Rarely Asked Questions—Issue 122
The Truth About Voltage Feedback Resistors

By Tina Collins

Question:

The stability of my fully differential and voltage feedback amplifiers seems highly impacted by the value of my feedback resistors—the R_F/R_G ratio is always correct, so what's happening?

Answer:

When a signal needs gain, an amplifier is the component of choice. The ratio of the feedback and gain resistors, R_F/R_G, for a voltage feedback and a fully differential amplifier, determines the gain. Once the ratio is set, the next step is to select a value for either R_F or R_G. The choice of R_F can impact the stability of the amplifier.

An amplifier's internal input capacitance, found in the specification table of the data sheet, interacts with R_F to form a pole in the transfer function. If R_F is exceedingly large, this pole will affect stability. If the pole occurs at a frequency much larger than the crossover frequency, it will not affect stability. However, if the location of the pole as determined by $f = 1/(2\pi R_F C_{in,amp})$ occurs near the crossover frequency, the phase margin will be reduced leading to potential instability.

The example of Figure 1 shows the lab results of the small signal closed-loop gain vs. frequency response for the ADA4807-1 voltage feedback amplifier in a noninverting gain of 2 configuration with feedback resistors 499 Ω, 1 kΩ, and 10 kΩ. The data sheet recommended R_F value is 499 Ω.

The degree of peaking in the small signal frequency response indicates instability. Increasing R_F from 499 Ω to 1 kΩ marginally increases peaking. This would imply the amplifier has sufficient phase margin with an R_F of 1 kΩ and is stable. This is not the case for the R_F of 10 kΩ. The high level of peaking present implies instability (oscillation) and it is not recommended.

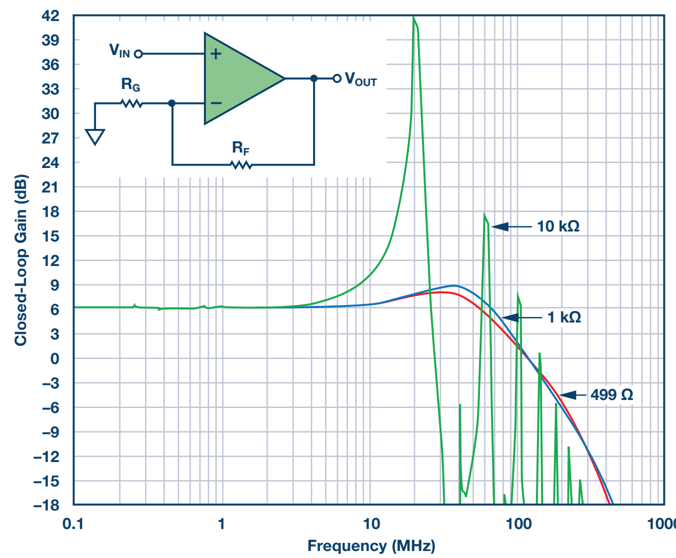

Figure 1. Lab results using different feedback resistors. $V_S = \pm 5$ V, $V_{OUT} = 40$ mV p-p, $R_{LOAD} = 1$ kΩ for R_F values of 499 Ω, 1 kΩ, and 10 kΩ.

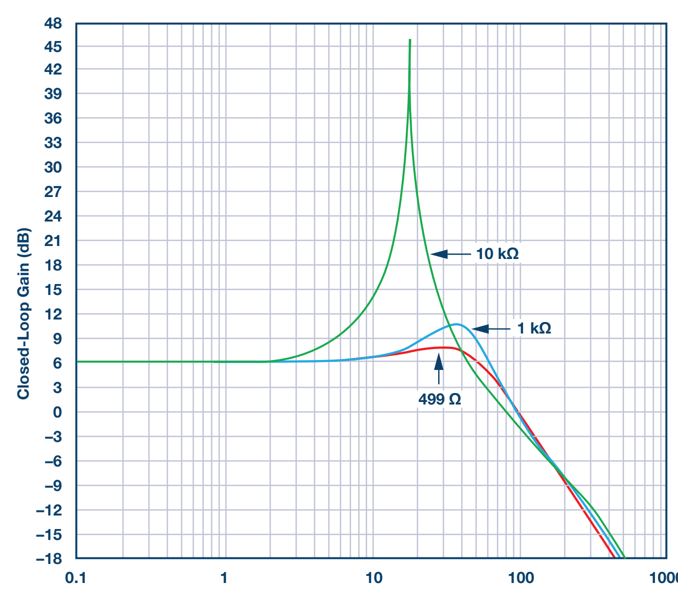

Figure 2. Simulation results using the ADA4807 SPICE model. $V_S = \pm 5$ V, G = 2 and $R_{LOAD} = 1$ kΩ for R_F values of 499 Ω, 1 kΩ, and 10 kΩ.

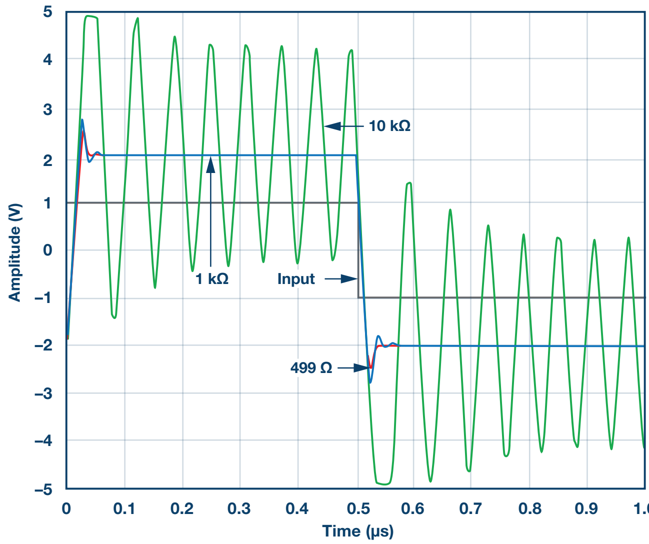

Figure 3. Pulse response simulation results using the ADA4807 SPICE model. V_S = ±5 V, G = 2 and R_{LOAD} = 1 kΩ for R_F values of 499 Ω, 1 kΩ, and 10 kΩ.

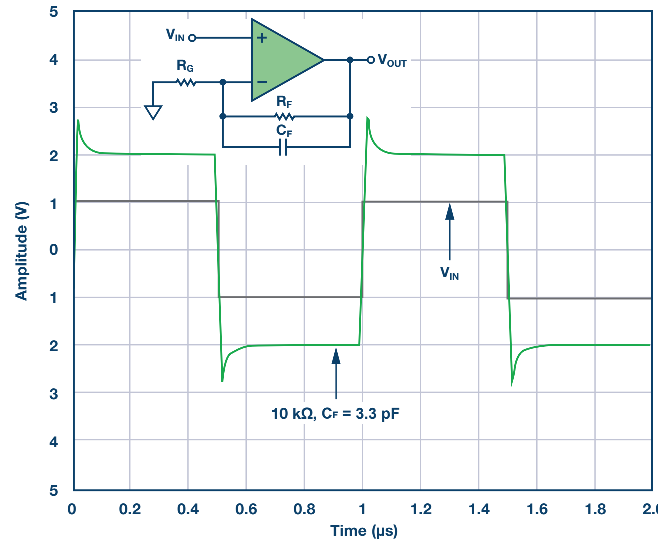

Figure 4. Pulse response simulation results with a 3.3 pF feedback capacitor, C_F. V_S = ±5 V, G = 2, R_F = 10 kΩ and R_{LOAD} = 1 kΩ.

Validating a circuit in the lab is not a mandatory step for verifying potential instabilities. Figure 3 shows the simulation results using the SPICE model with the same R_F values of 499 Ω, 1 kΩ, and 10 kΩ. The results are consistent with Figure 1. Figure 3 shows the instability in the time domain. Adding a zero to the transfer function by placing a feedback capacitor across R_F will remove the instability as shown in Figure 4.

There are trade-offs in the selection of R_F, which are power dissipation, bandwidth, and stability. If power dissipation is critical, and the data sheet recommended feedback value cannot be used or a much higher R_F value is necessary, placing a feedback capacitor in parallel with R_F is an option. This choice results in lower bandwidth.

When selecting the R_F for a voltage feedback and a fully differential amplifier, consideration needs to be given to the system requirements. If speed is not critical, a feedback capacitor will help to stabilize a large R_F value. If speed is critical, the recommended data sheet R_F value is advised.

Ignoring the relationship of R_F with respect to stability, bandwidth, and power, can hinder a system or, worse yet, prevent the system from achieving its full performance.

References:

Jung, Walter G. *Op Amp Applications Handbook*. Analog Devices, 2002.

MT-033 Tutorial. Voltage Feedback Op Amp Gain and Bandwidth.

MT-044 Tutorial. Op Amp Open-Loop Gain and Open-Loop Gain Nonlinearity.

MT-059 Tutorial. Compensating for the Effects of Input Capacitance on VFB and CFB Op Amps Used in Current-to-Voltage Converters.

Tina Collins [Tina.Collins@analog.com] is an applications engineer in the Linear Products and Technology group in Wilmington, MA. Her main interests are analog and mixed-signal design for high speed amplifiers. Tina joined Analog Devices in 2001. Prior to becoming an applications engineer in 2013, she focused on developing and testing high speed amplifiers. Tina received a B.S.E.E. from the University of Florida in 2001 and an M.S.E.E. from Northeastern University in 2010.