APPLICATION NOTE

COMPENSATING THE CURRENT MODE AMPLIFIER USING THE QS-I-TEST EVALUATION TEST BOX

CHOOSING A FEEDBACK RESISTOR VALUE

The QS-I-TEST evaluation box is a versatile system that allows the user to choose from 6 different feedback resistors so that an optimum gain and bandwidth can be found for the desired experiment. The QS-I-TEST evaluation box circuit board layout is shown on the last page to illustrate how this works.

Insert the detector being tested into the appropriate socket. Align the locator tab on the SPH package to the locater tab on the circuit board. If the device is an QS-IL series and the standard feedback resistor on the device is being used, performance can be improved by bending pin 2 of the device so it does not engage the socket on the board. This will reduce the stray capacitance on the pin and improve the bandwidth of the device. If a different responsivity is desired, then pin 2 is plugged in. The desired feedback resistor is selected by placing the supplied jumper on the appropriate pair of pins. The feedback values range from 10 GΩ to 100 kΩ in decades. Selecting a resistor with the jumper places it in parallel with the standard resistor on the SPH device, thus changing the effective feedback resistance.

COMPENSATING THE AMPLIFIER FOR THE CHOSEN FEEDBACK RESISTOR

When using the QS-I-TEST evaluation box, care must be taken when choosing the feedback resistor value. The following discussion explains why this is necessary and refers to the schematic shown in Figure 1.

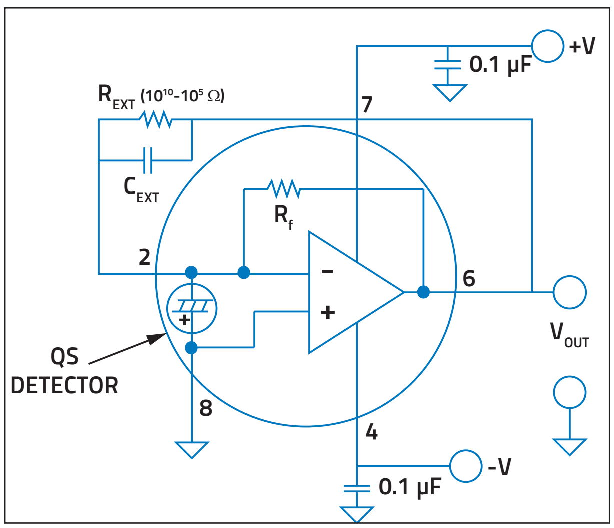

Figure 1: Schematic of the QS-I-TEST circuitry

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The presence of the amplifier introduces a zero in the voltage noise gain. There are 2 dominant poles set by circuit parameters as well as a 3rd pole set by the amplifier gain bandwidth. The 3rd pole is widely separated and can be ignored. The pole and zero of concern for this discussion are given by:

$$f_{zero} = \frac{1}{2\pi R_{feedback}(C_{element} + C_{amp} + C_{feedback})} \qquad f_{pole} = \frac{1}{2\pi R_{feedback} C_{feedback}}$$

The amplifier will have an uncompensated voltage gain equal to the open loop gain at DC. The gain will drop to 1 at the gain bandwidth frequency. The slope of this drop will be 20 dB/decade, and will start dropping at a frequency equal to:

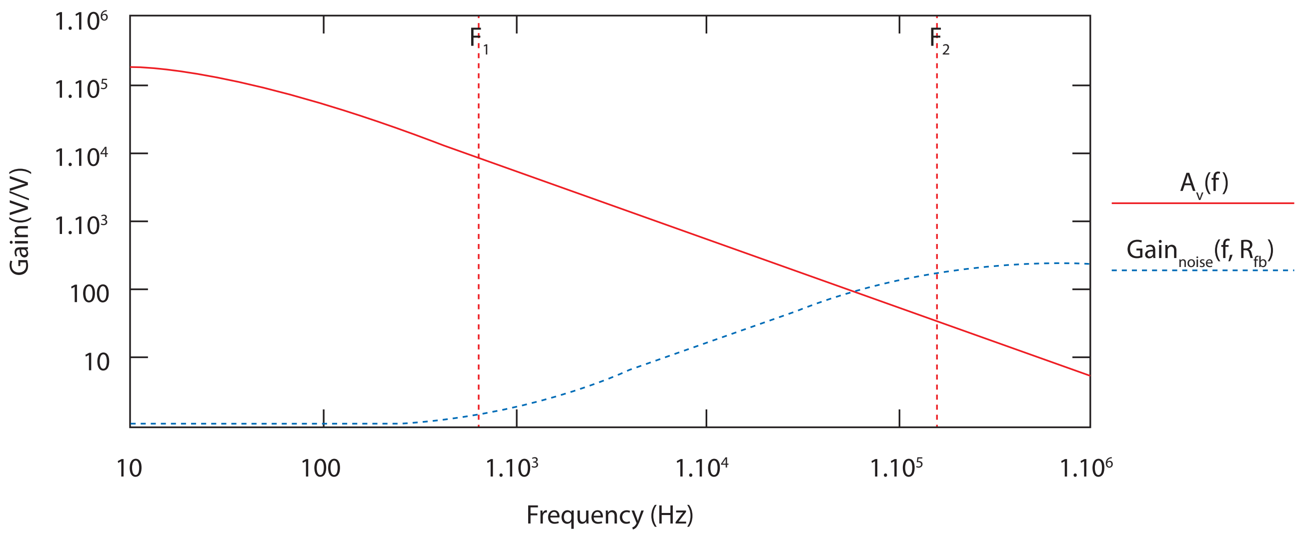
$$f_{amp\_pole} = \frac{f_c}{\text{OpenLoopGain}} \qquad \therefore \quad f_{amp\_pole} = \frac{f_c}{A_{OL}}$$

The zero in the voltage noise gain that must be compensated or the amplifier will oscillate. The noise due to the amplifier input noise voltage will be given by:

$$V_{noise} = \frac{e_{noise}\sqrt{1+\left(\frac{f}{f_{zero}}\right)^2}}{\sqrt{1+\left(\frac{f}{f_{zero}}\right)^2}}$$

The amplifier noise gain curve starts rising at 20 dB/decade when it hits the position of the zero at F1. It then flattens out when the zero is canceled by the pole at F2. This flattening must start at or before the noise curve crosses the open loop gain curve of the amplifier.
If it does not, then the amplifier will be unstable and may oscillate. The values of the feedback resistor, the feedback capacitance, and the amplifier parameters must be chosen to meet this condition. The amplifier open loop gain curve and noise voltage gain curves are plotted below to illustrate this point.

Figure 2: Transimpedance Amplifier Noise Gain and Open Loop Gain



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The value of the feedback capacitor that will ensure stability is found from the following equations:

$$C_c = \frac{1}{2\pi R_{feedback} f_c} \qquad f_c = \text{Op Amp Unity Gain Frequency}$$

$$C_{in} = C_{element} + C_{amplifier} + C_{stray}$$

$$C_{feedback} = \frac{C_c}{2}\left(1 + \sqrt{1 + \frac{4C_{in}}{C_c}}\right)$$

This value stabilizes the circuit while maximizing the bandwidth. If bandwidth is not a concern, then a larger value can be chosen. Larger feedback capacitors have the advantage of reducing noise.

The following table shows the values of the element capacitance and suggested feedback capacitors for the available feedback resistors used on the QS-I-TEST evaluation box. Values are shown for the QS-IL detector series as the amplifier used in the QS-IF detectors is a high bandwidth device and does not generally require external compensation. Note that, as the value of the feedback resistor becomes large, the value of the required feedback capacitor is reduced to the levels of stray capacitance. Once this level is reached, no external capacitor needs to be used, unless desired for noise reduction.

Feedback Resistor, R_f	Feedback Capacitance, C_F				
	QS1-IL C_D = 15 pF	QS2-IL C_D = 24 pF	QS3-IL C_D = 54 pF	QS5-IL C_D = 75 pF	QS9-IL C_D = 280 pF
100 kΩ	2.5 pF	3.1 pF	4.4 pF	5.1 pF	9.6 pF
1 MΩ	0.8 pF	1.0 pF	1.4 pF	1.6 pF	3.1 pF
10 MΩ	0.3 pF	0.4 pF	0.4 pF	0.5 pF	1.0 pF
100 MΩ	0.08 pF	0.09 pF	0.13 pF	0.16 pF	0.3 pF
1 GΩ	0.02 pF	0.03 pF	0.04 pF	0.05 pF	0.09 pF
10 GΩ	0.008 pF	0.009 pF	0.01 pF	0.02 pF	0.03 pF

Note: Amplifier capacitance = 2.5 pF, Stray Capacitance = 0.2 pF, and unity gain bandwidth = 5 MHz.

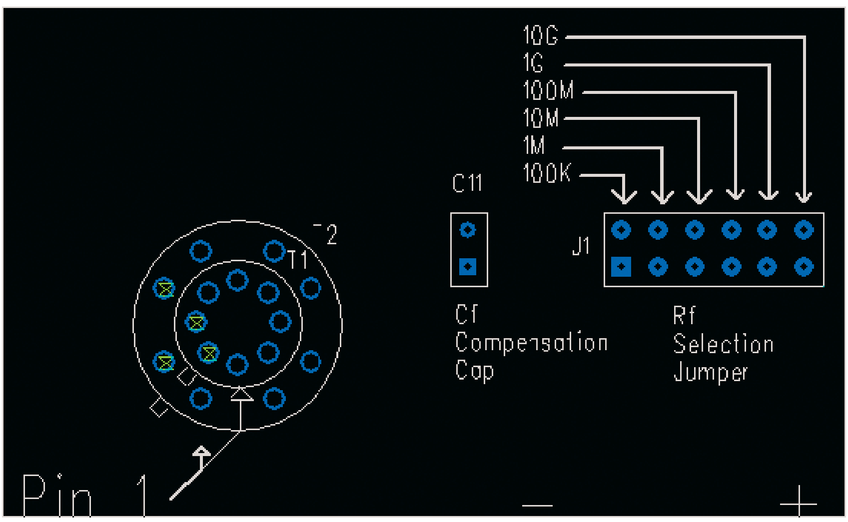

Figure 3: QS-I-TEST Board Location of Cf Compensation Cap and Rf Selection Jumper