Phase Locked Oscillators

Series 600

Spectrum Microwave's experience with Phase Locked Oscillators covers a period of 25 years; we have worked closely with Systems Engineers on some of the most technically sophisticated programs in the country. The phase locked oscillator must be compatible with other components in the system and must not only operate properly on the "bench" but must also operate properly in complex systems. It is necessary to discuss power supply noise, load impedances, and other system considerations to provide a design that will be successful during the first integration into the system, thereby avoiding returns, which cause delays for the end-user.

Features

- **Low Phase Noise**
- **Low Microphonics**
- **Rugged Construction**
- **Military Options**

APPLICATION INFORMATION

Oscillator Noise AM and FM (Phase)

The perfect oscillator produces a signal whose spectrum would consist of a single line of infinitesimal width. No perfect oscillator has yet been discovered; consequently, oscillators have noise spectra in accordance with well-established theory. The spectrum of a typical low noise oscillator is shown in Figure 1.

AM noise is generally far enough below FM noise in an oscillator that it is of little concern. FM noise can vary considerably among manufacturers and shouldn't be taken for granted because it can be the limiting factor in applications like narrow-band communication links, frequency synthesizers, Doppler radars, etc. It limits the range resolution, sensitivity, and channel spacing of these systems. Control of the discrete noise components is as much the task of the Systems Engineer as the Oscillator Designer. "Pickup" on the tuning line due to unshielded wires, poor filtering, grounding, etc. will produce noise sidebands. The oscillator should be isolated from digital circuitry and separate power supplies should be used when possible.

FM noise may be due to discrete modulation signals such as power line frequencies and mechanical vibrations. These produce discrete sideband noise at the frequency of modulation, as shown in Figure 1; they are also called spurious signals. FM noise can also be due to random type modulation caused by thermal variations and flicker noise within the device, the Q of the tank circuit, etc. The spectral density plot of these sidebands shows a continuous spectrum over a wide range of frequencies similar to broadband noise, sometimes called "hash."

From FM theory, the ratio of power in the carrier to one of the sidebands due to this noise can be predicted by:

$$dB = 20 \log - \frac{2fm}{\Delta F} \qquad (1)$$

Where fm = frequency of noise in Hz. The phase noise of a VCO can be improved by phase locking it to a stable reference, such as a low-frequency Crystal Oscillator; this Reference Oscillator can be either internal or external. The phase noise of the Output Oscillator will then be 20logN in dB greater than the Reference Oscillator within the loop bandwidth [N = F Out/F Ref]. The phase noise outside the loop bandwidth will still be that of the Output Oscillator. Figure 2 is a commonly used plot for showing phase noise.

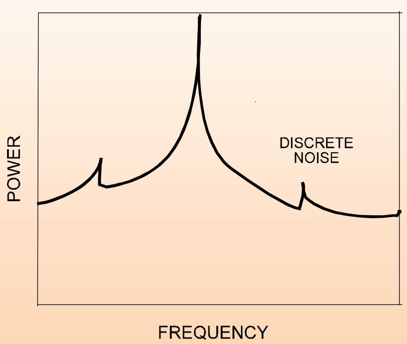

FIGURE 1

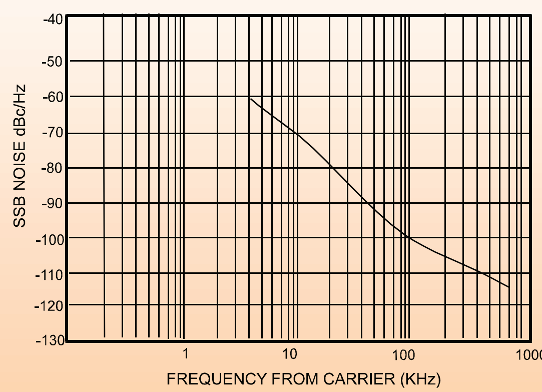

FIGURE 2

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Measuring Phase Noise

Figure 3 shows a common method of measuring Phase Noise. In the two-source method, the signal of the unit under test is down-converted in a double balanced mixer, which acts like a phase detector. One of the sources is tunable and is adjusted 90 degrees out of phase to the other unit (quadrature). The output of the mixer is then proportional to the fluctuating phase difference between the inputs. Now the phase noise can be observed using a low-noise, low-frequency spectrum analyzer. This is the most sensitive method for measuring phase noise. One source, the Reference, should have better phase noise than the unit under test because the phase noise (from both units) contributes to the total noise measurement. If two identical oscillators are available, they can be used as the unit under test and as the Reference. In this case, 3 dB can be subtracted from the final data to show the noise contribution from one source. When modifying a fixed oscillator to act as the Reference, the tuning should be kept to a minimum so that the phase noise is not degraded.

A second method, shown in Figure 4, is called the discriminator method. This is convenient because it requires only a single oscillator; however, it is a less sensitive method. It is used for measuring VCOs with wide tuning ranges and for other less stable sources. The signal is split into two equal paths; one path has a delay line, which is selected to be long enough for the offset frequency being measured to uncorrelate the noise with respect to the other path. An amplifier makes up the loss of the delay line. The second path has a phase shifter of some sort to get the signals in quadrature (90 degrees out of phase). The mixer acts as a phase detector as in the first example.

Selecting an External Reference

10 MHz and 100 MHz external references are very common. For very close-in phase noise, the choice of either may result in the same output phase noise.

For close-in phase noise (<100 Hz), a 10 MHz reference is probably 20 dB better than a 100 MHz reference and either may be used. However, at offsets greater than 1 KHz, the 10 MHz reference might not be 20 dB better; in fact, at 1 KHz, they may be equal. If so, then using the 10 MHz reference will result in 20 dB higher phase noise at 1 KHz and beyond due to the N being 10 times greater (assuming a wide loop bandwidth).

Simple Phase Locked Oscillator

Figure 5 shows a simplified block diagram for a Phase Locked Oscillator. An internal or external crystal oscillator reference is normally used; this type of circuit is used when the output frequency is some multiple "N" of the input reference frequency. An internal reference can always be selected to give the desired output frequency. In cases where the customer selects 10 MHz or 100 MHz as a reference and the output frequency is not a multiple of these frequencies, a different phase locking scheme is used. The approach generally involves a programmable divider to obtain the frequencies required for the Phase Detector. The DRO or CRO, when phase locked to a crystal reference, will have the same stability as the Reference Crystal Oscillator and will have improved phase noise within the loop bandwidth.

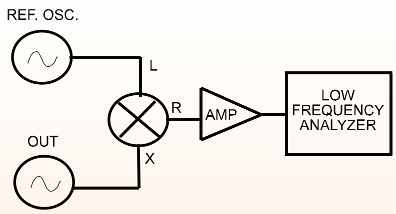

FIGURE 3 Phase Detector Method

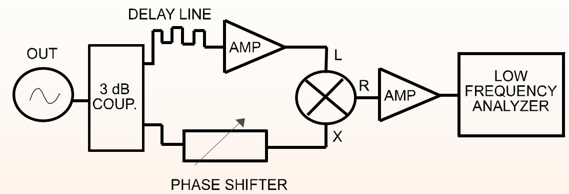

FIGURE 4 Discrimination Method

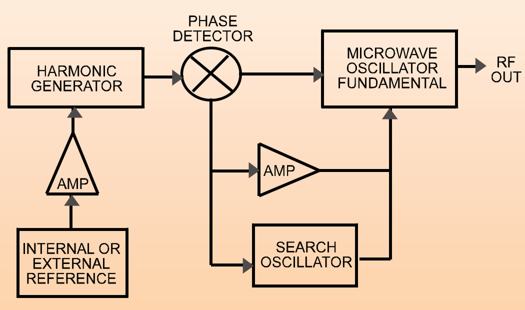

FIGURE 5 Phase Locked Fundamental Oscillator

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