SIGNAL INPUT AMPLIFIER and FILTERS

A lock-in can measure signals as small as a few nanovolts. A low noise signal amplifier is required to boost the signal to a level where the A/D converter can digitize the signal without degrading the signal to noise. The analog gain in the SR830 ranges from roughly 7 to 1000. As discussed previously, higher gains do not improve signal to noise and are not necessary.

The overall gain (AC plus DC) is determined by the sensitivity. The distribution of the gain (AC versus DC) is set by the dynamic reserve.

Input noise

The input noise of the SR830 signal amplifier is about 5 nVrms/√Hz. What does this noise figure mean? Let's set up an experiment. If an amplifier has 5 nVrms/√Hz of input noise and a gain of 1000, then the output will have 5 µVrms/√Hz of noise. Suppose the amplifier output is low pass filtered with a single RC filter (6 dB/oct roll off) with a time constant of 100 ms. What will be the noise at the filter output?

Amplifier input noise and Johnson noise of resistors are Gaussian in nature. That is, the amount of noise is proportional to the square root of the bandwidth in which the noise is measured. A single stage RC filter has an equivalent noise bandwidth (ENBW) of 1/4T where T is the time constant (RxC). This means that Gaussian noise at the filter input is filtered with an effective bandwidth equal to the ENBW. In this example, the filter sees 5 µVrms/√Hz of noise at its input. It has an ENBW of 1/(4x100ms) or 2.5 Hz. The voltage noise at the filter output will be 5 µVrms/√Hz x √2.5Hz or 7.9 µVrms.
For Gaussian noise, the peak to peak noise is about 5 times the rms noise. Thus, the output will have about 40 µV pk-pk of noise.

Input noise for a lock-in works the same way. For sensitivities below about 5 µV full scale, the input noise will determine the output noise (at minimum reserve). The amount of noise at the output is determined by the ENBW of the low pass filter. See the discussion of noise later in this section for more information on ENBW. The ENBW depends upon the time constant and filter roll off. For example, suppose the SR830 is set to 5 µV full scale with a 100 ms time constant and 6 dB/oct of filter roll off. The ENBW of a 100 ms, 6 dB/oct filter is 2.5 Hz. The lock-in will measure the input noise with an ENBW of 2.5 Hz. This translates to 7.9 nVrms at the input. At the output, this represents about 0.16% of full scale (7.9 nV/5 µV). The peak to peak noise will be about 0.8% of full scale.

All of this assumes that the signal input is being driven from a low impedance source. Remember resistors have Johnson noise equal to 0.13x√R nVrms/√Hz. Even a 50Ω resistor has almost 1 nVrms/√Hz of noise! A signal source impedance of 2kΩ will have a Johnson noise greater than the SR830's input noise. To determine the overall noise of multiple noise sources, take the square root of the sum of the squares of the individual noise figures. For example, if a 2kΩ source impedance is used, the Johnson noise will be 5.8 nVrms/√Hz. The overall noise at the SR830 input will be $[5^2 + 5.8^2]^{1/2}$ or 7.7 nVrms/√Hz.

We'll talk more about noise sources later in this section.

At lower gains (sensitivities above 50 µV), there is not enough gain at high reserve to amplify the input noise to a level greater than the noise of the A/D converter. In these cases, the output noise is determined by the A/D noise. Fortunately, at these sensitivities, the DC gain is low and the noise at the output is negligible.

Notch filters

The SR830 has two notch filters in the signal amplifier chain. These are pre-tuned to the line frequency (50 or 60 Hz) and twice the line frequency (100 or 120 Hz). In circumstances where the largest noise signals are at the power line frequencies, these filters can be engaged to remove noise signals at these frequencies. Removing the largest noise signals before the final gain stage can reduce the amount of dynamic reserve required to perform a measurement. To the extent that these filters reduce the required reserve to either 60 dB or the minimum reserve (whichever is higher), then some improvement might be gained. If the required reserve without these notch filters is below 60 dB or if the minimum reserve is sufficient, then these filters do not significantly improve