THE PHASE SENSITIVE DETECTORS (PSD's)

The SR830 multiplies the signal with the reference sine waves digitally. The amplified signal is converted to digital form using a 16 bit A/D converter sampling at 256 kHz. The A/D converter is preceded by a 102 kHz anti-aliasing filter to prevent higher frequency inputs from aliasing below 102 kHz. The signal amplifier and filters will be discussed later.

This input data stream is multiplied, a point at a time, with the computed reference sine waves described previously. Every 4 µs, the input signal is sampled and the result is multiplied by the two reference sine waves (90° apart).

Digital PSD vs Analog PSD

The phase sensitive detectors (PSD's) in the SR830 act as linear multipliers, that is, they multiply the signal with a reference sine wave. Analog PSD's (both square wave and linear) have many problems associated with them. The main problems are harmonic rejection, output offsets, limited dynamic reserve and gain error.

The digital PSD multiplies the digitized signal with a digitally computed reference sine wave. Because the reference sine waves are computed to 20 bits of accuracy, they have very low harmonic content. In fact, the harmonics are at the -120 dB level! This means that the signal is multiplied by a single reference sine wave (instead of a reference and its many harmonics) and only the signal at this single reference frequency is detected. The SR830 is completely insensitive to signals at harmonics of the reference. In contrast, a square wave multiplying lock-in will detect at all of the odd harmonics of the reference (a square wave contains many large odd harmonics).

Output offset is a problem because the signal of interest is a DC output from the PSD and an output offset contributes to error and zero drift. The offset problems of analog PSD's are eliminated using the digital multiplier. There are no erroneous DC output offsets from the digital multiplication of the signal and reference. In fact, the actual multiplication is totally free from errors.

The dynamic reserve of an analog PSD is limited to about 60 dB. When there is a large noise signal present, 1000 times or 60 dB greater than the full scale signal, the analog PSD measures the signal with an error. The error is caused by non-linearity in the multiplication (the error at the output depends upon the amplitude of the input). This error can be quite large (10% of full scale) and depends upon the noise amplitude, frequency, and waveform. Since noise generally varies quite a bit in these parameters, the PSD error causes quite a bit of output uncertainty.

In the digital lock-in, the dynamic reserve is limited by the quality of the A/D conversion. Once the input signal is digitized, no further errors are introduced. Certainly the accuracy of the multiplication does not depend on the size of the numbers. The A/D converter used in the SR830 is extremely linear, meaning that the presence of large noise signals does not impair its ability to correctly digitize a small signal. In fact, the dynamic reserve of the SR830 can exceed 100 dB without any problems. We'll talk more about dynamic reserve a little later.

An analog linear PSD multiplies the signal by an analog reference sine wave. Any amplitude variation in the reference amplitude shows up directly as a variation in the overall gain. Analog sine wave generators are susceptible to amplitude drift, especially as a function of temperature. The digital reference sine wave has a precise amplitude and never changes. This eliminates a major source of gain error in a linear analog lock-in.

The overall performance of a lock-in amplifier is largely determined by the performance of its phase sensitive detectors. In virtually all respects, the digital PSD outperforms its analog counterparts.

We've discussed how the digital signal processor in the SR830 computes the internal oscillator and two reference sine waves and handles both phase sensitive detectors. In the next section, we'll see the same DSP perform the low pass filtering and DC amplification required at the output of the PSD's. Here again, the digital technique eliminates many of the problems associated with analog lock-in amplifiers.