increasingly useful the lower the reference frequency. Imagine what the time constant would need to be at 0.001 Hz!

In the SR830, synchronous filters are available at detection frequencies below 200 Hz. At higher frequencies, the filters are not required (2F is easily removed without using long time constants). Below 200 Hz, the synchronous filter follows either one or two stages of normal filters. The output of the synchronous filter is followed by two more stages of normal filters. This combination of filters notches all multiples of the reference frequency and provides overall noise attenuation as well.

Long Time Constants

Time constants above 100 seconds are difficult to accomplish using analog filters. This is simply because the capacitor required for the RC filter is prohibitively large (in value and in size!). Why would you use such a long time constant? Sometimes you have no choice. If the reference is well below 1 Hz and there is a lot of low frequency noise, then the PSD output contains many very low frequency components. The synchronous filter only notches multiples of the reference frequency, the noise is filtered by the normal filters.

The SR830 can provide time constants as long as 30000 seconds at reference frequencies below 200 Hz. Obviously you don't use long time constants unless absolutely necessary, but they're available.

DC Output Gain

How big is the DC output from the PSD? It depends on the dynamic reserve. With 60 dB of dynamic reserve, a noise signal can be 1000 times (60 dB) greater than a full scale signal. At the PSD, the noise can not exceed the PSD's input range. In an analog lock-in, the PSD input range might be 5V. With 60 dB of dynamic reserve, the signal will be only 5 mV at the PSD input. The PSD typically has no gain so the DC output from the PSD will only be a few millivolts! Even if the PSD had no DC output errors, amplifying this millivolt signal up to 10 V is error prone. The DC output gain needs to be about the same as the dynamic reserve (1000 in this case) to provide a 10 V output for a full scale input signal. An offset as small as 1 mV will appear as 1 V at the output! In fact, the PSD output offset plus the input offset of the DC amplifier needs to be on the order of 10 µV in order to not affect the measurement. If the dynamic reserve is increased to 80dB, then this offset needs to be 10 times smaller still. This is one of the reasons why analog lock-ins do not perform well at very high dynamic reserve.

The digital lock-in does not have an analog DC amplifier. The output gain is yet another function handled by the digital signal processor. We already know that the digital PSD has no DC output offset. Likewise, the digital DC amplifier has no input offset. Amplification is simply taking input numbers and multiplying by the gain. This allows the SR830 to operate with 100 dB of dynamic reserve without any output offset or zero drift.

What about resolution?

Just like the analog lock-in where the noise can not exceed the input range of the PSD, in the digital lock-in, the noise can not exceed the input range of the A/D converter. With a 16 bit A/D converter, a dynamic reserve of 60 dB means that while the noise has a range of the full 16 bits, the full scale signal only uses 6 bits. With a dynamic reserve of 80 dB, the full scale signal uses only 2.5 bits. And with 100 dB dynamic reserve, the signal is below a single bit! Clearly multiplying these numbers by a large gain is not going to result in a sensible output. Where does the output resolution come from?

The answer is filtering. The low pass filters effectively combine many data samples together. For example, at a 1 second time constant, the output is the result of averaging data over the previous 4 or 5 seconds. At a sample rate of 256 kHz, this means each output point is the exponential average of over a million data points. (A new output point is computed every 4 µs and is a moving exponential average). What happens when you average a million points? To first order, the resulting average has more resolution than the incoming data points by a factor of million . This represents a gain of 20 bits in resolution over the raw data. A 1 bit input data stream is converted to 20 bits of output resolution.

The compromise here is that with high dynamic reserve (large DC gains), some filtering is required. The shortest time constants are not available when the dynamic reserve is very high. This is not really a limitation since presumably there is noise which is requiring the high dynamic reserve and thus substantial output filtering will also be required.