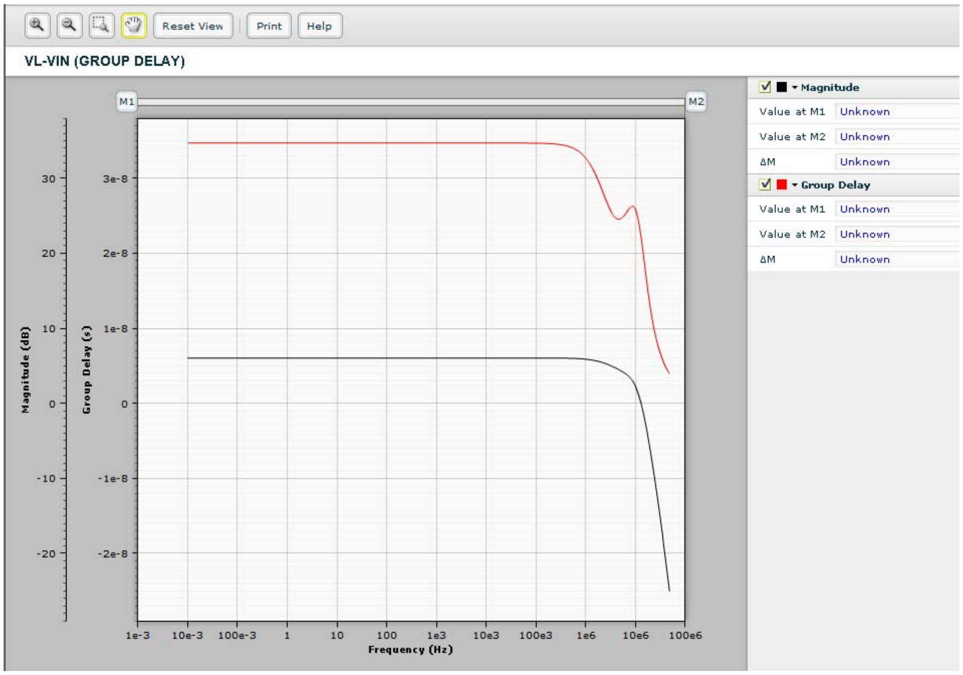



***FIGURE 5-14:*** *Magnitude-Group Delay Waveform.*

Magnitude - Group Delay waveform has the same user interface as Magnitude - Phase waveform (**Section 5.2.4.4.1**).

### 5.2.5 Transient Step

Transient Step can be chosen from the Select drop-down menu.

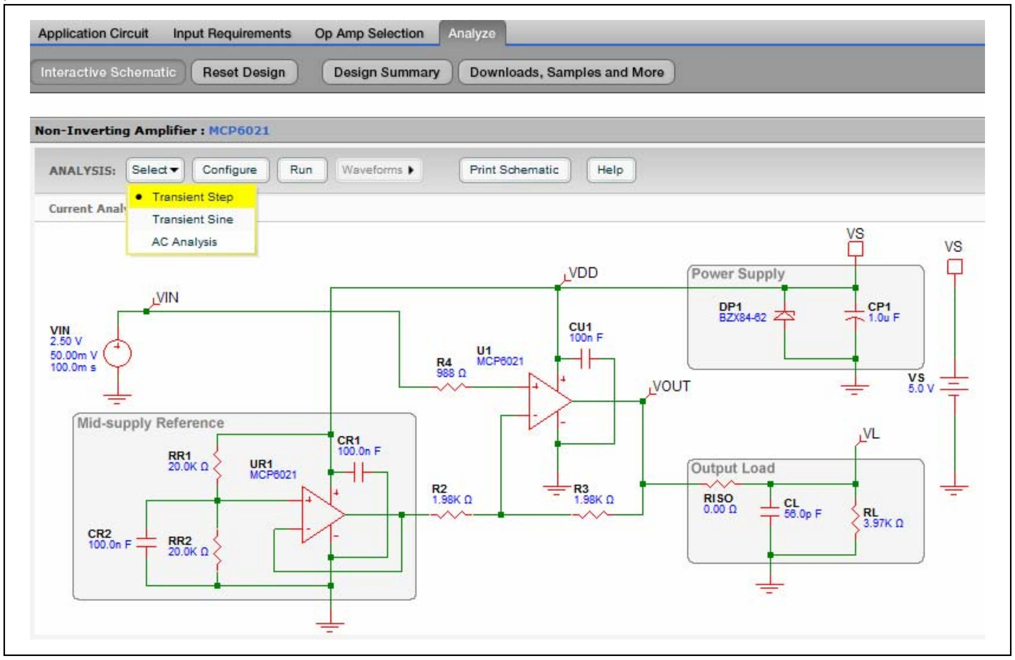



*FIGURE 5-15:* *Select Transient Step.*

#### 5.2.5.1 CONFIGURE SIMULATION

The **Configure Simulation: Transient Step** text boxes allow the user to set up the stop time, or duration of the step response. The allowable range of Stop Time: 1 µs to 1s.

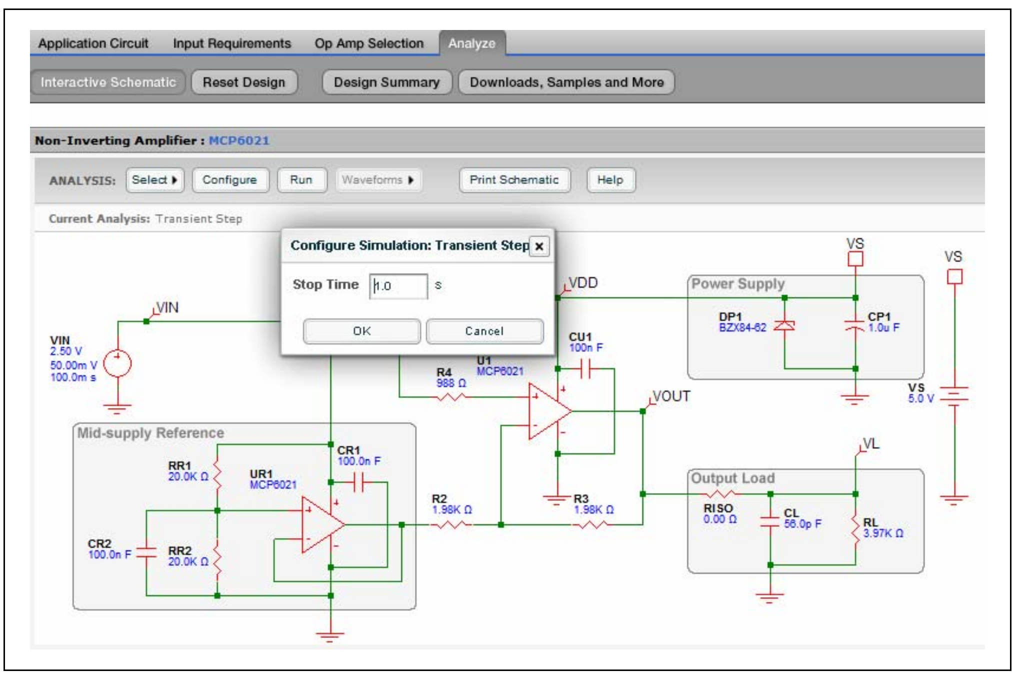



*FIGURE 5-16:* *Configure Simulation: Transient Step.*

### 5.2.5.2 EDIT VOLTAGE SOURCE

The Configure Source text boxes allow the user to set up the Center, Step Amplitude, and Delay of $V_{IN}$.

- The allowable range of Center: 0V to 5.5V
- The allowable range of Step Amplitude: 0V to 10V
- The allowable range of Delay: 1 µs to 1s

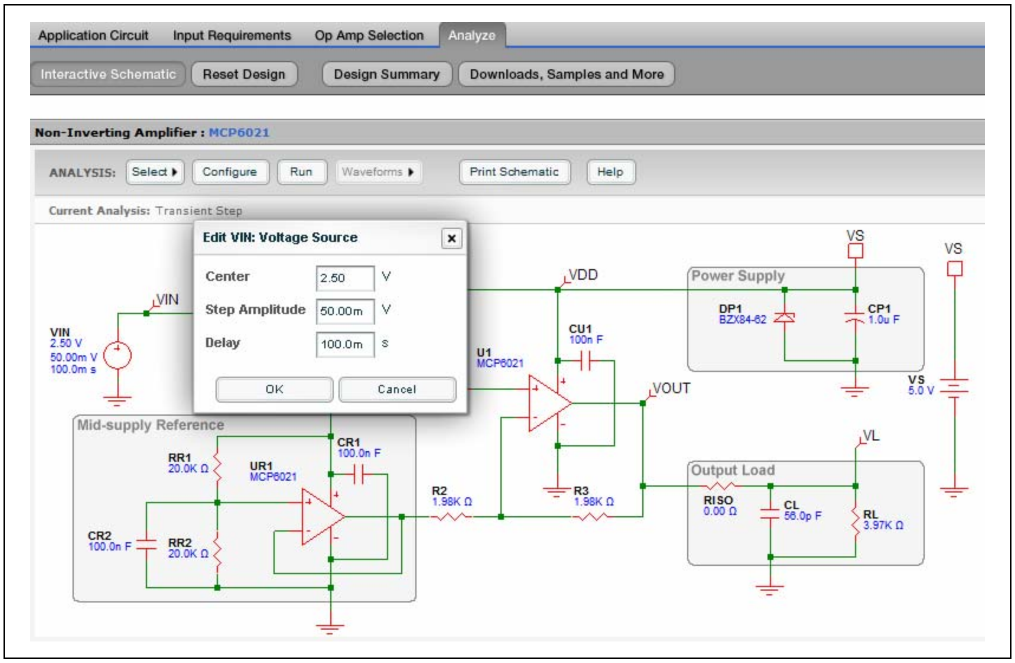



***FIGURE 5-17:*** *Edit Voltage Source.*

#### 5.2.5.3 RUN SIMULATION

1. Click the **Run** button to start the simulation. The Simulation Complete message box appears when the simulation is complete. Click the **OK** button to view the waveforms.

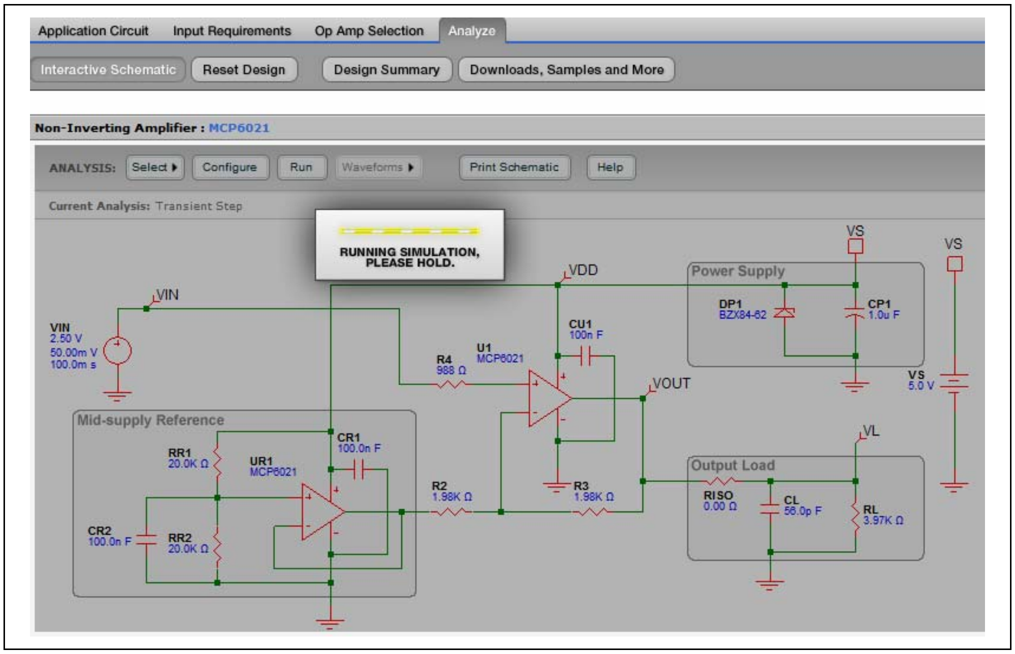


*FIGURE 5-18: Run Simulation.*

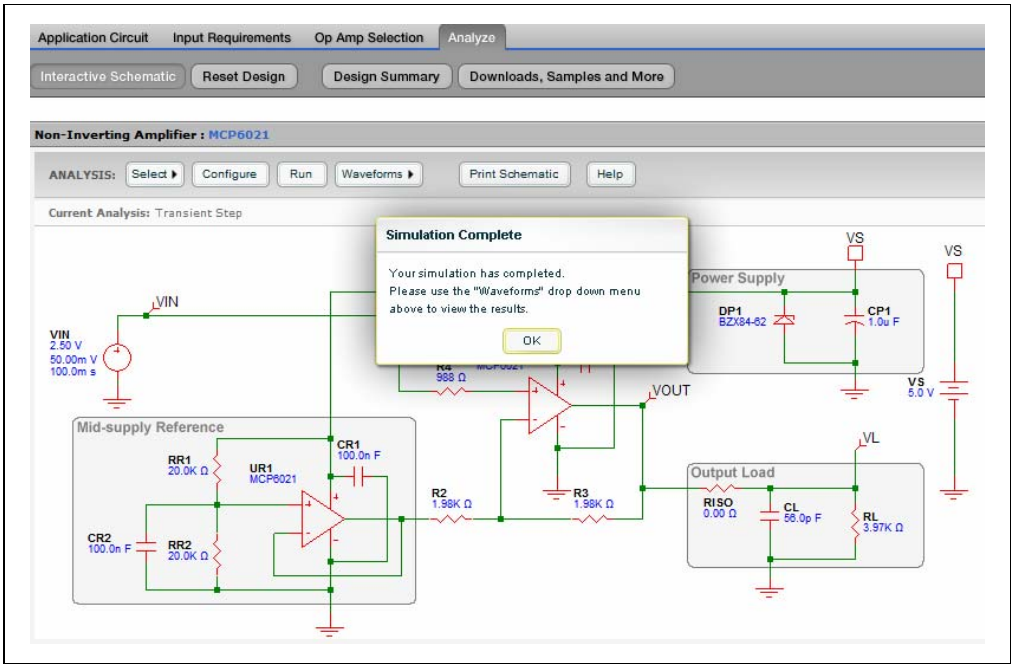


*FIGURE 5-19: Simulation Complete.*

#### 5.2.5.4 VIEW WAVEFORMS

1. Click the Waveform drop-down menu and select Transient Response.

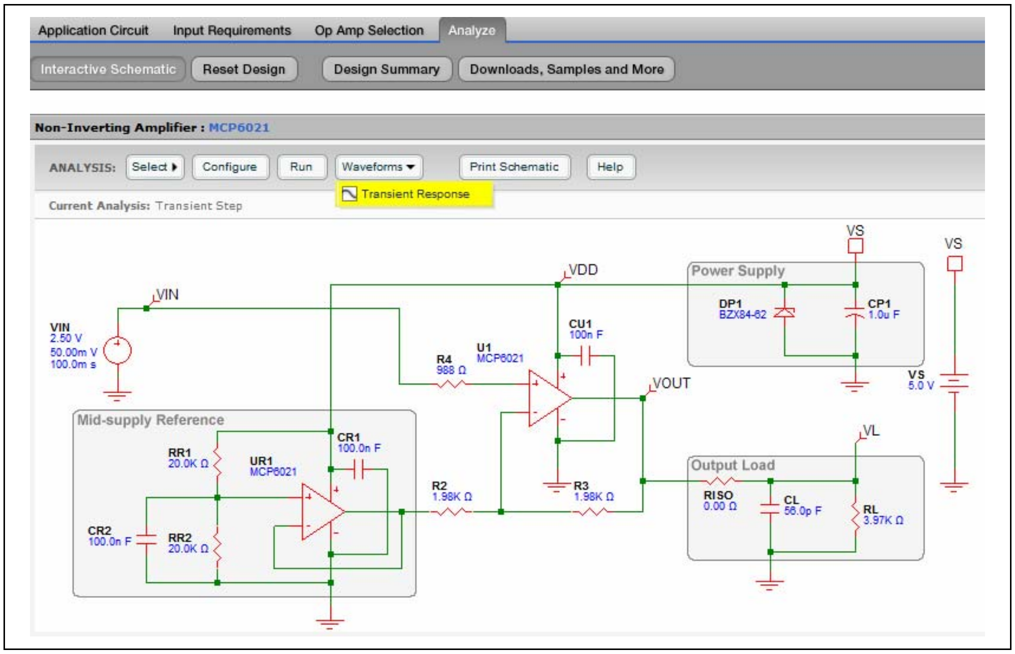



*FIGURE 5-20: Waveforms.*

#### 5.2.5.5 TRANSIENT STEP RESPONSE

The y-axis displays the voltage of the transient step response. The x-axis displays the time.

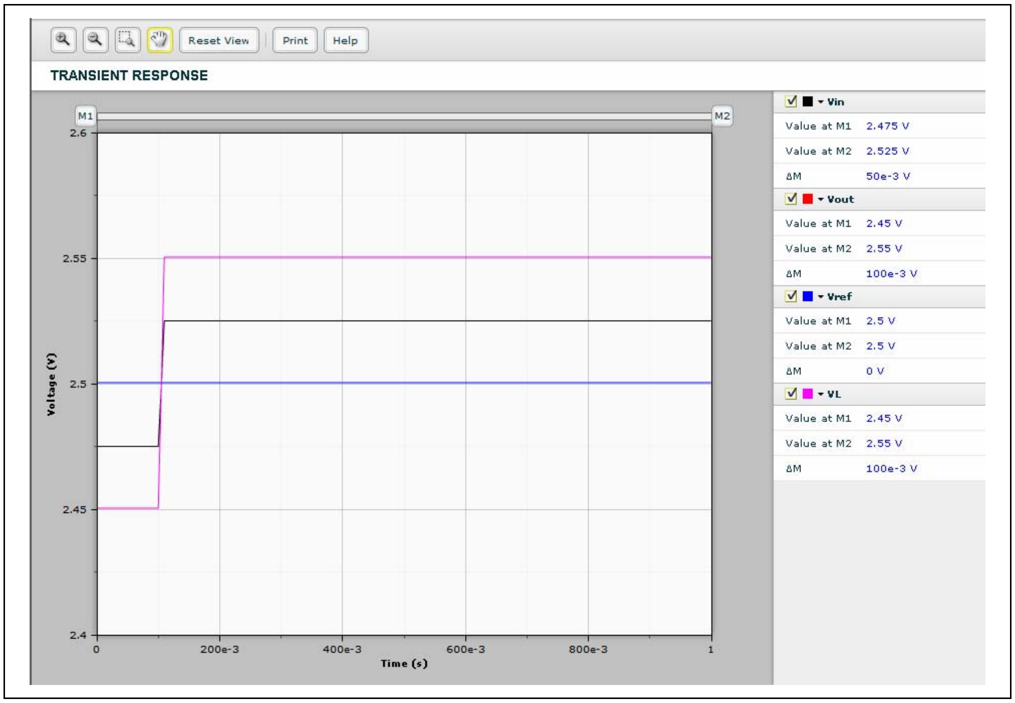



*FIGURE 5-21: Transient Step Response.*

Transient Step Response waveform has the same user interface as Magnitude-Phase waveform. For more information, refer to **Section 5.2.4.4.1**.

### 5.2.6 Transient Sine

1. Click the Select drop-down menu and choose Transient Sine.

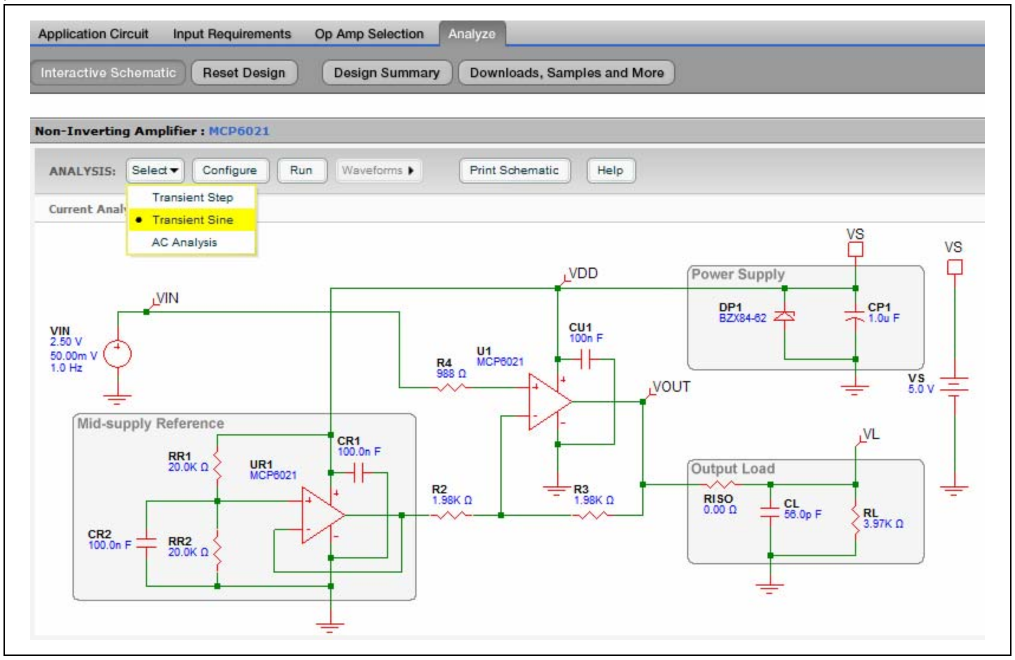



*FIGURE 5-22: Select Transient Sine.*

#### 5.2.6.1 CONFIGURE SIMULATION

The Configure Simulation: Transient Sine text box allows the user to set up the number of periods. The allowable range of Number of Periods: 0.5T to 10T.

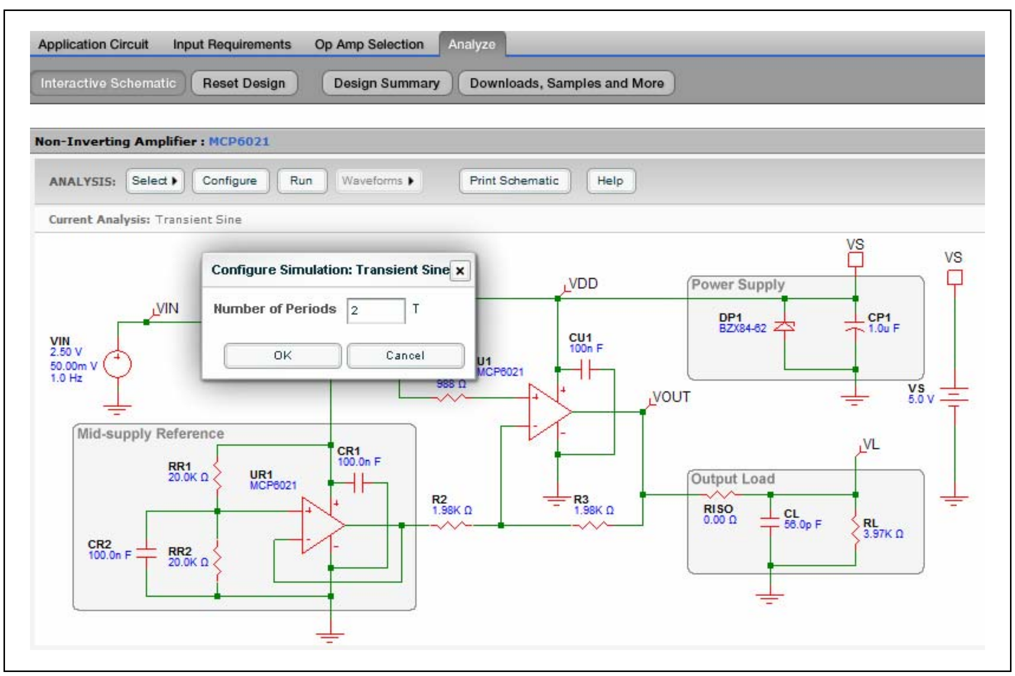



*FIGURE 5-23: Configure Simulation: Transient Sine.*

### 5.2.6.2 EDIT VOLTAGE SOURCE

The Configure Source text boxes allow the user to set up the Center, Peak-to-Peak, and Frequency of $V_{IN}$.

- The allowable range of Center: 0V to 5.5V
- The allowable range of Peak-to-Peak: 0V to 10V
- The allowable range of Frequency: 1 Hz to 100 MHz

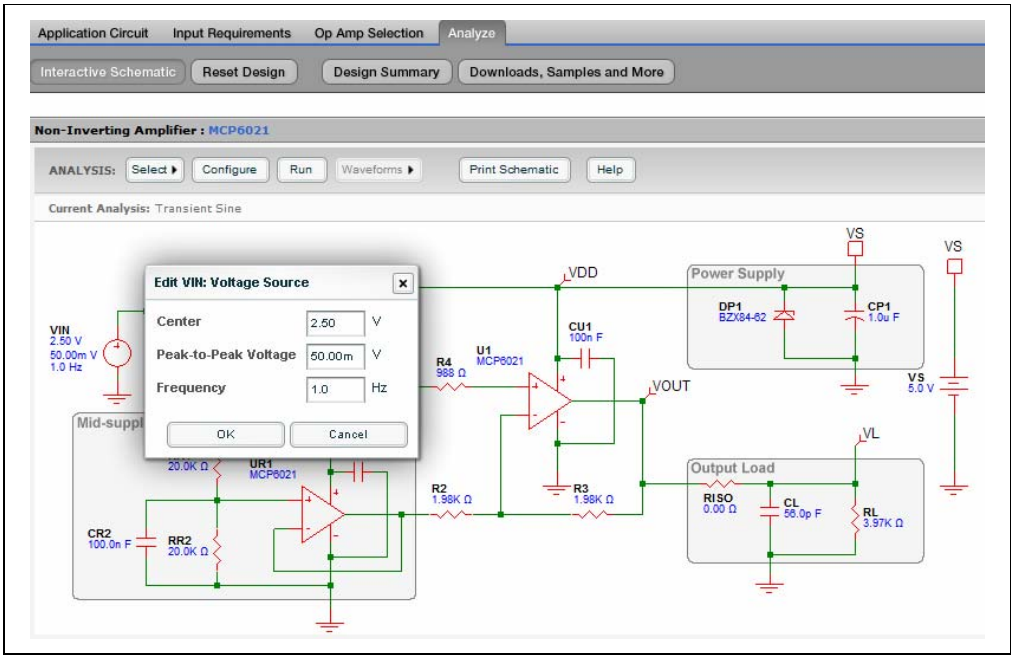



*FIGURE 5-24: Edit Voltage Source.*

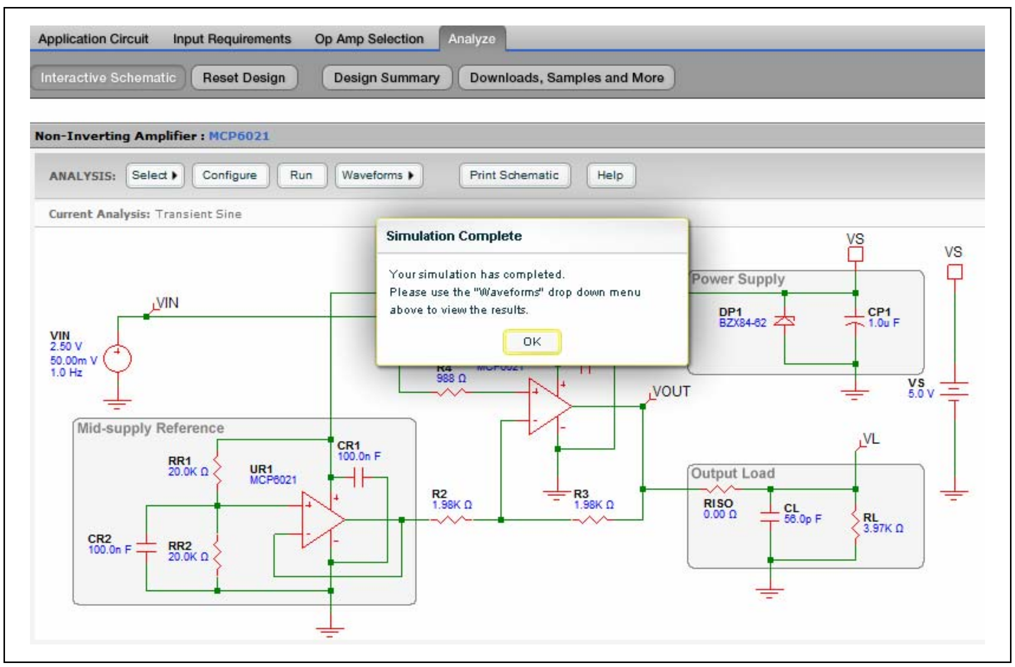



*FIGURE 5-25: Simulation Complete.*

### 5.2.6.3 RUN SIMULATION

1. Click the **Run** button to start the simulation. The Simulation Complete message box appears when the simulation is complete.
2. Click the **OK** button to view the waveforms.

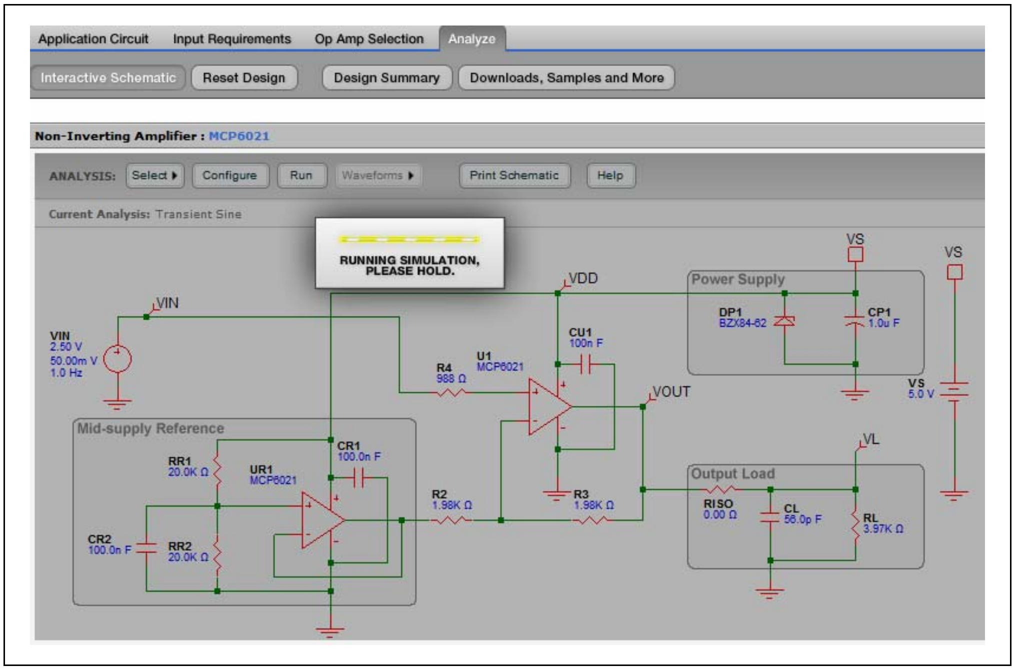



*FIGURE 5-26: Run Simulation.*

### 5.2.6.4 VIEW WAVEFORMS

1. Click the Waveform drop-down menu and select Transient Response.

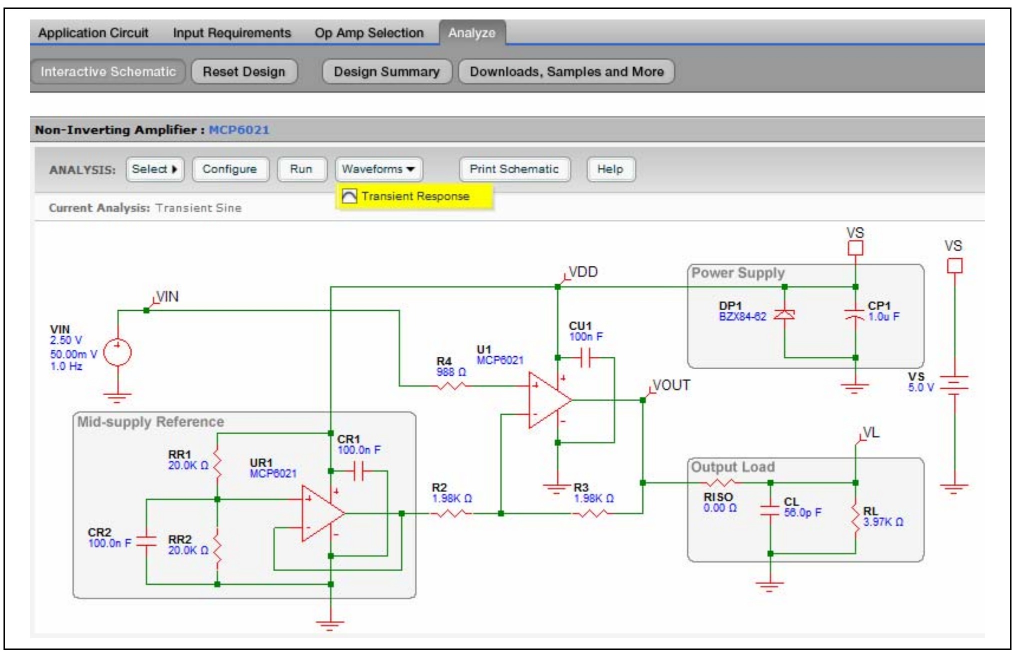



*FIGURE 5-27: Waveforms.*

#### 5.2.6.5 TRANSIENT SINE RESPONSE

The y-axis displays the voltage of the transient sine response. The x-axis displays the time.

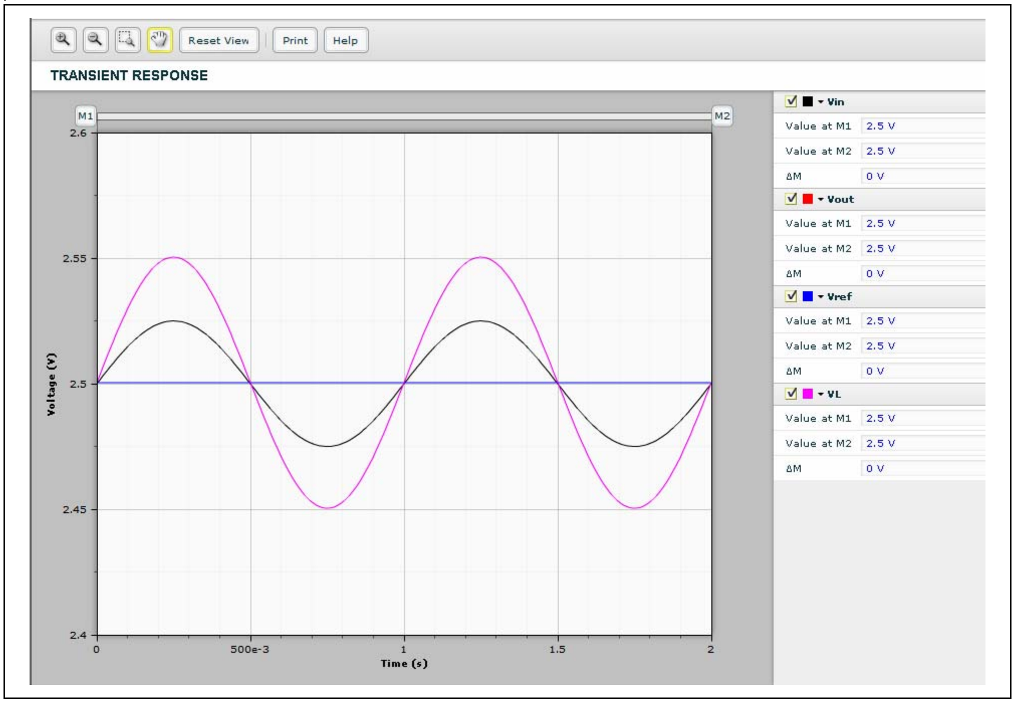



***FIGURE 5-28:*** *Transient Sine Response.*

The Transient Sine Response waveform has the same user interface as the Magnitude-Phase waveform. For more information, refer to **Section 5.2.4.4.1**.

## 5.3 RESET DESIGN

Restore the schematic to the original application circuit that was generated from the user's inputs on the Input Requirements page. This action will reset all component values back to their default values.

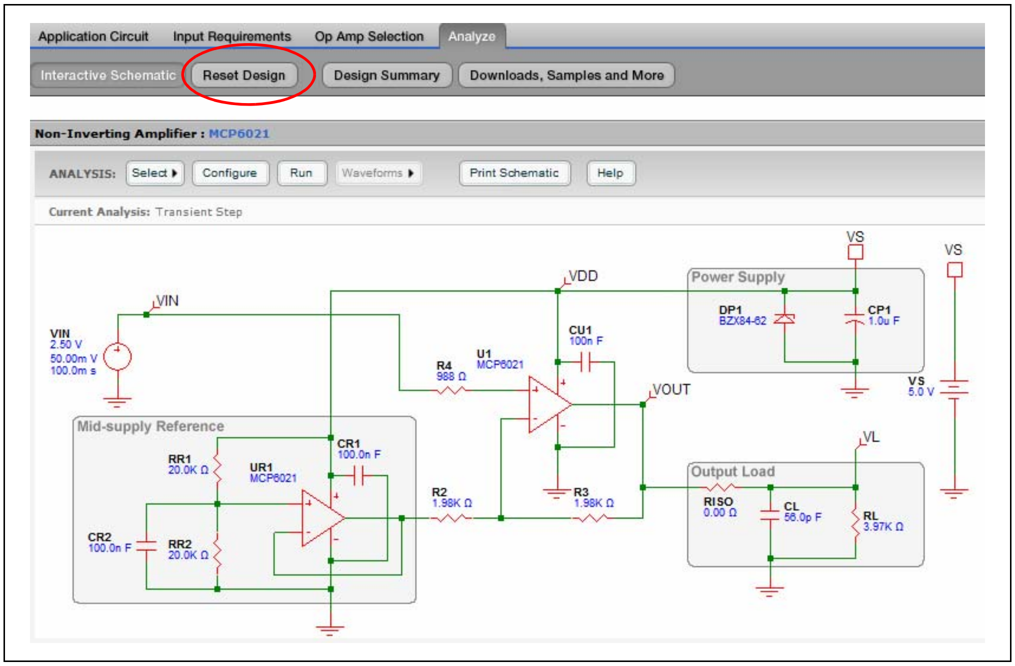
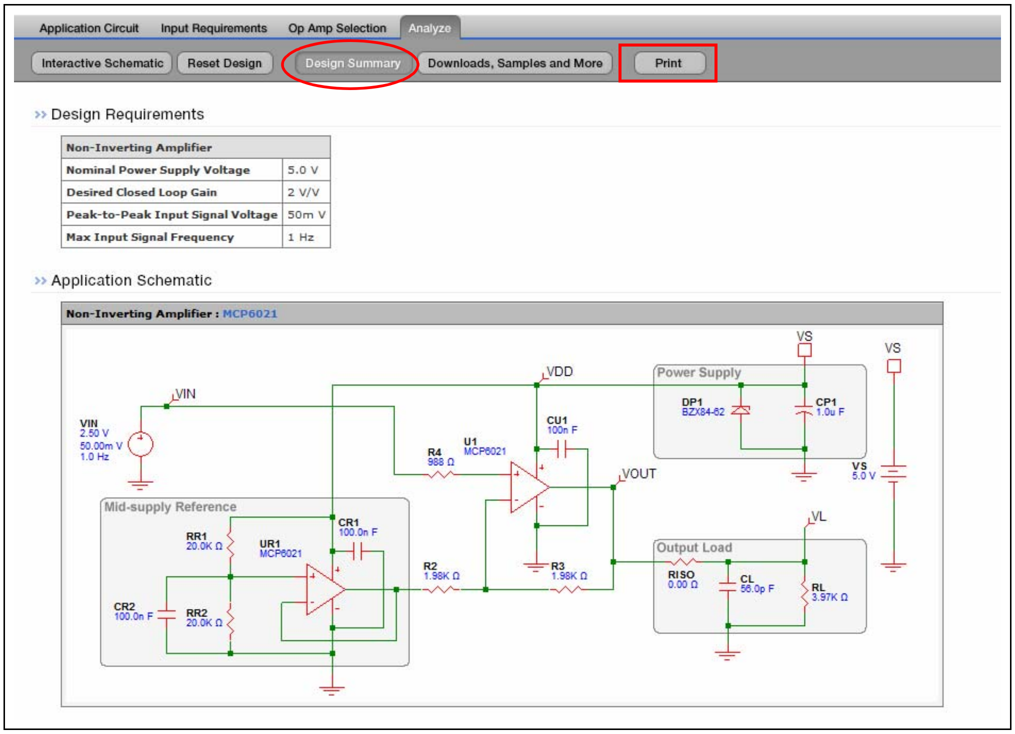



***FIGURE 5-29:*** *Reset Design.*

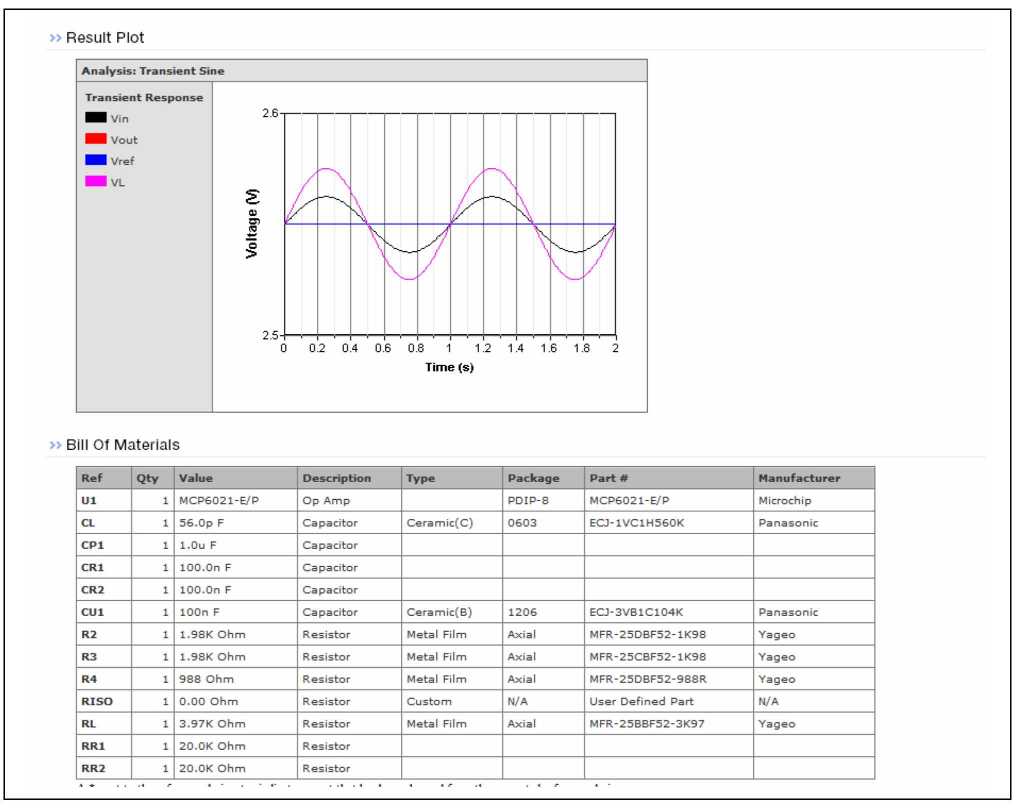
## 5.4 DESIGN SUMMARY

Display or print a single page summary of the application circuit solution, including Design Requirements, Application Shematic, Result Plot and Bill of Materials.




| Non-Inverting Amplifier | |
|---|---|
| Nominal Power Supply Voltage | 5.0 V |
| Desired Closed Loop Gain | 2 V/V |
| Peak-to-Peak Input Signal Voltage | 50m V |
| Max Input Signal Frequency | 1 Hz |

***FIGURE 5-30:*** *Design Summary.*




| Ref | Qty | Value | Description | Type | Package | Part # | Manufacturer |
|---|---|---|---|---|---|---|---|
| U1 | 1 | MCP6021-E/P | Op Amp | | PDIP-8 | MCP6021-E/P | Microchip |
| CL | 1 | 56.0p F | Capacitor | Ceramic(C) | 0603 | ECJ-1VC1H560K | Panasonic |
| CP1 | 1 | 1.0u F | Capacitor | | | | |
| CR1 | 1 | 100.0n F | Capacitor | | | | |
| CR2 | 1 | 100.0n F | Capacitor | | | | |
| CU1 | 1 | 100n F | Capacitor | Ceramic(B) | 1206 | ECJ-3VB1C104K | Panasonic |
| R2 | 1 | 1.98K Ohm | Resistor | Metal Film | Axial | MFR-25DBF52-1K98 | Yageo |
| R3 | 1 | 1.98K Ohm | Resistor | Metal Film | Axial | MFR-25CBF52-1K98 | Yageo |
| R4 | 1 | 988 Ohm | Resistor | Metal Film | Axial | MFR-25DBF52-988R | Yageo |
| RISO | 1 | 0.00 Ohm | Resistor | Custom | N/A | User Defined Part | N/A |
| RL | 1 | 3.97K Ohm | Resistor | Metal Film | Axial | MFR-25BBF52-3K97 | Yageo |
| RR1 | 1 | 20.0K Ohm | Resistor | | | | |
| RR2 | 1 | 20.0K Ohm | Resistor | | | | |

***FIGURE 5-31:*** *Continued Design Summary.*

## 5.5 DOWNLOADS, SAMPLES AND MORE

Download tools and materials, including the Bill of Materials, Schematic, and MINDI Simulator Tool. Link to Microchip Direct web page, Sample/Order a device, and Order an Evaluation Board.

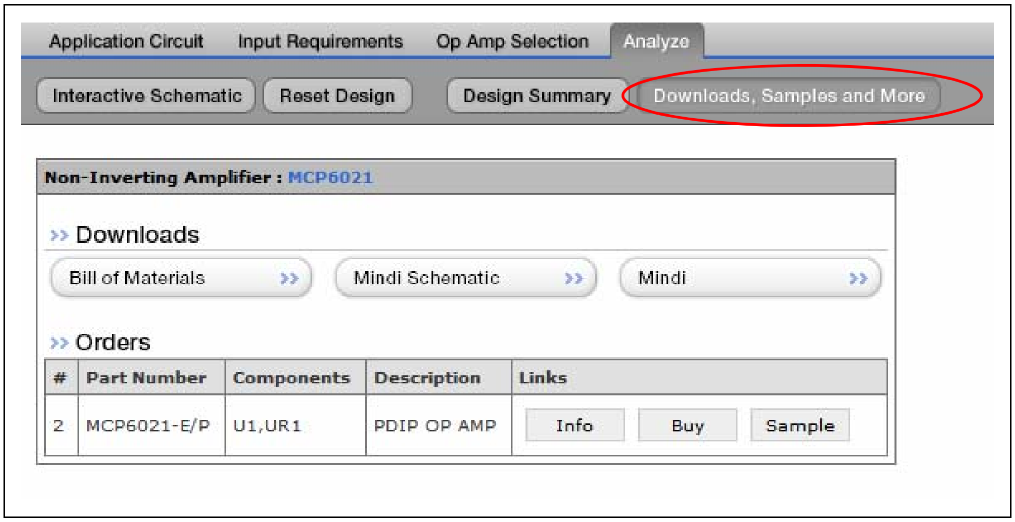



***FIGURE 5-32:*** *Download, Samples and More.*

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