Recycle precision potentiometers as useful voltage sources

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An analog- or a mixed-signal lab cannot have too many voltage sources. A simple, reasonably high-precision voltage source can set bias points in an op-amp circuit, tweak the feedback node of a power supply through a large resistor, or run a quick linearity test on an ADC. Engineers often use a dc-power supply because it is the only thing they can find, and many labs lack a true voltage-calibration source. This Design Idea describes a circuit that recycles old precision potentiometers that have direct-reading scales into useful laboratory "volt boxes."

Several types of potentiometers work in the circuit in **Figure 1**. Standard 10-turn potentiometers typically have 0.1% linearity and work well for general-purpose tweaking. However, a five-decade Kelvin-Varley divider with a total resistance of 100 kΩ or less achieves 10-ppm accuracy. Having some indication from a voltage source that its output is correct proves useful. A digital panel meter is one way of achieving this goal. However, even a 0.1% potentiometer is more accurate than most of these meters. So, to indicate that the output is correct, you need to know only whether the power is on, whether the supply voltage is high enough, and whether the output amplifier is working properly and not sourcing or sinking too much current or oscillating.

A single red-green-blue LED provides all three indications. The green LED flashes at a low duty cycle when the power is on and stays lit continuously when the battery voltage is too low. The red LED illuminates when the output is out of regulation because IC_{4B} is a low-duty-cycle relaxation oscillator that pulses a green LED for 5 msec at approximately 0.5 Hz. The blue LED lights when sinking too much current. If the output is oscillating, the LED glows purple.

IC_{4A} compares the positive battery voltage to the precision 10V reference output and continuously turns on the green LED when the positive battery voltage drops below 11.5V. This level is the dropout voltage of the reference, so you know it's time to change the batteries. The load on the positive supply is greater than that on the negative supply, so these cells wear out first. And, because only two cells constitute the negative supply, battery wastage is minimal. Alternatively, you can move the negative cells to the positive side to squeeze the last bit of juice from them.

The reference is IC_1, an LT1236-10 with an added trim circuit. The LT1236 is quiet and stable over time and temperature. Its output drives the top of the precision potentiometer or Kelvin-Varley divider. The output of the circuit is trimmed to 10V when the potentiometer or divider is at its maximum value. The two halves of an LT1881 amplifier, IC_{2A} and IC_{2B}, buffer the output of the potentiometer or divider. The combined bias current for both buffers is 400 pA maximum, which causes a change of approximately 10 μV in the output voltage of a 100-kΩ potentiometer when it is at midscale. Make sure to properly guard the noninverting inputs to prevent leakage. The 50-μV maximum offset and 130-dB CMRR (common-mode-rejection ratio) keep overall accuracy well within 10 ppm of a 10V total span.

One-half of the LT1881 is the voltage output of the volt box. The other half is necessary to drive the two inputs to IC_5, an LT1017 dual comparator that has an input-bias current of 15 nA per comparator. Q_1 to Q_6 form a 100-μA current sink and source referred to the negative supply and positive supply, respectively. You adjust potentiometers R_1 and R_2 to set up a window around the output voltage that is compared with the output of IC_{2A}, which is a replica of the correct output voltage. If IC_{2B} is sourcing or sinking too much current, one of the comparators will trip, turning on the respective LED. If the output is oscillating, both LEDs will light. The window is adjustable from 0 to approximately ±9.3 mV; ±1 mV is a good place to start.

Should you need more output current than the 5 mA that the LT1881 guarantees, you can switch in an LT1010 buffer to provide a "turbo-boost" feature, increasing the output-current capability to ±150 mA and greatly increasing the ability to drive capacitive loads. You should normally disable this buffer because it draws 10 mA more from the supply. Switch S_3 allows reverse polarity, and, if you use a center-off switch, you can disconnect the output. S_1 is the power switch and can also select power from an external supply or battery power when isolation is critical. **EDN**

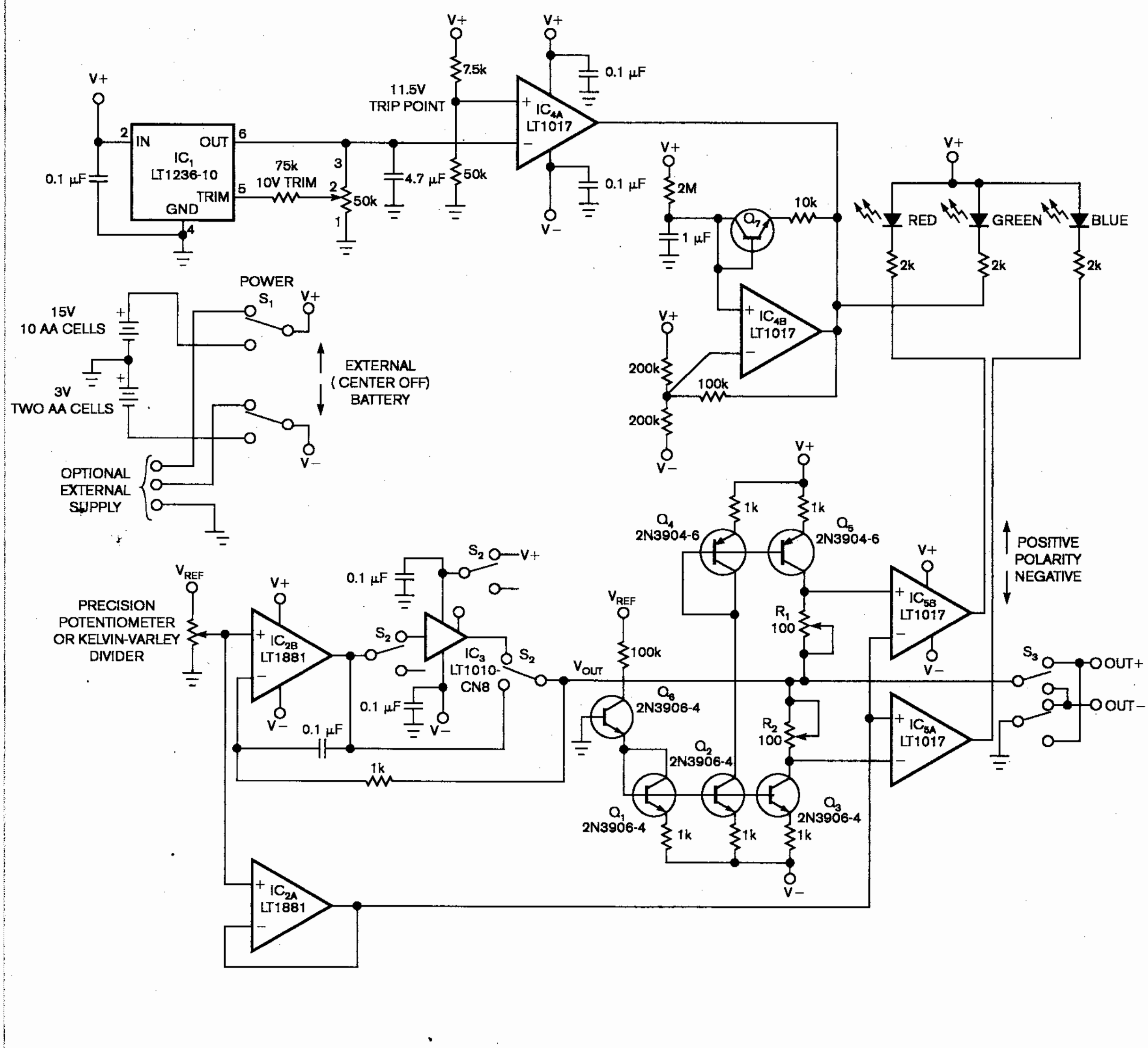

Figure 1 You can recycle old 10-turn potentiometers as precision "volt boxes." The LEDs provide a visual indication that the output voltage is in regulation.