17. Op amps ... G = 1 stable and decompensated

Unity-gain-stable operational amplifiers (op amps) are stable in the common G = +1 configuration, returning 100 percent of the output signal back to the inverting input. While it would be incorrect to call this truly a "worst case" for stability, you could reasonably call it a very common, testy case.

Decompensated op amps have smaller compensation capacitors that yield wider gain bandwidth (GBW) and faster slew rates. While higher speed normally demands more power, the same basic op amp can be significantly faster while operating on the same current. But they are not unity gain stable – they must be used in noise gains significantly greater than unity.

Figure 42 shows the critical portion of a gain vs. frequency graph for an idealized pair of unity-gain-stable and decompensated op amps. The decompensated version has five times the GBW – 10 MHz vs. 2 MHz. Slew rate gets the same boost. Note that the unity-gain bandwidth of the unity gain stable op amp is slightly less than its GBW, a common behavior. The unity-gain bandwidth of the decompensated amplifier is half its GBW. You have no business operating this amplifier with noise gain near the unity-gain bandwidth because a second pole at 3 MHz greatly affects the gain/phase behavior in this region. Phase margin would be poor or nonexistent.

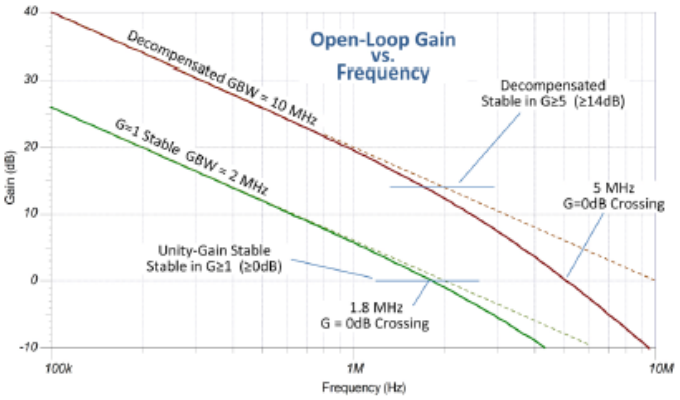


Figure 42: Graph of open-loop gain versus frequency for an idealized pair of unity-gain stable and decompensated op amps.

Decompensated op amps seem to hold a certain mystery, leaving some users uncertain about whether their circuits will be stable. **Figure 43a** shows a common misstep. Although this amplifier is connected in a signal gain of -10, a feedback capacitor rolls off the response at high frequency. This capacitor can be a virtual short circuit at high frequency where stability issues are a concern – unity gain. It is OK to use a small feedback capacitor to compensate the feedback network for flat gain, but a larger cap that rolls off response is sure to create problems.

Likewise, the multiple-feedback filter in **Figure 43b** invites trouble regardless of the low-frequency gain of the filter. The integrator (**Figure 43c**) is yet another application not suited to decompensated op amps.

TI has improved its op amp designs. We are smarter now and we have much better integrated circuit (IC) processes. With a few hundred microamperes, we can now make an amplifier that once required a couple of milliamperes. So sometimes a modern unity-gain-stable op amp may come very close to, or even beat, the speed/power of an older decompensated amp. Still, a decompensated op amp may be the best solution for a demanding application.

Let me be clear, I am not trying to urge you to select decompensated op amps over unity-gain-stable op amps. Each has merits, and you get to "vote" with your design choices. Whatever your selection, you should clearly understand the differences and issues. If you are unsure, help is available in the Precision Amplifiers forum on TI's E2E Community.

Here are some examples of decompensated and unity-gain-stable op amp pairs:

- OPA228 (OPA227 unity-gain-stable version) precision, low-noise, bipolar junction transistor (BJT) op amp.
- OPA637 (OPA627 unity-gain-stable version) precision, high-speed, junction FET (JFET) op amp.
- OPA345 (OPA344 unity-gain-stable version) rail-to-rail, CMOS op amp.
- LMP7717 (LMP7715 unity-gain-stable version) 88-MHz, CMOS op amp.

To see this original post with comments, click here.

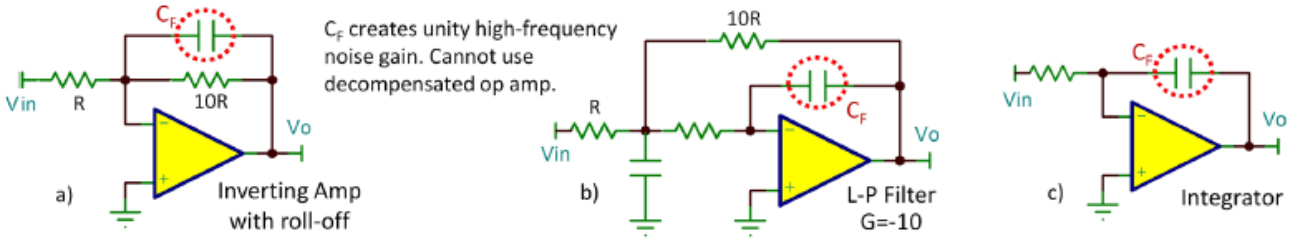


Figure 43: Using a decompensated op amp with a feedback capacitor to roll off the response at high frequency can lead instability (a); a multiple-feedback filter encounters problems irrespective of the filter's frequency gain (b); and an integrator is also unsuitable for decompensated op amps (c).

18. The inverting attenuator G = –0.1: is it unstable?

Unity-gain-stable operational amplifiers (op amps) are stable in a gain of one or greater, but not less, right? What to do (**Figure 44**)?

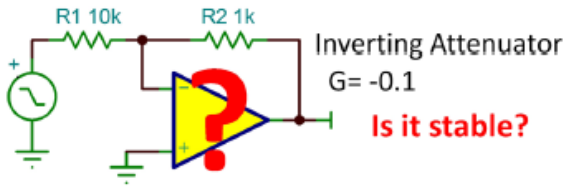


Figure 44: Example of an inverting attenuator.

OK, here is the short answer: an inverting attenuator is stable! You want to know why, right? There are a couple of ways to look at this issue, and a quick look may add clarity to general stability issues.

Consider this: If G = –0.1 were unstable, then even lower gain should be worse, right? Let us draw a circuit: a unity-gain amplifier with a 1-Ω feedback resistor, shown in **Figure 45**. Then consider possible circuit-board leakage forming an input resistor, R1 = 10 GΩ. This is a stray "input signal" amplified at very low inverting gain. Is it unstable? Certainly not! It is just a unity gain buffer with virtually no input. Stable.

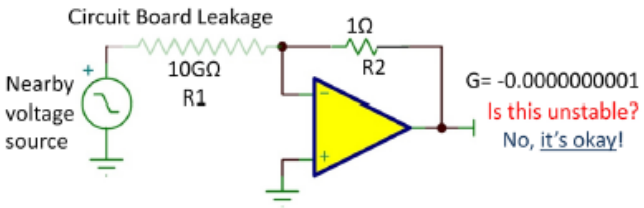


Figure 45: A unity-gain amplifier circuit with a 1-Ω feedback resistor is stable.

Think of the stability of an op amp as related to how much output signal is fed back to the inverting input. Stability experts refer to this feedback factor as beta (β). In unity gain, 100 percent of the output voltage is returned to the inverting input, so β is one. The example in **Figure 45** is essentially the same with nearly all of the output signal fed back to the inverting input.

Figure 46a shows an inverting amplifier and **Figure 46b** shows a noninverting amplifier. The circuits are the same; the input signal is just applied to different nodes. Both circuits return the same amount of output signal to the inverting input so their stability behavior is the same. β is the same.

Op amp wonks also use the term "noise gain" – so named because the op amp's voltage noise is amplified to the output by this factor. It is just another way to quantify the amount of feedback. An op amp circuit prone to oscillations or instability is incited by its own internal noise, amplified and fed back to the inverting input. The inverting amplifier, **Figure 46a**, has the same noise gain, β, and therefore the same stability behavior as its noninverting cousin, even though the input signal gain is different.

Are there circuits with noise gains less than one? Is β ever greater than one? Noise gains less than unity and β greater than one occur when gain is included in the feedback loop. Multiple amplifiers in a larger feedback loop, such as a control system, can face this issue. It also occurs when a transistor (common-emitter or common-source configuration) is included inside the feedback loop of an op amp. These circuits can have tricky stability problems.

Of course, there are other possible causes of oscillations or instability in an inverting attenuator. Capacitive load, excessively high resistor values or too much capacitance at the inverting input can cause instability – but these are unrelated to the basic inverting-attenuator configuration. Misconceptions about the "dangers" of the inverting attenuator persist. Relax. Simulate stability in TINA-TI software or your favorite SPICE program to confirm it. And if you have doubts or problems, check with the experts in the Precision Amplifiers forum on TI's E2E Community.

To see this original post with comments, click here.

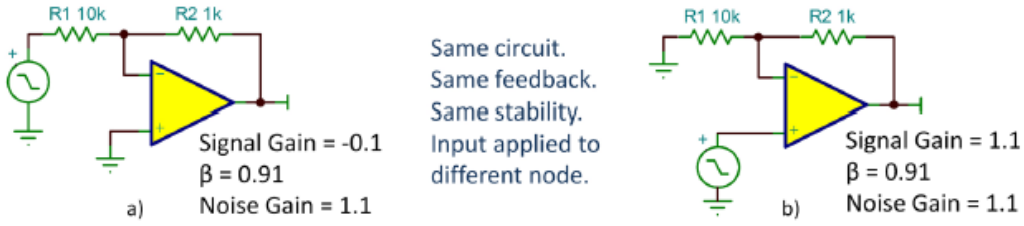


Figure 46: These two circuits, an inverting amplifier (a) and noninverting amplifier (b) have the same feedback factor and stability issues, but with the input signal are applied to different nodes.