

Get Precision Performance from a Digitally Controlled Potentiometer (DCP)

Introduction

The resistance accuracy of a polysilicon DCP is typically within the $\pm 20\%$ range. However, the relative accuracy or matching of the resistive elements in the particular resistor array is excellent, and is usually within $\pm 1\%$ or better. Therefore, this discrepancy between relative and total accuracy must be carefully calculated during the design stage to avoid or minimize an additional adjustment of the application circuitry in production. This application note discusses how the DCP accuracy affects the design and some techniques to improve final system accuracy.

DCPs are commonly used in two ways in application designs such as a voltage divider and as a variable resistor.

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1. Voltage Divider Mode

A DCP used as a voltage divider with the R_H and R_L terminals connected to the voltage rails, the final accuracy of the wiper R_W depends only on the internal resistance matching and is the same from part to part, regardless of their total resistance accuracy. This is because of the division of voltage between R_H and R_L terminals between a particular number of taps, that is, scaled among n numbers of equal resistive elements in the divider string.

[Equation 1](#) and [Equation 2](#) calculate the output voltage V_{OUT} for the wiper position m , shown in the configuration of [Figure 1](#).

(EQ. 1)
$$V_{OUT} = \frac{V_{IN}}{R_{TOTAL}} \times \frac{R_{TOTAL}}{n-1} \times m$$

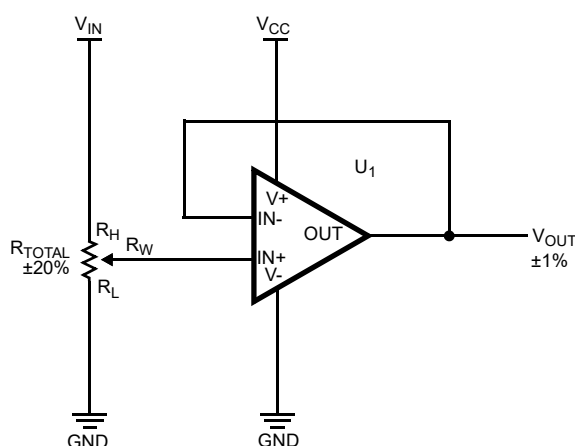


Figure 1. High-Accuracy Voltage Divider

or:

$$(EQ. 2) \quad V_{OUT} = \frac{V_{IN}}{n-1} \times m$$

Where, m is a current wiper position and n is a total number of taps. Seen from Equation 2, the resistance accuracy cancels out and has no effect on V_{OUT} .

However, if a DCP has another resistor(s) on its R_H and/or R_L terminal, the accuracy of the output signal becomes a function of the initial accuracy of the DCP. This is because the scaled factor is not equal among the divider string, Figure 2.

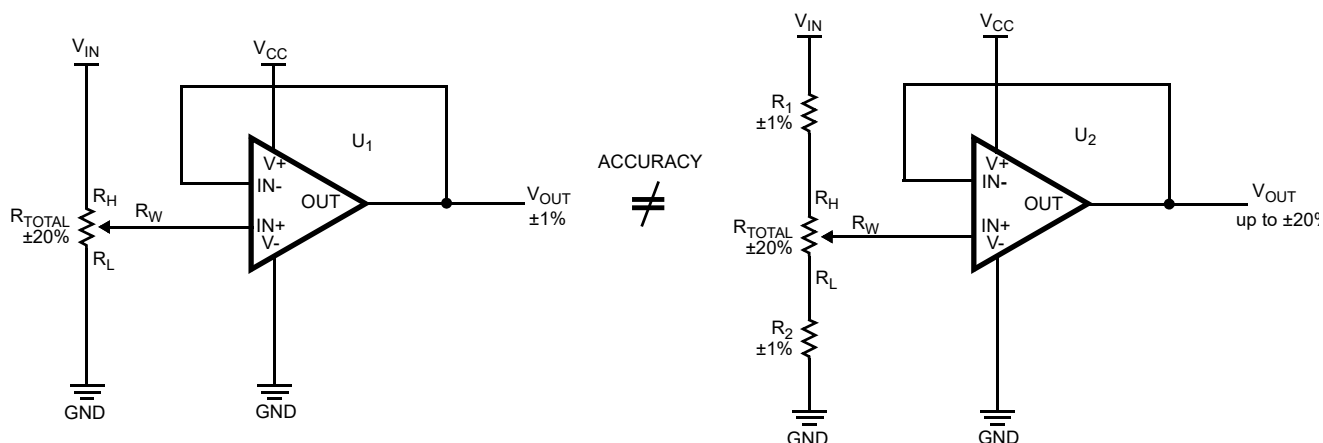


Figure 2. Example of Accuracy Inequality

The output function for the circuitry with R_1 and R_2 in Figure 2 shown in Equation 3:

$$(EQ. 3) \quad V_{OUT} = \frac{V_{IN}}{R_1 + R_{TOTAL} + R_2} \times \left(R_2 + \frac{R_{TOTAL}}{(n-1)} \times m \right)$$

Where n is the total number of taps and m is the current wiper position.

The wiper resistance is not included, because it has no effect in this particular configuration, assuming an ideal op amp.

2. Rheostat Mode

A combination of initial accuracy ($\pm 20\%$) and an additional error from wiper resistance determines the output accuracy of a DCP when used as a variable resistor, because the wiper switch is not ideal (it has a resistance, around 70Ω) and its value can vary among the taps. The effect of wiper resistance is reduced in a rheostat configuration, For example: when the wiper connects to one of the end terminals (see Figure 3).

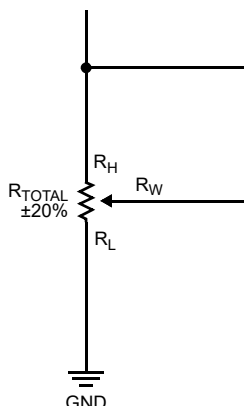


Figure 3. Rheostat/Variable Resistor Configuration (A)

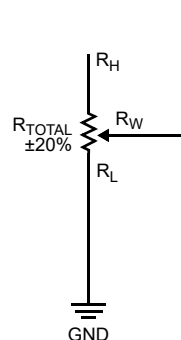


Figure 4. Rheostat/Variable Resistor Configuration (B)

In rheostat configuration (Figure 3), wiper resistance appears in parallel with the part of the resistor string and its effect depends on the selected wiper position.

Another configuration leaves one of the end terminals floating as shown in Figure 4. In this case, the datasheet provides a graph that makes calculation of the total resistance at each tap easier. Use Equation 4 to calculate resistance at tap m .

$$(EQ. 4) \quad R_m = \frac{R_{TOTAL}}{n-1} \times m + R_{WIPER} + R_{OFFSET}$$

3. Design Examples for Improving Circuitry Accuracy

The initial accuracy of the regular DCP is in $\pm 20\%$ range, the application accuracy can be improved using specific techniques. Modify the design in Figure 2 to get higher accuracy, as shown in Figure 5.

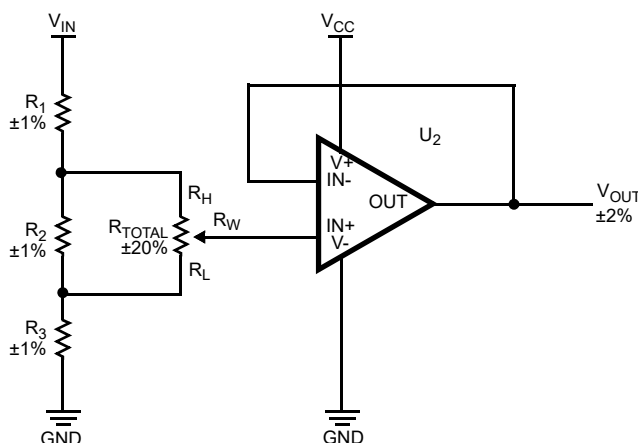


Figure 5. Example of Increased Accuracy in Voltage Divider Mode

In Figure 5, the string of fixed resistors R_1 , R_2 , and R_3 divides the input signal V_{IN} , and a DCP is in parallel with R_2 . This configuration preserves the flexibility of the variable output with higher accuracy. To achieve the required accuracy, the value of R_{TOTAL} must be about five to ten times the value of R_2 .

Combine the DCP with high-precision fixed resistors in parallel and serial configuration using the DCP as a variable resistor to obtain better accuracy, Figure 6.

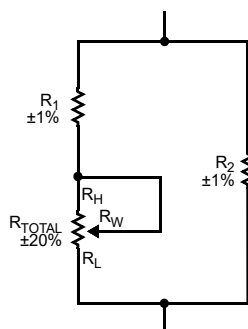


Figure 6. DCP in Both Serial and Parallel Configuration with Fixed Resistors

Use $\pm 20\%$ 10k 256-taps DCP and circuitry as shown in Figure 6 to get a variable resistor from 5.5k Ω to 10.695k Ω with accuracy ranging from $\pm 1.1\%$ to $\pm 8.5\%$ (see Table 1).

Table 1. DCP in Both Serial and Parallel Configuration with Fixed Resistors

	DCP Rtotal (k Ω)	R1 (k Ω)	R2 (k Ω)	Minimum Total Resistance, DCP At Tap 1 (k Ω)	Maximum Total Resistance, DCP At Tap 255 (k Ω)	Step Resolution (k Ω)	Total Accuracy For Tap 1	Total Accuracy For Tap 255
Min	8	6.742	29.106	5.495	9.786	0.021	-1.08%	-8.50%
Nom	10	6.81	29.4	5.555	10.695	0.026		
Max	12	6.878	29.694	5.615	11.541	0.031	1.08%	7.90%

The ISL22317 has a 1% precision, non-volatile, 128-tap DCP available with the resistance options of 10k Ω , 50k Ω , and 100k Ω , and it can be configured either as a two-terminal variable resistor or as a three-terminal potentiometer. The ISL22317 provides high accuracy, 0 Ω wiper resistance and low temperature coefficient, eliminating any requirement for complex precision algorithms and additional circuitry.

DCPs are an alternative to the Digital Analog Converters (DACs). When a design requires fine tuning within limited range, use an 8-bit DCP to achieve a better resolution than a 10-bit DAC. The DCP resolution table as a function of terminal voltages and number of taps is shown in Table 2.

Table 2. DCP Resolution per Tap^[1]

Differential Terminal Voltages: VH-VL	16 Taps	32 Taps	64 Taps	100 Taps	128 Taps	256 Taps	1024 Taps
	4 Bits	5 Bits	6 Bits	7 Bits	7 Bits	8 Bits	10 Bits
10V	667	323	159	101	79	39	10
9V	600	290	143	91	71	35	9
8V	533	258	127	81	63	31	8
7V	467	226	111	71	55	27	7
6V	400	194	95	61	47	24	6
5.5V	367	177	87	56	43	22	5
5V	333	161	79	51	39	20	5
4V	267	129	63	40	31	16	4
3V	200	97	48	30	24	12	2.9
2V	133	65	32	20	16	8	2.0
1V	67	32	16	10	8	3.9	1.0
0.5V	33	16	8	5	3.9	2.0	0.5

1. Resolution (chart specifies LSB in mV/tap)

4. Revision History

Revision	Date	Description
2.00	Oct 15, 2026	▪ Applied latest template ▪ Added Revision History section
1.00	Jun 5, 2009	Removed $\pm 1\%$ from V_{out} Figure 2 (from circuit on right hand side) Changed V_{out} from $\pm 1\%$ to $\pm 2\%$ in Figure 4
0.00	Sep 29, 2008	Initial release

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