Keywords: Initial accuracy, digital pots, potentiometer, end-to-end tolerance, resistance, voltage, dividers, ratiometric, ratio, steps, LSB, taps, error, temperature, coefficient, series resistor, noise, change, reference, buffer, amplifier

APPLICATION NOTE 4290

Ratiometric Design Overcomes the 25% Tolerance of a Digital Potentiometer

By: Bill Laumeister, Strategic Applications Engineer
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Abstract: This application note explains how to eliminate the voltage change when a digital potentiometer is used as a voltage-divider in series with other resistors.

Introduction

Mechanical and electronic digital potentiometers tend to have loose end-to-end tolerances. Maxim digital pots typically have a 20% to 30% resistance tolerance. The resistance tolerance can be problematic when the digital pot is used as a voltage-divider in series with other resistors. That configuration will result in an unacceptable voltage change over tolerance.

This application note discusses a ratiometric method to convert that resistance tolerance into an acceptable current change. The proposed design also effectively removes the voltage change. In the circuit presented here the voltage output depends only on the ratio of the steps of the pot. The temperature coefficient is better controlled in the design.

Ratiometric Method for the Design

The design challenge is straightforward: a variable voltage between 3V and 4.5V with a tolerance of 3%. Start with the schematic in **Figure 1** and do the math. The digital pot is 50kΩ (25% tolerance); R1 is 16.5K (1%) and R2 is 100K (1%). The 25% tolerance of the pot's end-to-end resistance will dominate in this design.

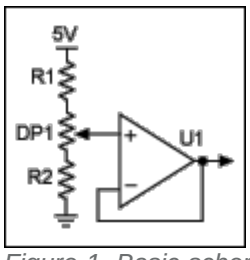

Figure 1. Basic schematic.

Now consider the same design with a different pot. If the pot is 37.5kΩ, the top of the pot is 4.46V and the bottom is 3.25V. Continuing on, if the pot is 62.5kΩ, the top of the pot is 4.54V and the bottom is 2.79V. This basic approach does not solve the changing voltage problem because the pot's end-to-end tolerance is in the circuit.

The next circuit in **Figure 2** only uses the pot's ratio.

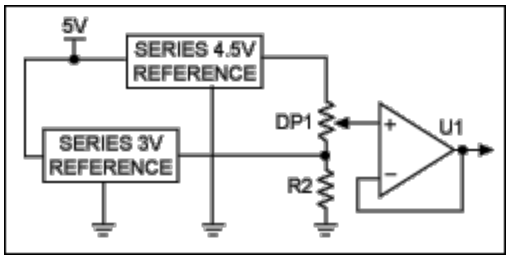

Figure 2. Alternate design features two voltage references.

By using two voltage references the tolerances and the temperature coefficient are controlled. The absolute end-to-end tolerance of the digital pot changes the current, but does not affect the voltage. The output voltage is ratiometric; the voltage out depends *only* on the ratio of the steps of the pot.

Both references use feedback to control the output voltage. R2 (~25K to 50K) ensures that both references source current. Bypass capacitors are discussed in the data sheet for each Maxim digital pot. Some capacitors may be required, depending on the board layout.

Ultimately, an application dictates the system's requirements. Device temperature coefficients can be predicted from the respective digital pot data sheets. The pots also offer a choice of noise specifications. Maxim's complete list of digital pots and voltage references is available on the website.

Related Parts		
DS1805	Addressable Digital Potentiometer	Free Samples
MAX5160	Low-Power Digital Potentiometers	Free Samples
MAX5161	Low-Power Digital Potentiometers	Free Samples
MAX5400	256-Tap SOT-PoT, Low-Drift Digital Potentiometers in SOT23	Free Samples
MAX5463	32-Tap FleaPoT™, 2-Wire Digital Potentiometers	Free Samples
MAX5464	32-Tap FleaPoT™, 2-Wire Digital Potentiometers	Free Samples
MAX5465	32-Tap FleaPoT™, 2-Wire Digital Potentiometers	Free Samples
MAX6023	Precision, Low-Power, Low-Dropout, UCSP Voltage Reference	Free Samples
MAX6029	Ultra-Low-Power Precision Series Voltage Reference	Free Samples
MAX6045A	Precision, Low-Power, Low-Dropout, SOT23-3 Voltage References	

MAX6045B	Precision, Low-Power, Low-Dropout, SOT23-3 Voltage References	
MAX6063A	Precision, Micropower, Low-Dropout, High-Output-Current, SOT23 Voltage References	Free Samples
MAX6063B	Precision, Micropower, Low-Dropout, High-Output-Current, SOT23 Voltage References	
MAX6067B	Precision, Micropower, Low-Dropout, High-Output-Current, SOT23 Voltage References	Free Samples
MAX6103	Low-Cost, Micropower, Low-Dropout, High-Output-Current, SOT23 Voltage References	Free Samples
MAX6107	Low-Cost, Micropower, Low-Dropout, High-Output-Current, SOT23 Voltage References	Free Samples
MAX6145	SOT23, Low-Cost, Low-Dropout, 3-Terminal Voltage References	Free Samples

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