Eliminating stray signals in remotely gain-switched op amps

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When the gain switch for a variable-gain amplifier is physically distant from the amplifier itself, stray signal pickup and/or capacitance loading can affect circuit performance. A special switching arrangement, however, can eliminate both of these problems.

The circuits drawn in (a) show how cable capacitance can be introduced at the amplifier's input. While the circuits of (b) show where noise generators appear when the amplifier input leads remain open. (In all these circuits, the amplifier is connected in its non-inverting mode.)

In contrast, the switching arrangement illustrated in (c) has no current paths through unused resistors, and it eliminates switching at the amplifier input. All of the resistors are used with each gain configuration, and all of the lines to the switch are always connected either directly to signal ground or to the low-impedance output of the amplifier.

The maximum allowable cable capacitance, therefore, is now determined by the capacitance load that the amplifier can tolerate, rather than the signal phase shift. Another advantage of this switching arrangement is that the circuit's bias-current compensation remains optimum for each gain, as long as the correct value is selected for resistor R_0.

To make use of this type of switching, the resistors required, as well as the right switching arrangement, must be determined for the specific set of desired gains: G_0, $G_1, \ldots, G_n$. First, arrange the gains in ascending order according to magnitude (so that G_i is less than G_{i+1}), but let $G_0 = 1$ and $G_{n+1} = \infty$. Since there will be $n+1$ resistors required, they should be designated as R_1, $R_2, \ldots, R_{n+1}$. Compute the values of resistors R_2 through R_{n+1} sequentially, in terms of resistor R_1:

$$R_{i+1} = \frac{G_{i+1}(G_i - G_{i-1})R_i}{G_{i-1}(G_{i+1} - G_i)}$$

where i varies between 1 and n.

Next, arrange the switch so that, starting with the minimum gain of G_0, all the resistors connect from the amplifier's inverting input to the output. To obtain gain G_1, switch the end of R_1 from the output to ground, leaving everything else unchanged. To obtain gain G_2, switch the end of R_2 from the output to ground, leaving everything else unchanged. In general, then, to obtain gain G_i, resistors R_1 through R_i are connected to ground, and resistors R_{i+1} through R_{n+1} are connected to the output.

This same switching technique can be used for an inverting amplifier configuration. However, gain G_0 must be set equal to zero, and the values for resistors R_2 through R_{n+1} are found sequentially in terms of resistor R_1 from:

$$R_{i+1} = \frac{(G_{i+1} + 1)(G_i - G_{i-1})R_i}{(G_{i-1} + 1)(G_{i+1} - G_i)}$$

where i again varies between 1 and n.

Resistor R_0 can be computed as the parallel combination of all the gain resistors, R_1 through R_{n+1}. Or, for the non-inverting amplifier, it can be determined by:

$$R_0 = [(G_1 - 1)/G_1]R_1$$

And for the inverting amplifier, the value of R_0 is:

$$R_0 = [G_1/(G_1 + 1)]R_1$$

Circuits (d) and (e) give the resistor values for producing gains of 2, 5, and 10 when $R_1 = 1$. Amplifier (d) is noninverting, while amplifier (e) is inverting. ☐

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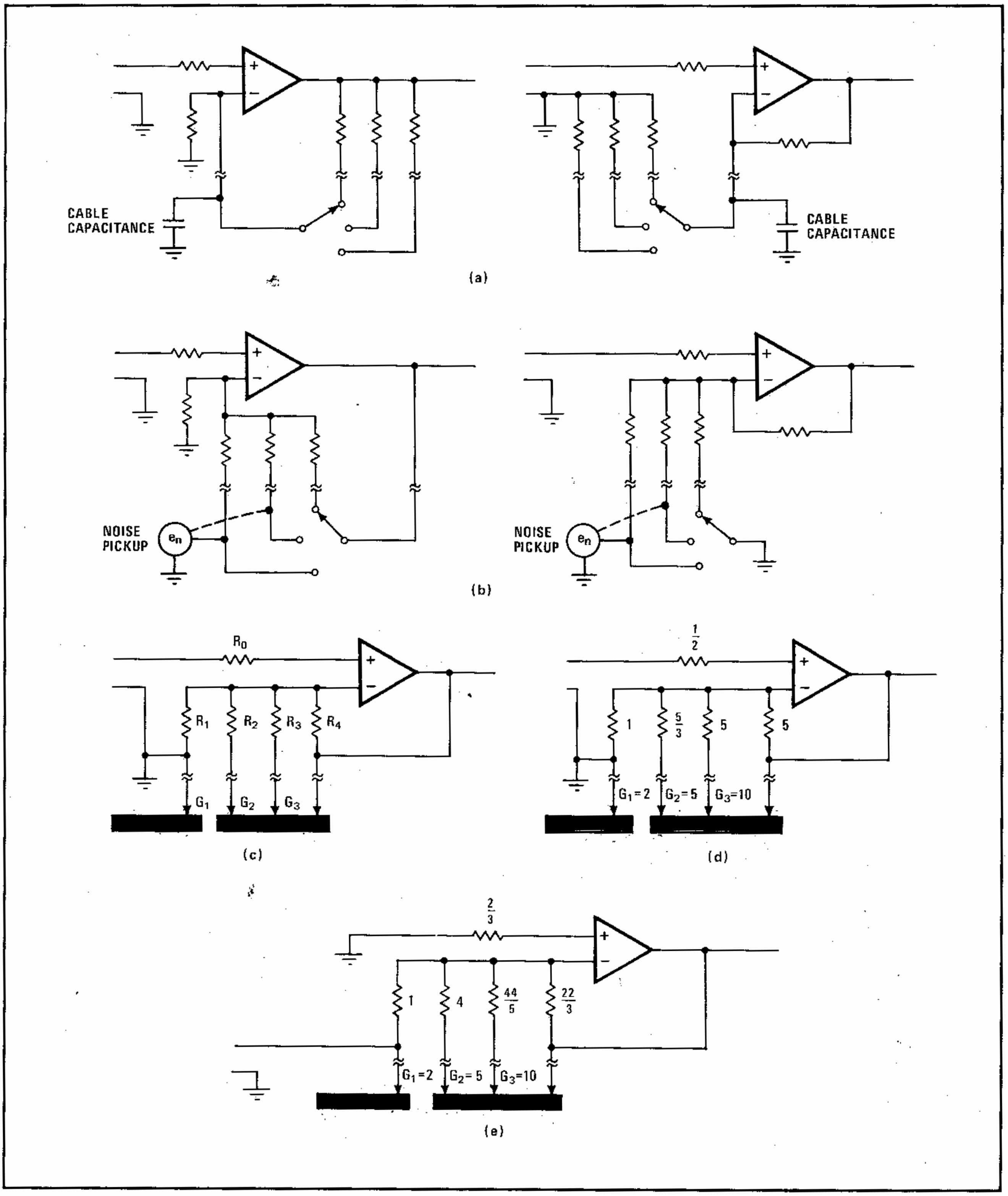

Switched-gain amplifiers. Remotely switched variable-gain amplifiers can suffer from the capacitance loading (a) of long wires or can pick up noise (b) through unused resistor paths. The switching arrangement of (c) doesn't have these problems because all of the switched points have low-impedance paths to ground. The noninverting (d) and inverting (e) amplifiers given here provide gains of 2, 5, and 10.