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VOLTAGE-FEEDBACK AMPLIFIERS vs CURRENT-FEEDBACK AMPLIFIERS: BANDWIDTH AND DISTORTION CONSIDERATIONS

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Designers specify amplifiers based on certain key parameters, one of which is bandwidth. Traditionally, the gain-bandwidth product of an amplifier told the user everything he needed to know about its small-signal AC performance. The useful bandwidth of an amplifier was determined by dividing the gain-bandwidth product (GBW) by the desired closed-loop gain. However, this simple formula cannot be used with current-feedback amplifiers.

Current-feedback amplifiers have nearly constant bandwidth for varying closed-loop gains. The reason is that the user can adjust the open-loop gain of the current-feedback amplifier by changing the feedback network without affecting the open-loop pole. The concept can be more readily understood with the aid of Figure 1, which shows a simplified AC model for the current-feedback amplifier.

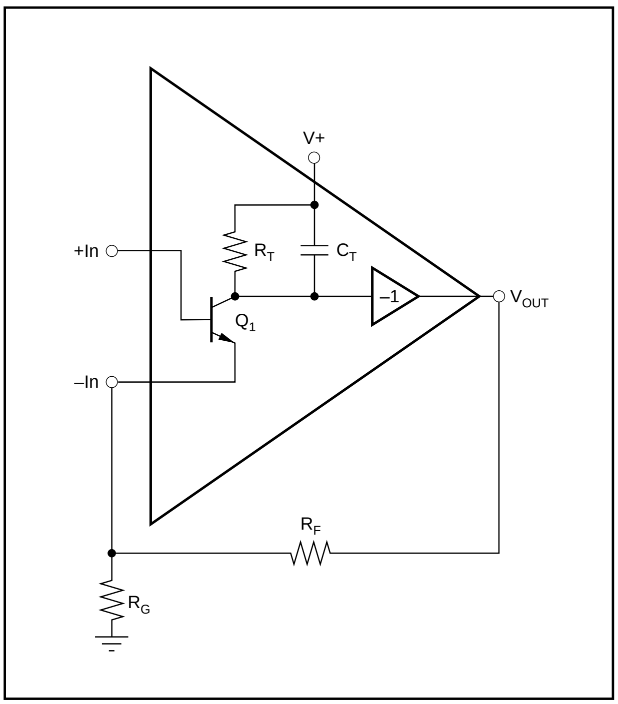

FIGURE 1. Current-Feedback Amplifier Simplified for AC Analysis.

The primary determinants of AC performance for the current-feedback amplifier are the transresistance, R_T, and the transcapacitance, C_T. A well specified current-feedback amplifier's data sheet will list these parameters. Figure 1 shows the current-feedback amplifier with a bipolar transistor as the input device. This is convenient because it has a low impedance inverting input (the emitter) and a high impedance noninverting input (the base). For this analysis, the bipolar transistor is considered ideal (i.e., infinite beta, zero base-emitter voltage, no base-collector capacitance). The collector terminates in R_T, C_T and an inverting buffer. The feedback network consists of R_F and R_G.

Figure 2 shows the same circuit reconfigured for analysis. The feedback network is now the emitter load for the input transistor. Open-loop voltage gain can be determined by inspection to be:

$$A_{OL} = \frac{R_T \,||\, (j2\pi f C_T)^{-1}}{R_F \,||\, R_G}$$

$$= \frac{R_F + R_G}{R_G} \frac{R_T}{R_F} \frac{1}{1 + j2\pi f R_T C_T}$$

$$= A_{CL} \frac{R_T}{R_F} \frac{1}{1 + j2\pi f R_T C_T}$$

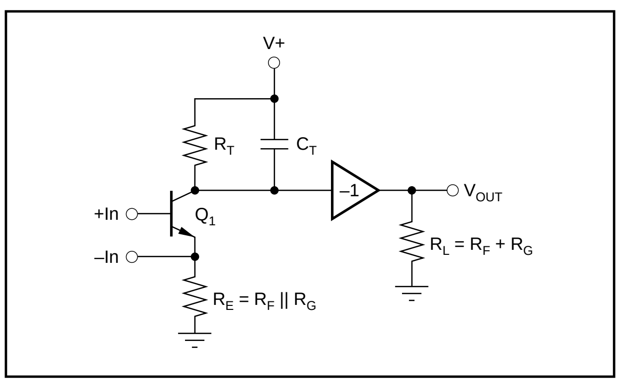

FIGURE 2. Current-feedback Amplifier Simplified and Reconfigured for Analysis.

The last expression shows that the open-loop gain for the current-feedback amplifier varies directly with closed-loop gain (for a given R_F). This is why the current-feedback amplifier has a gain-independent bandwidth. This simplified analysis holds true for low to moderate gains, less than 25V/V, but becomes limited when second-order effects start to dominate.

What this means is that the designer has to look more carefully at how the amplifier is specified. Gain-bandwidth is not meaningful when evaluating a current-feedback amplifier. However, it is an easy way to evaluate traditional voltage-feedback op amps. It is better for the designer to first determine the required gain and then make bandwidth comparisons.

For instance, assume that the application requires processing a 10MHz signal and the amplifiers under consideration are the OPA621 and the OPA603. The OPA621 is a voltage-feedback op amp with 500MHz gain-bandwidth product. The OPA603 is a current-feedback amplifier that can be configured for a useful bandwidth of 100MHz. At first glance, both amplifiers appear adequate but this assumption neglects gain considerations. The circuit configurations of Figure 3 show resistor values for gains of +2V/V and +10V/V. For these gains, the OPA621 has closed-loop bandwidths of 250MHz and 50MHz, respectively.

With the aid of the data sheets for each of these products, a reasonable comparison of open-loop gain can be made. From the OPA621 data sheet, A_{OL} = 60dB = 1,000V/V. This and the GBW are enough information to describe the open-loop gain versus frequency:

$$A_{OL} = \frac{1,000}{1 + jf / (500\text{MHz} / 1,000)} = \frac{1,000}{1 + jf / 500\text{kHz}}$$

The OPA603 data sheet gives R_T = 400kΩ and C_T = 1.8pF. For these applications, the OPA603 was configured with R_F = 1kΩ. The resulting open-loop gain curves are plotted in Figure 4.

Loop gain is the area bounded above by the open-loop gain curve and below by the desired closed-loop gain. Loop gain is important because it provides a measure of an amplifier's ability to reduce error and maintain fidelity with the original signal. For a gain of +2V/V (6dB), the OPA621 has 9dB more loop gain than the OPA603 at 10MHz. In a gain of +10V/V (20dB), the situation is reversed and the OPA603 has 5dB more loop gain than the OPA621. This is confirmed in the distortion figures tabulated below.

	A_{CL} = +2V/V		A_{CL} = +10V/V	
	OPA603	**OPA621**	**OPA603**	**OPA621**
2nd Harmonic	–65dBc	–68dBc	–63dBc	–50dBc
3rd Harmonic	–78dBc	< –90dBc	–62dBc	–70dBc
Effective Bits	10.5	11	10	8

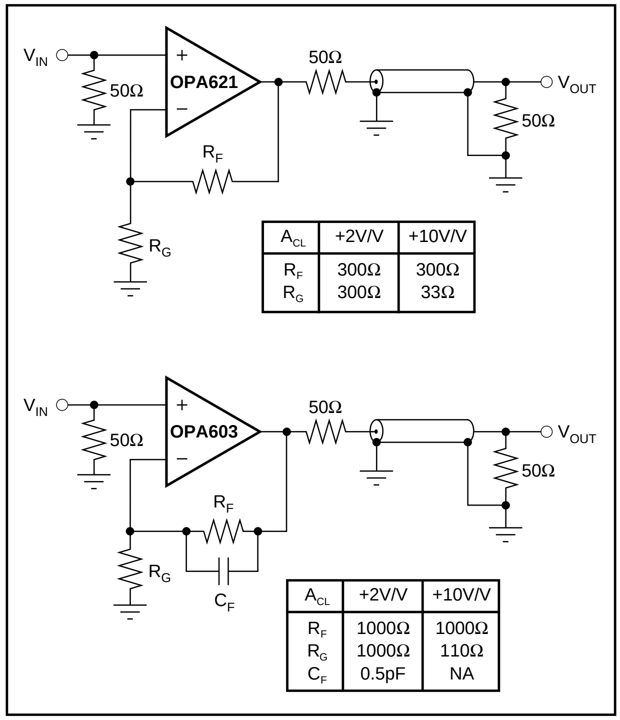

FIGURE 3. Application Circuits for OPA621 and OPA603.

This provides a simple way to compare the useful bandwidths of voltage-feedback amplifiers and current-feedback amplifiers. First, determine the closed-loop gain required, then use data sheet specifications in the formulas presented above to compare the open-loop responses as an approximate indicator of the best op amp for lower distortion.

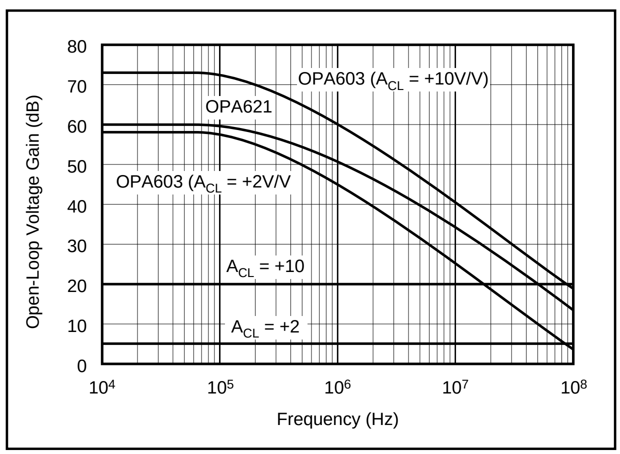

FIGURE 4. Open-Loop Gain Comparisons of the OPA621 and OPA603.