Controlling op amp gain with one potentiometer

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A single potentiometer and a few resistors can control the gain of an operational amplifier from a selected negative value, through a null, to its positive open-loop gain. The variable-gain circuit, which is shown in (a), maintains a high input impedance, even at high amplification. It makes a convenient wide-range voltage reference for a voltage regulator because it eliminates the need to switch the op amp's circuit for above- or below-reference operation.

A graph of voltage gain versus potentiometer rotation is also shown in (a). The equation for output voltage can be written as:

$$E_o = [E_i R_F/(R_I + R_1)][(R_1/R_2) - (R_{I+}/R_{I-}) + (R_1/R_F)]$$

where R_{I^+} is the resistor at the op amp's noninverting input, and R_{I-} the resistor at the inverting input. Varying feedback resistor R_F changes the magnitudes of both the positive and negative gains without changing the appearance of the graph; varying resistance ratio R_{I+}/R_{I-} shifts the null point.

As resistor R_{I-} approaches infinity, op amp gain varies from null to positive infinity only, as illustrated in (b). The equation for output voltage becomes:

$$E_o = [E_i R_F/(R_{I+} + R_1)][(R_1/R_2) + (R_1/R_F)]$$

As can be seen from the figure, the gain curve for this circuit is nearly logarithmic.

For a potentiometer rotation of 10% to 90%, amplifier gain can be varied over four decades. The gain at 50% rotation is the ratio $(R_f + R_2)/(R_{I+} + R_1)$. Any general-purpose differential op amp can be used in the circuit. □

Wide-range gain adjustment. Potentiometer varies gain of operational amplifier (a) from chosen negative value to positive open-loop value. Null point can be shifted by changing resistance ratio of noninverting input resistor R_{I+} to inverting input resistor R_{I+}. Removing R_{I+} permits positive gains to be controlled over wide range, as shown in (b). Circuit's input impedance remains high over full gain range.