

CURRENT FEEDBACK AMPLIFIERS: REVIEW, STABILITY ANALYSIS, AND APPLICATIONS

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INTRODUCTION

Many Engineers still refuse to design with Current FeedBack (CFB) amplifiers. This is due to a few misunderstandings, which can be easily clarified.

The majority of op amp circuits are closed-loop feedback systems that implement classical control theory analysis. Analog designers are comfortable with Voltage FeedBack (VFB) op amps in a closed-loop system and are familiar with the ideal op amp approximations feedback permit. This application bulletin will demonstrate how CFB op amps can be analyzed in a similar fashion. Once the closed-loop similarities are understood, it is easy to see that most circuits commonly built with VFB amplifiers can utilize CFB amplifiers, yielding better results at high frequencies.

REVIEW

Figure 1 illustrates the open-loop terminal characteristics of a VFB amplifier. Ideally both the inverting and non-inverting inputs have infinite impedance. The output is a voltage source with zero impedance. The potential difference between the inverting and non-inverting inputs controls the voltage source ($A(s)$). Feedback drives this potential difference to zero.

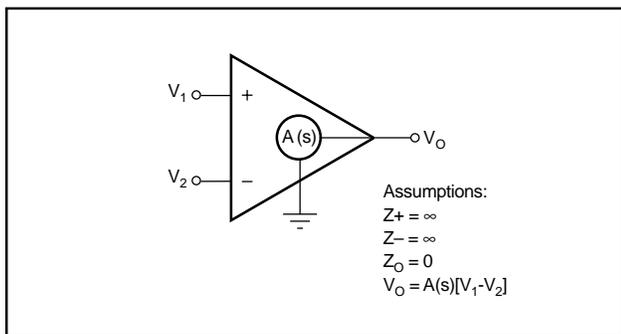


FIGURE 1. VFB Op Amp Model.

Figure 2 displays the terminal characteristics of a CFB amplifier. Ideally the unity gain buffer, between the inputs of the amplifier, cause the non-inverting input impedance to be infinite while the inverting input impedance is zero. The output impedance is zero, due to the voltage source. The current out of the inverting input controls the voltage source ($Z(s)$). Feedback forces this current to zero.

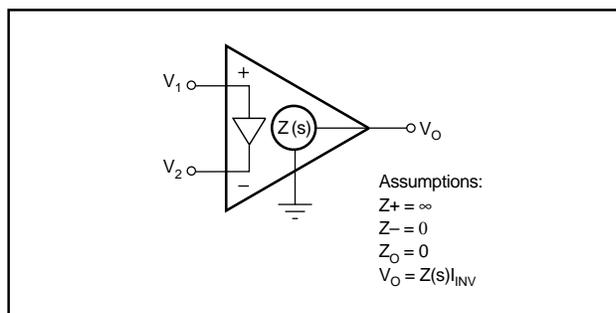


FIGURE 2. CFB Op Amp Model.

Figure 3 shows the basic configuration for inverting gain. This circuit holds true for both CFB and VFB amplifiers. A point to remember is that the value of the feedback resistor is limited for CFB amplifiers. A recommended value will be provided in the data sheet.

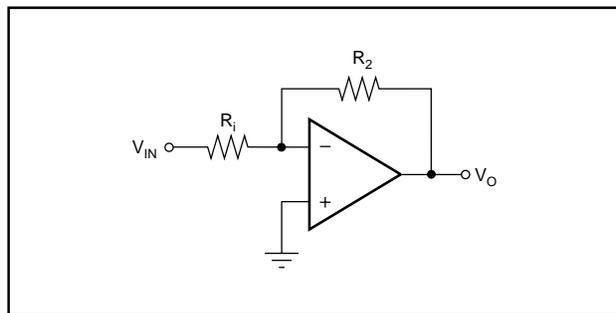


FIGURE 3. Inverting Gain Circuit.

For a the VFB amplifier of figure 3, the transfer function is obtained utilizing the following equations:

$$\begin{aligned} V_1 &= 0 \\ V_O &= -A(s)V_2 \\ \frac{V_i - V_2}{R_1} &= \frac{V_2 - V_O}{R_2} \end{aligned}$$

The transfer function of a VFB amplifier, configured as figure 3, is:

$$\frac{V_O}{V_i} = \frac{-\frac{R_2}{R_1}}{1 + \frac{R_2}{R_1} \frac{1}{A(s)}}$$

As $A(s)$ approaches infinity, the closed loop-gain is $-(R_2/R_1)$. The denominator of the transfer function determines the frequency response of the closed-loop circuit. The noise gain $(1 + R_2/R_1)$ and the frequency dependent source appear in the denominator. This links the closed-loop gain and bandwidth. A high gain configuration circuit will have less bandwidth than a lower gain circuit. As the circuit moves to lower gains, bandwidth increases, but phase margin is lost, causing instability.

For the CFB amplifier of figure 3, the transfer function is obtained utilizing the following equations:

$$\begin{aligned} V_1 &= 0 \\ V_O &= Z(s)I_{inv} \\ \frac{V_i}{R_1} + I_{inv} &= -\frac{V_O}{R_2} \end{aligned}$$

The transfer function of a CFB amplifier, configured as figure 3, is:

$$\frac{V_O}{V_i} = \frac{-\frac{R_2}{R_1}}{1 + \frac{R_2}{Z(s)}}$$

As $Z(s)$ approaches infinity, the closed-loop gain is $-(R_2/R_1)$. Notice that only the feedback resistor appears in the term with $Z(s)$. Only the feedback resistor affects the closed-loop frequency response.

A CFB op amp is commonly compensated for maximally flat response at a specified gain with a specified feedback resistor. The closed-loop bandwidth is determined by the feedback resistor, not the gain. This says that a feedback resistor twice the value of the manufacturers recommended value will have half the bandwidth. As the feedback impedance is reduced, there is a loss of phase margin. When $R_2/Z(s)$ equals negative one, the loop is unstable.

The design trade-offs between CFB amplifiers and VFB amplifiers differ. In general, VFB amplifiers offer:

- Lower Noise
- Better DC Performance
- Feedback Freedom

In general, CFB amplifiers offer:

- Gain-Bandwidth Impedance
- Faster Slew Rates
- Lower Distortion
- Feedback Restrictions

A common error in implementing a CFB amplifier is to short the output to the inverting input in order to configure a unity-gain buffer. This will cause the circuit to oscillate. The circuit requires the recommended feedback resistor in the feedback in place of the short to maintain stability.

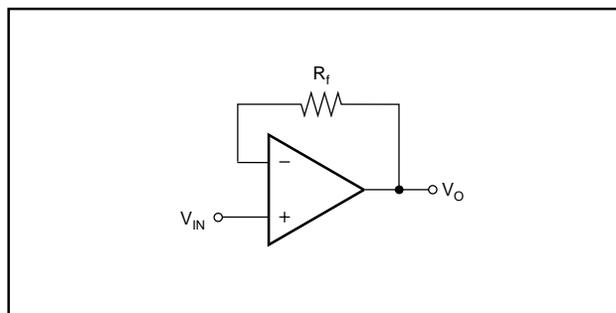


FIGURE 4. Unity-Gain Buffer.

Another example is an integrator circuit. This is commonly accomplished by placing a capacitor between the inverting input and the output of the amplifier. Keep in mind that at high frequencies a capacitor could easily have impedance less than that required for stability. The proper feedback resistor should be placed in series with the feedback capacitor. This will stabilize the amplifier, and introduce a high-frequency zero into the integrator transfer function.

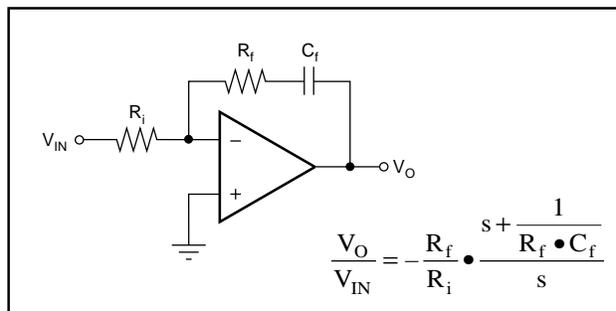


FIGURE 5. Integrator Circuit.

The low open-loop inverting input impedance also causes much concern among designers and is often viewed as making CFB amplifiers unsuitable as differential amplifiers. In fact, the low input impedance can result in a better high-frequency differential amplifier than a similar circuit implementing a VFB amplifier.

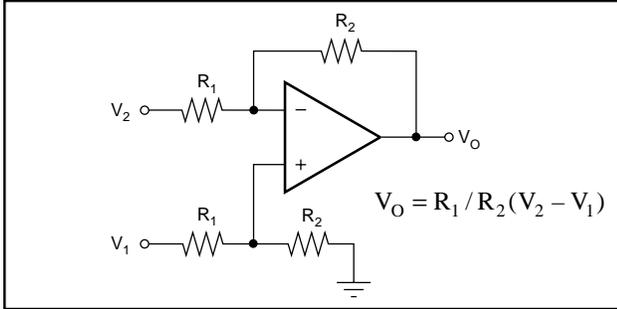


FIGURE 6. Differential Amplifier.

It can be seen that both VFB and CFB allow the same closed-loop assumptions to be made. VFB has a gain-bandwidth product, which limits the lowest stable gain. The lowest stable feedback impedance limits the lowest stable gain, for a CFB amplifier.

Both amplifier topologies can be used in closed-loop configurations implementing the same methods of analysis. CFB amplifiers can be designed into any arbitrary gain configuration and implement many circuit functions gaining better performance at higher frequencies.

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