

Technote 3

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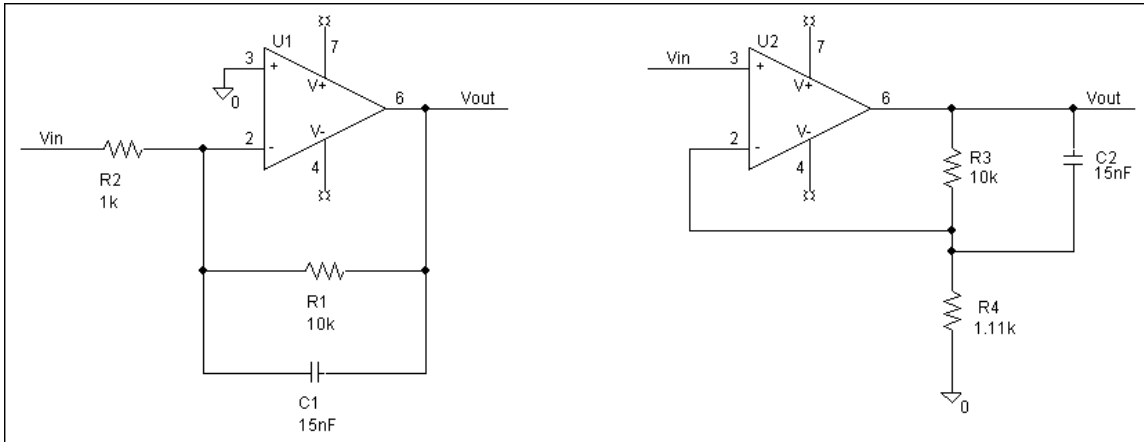
Inverting and Non-Inverting Amplifiers

Tim J. Sobering
SDE Consulting
sdeconsulting@pobox.com

Inverting and Non-Inverting Amplifiers

Which amplifier configuration yields the best noise performance?

Which amplifier configuration yields the lowest distortion?



Assume both opamps are identical and have a gain-bandwidth product of 100 kHz.

Inverting Amplifier
 DC Gain = -10 V/V
 BW = 1.06 kHz

Non-Inverting Amplifier
 DC Gain = 10 V/V
 BW = 1.06 kHz

Transfer Function:

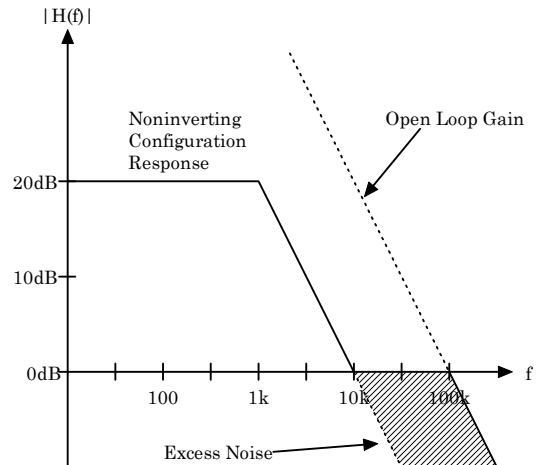
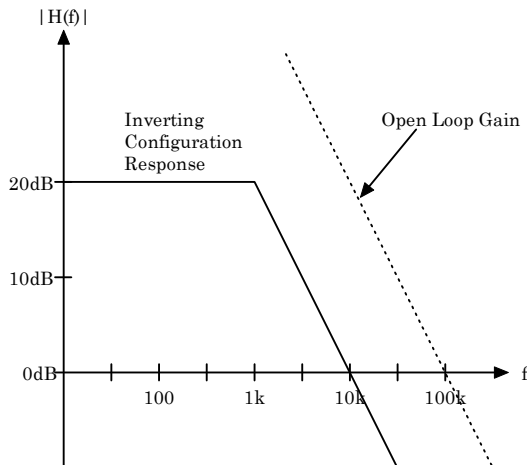
$$H(j\omega) = \frac{R_1}{R_2} \left(\frac{1}{1 + j\omega R_1 C_1} \right)$$

Transfer Function:

$$H(j\omega) = 1 + \frac{R_3}{R_4} \left(\frac{1}{1 + j\omega R_3 C_2} \right)$$

Above the frequency set by the pole at $\omega = (R_1 C_1)^{-1}$, gain decreases at -20 dB/decade as shown below.

Above the frequency set by the pole at $\omega = (R_3 C_2)^{-1}$, gain decreases at -20 dB/decade until response reaches 0dB. At that point, the "1 +" term of the equation dominates until the response intersects the open loop gain curve, as shown below.



Note that the magnitude of the signal gain for both amplifiers is the same, but the “internal” noise performance for these amplifiers is different. This is because the noise gain for the inverting amplifier is +11 V/V, while the noise gain for the non-inverting amplifier is +10 V/V because the voltage and current noise sources see different gains to the output. Any “external” noise (the noise present in the input signal) sees the same gain to the output, but the transfer functions are different as shown in the figures above. Many designers do not understand the concept of “noise gain” and Gain Bandwidth Product.

For example, if the feedback capacitors were removed in the two amplifier configurations above, the signal gains would still both have a magnitude of 10 V/V. However, the bandwidth of the inverting amplifier would be 9.09 kHz because it has a noise gain of +11 V/V, while the non-inverting amplifier would have a bandwidth of 10 kHz and a noise gain of +10 V/V. Signal Gain and Noise Gain are different between the two configurations.

Another, less obvious effect is that in the inverting configuration there is no resistance from the non-inverting input to ground. However, the non-inverting configuration will inevitably be driven from a source with a nonzero source resistance, which provides a path for the non-inverting input noise current and the source resistance also has an associated thermal noise. Thus, the non-inverting configuration has two additional noise sources that are amplified by the noise gain. Depending on the source impedance, these contributions can be significant.

Distortion is a much more subtle effect. Assuming everything else is equal, the one difference between the configurations is that they have different input common mode voltages. The common mode input voltage for the inverting amplifier (assuming bipolar supplies) is zero. However, for the non-inverting configuration, the common mode input voltage is a function of the input signal amplitude, and non-ideal amplifiers have a non-zero common mode gain. Depending on the CMRR for the amplifier, the amplitude of the signal, and the requirements of the application, this effect may be significant. There is a good discussion of this in “Opamp Applications”, Walter G. Jung, Editor, pp. 1.88 – 1.89, Analog Devices, 2002.