RF/Microwave PLLs Integrate Low Noise VCOs

Feature Article from Hittite Microwave Corporation

Low-noise local oscillators (LOs) are critical to many RF/microwave systems in commercial, industrial, and military applications.

Simply put, the higher the performance of the LO, the better the performance of the system in terms of receive signal sensitivity and bit error rate (BER) capability. One of the most common methods of generating a stable LO source is to combine a low phase noise voltage controlled oscillator (VCO) with a stable reference oscillator to form a phase locked loop (PLL) frequency synthesizer. Unfortunately, interactions between components within the PLL synthesizer, including the charge pump and loop filter, can offer challenges for the best designers, not to mention issues that arise due to circuit board layout and power supply noise. By leveraging our expertise in frequency generation components, Hittite Microwave has developed a line of PLLs with integrated VCOs to simplify the development of PLL-based frequency synthesizers. The new product lines include eight PLL/VCO sources covering 665 MHz to 5.1 GHz and four PLL/VCO sources spanning 7.3 to 13.4 GHz.

Each of the synthesizers (see **table 1**) includes an advanced fractional-N frequency synthesizer and a low noise VCO and is supplied in an industry standard 6x6 mm QFN plastic package that requires a minimal number of external components to achieve high performance. **Figure 1** is a simplified block diagram showing many of the core functions within the PLL with integrated VCO products, and how they may be used to drive the LO port of a typical RF/microwave transceiver. The advanced PLL/synthesizer section was designed for low phase noise applications and includes a low noise phase/frequency detector (PFD), a precision controlled charge pump, and an advanced modulator design that allows ultra fine frequency steps.

HMC764LP6CE PLL with Integrated VCO on Hittite's Evaluation PCB

The PLL/synthesizer section also provides the ability to alter both the PFD gain and the cycle slipping characteristics of the PFD. The Cycle Slip Prevention (CSP) mode essentially holds the PFD gain at maximum until the frequency difference from the goal is near zero. The CSP mode allows significantly faster lock times and can reduce the time to arrive at a new frequency by 50 percent compared to conven-

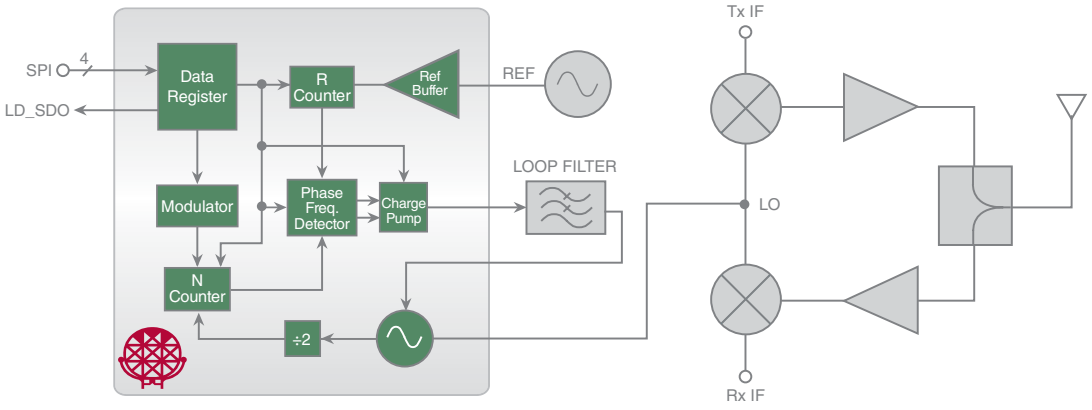

Figure 1: Hittite PLL with Integrated VCO Block Diagram

Compact PLLs with Integrated VCOs

tional PFDs. A high frequency reference path allows the use of reference sources up to 220 MHz, while source buffers in the reference path support both square wave and 50 Ohm sinusoidal reference oscillators. Low close-in phase noise and low spurious noise also permit architectures with wider loop bandwidths for faster frequency hopping and low microphonics; spurious outputs are low enough to eliminate the need for costly direct digital synthesizer (DDS) references in many applications.

For example, model HMC826LP6CE is one of eight PLL/VCOs optimized for RF market applications, and targeted at cellular/4G, WiMAX, and measurement equipment. Each of the eight devices combines the functions of a high performance fractional-N PLL/synthesizer and fully integrated low-noise VCO. The architecture supports high performance

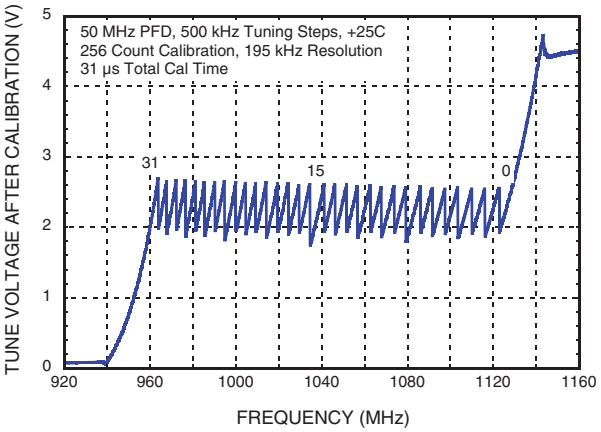

Figure 2: HMC826LP6CE - Tuning Voltage as a Function of Offset Frequency

Table 1: Hittite's PLLs with Integrated VCOs at a Glance

Hittite Part Number	Frequency Ranges (GHz)	Market Application	Phase Noise (dBc/Hz) (@10 kHz Offset, *Integer Mode, Fcomp=50 MHz, BW=100 kHz)	Phase Noise (dBc/Hz) (@1 MHz Offset, Open Loop VCO)	Pout (dBm)	RMS Jitter Fractional Mode (fs)	Int. Phase Noise Frac. Mode (deg rms)
HMC822LP6CE	0.665 - 0.780 1.330 - 1.560 2.660 - 3.120	RF (Cellular/4G, WiMAX)	-115	-142	10	190	0.1
HMC824LP6CE	0.780 - 0.870	RF (Cellular/4G, WiMAX)	-120	-147	12	190	0.05
HMC821LP6CE	0.860 - 1.040 1.720 - 2.080 3.440 - 4.160	RF (Cellular/4G, WiMAX)	-113	-140	10	190	0.12
HMC826LP6CE	0.990 - 1.105	RF (Cellular/4G, WiMAX)	-118	-145	10	190	0.07
HMC820LP6CE	1.095 - 1.275 2.190 - 2.550 4.380 - 5.100	RF (Cellular/4G, WiMAX)	-110	-139	10	190	0.17
HMC828LP6CE	1.285 - 1.415	RF (Cellular/4G, WiMAX)	-116	-142	10	190	0.1
HMC831LP6CE	1.815 - 2.010	RF (Cellular/4G, WiMAX)	-112	-141	9	190	0.13
HMC836LP6CE	3.365 - 3.705	RF (Cellular/4G, WiMAX)	-107	-135	0	190	0.25
HMC764LP6CE	7.0 - 8.2	Microwave (Microwave Radio)	-102	-140	15	196	0.55
HMC765LP6CE	7.8 - 8.5	Microwave (Microwave Radio)	-102	-139	13	193	0.58
HMC783LP6CE	11.5 -12.5	Microwave (Microwave Radio)	-100	-134	11	181	0.78
HMC807LP6CE	12.4 - 13.4	Microwave (Microwave Radio)	-98	-134	8	175	0.81

* Figure of Merit (FOM) of Synthesizer is -225/-226 dBc/Hz (Frac/Integer)

Meet Demanding System Requirements

VCOs with voltage tuning requirements of less than 5V (Figure 2). In this topology, an operational amplifier is not required in the loop filter, saving both cost and circuit board space while improving performance. The devices can be locked at one temperature extreme and then operated over the full temperature range without the need for relocking or recalibration. This capability is required in high reliability applications, but not offered by some competing solutions.

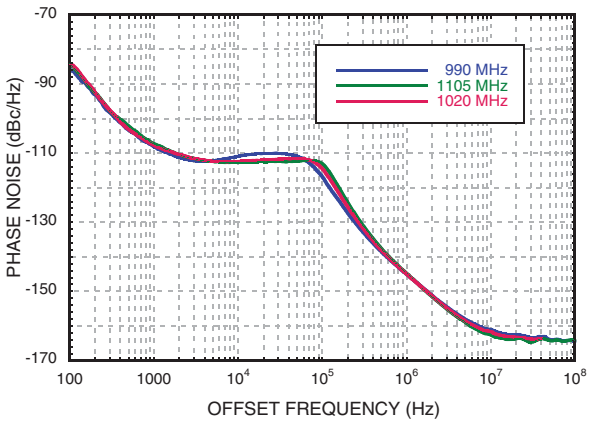

Figure 3: HMC826LP6CE - SSB Phase Noise vs. Offset Frequency

As shown in Figure 3, these devices offer exceptional phase noise performance - typically 10 dB better than competing devices both in-band and at the far out noise floor, all without the need to choose between low spurious or low noise modes. The typical integrated noise of -55 dBc at offset frequencies from 100 Hz to 1 MHz is equivalent to 0.1 deg. of root-mean-square (RMS) jitter, or 278 fs RMS jitter in the time domain at an output frequency of 1 GHz.

The model HMC826LP6CE offers a marked improvement in performance over existing integrated solutions. It has approximately 10 dB lower close-in phase noise and 12 dB lower phase noise floor at offset frequencies greater than 20 MHz compared to a commercial alternative. In addition, the HMC826LP6CE offers superior spurious performance with much lower fractional spurious content across the band and a cleaner overall spectral output. The HMC826-LP6CE features consistent performance over temperature and at the band edges, to ensure no drop-outs at those frequencies.

The eight RF models include three PLLs with integrated VCOs that offer multiple outputs based on dividing or multiplying the fundamental (fo) output frequency [divided (fo/2), fundamental (fo), and doubled (2fo)] for added versatility and ease of use in multi-band applications. Furthermore, the entire family features a common 6x6 mm QFN package footprint and common SPI control protocol.

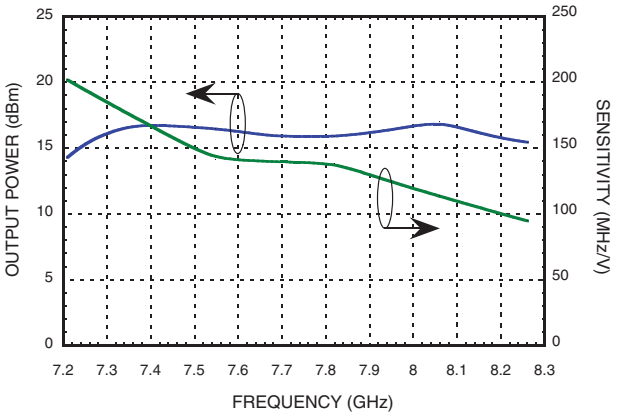

Figure 4: HMC764LP6CE - Tuning Sensitivity and RF Output Power as a Function of Output Frequency

The HMC764LP6CE PLL with integrated VCO is one of four devices optimized for microwave market applications. Typical applications include microwave and millimeter-wave radios, industrial/medical test equipment, military communications, electronic warfare (EW), and electronic countermeasure (ECM) subsystems. As shown in Figure 4, the model HMC764LP6CE PLL with integrated VCO exhibits consistent tuning sensitivity and high output power to +16 dBm across its bandwidth, making it ideal for driving the LO port of many of Hittite's high linearity, double-balanced and in-phase/quadrature (I/Q) mixer and receiver products.

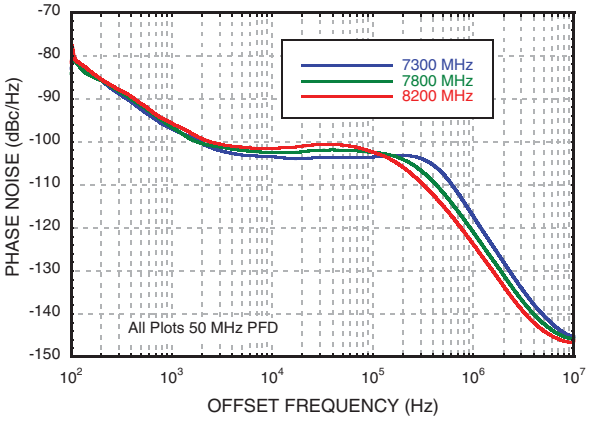

Figure 5: HMC764LP6CE - SSB Phase Noise vs. Offset Frequency

RF/mWave PLLs Integrate Low Noise VCOs

Figure 5 shows the outstanding SSB phase noise performance versus offset frequency for the low, mid, and high frequency ranges of the HMC764LP6CE PLL with integrated VCO. This data was measured with a reference frequency of 50 MHz, a loop bandwidth of 100 kHz, and a comparison frequency of 50 MHz at the PFD. The phase noise performance is consistent over temperature and mechanical shock due to the monolithic construction. Furthermore, a built-in frequency shift keying (FSK) mode allows the device to be used as a simple low-cost direct frequency modulation (FM) transmitter source.

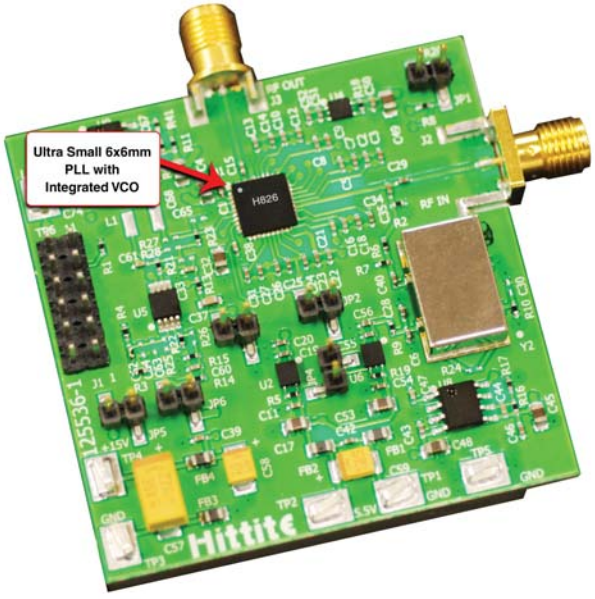

Figure 6: Evaluation PCB, Included in Each Evaluation Kit

Even with such advanced capabilities and a high level of integration, developing a high performance programmable LO can still require considerable design time and potentially several design iterations. For these reasons, Hittite offers Evaluation Kits in support of the new PLLs with integrated VCOs. These kits enable immediate measurements of a design. **Figure 6** shows a typical evaluation PCB and the mounted PLL with integrated VCO device. It is part of the easy-to-use, universal evaluation kit developed to help reduce non recurring engineering (NRE) costs, minimize design time, and facilitate rapid prototyping of new designs. The Evaluation Kit includes an on-board reference oscillator and voltage regulators, and supports universal loop filter configurations. Included software allows the user to program the PLL and access its advanced features. A complete operating guide provides step-by-step instructions to enable a user to quickly power up and initialize the evaluation board. The guide includes a comprehensive discussion of the components used within the evaluation board, and covers advanced topics such as reconfiguring the evaluation board for an external reference, and implementing on-board selectable order passive or active loop filters.

Each Evaluation Kit contains Hittite's proprietary PLL Design Software Suite to allow users to tailor the standard evaluation PCB loop filter to their specific application. Comprehensive personal computer (PC) based PLL Control Software is provided, with PC compatible register files to program the PLL via a Universal Serial Bus (USB) interface. Within a very short time, a user can evaluate the fully locked LO with only a PC, a signal analyzer, and DC power supplies. Hittite's application engineering department is also available to help customers become more familiar with these compact PLLs with integrated VCOs.

Hittite's new line of PLLs with integrated VCOs are ideal for numerous small form factor applications including microwave/millimeterwave radios, test equipment, microwave sensors, fiber optic communications, and military communications and sensors. Hybrid based synthesizers sometimes employ a fiberglass based substrate material with a discrete VCO, a large resonator, and a stamped metal cover. This assembly technique can present problems in users' systems related to RF grounding, as well as unwanted electrical and microphonic coupling effects. Compared with a discrete hybrid synthesizer/VCO configuration, Hittite's solutions allow designers to achieve their goals for consistent performance, high reliability, and small size. Each of Hittite's PLL with integrated VCO products are housed in industry standard SMT-compatible 6x6 mm QFN leadless packages. These housings are RoHS compliant and compatible with high speed, high volume surface mount technology (SMT) assembly lines. Hittite can also offer these products with a traditional Pb/Sn lead finish for military and telecommunications applications.