# Program an op-amp gain block with a limited-adjustability, monolithic, solid-state resistor

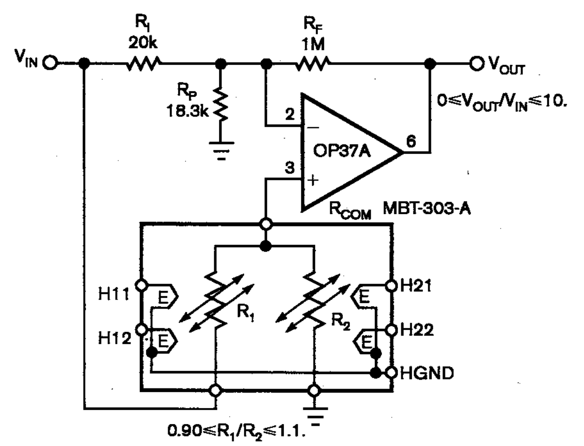
W Stephen Woodward, Chapel Hill, NC

Solid-state replacements for traditional electromechanical trimmer potentiometers are increasingly available in a variety of technologies from a variety of vendors. These replacements have many obvious advantages, such as automatic adjustability, miniaturization, and immunity to vibration. Some of these devices have only limited programmable spans, however. This limitation can sometimes be problematic and may preclude the use of a solid-state option in some design applications. An example of this shortcoming is the Rejustor family of devices, which Microbridge (www.mbridgetech.com) recently introduced. The MBT-303-A Rejustor voltage divider is programmable over a span of only ±10%. When such a limited-capability device sets the gain of a typical amplifier circuit, the correspondingly narrow range of accessible gains may be woefully inadequate.

**Figure 1** suggests a generally applicable workaround that works not only with rejustors, but also with all limited-adjustability, programmable dividers with a ±10%-ratio-adjustment range. It uses a single op amp in a differential topology that, in effect, subtracts the minimum programmable-divider ratio from the maximum and amplifies the difference. This approach expands the programmable-gain span to include zero and any desired figure. Potential applications for this trick include any design situation requiring a wide range of inverting and noninverting programmable-gain factors.

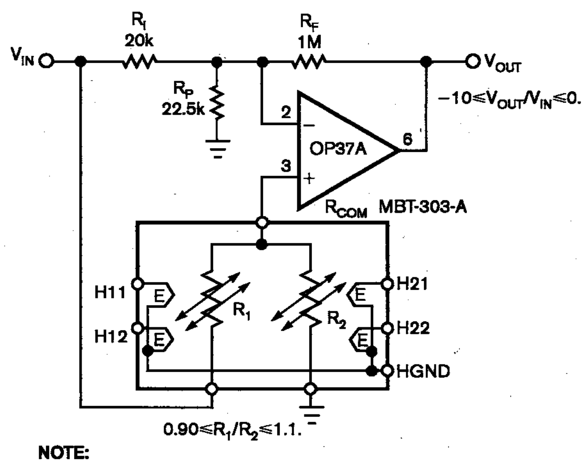
Although the circuit in **Figure 1** implements a programmable gain of zero to 10, you can implement almost any range with a suitable choice of resistors and op amps. **Figure 2** illustrates a gain of zero to −10 for the inverting case. The design equations are $R_F/R_I$, which is five times the maximum desired gain; $R_P=1/((1/0.9/R_I)-(1/R_F))$ for noninverting gain; and $R_P=1/((1/1.1/R_I)-(1/R_F))$ for inverting gain. The availability of stock resistances sometimes determines a starting value for $R_I$ or $R_F$. For example, the circuit in **Figure 1**, where $R_F$ has a value of 1 MΩ, accommodates the fact that many inexpensive precision-resistor families, such as those made of metal film, have maximum resistances of 1 MΩ. However, if resistor availability isn't a factor, then choosing $R_I$ to have the same value as $R_1$ minimizes sensitivity to op-amp bias-current errors. Choosing $R_P$ midway between the resistances for the noninverting- and inverting-gain equations reveals an additional flexibility of the circuit. That variation results in a bipolar—that is, both inverting and noninverting—gain range, with a gain of zero at midspan.

This topology eliminates the inflexibility penalty that limited divider programmability imposes. This benefit, however, incurs a price in the op amp's performance. Because of the partial cancellation of amplifier gain, the gain-bandwidth product and dc accuracy of the op amp must surpass the overall maximum gain and offset requirements of the gain block by at least a factor of five. One way to accommodate this requirement is to incorporate a decompensated, precision op amp, such as the classic OP37, which is stable only for closed-loop gains higher than five. **EDN**




NOTES:
Set $R_P$=20.4 kΩ FOR A PROGRAMMABLE-GAIN RANGE OF $-5 \le GAIN \le +5$.
$V_{OUT}/V_{IN}=50(R_2/R_1-0.9)=0$ IF $R_2/R_1=0.9$ AND =10 IF $R_2/R_1=1.1$.

Figure 1 Adding an op amp and associated components to a Rejustor solid-state resistor allows you to trim the output over the full input-voltage range.




NOTE:
$V_{OUT}/V_{IN}=50(R_2/R_1-1.1)=0$ IF $R_2/R_1=1.1$ AND $=-10$ IF $R_2/R_1=0.9$.

Figure 2 Adjusting the value of $R_P$ allows the circuit to function as an inverting trimmer.