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CLASSICAL OP AMP OR CURRENT-FEEDBACK OP AMP? THIS COMPOSITE OP AMP GIVES YOU THE BEST OF BOTH WORLDS

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Classical op amps such as the OPA627 have excellent performance in applications where the required gain bandwidth is low compared to the gain-bandwidth product of the op amp. However, increasing closed-loop gain decreases the error-reducing loop gain. Furthermore, starting at relatively low frequencies, the loop gain rolls-off at 20dB/decade of signal frequency increase. In combination these effects can produce significant errors, especially at higher frequencies where the loop gain can be very low.

Current-feedback op amps, such as the OPA603, have good dynamic performance at both low and high gains. This is because the feedback components set both closed-loop gain and open-loop gain, making loop gain and dynamic performance relatively independent of closed-loop gain. Unfortunately, the DC performance (V_{OS}, dV_{OS}/dT, CMR, etc) of current feedback amplifiers is poor compared to classical op amps.

A composite amplifier using a classical amplifier and the OPA603 current-feedback amplifier can combine the best qualities of both amplifiers.

Figures 1 and 2 show noninverting and inverting composite amplifiers. Table I shows suggested component values for selected gains and measured performance results.

DC performance of the composite amplifier is excellent. Since the OPA603 is in the feedback of the OPA627, the composite amplifier retains the excellent DC characteristics of the OPA627. In fact, since the OPA627 does not drive the load directly, its DC accuracy can be better than the OPA627 alone. Thermal feedback within an amplifier driving large loads will cause errors due to internal thermal gradients and package self-heating. The composite amplifier with an OPA603 can drive 150Ω loads to ±10V with no thermal feedback to the OPA627.

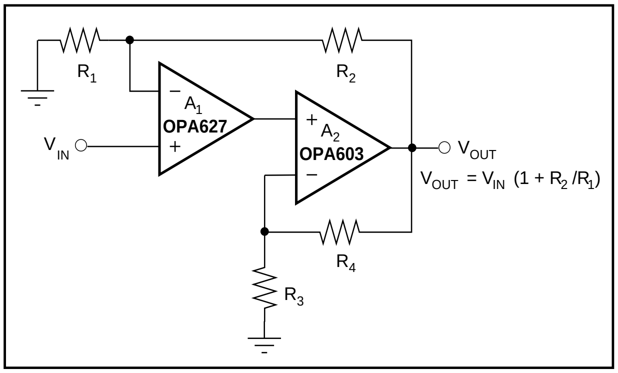

FIGURE 1. Composite Noninverting Amplifier with Precision of OPA627 and Speed of OPA603.

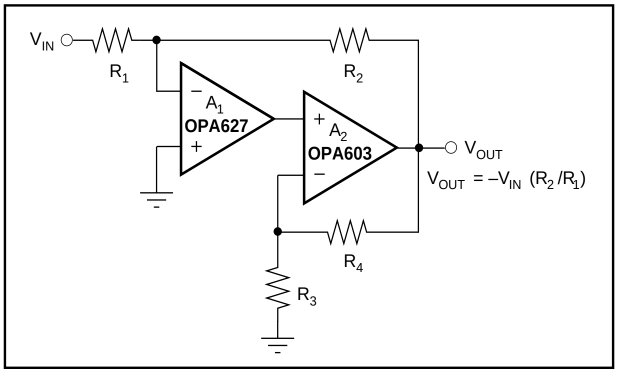

FIGURE 2. Composite Inverting Amplifier with Precision of OPA627 and Speed of OPA603.

OVERALL GAIN [V/V]	GBW [Hz]	A_1	OPA603 GAIN [V/V]	R_1 (1) [Ω]	R_2 [Ω]	R_3 (4) [Ω]	R_4 [Ω]	SLEW RATE [V/µs]	SETTLING (0.1%) (2) [ns]	SETTLING (0.01%) (2) [ns]
5	90M	OPA627	3	255	1020	499	1020	100	265	520
10	180M	OPA627	6	110	1000	200	1020	240	240	500
20	330M	OPA627	12	52.3	1000	93.1	1020	620	200	520
50	750M	OPA627	26	49.9	2430	40.2	1020	730	320	530
100	1.5G	OPA627	52	49.9	4990	20	1020	730	330	(3)
200	2.5G	OPA637	18	49.9	10k	60.4	1020	580	350	(3)
500	6.0G	OPA637	42	49.9	25k	24.3	1020	590	580	(3)
1000	10.0G	OPA637	85	49.9	50k	12.1	1020	510	640	(3)

NOTES: (1) R_1 shown is for noninverting composite amplifier. For inverting amplifier, R_1 = Gain/R_2. (2) Settling time for 10V output step. (3) Output noise exceeds 0.01% at this gain. (4) For intermediate gains, use the higher value R_3.

TABLE I. Measured Results for Selected Composite-Amplifier Examples.

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The gain of the composite amplifier is set by R_1 and R_2 alone. Errors due to R_3 and R_4 do not affect the gain of the composite amplifier. The gain of the second amplifier, set by R_3 and R_4, should be within ±5% to assure expected dynamic performance.

Slew rate and full-power response of the classical amplifier are boosted in the composite amplifier. Since the OPA603 adds gain at the output of the OPA627, the slew rate of the OPA627 is increased by the gain of the OPA603. For example, in the gain-of-100 composite amplifier, the slew rate and full-power response of the OPA627 is increased from 40V/µs min (600kHz) to over 700V/µs (11MHz).

Settling time of the classical amp is preserved, even at higher gains. Settling time of a classical op amp is limited by the time needed to slew to its final value plus the time for its internal circuitry to settle to the desired accuracy. Settling time for a classical op amp is no better than predicted by a single-pole response:

$$T_S = \frac{\ln(100/\%)}{2 \cdot \pi \cdot f_{UGBW}}$$

Where:
T_S = Settling time [µs]
f_{UGBW} = Amplifier unity-gain bandwidth [MHz]
ln(100/%) = Number of time constants needed to settle to desired accuracy, e.g:

ACCURACY (%)	BITS (TO 1/2LSB)	NUMBER OF TIME CONSTANTS
1.0%	6	4.6
0.1%	9	6.9
0.01%	12	9.2
0.0008%	16	11.7

TABLE II.

The bandwidth of a classical op amp decreases with increasing closed loop gain. In a gain of 100V/V, the bandwidth of the OPA627 decreases from 16MHz to 160kHz. The 0.1% settling time therefore can be no better than that of a 160kHz single pole system, or 6.9µs. In the composite amplifier, with the OPA603 in a gain of 52V/V, the OPA627 operates in a loop gain of 2V/V resulting in a measured 0.1% settling time of 330ns.

Care must be taken when selecting the feedback amplifier, A_2, used in the composite. Excessive phase shift through A_2 will cause instability. The OPA603 has sufficient bandwidth to ensure stability when used with amplifiers as fast as the OPA627 (16MHz).

If the bandwidth and settling time advantages of the composite amplifier are needed, but not the slew rate boost, it is possible to make a composite amplifier using a dual op amp such as the OPA2107 as shown in Figures 3 and 4. It is best to use a dual op amp because of the inherent matching of dynamic characteristics. To ensure stability and the best transient response, set the gain of A_1 two times the gain of A_2 using the following relationship:

$$\text{Gain} = 1 + (R_2/R_1) \text{ noninverting}$$
$$\text{Gain} = -(R_2/R_1) \text{ inverting}$$
$$R_4 = 10\text{k}\Omega$$

For Figures 3 and 4,

$$R_3 = \frac{R_4}{\sqrt{R_2/(2 \cdot R_1)) - 1}}$$

For example, if Gain = 100, R_4 = 10kΩ, and R_3 = 1.65kΩ.

Cascading two gain stages (each with a gain of 10V/V) would give an overall transfer function of 100V/V and slightly better settling time, but the gain would depend on the accuracy of R_3 and R_4 in addition to R_1 and R_2. The table below shows predicted 0.01% settling time for the three cases.

CONFIGURATION	SETTLING TIME TO 0.01%
Single Amplifier	20µs
Composite Amplifier	4.6µs
Cascaded Amplifier	4.1µs(1)
NOTE: (1) For cascaded amplifier stages, the combined settling time is the square root of the sum of the squares of the individual settling times.	

TABLE III. Predicted Settling Time for Gain-of-100 Amplifiers Using OPA2107 Dual Op Amp (Unity Gain Bandwidth = 5MHz).

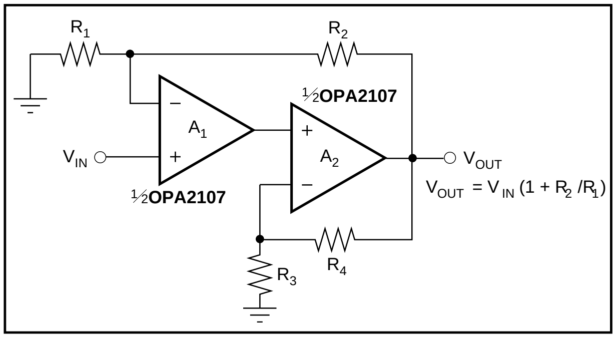

FIGURE 3. Composite Noninverting Amplifier Using Dual Op Amp Settles Fast.

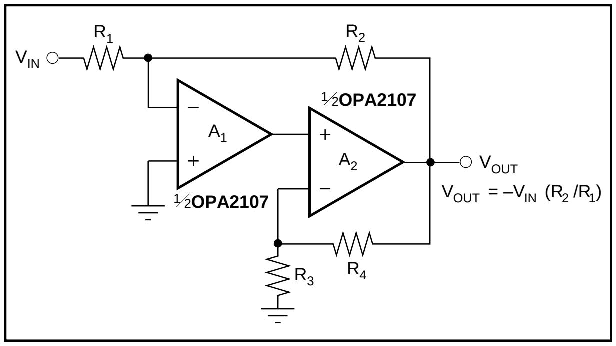

FIGURE 4. Composite Inverting Amplifier Using Dual Op Amp Settles Fast.