Voltage Controlled Oscillators

Series 100

SPECTRUM MICROWAVE INC. A Spectrum Control Business

Spectrum Microwave engineers have over 30 years' experience in the design and production of Voltage Controlled Oscillators; during these years, advances in the semiconductor field have been extraordinary. The available transistors during the 1960s were in the 2 GHz range; today in our designs, we use Bipolar transistors and FETs at frequencies to 18 GHz.

Spectrum Microwave's designs have progressed with the advances in semiconductor technology to provide our customers with state-of-the-art oscillators. Today's demands for lower phase noise, stability, and reliability are challenges that Spectrum Microwave continues to meet.

Features

- Proven Designs
- Low Cost 180/190 Models
- Linearized Units
- Small Size
- Up to Octave Tuning

APPLICATION INFORMATION

General

The focus of Spectrum Microwave's designs are fundamental varactor tuned transistor oscillators. There are important considerations the customer should be aware of when specifying Spectrum Microwave VCOs.

Power Output and Tuning Bandwidth

The varactor in small signal operation behaves much like a conventional variable capacitor. In large signal operation, the RF voltage on the varactor may be of the same magnitude as the DC bias or even greater. This results in the varactor conducting during part of the RF cycle, producing a detection current in the varactor; degradation of long-term stability, phase noise, residual FM, and harmonic distortion occur. This effect can be limited in high-power VCOs by reducing the bandwidth, operating the varactor in greater reverse bias and by using multiple varactors. For power levels of several hundred milliwatts, the effects may not be significant; however, by specifying only the power and bandwidth required, you can be assured of the best performance available.

Power Output and Tuning Bandwidth

Oscillator stability can be divided into long term and short term. Long-term stability is the relatively slow change in frequency with time; it can be measured easily using a frequency counter. Short-term stability is for exceedingly small time periods and must be measured in the frequency domain using a spectrum analyzer or phase noise measuring equipment. Short-term stability is discussed under Oscillator Noise. (See reverse side.)

Long-term stability is a simple parameter to compare. VCO stabilities of 100 to 200 ppm/ºC can be expected as an average frequency change for the -55ºC to +71ºC temperature range. Ovens can increase the stability of a VCO by a factor of 10. Proportional ovens maintain close temperature tolerance and do not cause RFI.

Spectrum Microwave's temperature specifications are of the oscillator itself. If an oscillator is dissipating considerable power and an adequate heat sink has not been used, its temperature will rise above the ambient temperature, and the stability may appear worse than specified.

Tuning Linearity

Varactor tuned oscillators are basically non-linear devices. The output frequency versus tuning voltage is an exponential function of the type shown in Figure 1. Linearity at Spectrum Microwave is determined as follows: A straight line is drawn from the beginning to the end of a tuning curve. Any deviation from this straight line of the actual curve is considered a frequency error and is figured as a percentage of the corresponding frequency on the straight line. For example, in Figure 1, the error is 30 MHz, the corresponding frequency is 1500 MHz; therefore, the linearity error is 2%. Please take note that a best straight line drawn through the actual curve would yield a much better linearity.

Linearizers are used to give a linear voltage versus frequency transfer function. They can also scale the tuning voltage to convenient levels such as 0 to 10 V. When a linearizer is used, the linearity is obtained in the same manner, except a straight line is drawn through 0 to 10 V.

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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 2.

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 should not 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.

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 2; they are also called spurious signals. FM noise can also be due to random type modulation caused by thermal vibrations 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."

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. Remember that any noise components on the tuning terminal have the same tuning sensitivity per volt as the desired modulation.

For example, if a VCO has a 50 MHz/V tuning sensitivity, noise of 1 mV peak to peak will FM the oscillator 50 KHz. From FM theory, the ratio of power in the carrier to one of the sidebands due to this noise can be predicted by:

$$dB = 20\log_{10} \frac{2\,fm}{\Delta F} \quad (1)$$

where fm = frequency of noise in Hz
ΔF = peak deviation in Hz

With this relationship, FM noise can be compared as "so many dB below the carrier" any place in the spectrum in a certain measurement bandwidth. A commonly used bandwidth is 1 Hz. The actual bandwidth used in making the measurement may be greater than 1 Hz; however, it can be converted to 1 Hz for comparison.

Figure 3 is a plot of FM noise commonly supplied by oscillator manufacturers.

Another way of presenting an oscillator's FM noise is to convert the "dB below the carrier" to an equivalent frequency deviation that would produce the same noise level in a 1 Hz bandwidth at the same distance from the carrier. The deviation is expressed in Hz RMS. For example, FM noise 80 dB down in a 1 Hz band 10 KHz from the carrier can be expressed as a frequency deviation of 1.4 Hz RMS. The Equation can be used to convert from one method to the other if peak is used, instead of RMS, for ΔF. Figure 4 is a convenient chart for converting between the two methods.

VSWR and Load Impedance

VCOs, depending on bandwidth and power output, may operate satisfactorily into loads with relatively bad VSWRs (2.0:1). An offset may occur in the tuning curve due to pulling, but the oscillator may still perform satisfactorily. In other cases, bad loads can cause the oscillator to skip frequencies, generate spurious signals, become noisy, have rapid slope changes in the tuning curve, and other undesirable effects. The load impedance should be discussed with the manufacturer if it is not 50 ohms. In some cases, internal attenuators can be used to give moderate isolation. In applications in which frequency pulling can't be tolerated, an isolator or buffer amplifier may be necessary.

Frequency pulling for an octave band oscillator (500 to 1000 MHz) without an isolator or buffer amplifier and an output power level of 100 mW is as follows:

VSWR 1.5:1	15 MHz
VSWR 3.0:1	30 MHz

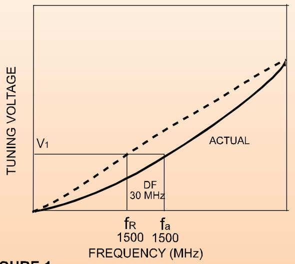

FIGURE 1

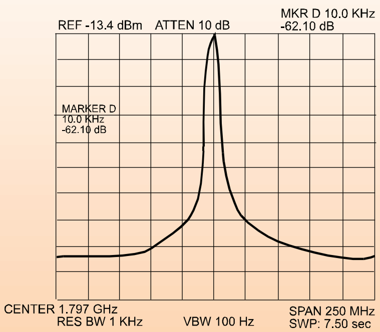

FIGURE 2

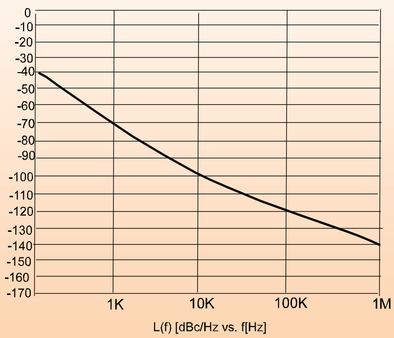

FIGURE 3

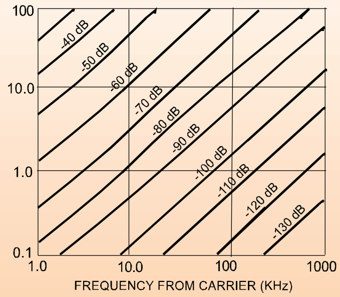

FIGURE 4

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