EXPERT TIPS, TRICKS AND TECHNIQUES

Microwave Journal invited the following contributors to share their tips, tricks and techniques in this month's cover feature. Call them Gigahertz Gurus or Microwave Merlins, each contributor was asked to offer up some useful advice covering areas such as testing, tweaking and troubleshooting in approximately 500 words or less.

COVER FEATURE
INVITED PAPERS

HOW LOW CAN YOU GO

Optimizing Phase Noise

Communication systems rely on a low-phase-noise VCO for reliable voice communications and to ensure transmitted data integrity. As data requirements increase beyond 2 Gb/s, the phase noise of the VCO becomes critical for achieving acceptable bit-error-rate (BER) performance. For low phase noise signal source (VCO) applications, simple tips can cut the design time and be useful for oscillator design engineers.

The frequency tuning feature is realized in an LC resonator VCO by varying the capacitance of the tuning diodes (Varactors). Select low loss resistance varactors and implement back-to-back in the tuning circuit for the minimization of tuning network noise. Care must be taken to avoid breakdown, saturation, or overheating effects in the varactor at the cost of reduced loaded-Q.

Maximize the resonator loaded Q-factor (high group delay); in the series LC-resonant circuits preferably use a large inductor, and in parallel LC-resonant circuits a large capacitor. Care must be taken to suppress the undesired modes in a high Q-factor resonator (especially quartz crystal, ceramic and acoustic resonators) by optimizing the drive-level across the resonator for a given dominant mode.

Use an active device (Bipolar/FET) with low 1/f noise and noise figure at operating frequencies. The trade-off is to use a high frequency transistor that has a small junction capacitance and operate it at moderately high bias voltage to reduce phase modulation due to junction capacitance noise modulation. Care must be taken to prevent modulation of the input and output dynamic capacitances of the transistor, otherwise it leads to amplitude-to-phase conversion and therefore introduces noise.

Since all noise sources, except thermal noise, are generally proportional to the average current flow through the active device, it is logical that reducing the current flow through the device will lead to lower noise levels. The 1/f noise depends on the current density in the transistor, therefore transistors with high I_{cmax} used at low currents will exhibit low flicker noise contribution. In BJTs, as VCE increases, the flicker corner increases as the white noise increases, but the magnitude of the 1/f noise is constant. As base current increases, the flicker corner frequency increases with the magnitude of the 1/f noise and the increased shot noise current. The effect of flicker noise can be reduced through RF feedback. An un-bypassed emitter resistor of a few ohms in a BJT circuit can improve the flicker noise significantly.

Passive components in the oscillator circuit also exhibit short-term instability. Passive components (resistors, capacitors, inductors, reverse-biased, varactor diodes) exhibit varying levels of flicker-of-impedance instability whose effects can be comparable to or higher than to that of the sustaining stage amplifier 1/f AM and PM noise in the oscillator circuit.

Maximize the output RF power carefully; otherwise severe phase noise degradation can occur due to active device noise elevation at compression. For low phase noise, tap the output signal through the resonator to the output load, thereby using the resonator transmission response selectivity to filter the carrier noise spectrum.

The VCO ground plane must be the same as that of the printed circuit board, including adequate decoupling capacitors between the DC supply and ground. Noisy power supplies may cause additional noise. Power supply induced noise may be seen at offsets from 20 Hz to 1 MHZ from the carrier. If the VCO is powered from a regulated power supply, the regulator noise will increase depending on the external load current drawn from the regulator. The phase noise performance of the VCO may degrade depending on the type of regulator used, and also upon the load current drawn from the regulator. To improve the phase noise performance of the VCO under external load conditions, it is always a good design philosophy to provide RF bypassing of power and DC control lines to the VCO.

For ultra low phase noise, use noise reduction techniques: DC noise-feedback, mode-coupling, injection-locking, degenerative noise filtering, feed-forward and other noise reduction techniques. Narrowing the current pulse width in the active device will decrease the time that noise is present in the circuit and therefore, decrease the effective noise factor for a given drive-level and minimize the phase noise.

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