DIABLO MOUNTAIN REASERCH, LLC.741 BUENA VISTA PLACE Walnut Creek, California 94597 TEL: 925 788-4807

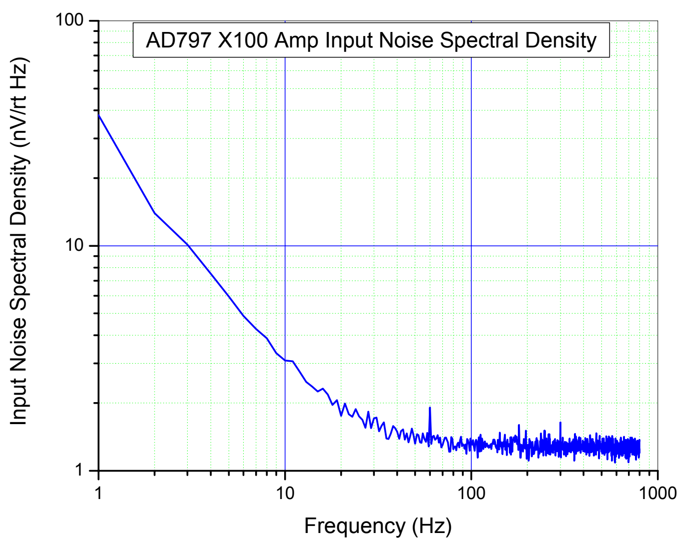
Low Noise / Low THD Gain of 100 Dual Amplifier/Driver and Measuring Below the Equipment Noise Level

When you can't see the noise of your DUT (Device Under Test), or dig out that small signal due to the noise floor of your measurement equipment, the most straightforward approach is to use a low noise preamp. We certainly need low noise preamps with RF spectrum analyzers due to their rather high~20dB high noise figure. Low frequency analyzers have finite noise floor limits. This technical note presents both a versatile low frequency low noise dual preamp, and a correlation based measurement approach to reducing the noise floor in measurements below 500KHz. The combined techniques result in a noise floor of less than 0.5nV/√Hz.

A representative low frequency signal analyzer is the SRS (Stanford Research Systems) SR780 or its updated version the SR785. A similar instrument is also available from Agilent; the 35670A, which replaces the venerable HP3562A Dynamic Signal Analyzer.

Even though the SR780 Analyzer has a respectable noise floor of ~7nV/√Hz at 1KHz, there is significant 1/f noise so that at 10Hz the noise level rises to about 15nV/√Hz at 10Hz, and 110nV/√Hz at 1Hz. A simple low noise dual preamp can significantly improve the noise floor to simplify measurements.

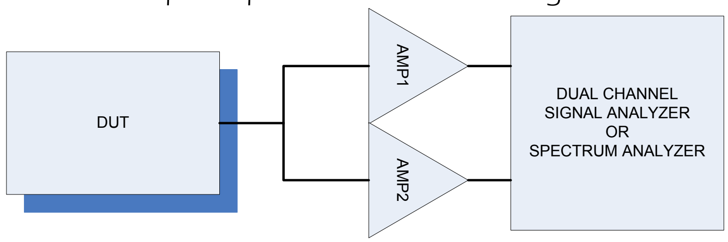
The gain of 100 dual preamp presented in this note (schematic on the last page) shows a very low typical noise floor of ~1.4nV/√Hz at 1KHz:



The AD797 based dual amplifier is capable of both low noise and very low THD (Total Harmonic Distortion), less than 0.001%. It's bandwidth at a gain of 100 is a very decent 550KHz, and the beefy TI BUF634 buffer provides ample drive for 50 ohm loads. The basic amplifier/buffer topology is stable for gains as low as 2, using RF/RI = 301 ohms. In picking your gain setting resistors, recall that a 50 ohm resistance results in ~1nV/√Hz. Although not shown in the schematic, battery power can be also used. In my construction, I put in the option of using either lab bench power or 9V batteries to aid in measurements where minimizing 60Hz, and harmonics, is important.

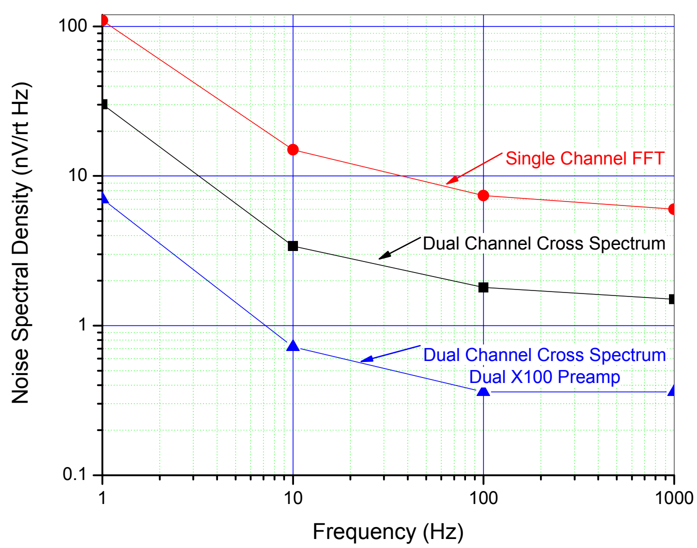
The Cross Spectrum (Correlation Approach) Measurement Technique

So, why build up two identical low noise preamps? Given the block diagram shown below:



we realize that the noise from each of the preamps, and two measurement input channels is uncorrelated, but the noise from the DUT (Device Under Test) is correlated in both channels. Thus we can use correlation [1], [2] or a cross spectrum approach (see [3] below, cross spectrum = Avg($FFT1_{conj}$*FFT2) with vector averaging).

The plot below shows the typical noise floor for the SRS SR780 signal analyzer, the improvement when using the two channel cross spectrum technique, and the best performance, 0.36nV/√Hz, using the cross spectrum technique with the dual low noise preamp:



This technique of correlation or cross spectrum processing has been known and used for many years (the earliest mention that I could easily find is from the 1970's, although it has been likely used prior to that era. The technique can be used for low frequency or high frequency and in both discrete and continuous time measurements.

1. M. Sampietro, G. Accomando, L. Fasoli, G. Ferrari and E. Gatti, "High Sensitivity Noise Measurement with a Correlation Spectrum Analyzer", *IEEE Transactions on Instrumentation and Measurement*, Vol. 49, No. 4, pp. 820-822, August 2000.

2. Bendat and Piersol, *Engineering Applications of Correlation and Spectral Analysis, 2nd Edition*. New York: John Wiley and Sons, 1993.

3. Stanford Research Systems, *Model SR780 Network Signal Analyzer Operating Manual and Programming Reference*. Note: Instruction manuals for the SR780 and SR785 are available on the Stanford Research Systems web site.

Schematic of the Dual X100 Preamp