# REFERENCE CHANNEL

A lock-in amplifier requires a reference oscillator phase-locked to the signal frequency. In general, this is accomplished by phase-locking an internal oscillator to an externally provided reference signal. This reference signal usually comes from the signal source which is providing the excitation to the experiment.

## Reference Input

The SR830 reference input can trigger on an analog signal (like a sine wave) or a TTL logic signal. The first case is called External Sine. The input is AC coupled (above 1 Hz) and the input impedance is 1 MΩ. A sine wave input greater than 200 mV pk will trigger the input discriminator. Positive zero crossings are detected and considered to be the zero for the reference phase shift.

TTL reference signals can be used at all frequencies up to 102 kHz. **For frequencies below 1 Hz, a TTL reference signal is required.** Many function generators provide a TTL SYNC output which can be used as the reference. This is convenient since the generator's sine output might be smaller than 200 mV or be varied in amplitude. The SYNC signal will provide a stable reference regardless of the sine amplitude.

When using a TTL reference, the reference input trigger can be set to Pos Edge (detect rising edges) or Neg Edge (detect falling edges). In each case, the internal oscillator is locked (at zero phase) to the detected edge.

## Internal Oscillator

The internal oscillator in the SR830 is basically a 102 kHz function generator with sine and TTL sync outputs. The oscillator can be phase-locked to the external reference.

The oscillator generates a digitally synthesized sine wave. The digital signal processor, or DSP, sends computed sine values to a 16 bit digital-to-analog converter every 4 μs (256 kHz). An anti-aliasing filter converts this sampled signal into a low distortion sine wave. The internal oscillator sine wave is output at the SINE OUT BNC on the front panel. The amplitude of this output may be set from 4 mV to 5 V.

When an external reference is used, this internal oscillator sine wave is phase-locked to the reference. The rising zero crossing is locked to the detected reference zero crossing or edge. In this mode, the SINE OUT provides a sine wave phase-locked to the external reference. At low frequencies (below 10 Hz), the phase locking is accomplished digitally by the DSP. At higher frequencies, a discrete phase comparator is used.

The internal oscillator may be used without an external reference. In the Internal Reference mode, the SINE OUT provides the excitation for the experiment. The phase-locked-loop is not used in this mode since the lock-in reference is providing the excitation signal.

The TTL OUT on the rear panel provides a TTL sync output. The internal oscillator's rising zero crossings are detected and translated to TTL levels. This output is a square wave.

## Reference Oscillators and Phase

The internal oscillator sine wave is not the reference signal to the phase sensitive detectors. The DSP computes a second sine wave, phase shifted by $\theta_{ref}$ from the internal oscillator (and thus from an external reference), as the reference input to the X phase sensitive detector. This waveform is $\sin(\omega_r t + \theta_{ref})$. The reference phase shift is adjustable in .01° increments.

The input to the Y PSD is a third sine wave, computed by the DSP, shifted by 90° from the second sine wave. This waveform is $\sin(\omega_r t + \theta_{ref} + 90°)$.

Both reference sine waves are calculated to 20 bits of accuracy and a new point is calculated every 4 μs (256 kHz). The phase shifts ($\theta_{ref}$ and the 90° shift) are also exact numbers and accurate to better than .001°. Neither waveform is actually output in analog form since the phase sensitive detectors are actually multiply instructions inside the DSP.

## Phase Jitter

When an external reference is used, the phase-locked loop adds a little phase jitter. The internal oscillator is supposed to be locked with zero phase shift relative the external reference. Phase