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StudentZone—ADALM2000 Activity: Making an Operational Amplifier from Previous Blocks

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Objective

By combining the circuit blocks already explored in previous StudentZone articles, this activity helps build a complete high open-loop gain amplifier from a few discrete devices.

Materials

- ADALM2000 Active Learning Module
- Solderless breadboard
- Jumper wires
- One 8.2 kΩ resistor (a close approximation can be made by connecting your 1.5 kΩ and 6.8 kΩ in series)
- One 47 kΩ resistor
- One 100 kΩ resistor
- Two 470 kΩ resistors
- One 10 kΩ resistor
- One 1 kΩ resistor
- Two 22 µF capacitors
- One 1 µF capacitor
- One 47 nF capacitor
- One small signal PNP transistor (2N3906)
- Three small signal NPN transistors (2N3904, SSM2212)

Description

On your solderless breadboard, construct the amplifier circuit shown in Figure 1.

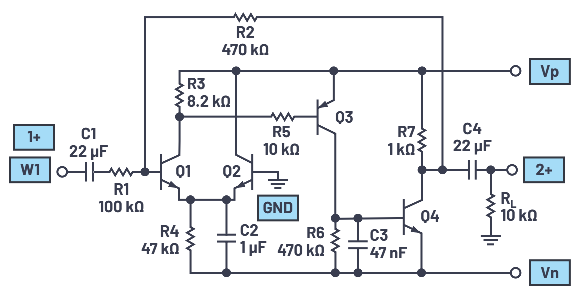


Figure 1. A high gain amplifier.

Hardware Setup

Connect your circuit to the ADALM2000 I/O connector as indicated by the blue boxes in Figure 1. It is best to ground the unused negative scope inputs when not being used. The SSM2212 NPN matched pair should be used for Q1 and Q2 transistors.

Procedure

Configure a waveform generator for a 1 kHz sine wave with an amplitude of 400 mV peak-to-peak and zero offset. Using Scope Channel 1 to observe the input at W1 and Scope Channel 2 to observe the output of the amplifier at R_L, record the input to output amplitude and phase relationship.

Configure the oscilloscope to capture several periods of the input and output signal, scaling the channels at a 500 mV/division.

An oscilloscope plot example is presented in Figure 3.

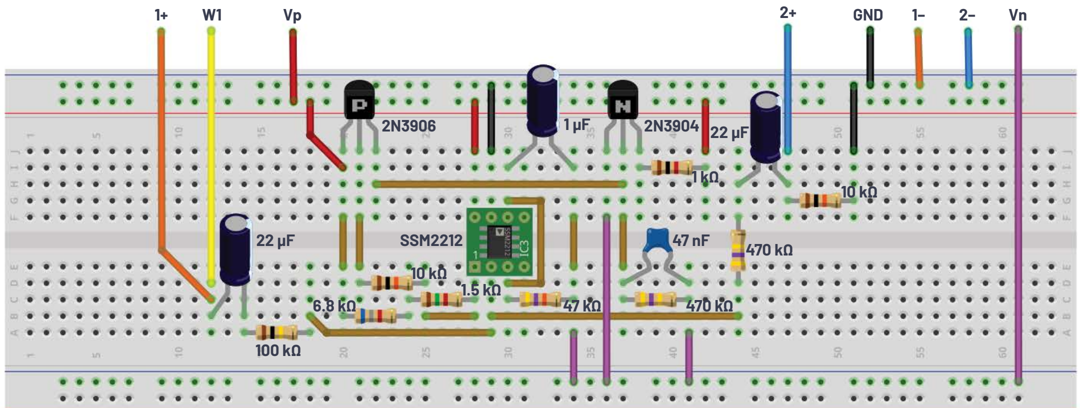


Figure 2. A high gain amplifier breadboard circuit.

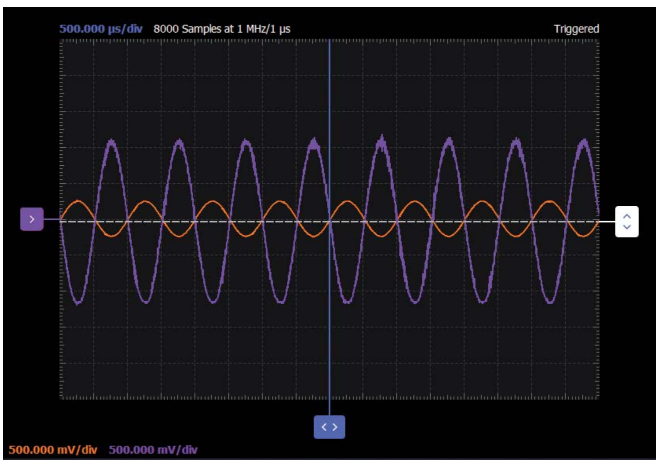


Figure 3. High gain amplifier waveforms.

Unity-Gain Amplifier

Objective

By combining some of the circuit blocks explored in previous articles, we can build a complete unity-gain buffer amplifier. The addition of the current mirror load for the differential stage is a key improvement to this simple amplifier.

Materials

- ADALM2000 Active Learning Module
- Solderless breadboard
- Jumper wires
- One 15 kΩ resistor (a 10 kΩ in series with a 4.7 kΩ can be substituted)
- Two small signal PNP transistors (2N3906 or an SSM2220 PNP match pair can be used)
- Six small signal NPN transistors (2N3904, use an SSM2212 NPN matched pair for Q1 and Q2; a TIP31C may be substituted for Q5 if you don't have enough 2N3904 devices)

Directions

Construct the circuit shown in Figure 4 on your solderless breadboard. Connect your circuit to the ADALM2000 I/O connector as indicated by the blue boxes. It is best to ground the unused negative scope inputs when not being used.

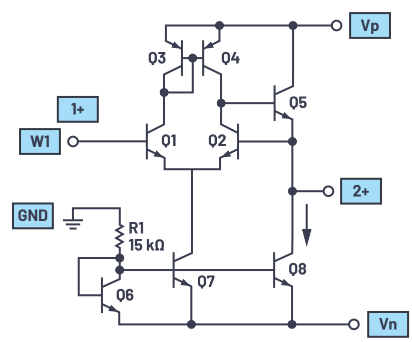


Figure 4. An amplifier with unity gain.

Hardware Setup

The breadboard connections of the circuit are shown in Figure 5.

Procedure

Configure AWG1 for a 1 kHz sine wave with an amplitude of 2 V peak-to-peak and zero offset. Using Scope Channel 1 to observe the input at W1 and Scope Channel 2 to observe the output of the amplifier, record the input to output amplitude and phase relationship.

Configure the oscilloscope to capture several periods of the input and output signal, scaling the channels at a 1 V/division.

An oscilloscope plot example is presented in Figure 6.

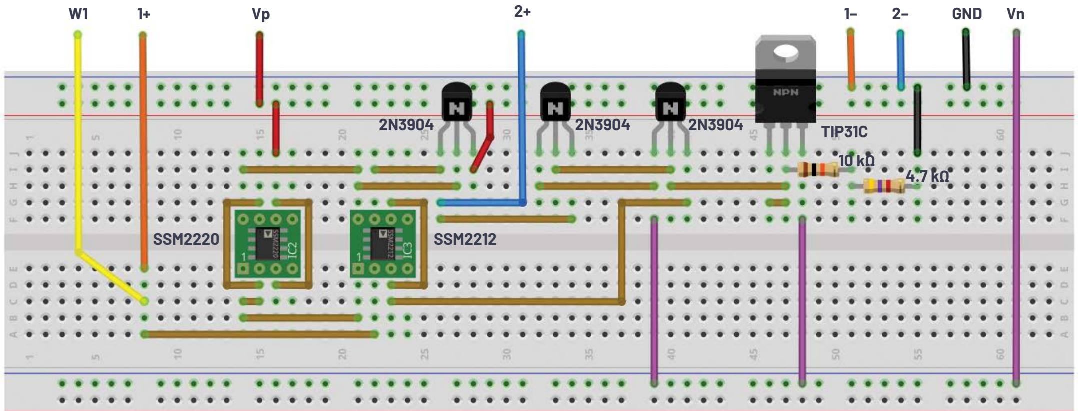


Figure 5. Voltage-to-frequency triangle wave generator breadboard connections.

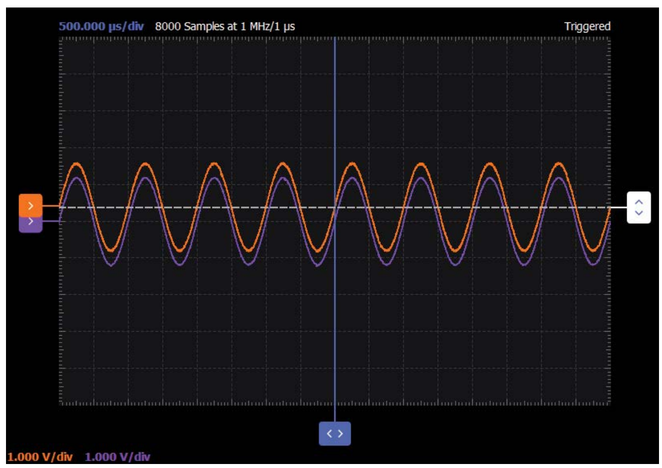


Figure 6. An amplifier with unity-gain waveforms.

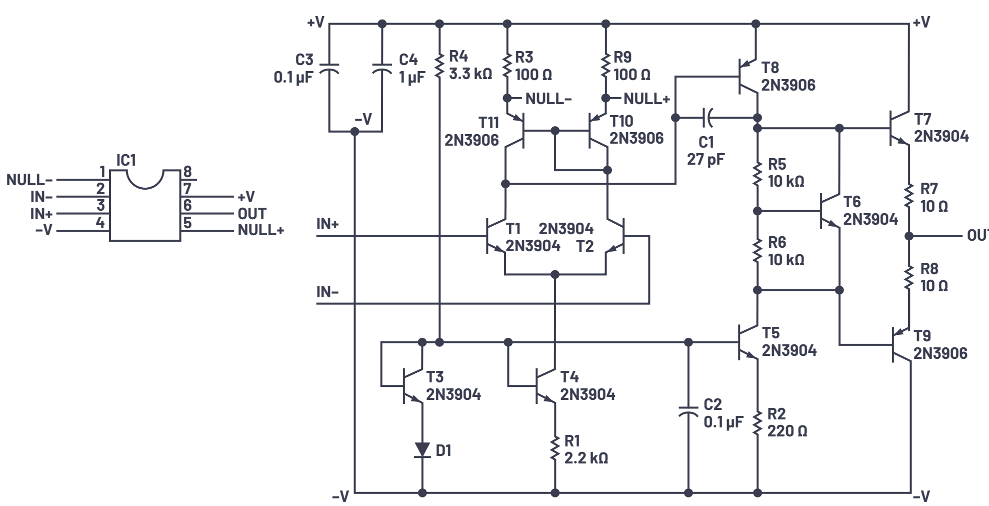


Figure 7. An operational amplifier PCB schematic.

Questions:

- For the circuit in Figure 1, what is the gain from the input source, W1, to the output seen at R_L? Which components set this gain?
- Change the value of compensation capacitor C3. How does raising and lowering the value of C3 affect the frequency response?

You can find the answers at the StudentZone blog.

Appendix: More Advanced Versions on a PC Board

PC board design files for this experiment and other related extensions can be found on the ADI GitHub education tool repository for experiment board design files. The PCB schematic is shown in Figure 7, and a photo of the board is shown in Figure 8.

The PCB uses the standard 8-pin DIP single op amp footprint and can be inserted into a solderless breadboard.

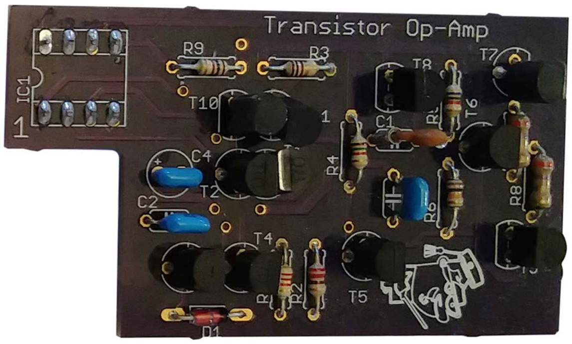
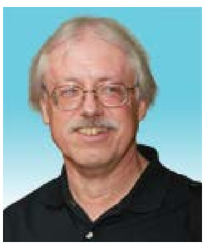


Figure 8. Operational amplifier PC board.



About the Author

Doug Mercer received his B.S.E.E. degree from Rensselaer Polytechnic Institute (RPI) in 1977. Since joining Analog Devices in 1977, he has contributed directly or indirectly to more than 30 data converter products and he holds 13 patents. He was appointed to the position of ADI Fellow in 1995. In 2009, he transitioned from full-time work and has continued consulting at ADI as a Fellow Emeritus contributing to the Active Learning Program. In 2016 he was named Engineer in Residence within the ECSE department at RPI. He can be reached at doug.mercer@analog.com.

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