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StudentZone—ADALM2000 Activity: Regulated Voltage References

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The objective of this activity is to build and investigate multiple types of voltage references/regulators in the following sections:

- Regulated Voltage Reference
- Enhanced Voltage Reference
- Shunt Regulator

Regulated Voltage Reference

Objective

The zero-gain amplifier (Q1, R2) and stabilized current source (Q2, R3) from the previous activities can be used in conjunction with a PNP current mirror stage (Q3, Q4) in negative feedback to build a circuit that provides a constant or regulated output voltage over a range of input voltages.

Materials

- ADALM2000 Active Learning Module
- Solderless breadboard
- One 2.2 kΩ resistor (or any similar value)
- One 100 Ω resistor
- Two small signal NPN transistors (2N3904 or SSM2212)
- Two small signal PNP transistors (2N3906 or SSM2220)

Directions

The breadboard connections are shown in Figure 1. The output of the AWG1 drives the emitters of both PNP transistors Q3 and Q4. Q3 and Q4 are wired as a current mirror with their bases connected with the collector of Q3. The collector of Q4 connects to resistor R1. Resistors R1 and R2, along with transistor Q1, are connected as shown in the November 2020 StudentZone activity, "ADALM2000 Activity: Zero-Gain Amplifier." Since the V_{BE} of Q2 is always smaller than the V_{BE} of Q1, you should select Q1 and Q2 from your inventory of devices such that (at the same collector current) Q2's V_{BE} is less than Q1's V_{BE}. The base of transistor Q2 is connected to the zero-gain output at the collector of Q1. The collector of Q2 connects to the input side of the PNP current mirror at the base and collector of Q3. The 2+ (single-ended) scope input is used to measure the output voltage at the collector of Q4.

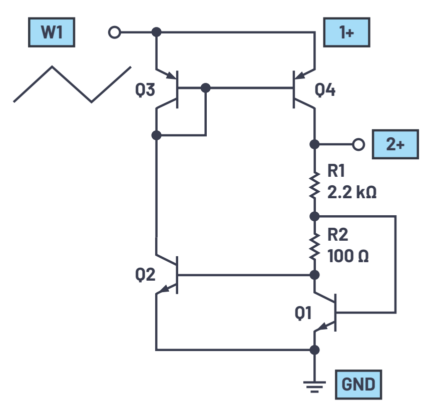

Figure 1. A regulator circuit.

Hardware Setup

Waveform Generator 1 should be configured for a 1 kHz triangle wave with 4 V amplitude peak-to-peak and 2 V offset. The single-ended input of Scope Channel 2 (2+) is used to measure the stabilized output voltage at the collector of Q4 (negative inputs 1– and 2– should be connected to ground).

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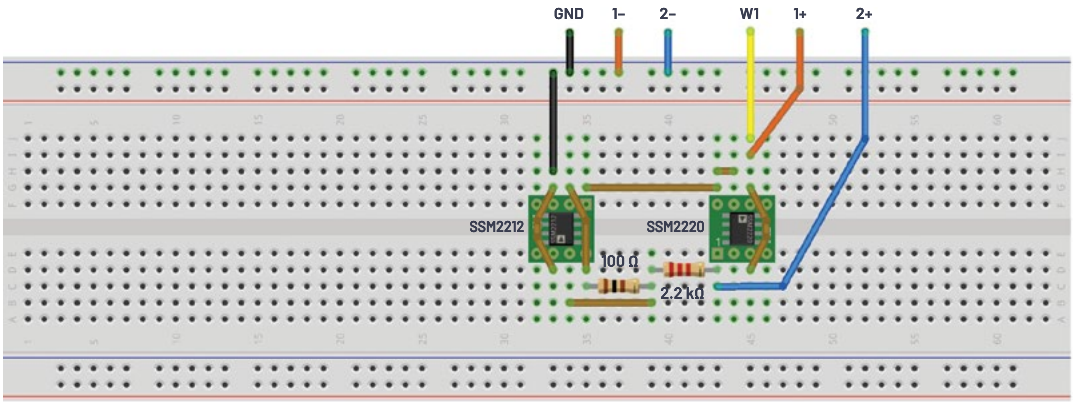


Figure 2. Regulator breadboard circuit.

Procedure

Plot the output voltage (as measured at the collector of Q4) vs. the input voltage. At what input voltage level does the output voltage stop changing/regulating? This is called the dropout voltage. For input voltages above the dropout voltage, how much does the output voltage change for each volt of change at the input? The change in V_{OUT}/change in V_{IN} is called line regulation. Connect a variable resistor from the output node to ground. With the input voltage fixed (that is, connected to the fixed Vp board power supply), measure the output voltage for various settings of the resistor. Calculate the current in the resistor for each setting. How does the output voltage vary vs. output current? This is called load regulation.

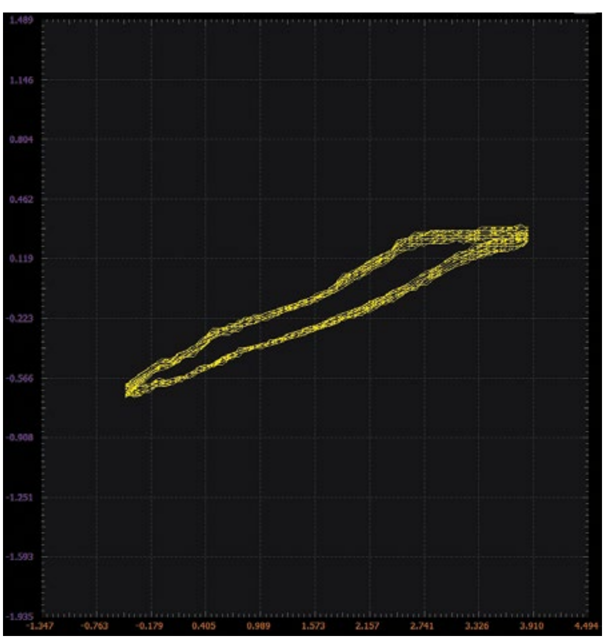


Figure 3. Regulator Scopy XY plot.

Enhanced Voltage Reference

Objective

The problem with the regulator circuit in the previous section is that the current available to an output load is limited by the feedback current supplied from NPN Q2 mirrored through PNPs Q3 and Q4. It would be desirable to build a circuit that provides a constant or regulated output voltage over not only a range of input voltages but also output load currents. This second circuit utilizes an emitter follower output stage to provide the current to the output.

Materials

- One 2.2 kΩ resistor
- One 100 Ω resistor
- One 10 kΩ variable resistor (potentiometer)
- One 4.7 kΩ resistor (resistors can be any similar value selected for desired circuit operation)
- Four small signal NPN transistors (2N3904 and SSM2212)

Directions

The breadboard connections are shown in Figure 4. As before, transistor Q1 and resistors R1 and R2 are configured as a zero-gain amplifier. Transistor Q2 and variable resistor R3 form a stabilized current source. If the SSM2212 matched NPN pair is used, it is best that it be used for devices Q1 and Q2. Common emitter stage Q3 and its collector load, R4, provide gain. Emitter follower Q4 drives the output node and closes the negative feedback loop.

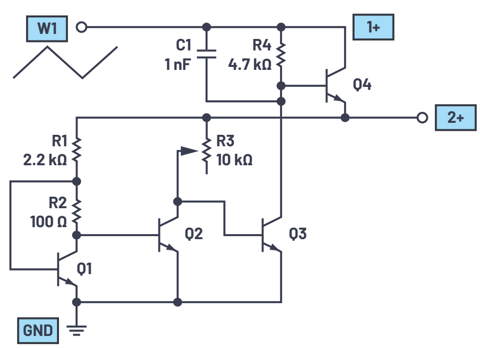


Figure 4. Enhanced regulator.

Hardware Setup

Waveform generator W1 should be configured for a 1 kHz triangle wave with 4 V amplitude peak-to-peak and 2 V offset. Scope Channel 2 (2+) is used to measure the stabilized output voltage at the emitter of Q4.

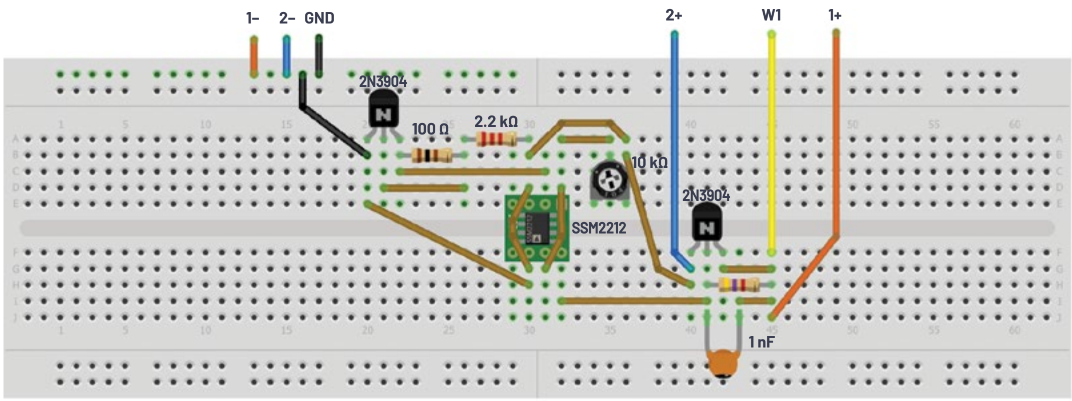


Figure 5. Enhanced regulator breadboard circuit.

Procedure

Repeat the dropout voltage, line, and load regulation measurements for this circuit. How are they different than the first regulator circuit?

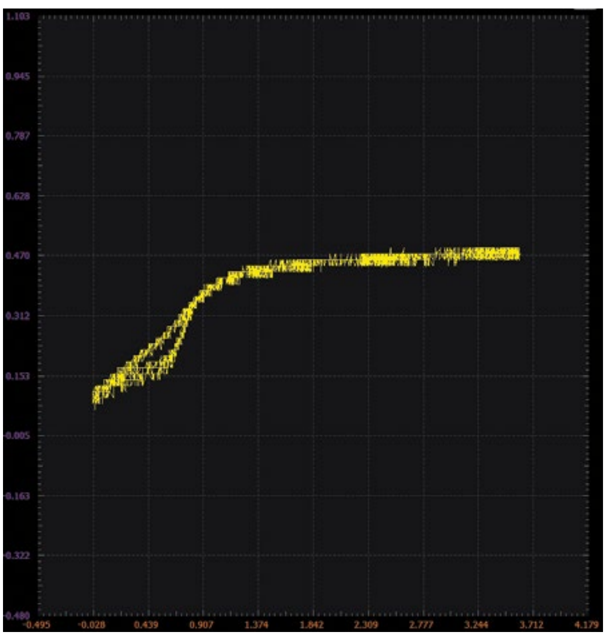


Figure 6. Enhanced regulator waveform XY plot.

Shunt Regulator

Objective

The zero-gain amplifier (Q1, R2) and stabilized current source (Q2, R3) can be used in conjunction with a common emitter amplifier stage (Q3) in negative feedback to build a 2-terminal circuit that provides a constant or regulated output voltage over a range of input currents.

Materials

- ADALM2000 Active Learning Module
- Solderless breadboard
- Jumper wires
- One 2.2 kΩ resistor (or any similar value)
- One 100 Ω resistor
- One 1 kΩ resistor (or similar value)
- One 10 kΩ variable resistor (potentiometer)
- Three small signal NPN transistors (2N3904 and SSM2212)

Directions

The breadboard connections are shown in Figure 7. The output of the function generator drives one end of resistor R4. Resistors R1 and R2, as well as transistor Q1, are connected as shown in the November StudentZone article, "ADALM2000 Activity: Zero-Gain Amplifier (BJT)." Resistor R3 and transistor Q2 are added as shown in the January 2021 article, "ADALM2000 Activity: Stabilized Current Source." If the SSM2212 matched NPN pair is used, it is best that it be used for devices Q1 and Q2. Q3 is added with its emitter grounded, its base connected to the collector of Q2, and its collector connected to the node that combines R1, R3, R4, and Scope Input 2+.

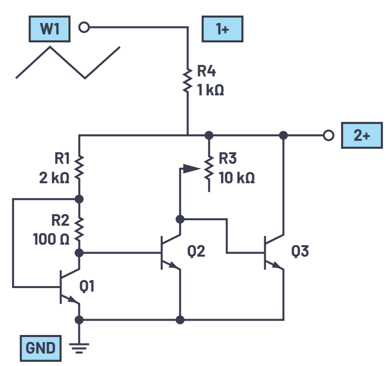


Figure 7. Band gap shunt regulator.

Hardware Setup

Waveform generator W1 should be configured for a 1 kHz triangle wave with 4 V amplitude peak-to-peak and 2 V offset. The single-ended input of Scope Channel 2 (2+) is used to measure the regulated output voltage at the collector of Q3.

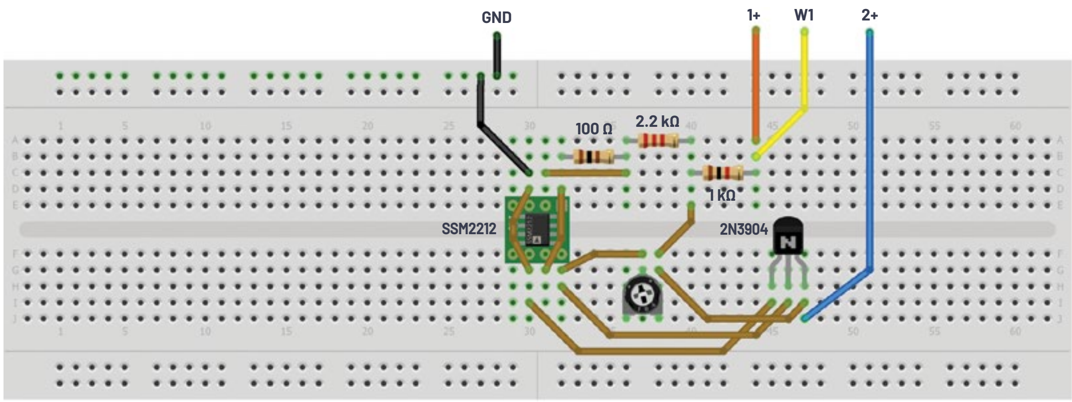


Figure 8. Band gap shunt regulator breadboard circuit.

Procedure

Configure the oscilloscope instrument to capture several periods of the two signals measured. Make sure to enable the XY feature. Plot examples using the oscilloscope are provided in Figure 9. The regulated output voltage should be observed as the variable resistor R3 is adjusted.

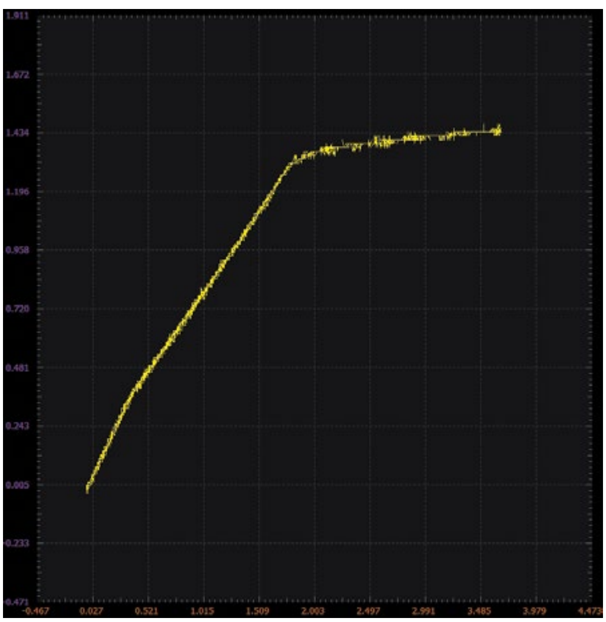


Figure 9. Output voltage vs. input voltage

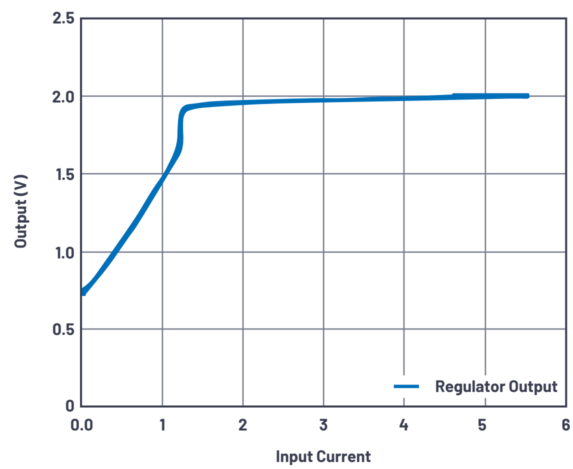
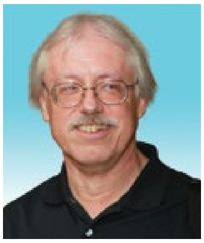


Figure 10. An output voltage vs. input current plot example.

Question:

What affects the regulated output voltage as a load to ground is applied to the output voltage of the band gap shunt regulator?

You can find the answer at the StudentZone blog.



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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