Bipolar current mirror scales, inverts signals

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A pair of operational amplifiers and a few resistors build this precision current mirror. Though simple and low in cost, the circuit excels the usual designs because it not only offers true bipolar operation but also can scale and/or invert any ac or dc input signal.

Input currents are applied to op amp A_1, which is biased by V_{ref}. If I_{in} is generated by a constant current source, V_{ref} may be brought to zero. Otherwise, it should be set to some arbitrary value to maintain circuit bias.

A current-to-voltage converter at the input and a voltage-to-current converter at the output comprise the current mirror. As a consequence of the configuration, the voltage appearing at the output of A will thus be:

$$V_{A1} = V_{ref} + I_{in}R_1$$

for $R_1 >> R_2$ and R_L. The voltage applied to the output circuit is therefore:

$$V_2 - V_1 = I_{in}R_1$$

Writing the nodal equations for V_L, V_3, and V_4 yields these results:

$$I_L = -V_L(1/R_2 + 1/bR_2) + V_3(1/bR_2) + V_2(1/R_2)$$
$$V_3 = A_2(s)\,(V_L - V_4) = (GB/s)(V_L - V_4)$$
$$V_4 = V_1[a/(1+a)] + V_3[1/(1+a)]$$

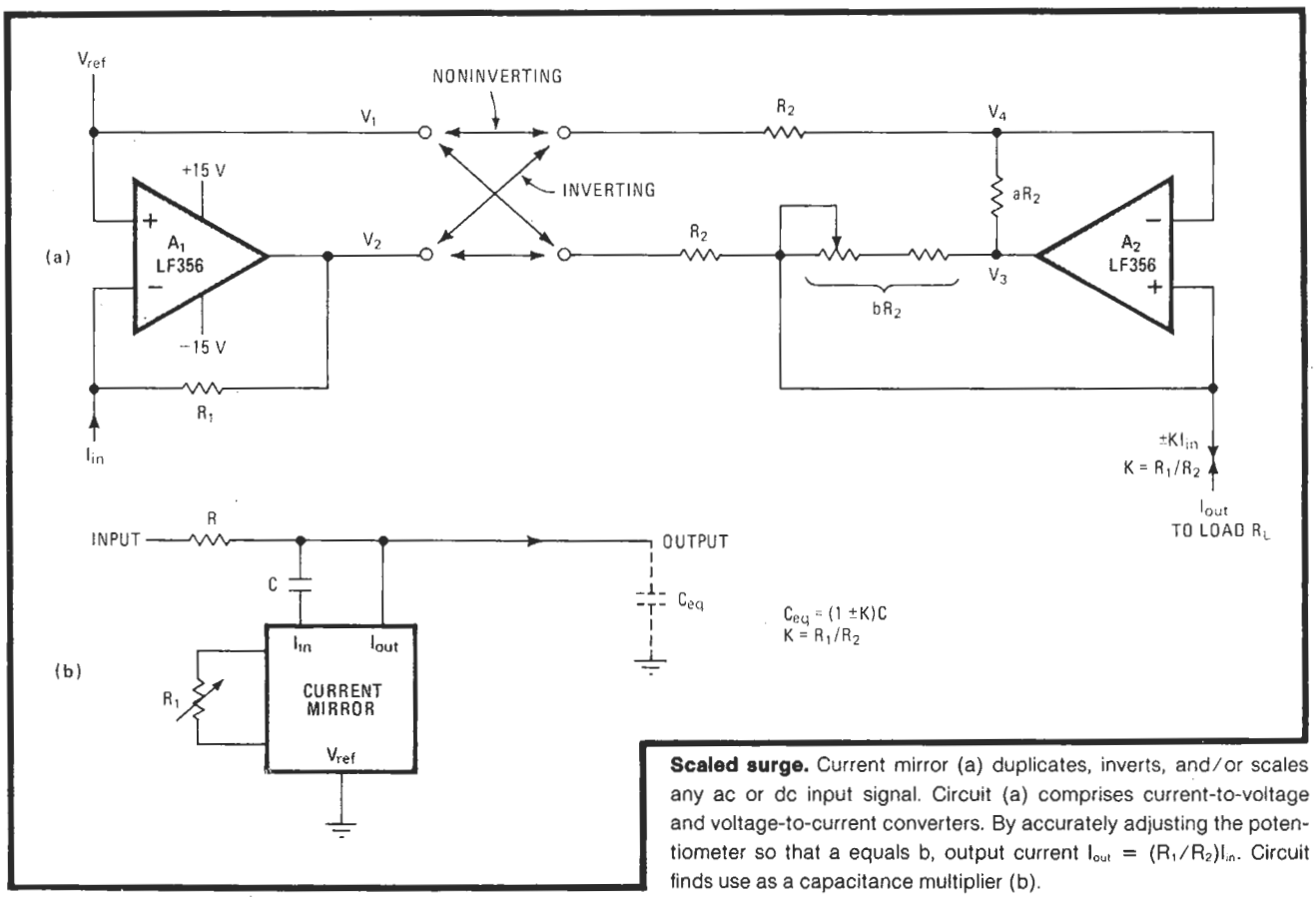
where GB is A_2's gain-bandwidth product. Substituting V_3 and V_4 into the equation for I_L, it is seen that $I_L = (R_1/R_2)I_{in}$, given that a = b and $s << GB/(1+b)$.

The output impedance can be set, within limits, by selection of aR_2 and bR_2. The output impedance is:

$$Z_o(s) = \left[\left(\frac{a}{1+a}\right)\left(S+\frac{GB}{1+b}\right)R_2\right] \div \left[S+\left(\frac{a-b}{1+a}\right)\left(\frac{GB}{1+b}\right)\right]$$

Since a must equal b for the circuit to work, this equation simplifies to $Z_o(s) = [1/(1+a)]\{1 + [1/1+a)]GB/s\}\,R_2$, and no other assumptions about resistor ratios are made.

In addition to its use as a scaled current mirror, the circuit will find other not-so-obvious applications. Such an example is its use as a capacitance multiplier (b). □



Scaled surge. Current mirror (a) duplicates, inverts, and/or scales any ac or dc input signal. Circuit (a) comprises current-to-voltage and voltage-to-current converters. By accurately adjusting the potentiometer so that a equals b, output current $I_{out} = (R_1/R_2)I_{in}$. Circuit finds use as a capacitance multiplier (b).