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## When potentiometers go to pot



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Potentiometers (**pot** s) can be used as position sensors or to adjust circuits for proper operation. They function best as an **adjustable voltage divider**. They can also be used as an **adjustable resistor** but with some potential pitfalls. Do you know the difference?

Used as an *adjustable voltage divider* , the absolute resistance value of the pot does not affect the output voltage. The output voltage is *ratimetric* with  $V_{in}$ . Most common potentiometers have relatively poor resistance accuracy and temperature coefficient. But if

the resistor element is homogenous, at 30% rotation you will get 30% of the applied voltage, regardless of its absolute resistance or temperature coefficient. Assuming the wiper is connected to high impedance circuitry, wiper contact resistance doesn't affect the output voltage. *Wiper contact resistance* is the resistance at the contact point of the wiper to the resistance element.

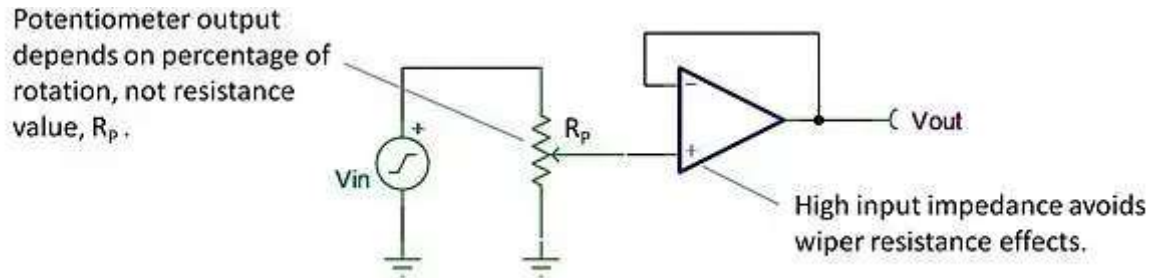





Figure 1.

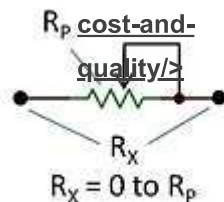
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But if you use a pot as a variable resistor, figure 2, its resistance accuracy and temperature coefficient can affect your circuits. Wiper contact resistance affects the resistance in the circuit and it can vary with position, temperature, vibration and age.

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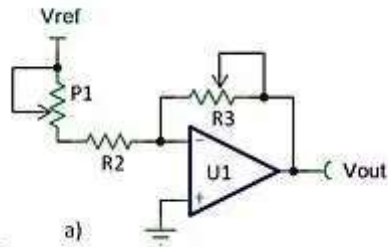
Potentiometer Connected as Variable Resistor

- $R_x$  and range affected  $R_p$
- $R_x$  affected by wiper resistance

Figure 2.

Sometimes a variable resistor is required but it's often possible to design circuits that use the pot in a ratiometric mode. Figure 3 shows two circuits that perform similar functions. Circuit 3a uses P1 as a variable resistor, creating a variable negative-going voltage at U1's output, linear with position of the pot. This circuit requires gain adjustment with R3 because of the wide resistance tolerance of P1. Furthermore, linearity and repeatability of the output voltage with pot position may be affected by wiper contact resistance.

Variable Resistor Connection



Ratiometric Connection

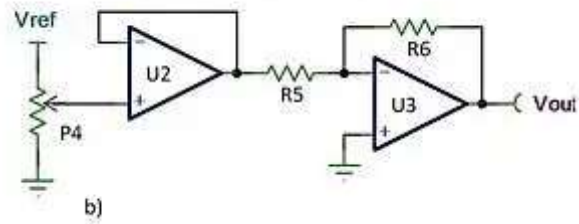


Figure 3.

The additional op amp, U2, in figure 3b allows the pot to be used in ratiometric mode, avoiding the pitfalls of figure 3a. U2 provides high input impedance which minimizes effects of contact resistance. The output of U2 varies accurately with pot position from 0V to Vref regardless of the resistance of the pot. With an accurate voltage range applied to the second stage, U3, fixed resistors can be used for R5 and R6 and the circuit may not require gain adjustment.

Does your circuit need an extra op amp or more complexity to operate a pot in ratiometric mode? That's for you to decide—one of those tricky value judgments that you must make. Sometimes there is no good way to avoid using a pot as a variable resistor. But by understanding the risks and sensitivities, you may be able to select the potentiometer to meet the needed performance. And you will know to be attentive to the possible issues during testing and qualification of your circuit.

Thanks for reading. Open comments are welcome below or privately [by email](#).

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## 7 COMMENTS ON “WHEN POTENTIOMETERS GO TO POT”



**didymus7**

September 4, 2012

Reference figure 3b: With our systems, we've always had the problem with being unable to accurately adjust trimpots. It would be interesting to try this type of circuit, however, I have two questions: First, the configuration in 3b would require a res

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**David Bell**

September 4, 2012

Adding a resistor from the wiper to ground in 3b would make the divider ratio highly non-linear no longer ratiometric wrt pot position. As for U3, if Vref is anywhere near Vcc, U3 would probe running at unity (inverting) gain.

DaveB

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**didymus7**

September 5, 2012

Guess you missed my implications entirely. Replace Vref with a signal voltage that needs to be adjusted in amplitude. Due to different sensors, the gain requires a substantial range (gain of 40). Therefore, with circuit 3b you guarantee that your c

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**didymus7**

September 5, 2012

I guess you misunderstood 'Dry Circuit Conditions'. This occurs when there is not enough current or no current running through the wiper of the pot. Over time an insulating oxide forms and no your circuit does not work. Depending on the size of the po

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**Bruce Trump**

September 5, 2012

First, a correction—a kind reader pointed out in a direct email that figure 3a does not produce linear change with rotation of P1. So true. If I were a politician I would say I misspoke. In reality made a quick simplification of an errant circuit to m

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**jkirchhof**

September 28, 2017

When you use potentiometers for adjustment it is always necessary to limit the range of the adjustment. E.g. you want to correct the offset of an amplifier. The offset which can occur in the worst case is e.g. +/- 100mV. Then you should use a voltage divider

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**jkirchhof**

September 28, 2017

sorry, "the additional tolerances" means "the additional tolerances"

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