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Circuit Note
CN-0005

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Devices Connected/Referenced	
ADR127	Micropower LDO Voltage Reference
AD8603	Micropower, Low Noise CMOS Operational Amplifier

Generating a Negative Precision Reference Without Precision Resistors

CIRCUIT FUNCTION AND BENEFITS

A traditional method for generating a negative reference from a positive reference is to simply use an inverting op amp. This approach requires two precision matched resistors. Errors in the matching will produce errors at the final output. The circuit described in this document is used to generate a negative precision reference without the use of precision resistors, thereby providing higher accuracy with fewer components.

CIRCUIT DESCRIPTION

This circuit utilizes the ADR127, a 1.25 V, high precision series voltage reference, and the AD8603, a low noise, low distortion, low offset operational amplifier. The ADR127 provides a highly accurate 1.25 V output. The AD8603 is an ideal complementary product, since it uses very low power, has excellent PSRR, and can operate off of a supply voltage as low as 1.8 V. In this circuit, the lowest allowable power supply voltage is 3 V (±1.5 V) to maintain sufficient headroom for both the reference and the op amp.

Notice that the ADR127 reference is floating, with its input connected to the $+V_{DD}$ supply, its output connected to the inverting input of the AD8603 (through a 1 kΩ isolation resistor), and the ADR127 GND pin connected to the AD8603 output. (The circuit will not work if the ADR127 GND pin is connected to the actual circuit board ground plane.) In this configuration, the ADR127 acts as a 1.25 V voltage source connected inside the feedback loop of the op amp. Negative feedback forces the op amp output to −1.25 V. The only errors in the output voltage are those due to the input offset voltage of the op amp and the error due to the reference itself. The error due to the bias current flowing through the 1 kΩ resistor is negligible since the op amp is CMOS and has extremely low input bias current. The op amp selected must, therefore, have low offset voltage and a rail-to-rail output if the negative supply voltage is close to the reference output.

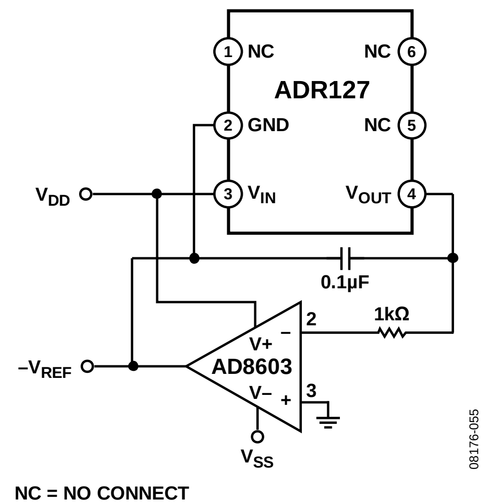

Figure 1. Circuit to Generate a Negative 1.25 V Reference Voltage

Headroom issues relating to the reference and the op amp must be considered in this circuit for proper operation. The V_{DD} supply must be large enough so that the headroom requirement of the reference is met. The ADR127 requires a supply voltage headroom of at least 1.45 V ($V_{IN} – V_{OUT}$); therefore, V_{DD} should be at least 1.5 V (allowing 50 mV margin). The requirement on the negative supply is determined by the op amp output stage headroom requirement. The AD8603 has a rail-to-rail output stage; but, even so, at least several hundred millivolts output headroom should be allowed in this circuit. The AD8603 must output −1.25 V, so a V_{SS} of at least −1.5 V should be used, providing an output headroom of 250 mV. As long as the headroom requirements are met, any supply voltage between ±1.5 V and ±2.5 V can be used. The AD8603 is specified for a 5 V supply and has an absolute maximum supply voltage of 6 V, or ±3 V, when using symmetrical supplies.

The 0.1 µF capacitor decouples the reference between its input and output pins. The 1 kΩ resistor isolates the capacitor from the inverting input of the op amp. A low inductance 0.1 µF ceramic decoupling capacitor (not shown in the figure) should

Rev. A

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be connected to V_{DD} very close to the two ICs. In most cases, the final output of the op amp ($-V_{REF}$) will be heavily decoupled, which means that the op amp selected must be stable with large capacitive loads. A typical decoupling network consists of a 1 µF to 10 µF electrolytic capacitor in parallel with a 0.1 µF low inductance ceramic MLCC type.

COMMON VARIATIONS

The circuit is proven to work with good stability and accuracy with component values shown. Other ADI voltage references and precision op amps can be used in this configuration to develop negative references with other desired values.

When selecting reference and amplifier combinations, always ensure that the Supply Voltage Headroom specification ($V_{IN} - V_{OUT}$) of the reference is not violated. Since the reference $V_{OUT} = 0$, the minimum value of $+V_{DD}$ must be equal to or greater than the Supply Voltage Headroom. For example, to generate a −5 V reference using the ADR365 precision 5 V reference, we need a $+V_{DD}$ of at least 5.3 V, since the Supply Voltage Headroom specification of the ADR365 is 300 mV. The amplifier must supply a negative 5 V at its output, so in this case a good choice for the amplifier would be the AD8663 16 V, low noise, precision, rail-to-rail op amp. V_{SS} should be set at −5.5 V (to allow 0.5 V negative output headroom), and V_{DD} can range anywhere from 5.3 V to 10.5 V, due to the 16 V supply range of the AD8663. In most cases the supplies are symmetrical, so V_{DD} = +5.5 V and V_{SS} = −5.5 V would be good choices.

The ADR121 can be used with an appropriate op amp to generate a −2.5 V reference. Since the op amp must output a voltage of −2.5 V, a V_{SS} of at least −2.8 V should be used (assuming a rail-to-rail output stage). V_{DD} must be at least +0.3 V to meet the minimum $V_{IN} - V_{OUT}$ requirement of the ADR121. If the AD8603 is used, V_{DD} should be no higher than +2.2 V so that the total supply voltage across the AD8603 is no greater than 5 V. If symmetrical 2.8 V supplies or higher are required (±5 V, for example), an op amp with a higher supply voltage must be chosen.

LEARN MORE

Jung, Walter G. 2002. *Op Amp Applications*. Analog Devices. ISBN 0916550265. Chapter 7. Also available as *Op Amp Applications Handbook*. Elsevier/Newnes. 2005. ISBN 0750678445. Chapter 7, http://www.analog.com/library/analogDialogue/archives/39-05/op_amp_applications_handbook.html.

Kester, Walt. 2004. *Analog-Digital Conversion*. Analog Devices. ISBN 0916550273. Chapter 9. Also available as *The Data Conversion Handbook*. Elsevier/Newnes. 2005. ISBN 0750678410, Chapter 9, http://www.analog.com/library/analogDialogue/archives/39-6/data_ conversion_handbook.html.

Zumbahlen, Hank. 2006. *Basic Linear Design*. Analog Devices. ISBN 0915550281. Chapter 11. Also available as *Linear Circuit Design Handbook*. Elsevier-Newnes, 2008, ISBN 0750687037, Chapter 11, http://www.elsevierdirect.com/product.jsp?isbn=9780750687034&ref=CWS1.

Data Sheets

ADR127 Data Sheet. http://www.analog.com/en/ADR127/productsearch.html.

AD8603 Data Sheet. http://www.analog.com/en/AD8603/productsearch.html.

REVISION HISTORY

4/09—Rev. 0 to Rev. A

Updated Format .... Universal

10/08—Revision 0: Initial Version

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