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Using the MPLAB® Mindi™ Analog Simulator with the 8-Bit Operational Amplifier Module

Introduction

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The MPLAB® Mindi™ Analog Simulator is a free tool provided by Microchip Technology that allows users to simulate analog circuits in software prior to building them in hardware.

The Mindi environment includes model files that can be used to accurately simulate designs that may contain a wide variety of Microchip and other analog products, including discrete operational amplifiers, linear regulators, LED drivers and MOSFET drivers among many others. Additionally, the MPLAB Mindi Analog Simulator integrates model files for many new analog peripherals found on select PIC® and AVR® microcontrollers. One example of this is the Operational Amplifier peripheral currently available on the PIC18-Q41 and AVR DB device families.

This document will focus primarily on getting started using the MPLAB Mindi Analog Simulator to model a few basic circuits that use the PIC18-Q41 operational amplifier peripheral. The concepts and examples covered in this technical brief can easily be expanded upon or modified for other applications.

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1. MPLAB Mindi Analog Simulator Overview

Simulating designs using Mindi is a simple step that can be taken to reduce project risk and save development time, as the expected circuit response can be accurately modeled to ensure that it will fulfill the requirements of an application.

Before building anything in hardware, the MPLAB Mindi Analog Simulator can evaluate transient circuit responses to different input conditions and model the effect of noise in analog signal conditioning circuits over a wide range of operating conditions to simulate real-world applications. The latest version of this free tool can be downloaded from the MPLAB Mindi Analog Simulator product page.

The Mindi Analog Simulator includes several model libraries that are integrated into the tool upon download. For a complete list of the model libraries available, visit the MPLAB Mindi Software Libraries page.

One of the advantages of simulating analog components using the provided library files is that they contain accurate models that use data collected over temperature and operating voltage on actual silicon. In most cases, the simulated circuit response will be close to what can be expected in hardware using the same design.

1.1 Getting Started With the MPLAB Mindi Analog Simulator

After successfully downloading and installing the Mindi Analog Simulator, a new schematic can be created by selecting either the **New SIMetrix Schematic** or the **New SIMPLIS Schematic** option on the Welcome page. The SIMPLIS engine is primarily geared towards switching power systems, while the SIMetrix system is a more general-purpose SPICE-based simulation engine.

For the purposes of this technical brief, all schematics for the following examples were created using the SIMetrix simulation engine. Once a new schematic has been created, a blank canvas will appear along with several options to create an analog circuit for simulation.

1.2 MPLAB Mindi Model Libraries

A wide variety of common components are available when designing an analog circuit in Mindi, using either the quick access toolbar or by browsing the complete list of components under the **Place** tab at the top of the window.

There are several components, such as resistors and capacitors, that can be inserted into a schematic and assigned values to be used for simulation. Additionally, there are also many specific devices that have model libraries already integrated into Mindi that can be added to the schematic by selecting **From Model Library** under the **Place** tab. After selecting this option, a window will open showing all of the model libraries sorted by device type. These model libraries include common components such as comparators, diodes, MOSFETs, voltage regulators and operational amplifiers, among many other options.

The model library for the operational amplifier found on the PIC18-Q41 and other applicable PIC and AVR microcontrollers can be found under the Microcontroller Peripherals section in this window. When designing an analog circuit in Mindi, placing a component using the model library browser will ensure that the simulation is performed using the characterized parametric data for that device. Model libraries that are not included in Mindi can be imported by clicking *File → Model Library → Add/Remove Libraries…* on the top toolbar or by dragging the directory into the MPLAB Mindi command shell.

Tip: For more information, refer to the *Getting Started with the MPLAB® Mindi™ Analog Simulator (DS50002564)* document or visit *https://www.microchip.com/mplab/mplab-mindi*.

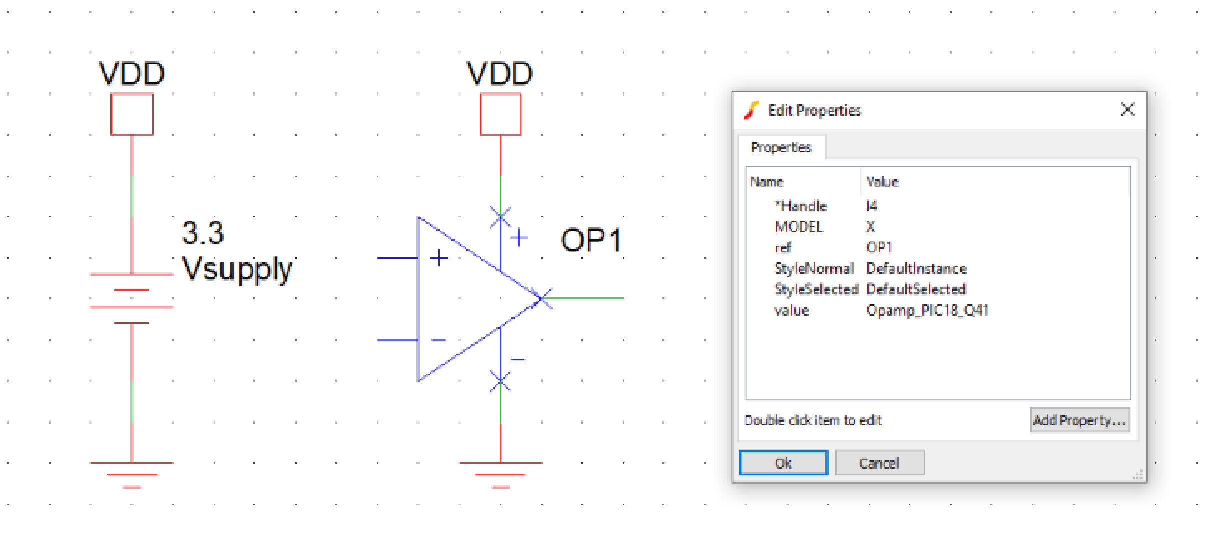
2. Building an Analog Circuit Using the Mindi Model Library

When simulating a circuit in Mindi, start by focusing on the analog device whose behavior is the primary interest of the simulation. This can be done either by finding the correct device in the model library browser and inserting it into the schematic from there, or by placing a generic version of that component into the schematic and manually filling in the parameters that determine the device behavior during simulation.

The main advantage of using devices that have model libraries instead of generic components in Mindi is that the model libraries contain the actual parametric data and electrical characteristics of that component. This allows for the simulation to be as accurate as possible. The examples discussed in this technical brief all use the PIC18-Q41 model library to simulate the circuit response of the operational amplifier peripheral found in this device family.

Figure 2-1 shows a schematic in Mindi where the PIC18-Q41 operational amplifier has been inserted along with the device properties window for that component. The PIC18-Q41 operational amplifier model requires that a positive and negative power supply be connected to the corresponding terminals to run a simulation. In this example, the power supply labeled V_{DD} (3.3V) and the ground reference (0V) were connected to the respective nodes of the operational amplifier.

Figure 2-1. PIC18-Q41 Mindi Model Library Symbol



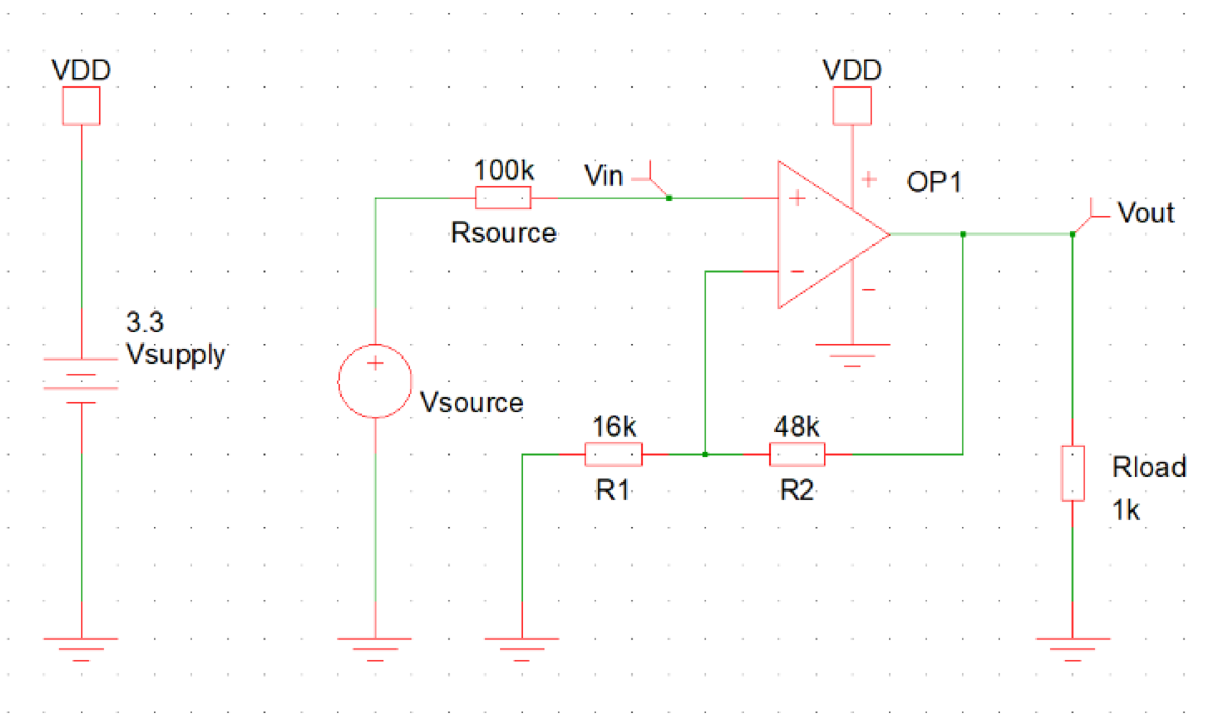
Once the main analog component of the circuit has been placed onto the schematic, the next step will be to finish drawing the circuit in Mindi by inserting the remaining parts needed to complete the design.

Using the PIC18-Q41 operational amplifier schematic (see example above), the next step to complete this circuit will be to place a feedback network and connect the inputs and output of the operational amplifier accordingly. In this instance, the PIC18-Q41 operational amplifier model will be used to simulate a non-inverting amplifier with a gain of 4. When all of the components have been placed and all of the connections have been made, an input source should be added to the schematic so that the circuit response can be simulated to model the application it will be used in.

There are many different voltage and current source options available in Mindi. In this example, a sinusoidal voltage source was used for simulation. Different sources can be added into a schematic by either using the quick access toolbar or by navigating to the **Place** tab at the top of the window and selecting from the list of available options.

In this example, the sinusoidal waveform connected to the non-inverting input of the PIC18-Q41 operational amplifier has a frequency of 50 Hz, an amplitude of 200 mV, and a positive offset of 200 mV to ensure that the sine wave generated is always larger than the ground reference. Figure 2-2 shows the complete schematic used in Mindi to simulate this circuit using the PIC18-Q41 operational amplifier library model.

Figure 2-2. PIC18-Q41 Non-Inverting Amplifier Mindi Schematic



3. Simulating an Analog Circuit Using Mindi

Once a schematic has been completed, the MPLAB Mindi Analog Simulator can be used to model the circuit response in several different ways. Since the circuit used in this example has a simulated input source already included, the easiest simulation to run will be to probe the input and output of the operational amplifier and plot the circuit response over time.

Mindi allows users to place fixed probes onto a schematic so that the resulting waveforms will appear once a simulation has been completed. A fixed probe can be placed by going to the **Probe** tab on the top toolbar and selecting from options, such as a voltage, current or power probe. As shown in the PIC18-Q41 non-inverting amplifier example, a fixed voltage probe labeled V_{IN} was placed on the amplifier input and a fixed voltage probe labeled V_{OUT} was placed on the amplifier output.

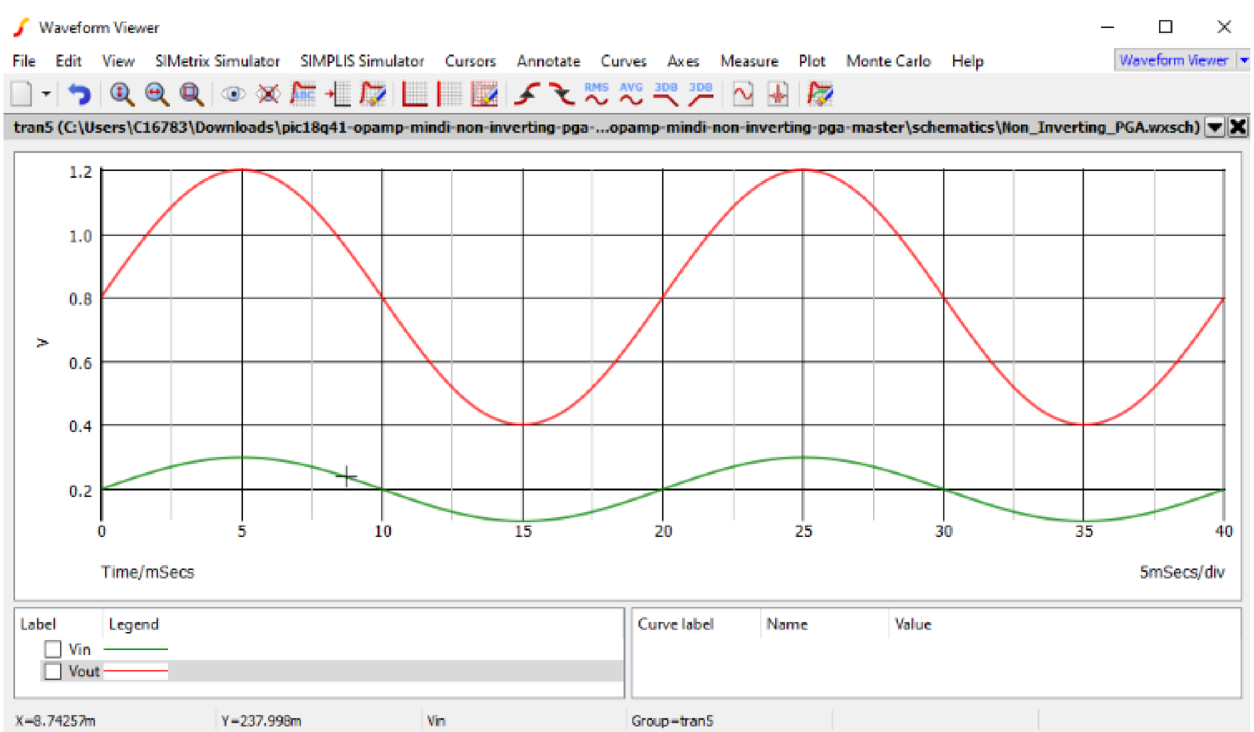
Mindi also allows users to probe circuits interactively in real time, allowing them to view a variety of different measurements and waveforms. Some of the interactive probe options can be found on the quick access toolbar in Mindi, but a complete list of the different interactive probes available can be viewed under the **Probe** tab.

To begin a simulation in Mindi, either press the play button located on the quick access toolbar or go to the **Simulator** tab and click **Run Schematic**. If there are any fixed probes placed in the circuit, the associated waveforms should appear once the simulation has completed.

There are several types of analysis available when running a simulation; they can be selected by clicking **Choose Analysis** under the **Simulator** tab on the top toolbar. In this example, a transient analysis of the operational amplifier input and output signal was performed over 40 ms. After an analog circuit has been successfully simulated, several different analysis options will populate on the Mindi toolbar and can be used to analyze the waveforms generated in greater detail.

These tools can be used for many functions, such as annotating simulation results, creating other graphs using the simulated data, or adding cursors and curves. Figure 3-1 shows the simulation results for the PIC18-Q41 non-inverting amplifier example that has been discussed up to this point. The waveforms generated represent the sinusoidal input source applied to the circuit (shown in green) and the operational amplifier output voltage (shown in red).

Figure 3-1. PIC18-Q41 Non-Inverting Amplifier Simulation Results



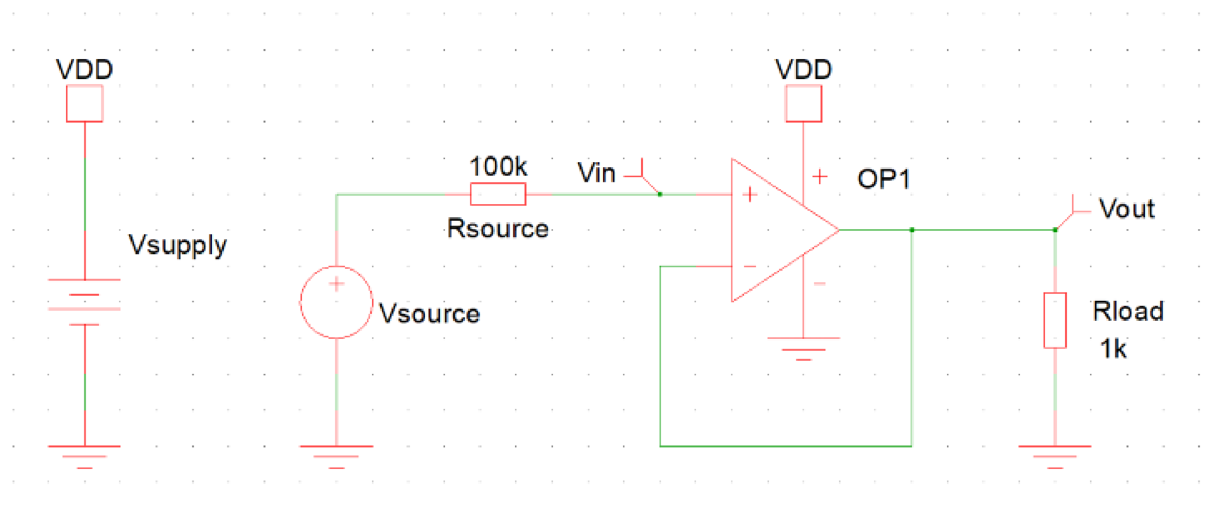
Tip: For more information about using the PIC18-Q41 Mindi model library to simulate a non-inverting amplifier, visit the PIC18-Q41 Non-Inverting Operational Amplifier Code Example.

4. PIC18-Q41 Unity Gain Buffer (Voltage Follower) Example

The operational amplifier peripheral found on the PIC18-Q41 family of devices is a versatile feature and can be used in many different configurations, depending on the application. The previous example demonstrated how Mindi could be used to simulate a non-inverting amplifier circuit utilizing the PIC18-Q41 model library provided alongside this device family. This example will demonstrate how Mindi can be used to simulate the operational amplifier on the PIC18-Q41 when it is configured as a unity gain buffer.

A unity gain buffer is an operational amplifier configuration commonly used in analog signal conditioning circuits. Unity gain buffers ideally have a gain of 1, and the inverting input is connected directly to the operational amplifier output to provide feedback. Figure 4-1 shows the complete schematic used in Mindi to simulate this circuit using the PIC18-Q41 operational amplifier library model.

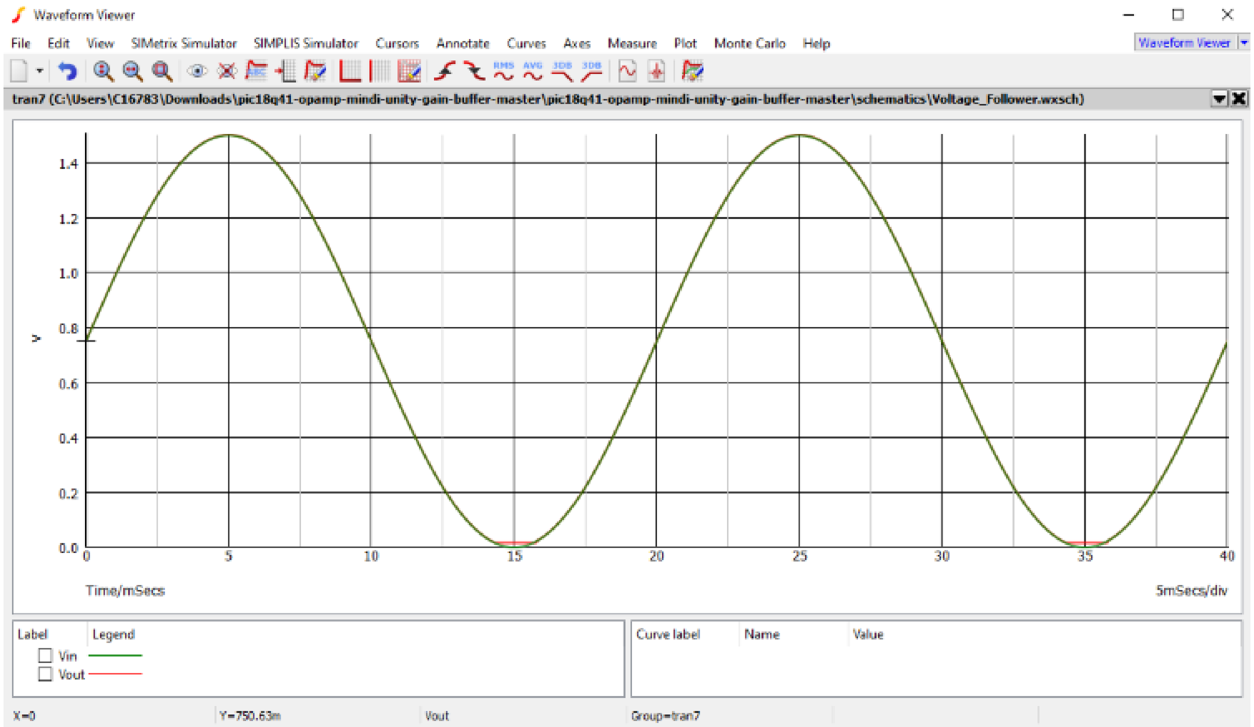
Figure 4-1. PIC18-Q41 Unity Gain Buffer Mindi Schematic



The simulation of this circuit was very similar to the previous example, where the transient response of the input and output of the operational amplifier was analyzed over 40 ms. The non-inverting amplifier example was designed to have a gain of 4, so the output signal may be four times larger than the input signal. The unity gain buffer in this example only has a gain of 1 and, by design, the input and output signals should have identical voltages. The input voltage source used in this simulation was set up to provide a sinusoidal waveform with an amplitude of 1.5V and an offset of 750 mV.

Figure 4-2 shows the simulation results for the PIC18-Q41 unity gain buffer. In this figure, the green waveform represents the operational amplifier input and the red waveform represents the operational amplifier output. The input and output waveforms of the operational amplifier overlap each other as they are equal due to the circuit configuration and expected gain of 1. For more information about using the PIC18-Q41 Mindi model library to simulate a Unity Gain Buffer (Voltage Follower), visit the PIC18-Q41 Unity Gain Buffer Code Example.

Figure 4-2. PIC18-Q41 Unity Gain Buffer Simulation Results



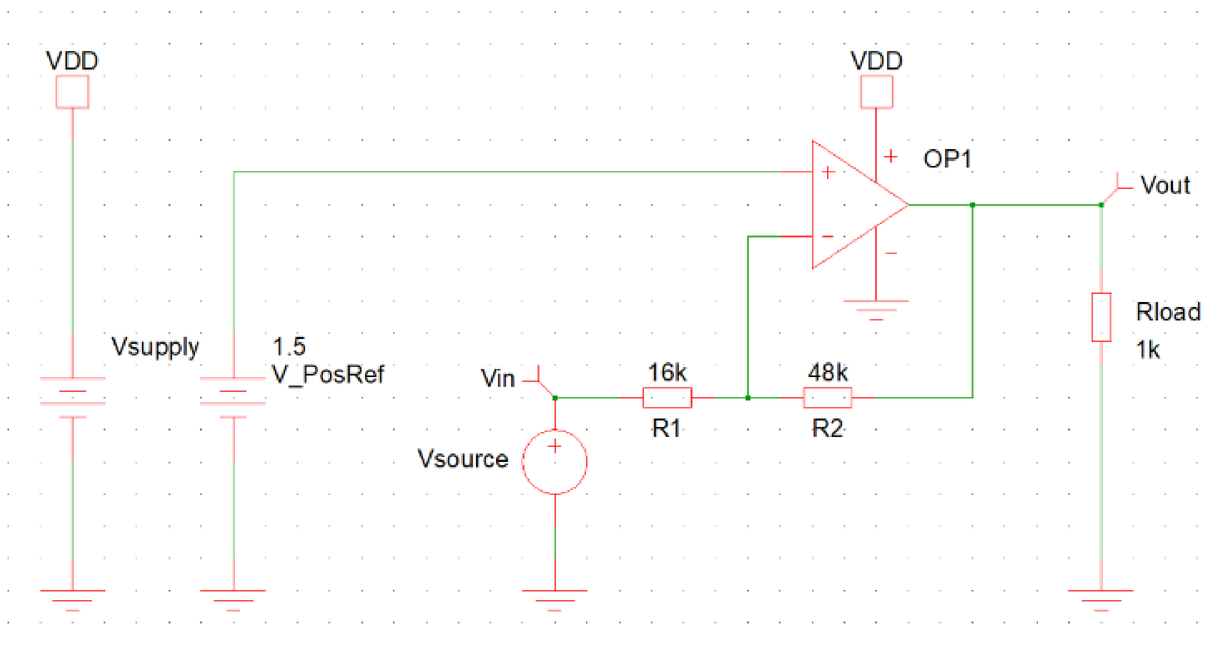
Tip: For more information about using the PIC18-Q41 Mindi model library to simulate a Unity Gain Buffer (Voltage Follower), visit the PIC18-Q41 Unity Gain Buffer Code Example.

5. PIC18-Q41 Inverting Amplifier Example

So far in this document, the PIC18-Q41 Mindi model has been used to simulate a non-inverting amplifier and a unity gain buffer when using the operational amplifier peripheral found on this device family.

This last example will demonstrate how Mindi can be used to simulate an inverting amplifier using the same model. An operational amplifier used in this configuration not only inverts the input signal, but also amplifies it depending on the feedback network of the circuit. Figure 5-1 shows the complete schematic used to simulate this design in Mindi.

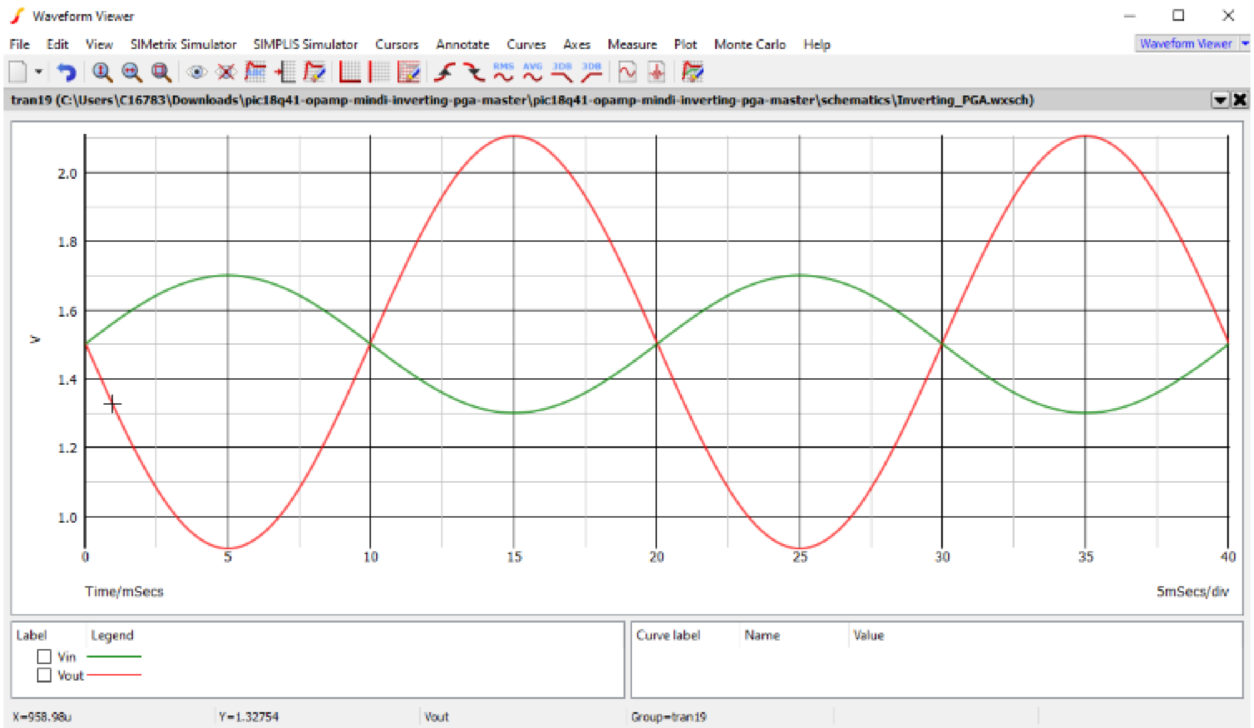
Figure 5-1. PIC18-Q41 Inverting Amplifier Mindi Schematic



In this example, Mindi was used to simulate the sinusoidal input signal and the resulting transient response of the operational amplifier over a time of 40 ms. A bias voltage of 1.5V was connected to the non-inverting input of the operational amplifier, and a sinusoidal input with an amplitude of 400 mV and an offset of 1.5V was connected to the inverting input, along with the feedback network illustrated in the circuit shown above.

Figure 5-2 shows the simulation results of this circuit using the PIC18-Q41 Mindi model. The green waveform represents the input voltage source connected to the operational amplifier, and the red waveform shows the resulting signal from the operational amplifier output.

Figure 5-2. PIC18-Q41 Inverting Amplifier Simulation Results



Tip: For more information about using the PIC18-Q41 Mindi model library to simulate a Unity Gain Buffer (Voltage Follower), visit the PIC18-Q41 Inverting Operational Amplifier Code Example.

6. Conclusion

The MPLAB Mindi Analog Simulator is a versatile tool that allows users to easily prototype and simulate analog circuits and designs. Pairing this tool with the operational amplifier Mindi model libraries provided with select PIC and AVR microcontrollers takes prototyping and modeling analog circuits to the next level. By using the model libraries provided with these device families, analog circuits utilizing the operational amplifier peripheral can be simulated and the models generated can be analyzed in greater depth to ensure the design is valid before implementing in hardware.

This technical brief provided a general overview of the MPLAB Mindi Analog Simulator and used a set of examples to demonstrate how the PIC18-Q41 model library can be used to prototype designs. For more information, visit www.microchip.com or view the device data sheet.

7. Revision History

Doc. Rev.	Date	Comments
A	12/2020	Initial document release.

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