Decompensated Op-Amp Gain Is Adjustable From Zero To Open-Loop

W. Stephen Woodward
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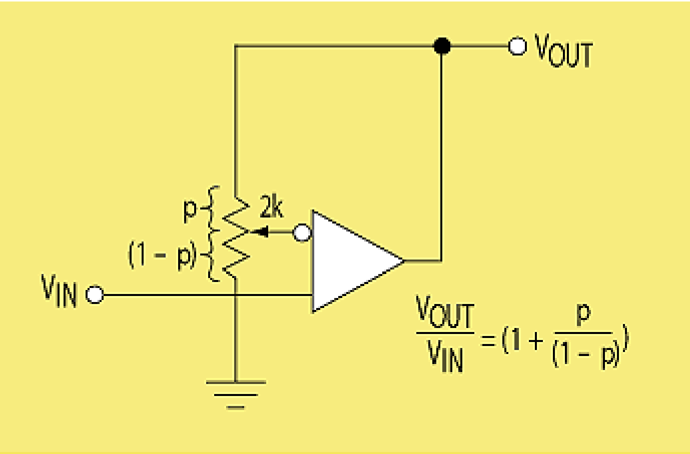
Over three decades ago, the internally frequency-compensated, monolithic op amp was introduced. Since then, many of these devices have been made available in two variations. While both versions are designed to maintain the same dc parameters, they demonstrate very different ac characteristics.

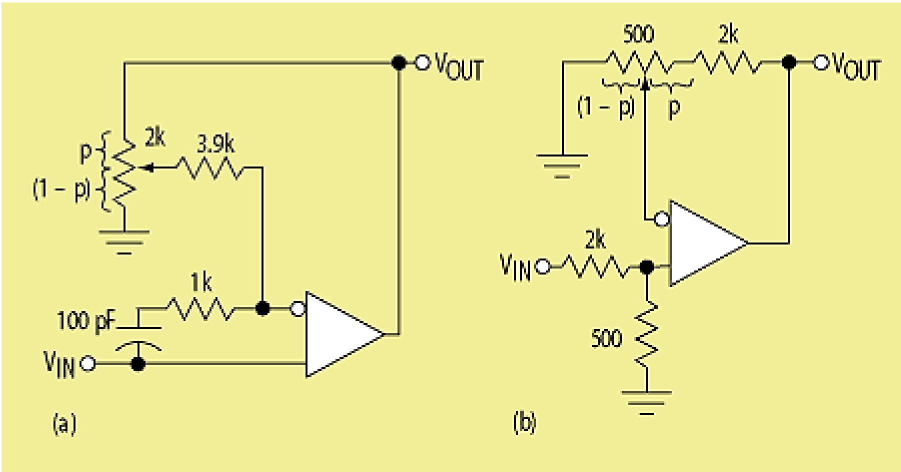
In op-amp duos such as these, one member is heavily frequency-compensated to provide stability at unity gain (exemplified by the LF156, OP27, and LT1007). Meanwhile, its partner plays the role of the much faster, albeit sometimes "twitchy," decompensated sibling (the LF157, OP37, and LT1037, respectively). In each case, the decompensated member enjoys about a four to five times advantage in slew rate and gain-bandwidth product over its more stable partner. "Decomps" are therefore the obvious choice for high-speed high-gain amplifier applications.

But sometimes there's a penalty for making this selection. This is true when an application requires a variable gain that can be set over a range extending below the op amp's minimum stable closed-loop gain (GMIN = typically 5). The problem exists in simple and versatile gain-set topologies whose gain is given by $G = 1 + p/[1 - p]$, where $0 < p < 1$ (Fig. 1). While perfectly usable with unity-gain-stable op amps, these configurations won't work with their high-pressure decompensated alter egos when G < GMIN. Trying to use this type of circuit to set a decomp's gain to unity or less will result in instability or outright oscillation.



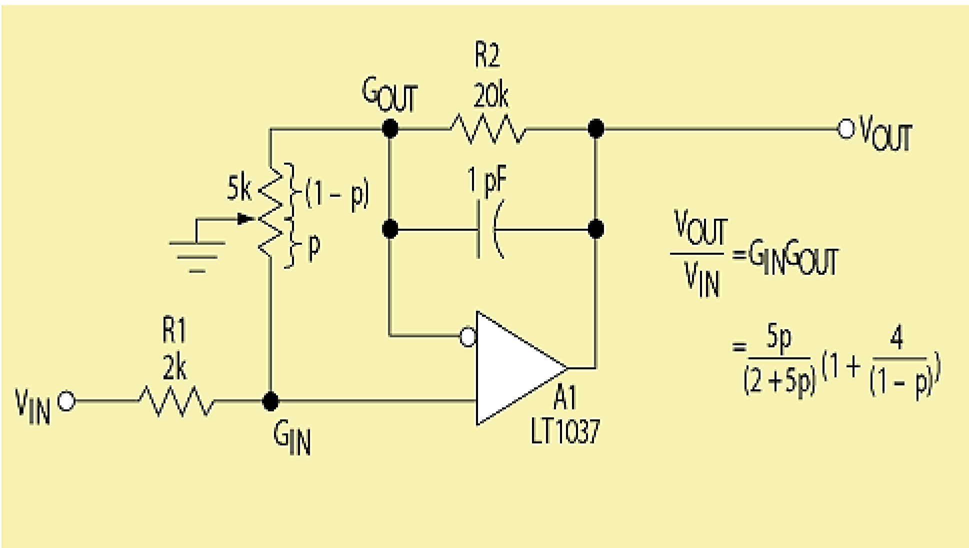
1. A decompensated op amp with the typical gain-set arrangement can exhibit instability when low gain settings are used.

In principle, the GMIN gremlin could be exorcised with an ac-gain-limiting, or it may be driven out with a brute-force 1/GMIN input attenuator (Fig. 2). While they definitely work, these circuits are far from ideal. The rub is that they unnecessarily erode the noise and gain performance at high gain settings (by a whopping 14 dB for the circuit in Figure 2b). As a result, such circuits waste most of the benefits of using a decompensated op amp in the first place. A better solution would be to make Figure 2's input-attenuator variable instead of fixed. Then it could get out of the way when G >> GMIN.



2. Overcoming the GMIN problem can be accomplished using an ac-gain-limiting network (a) or a brute-force 1/GMIN input attenuator (b).

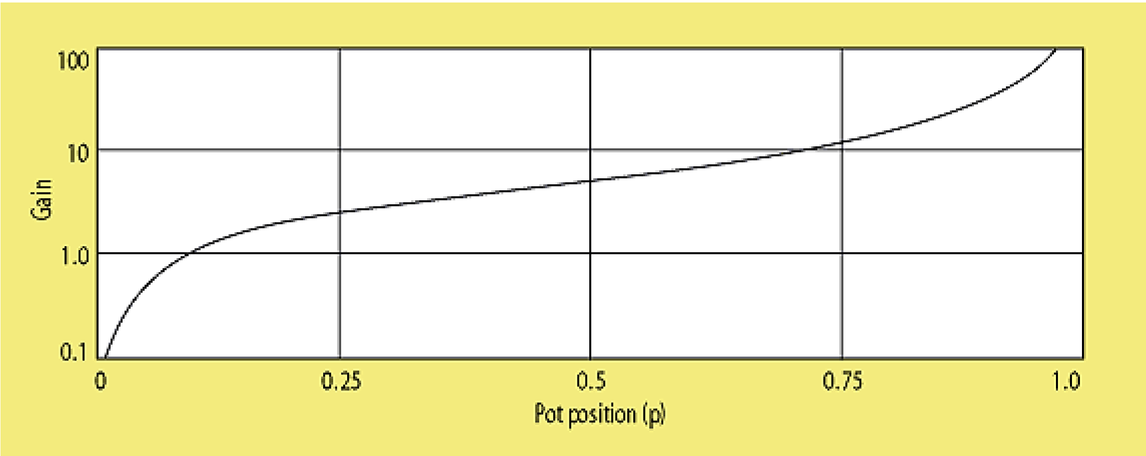
Figure 3 shows how to do this without incurring the cost of a dual potentiometer. The circuit here relies upon an idea suggested in a previous IFD (see "One Single-Section Potentiometer Sets The Gain On Two Channels," W. Stephen Woodward, Electronic Design, Feb. 5, 2001, p. 115). As described in this earlier article, grounding the pot wiper creates two mechanically linked but electrically independent variable resistors. The bottom half (pR) cooperates with R1 to form a variable input attenuator with a gain of: GI = 5p/(2 + 5p). So GI, the attenuator's gain, goes from zero to near unity, more or less, as p goes from 0 to 1.



3. By modifying Figure 2b's topology, the input attenuator can be made variable by grounding the pot wiper to create two mechanically linked but electrically independent variable resistors.

Meanwhile, the top half of the pot, $(1 - p)R$, forms a variable feedback network with R2. This network sets A1's closed-loop gain as a function of p: $GO = [1 + 4/(1 - p)]$. Note that $GO > 5$ (A1's G_{MIN}) for all values of p. Also, noise performance at high gain ($G >> 1$) is only 3 dB worse than it would be if there were no pR input attenuator at all.

The resulting composite gain-versus-p curve ($G = GI \times GO$) is graphed in Figure 4. It runs from zero (at $p = 0$) to open loop (at $p = 1$). Since it's dependent on the circuit layout, feedback-capacitor C is best optimized empirically. A good place to start, however, is $C = 1/(2\pi \times GBW \times R2)$. In this equation, GBW represents A1's gain-bandwidth product (60 MHz for the LT1037).



4. The resulting composite gain-versus-p curve (G = GI ¥ GO) is shown. The possible gain settings extend from zero (at p = 0) to the open-loop gain of the op amp (at p = 1).