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Low Cost PLL with Integrated VCO Enables Compact LO Solutions

by James Lee, market development engineer, and Paul Taylor, product manager, Analog Devices, Inc.

New PLL + VCO (phase-locked loop with integrated voltage controlled oscillator) technology enables rapid development of low phase noise synthesizer solutions for cellular/4F, microwave radio, and military applications from 25 MHz to 13.6 GHz.

Radio designers working in cellular/4G, microwave radio, test equipment and military subsystem applications rely on high quality local oscillators (LO) in order to meet system level goals for low BER (bit error rate), low spurious output, and low phase noise. All RF and microwave communication and sensor systems, whether based on analog or digital modulation, require a clean LO signal source; the higher the capacity of the radio, the more demanding the requirements on the LO signal. There are many different architectures in use, but 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 and a phase-locked loop (PLL) to form a frequency synthesizer. However, designers seeking the very best LO performance must contend with numerous challenges related to the interaction between the PLL/synthesizer, VCO, charge pump, and loop filter, not to mention issues that arise due to board layout and unwanted power supply noise.

Analog Devices has developed a core expertise in frequency generation components such as MMIC VCOs, phase-locked oscillators (PLOs), low noise prescalers, phase-frequency detectors (PFDs), and a line of dual mode (fractional/integer) PLL/synthesizer ICs with RF input frequencies to 13.6 GHz.

Analog Devices industry-leading PLL with integrated VCO products are summarized in Table 1 and 2. These PLL with integrated VCO products cover RF and microwave frequencies from 25 MHz to 13.6 GHz.

Table 1. Performance Summary for Analog Devices PLL with Integrated VCOs

Part Number	Frequency Ranges (GHz)	Market Application	Phase Noise (dBc/Hz) @ 10 MHz Offset, Integer Mode* F _{COMP} = 50 MHz, BW = 100 kHz	Phase Noise (dBc/Hz) @ 1 MHz Offset, Open-Loop VCO	Р _{оит} (dBm)	RMS Jitter Fractional Mode (f _s)	Int. Phase Noise Fractional Mode (° rms)
HMC830LP6GE	0.025 to 3.0	RF communication systems	-114 @ 2 GHz	–141 @ 2 GHz	+5	159	0.114 @ 2 GHz
HMC832LP6GE	0.025 to 3.0	RF communication systems	-114 @ 2 GHz	–139 @ 2 GHz	+7	159	0.114 @ 2 GHz
HMC835LP6GE	0.33 to 4.1	RF communication systems	-105 @ 4 GHz	-133 @ 4 GHz	+7	<160	0.23 @ 4 GHz
HMC833LP6GE	0.025 to 6.0	RF communication systems	-114 @ 2 GHz	-141 @ 2 GHz	-4	159	0.11 @ 2 GHz
HMC829LP6GE	0.045 to 1.05 1.4 to 2.1 2.8 to 4.2	RF communication systems	-108 @ 4 GHz	-134 @ 4 GHz	+4	159	0.23 @ 4 GHz
HMC834LP6GE	0.045 to 1.05 1.4 to 2.1 2.8 to 4.2 5.6 to 8.4	RF communication systems	-108 @ 4 GHz	-134 @ 4 GHz	+5 +2 +2 –10	159	0.23 @ 4 GHz
HMC764LP6CE	7.0 to 8.2	RF communication systems	-102 @ 7.6 GHz	-140 @ 7.6 GHz	+15	196	0.55 @ 7.6 GHz
HMC765LP6CE	7.8 to 8.5	RF communication systems	-102 @ 8.2 GHz	–139 @ 8.2 GHz	+13	193	0.58 @ 8.2 GHz
HMC767LP6CE	8.45 to 9.55	RF communication systems	-107 @ 9 GHz	-138 @ 9 GHz	+12	93	0.3 @ 9 GHz
HMC769LP6CE	9.05 to 10.15	RF communication systems	-106 @ 9.6 GHz	-140 @ 9.6 GHz	+12	82	0.28 @ 9.6 GHz
HMC783LP6CE	11.5 to 12.5	RF communication systems	–100 @ 12 GHz	-134 @ 12 GHz	+11	181	0.78 @ 12 GHz
HMC807LP6CE	12.4 to 13.4	RF communication systems)	–98 @ 13 GHz	–134 @ 13 GHz	+8	175	0.81 @ 13 GHz

*Figure of merit (FOM) of synthesizer is -221 dBc/Hz/-226 dBc/Hz (fractional/integer).

Table 2: Performance Summary for Analog Devices PLL with Integrated VCOs

Part Number	Frequency Ranges (GHz)	Market Application	Phase Noise (dBc/Hz) @10kHz Offset, Integer Mode, $F_{COMP} = 61.44$ MHz, BW = 20 kHz	Phase Noise (dBc/Hz) @1 MHz Offset, Open-Loop VCO	Р _{оит} (dBm)	RMS Jitter Fractional Mode (f _s)	Int. Phase Noise Fractional Mode (° rms)
ADF5355	0.05 to 13.6	RF communication systems	-90 @ 6.8 GHz	–132 @ 6.8 GHz	-3	150	-221
ADF4355-2	0.05 to 4.4	RF communication systems	-95 @ 3.4 GHz	–138 @ 3.4 GHz	+3	150	-221





Figure 1. Functional block diagram and typical application circuit for ADI PLL with integrated VCO products.

As shown in the functional block diagram in Figure 1, these products implement an advanced fractional-N synthesizer and an ultralow noise VCO in a standard 5 mm \times 5 mm and 6 mm \times 6 mm QFN plastic package; this high level of integration minimizes the number of external components. They were designed for ultralow phase noise commercial and military applications and include a very low noise phase frequency detector (PFD), a precision controlled charge pump, and an advanced modulator design that allows ultrafine frequency steps.

Ultralow in-close phase noise and low spurious 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 synthesis (DDS) references in many applications.

PLLs with Integrated VCOs for RF Market Applications

The HMC830LP6GE is one of eight wideband PLL with integrated VCO products which are targeted to cellular/4G, IF of microwave backhaul, and test and measurement applications. Each product within the family combines the functions of a high performance fractional-N PLL/synthesizer with a fully integrated low noise VCO. The architecture of the PLL with integrated VCO for RF applications enables high performance VCOs with sub-five volt tuning (see Figure 2). No op amp is required in the loop filter, saving both cost and board space, while improving performance. The PLL with Integrated VCO 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 2. Tuning voltage vs. frequency for the HMC830LP6GE PLL with integrated VCO.



Figure 3. SSB phase noise vs. offset frequency for the HMC830LP6GE PLL with integrated VCO.

As shown in Figure 3, these devices offer exceptional phase noise performance, which is 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 –55 dBc integrated noise from 100 Hz to 1 MHz is equivalent to 0.1° of rms jitter, or 278 fs rms at $F_{out} = 1$ GHz.



Figure 4. Worst spur, fixed 50 Mhz reference, output frequency = 2 GHz.

As shown in Figure 4, the HMC830LP6GE represents a significant improvement over alternative integrated solutions.

For example, the HMC830LP6GE offers approximately 5 dB lower close-in phase noise, and a 7 dB lower phase noise floor at offset frequencies greater than 20 MHz, compared to the TI LMX2581. In addition, the HMC830LP6GE

offers superior spurious performance, with much lower fractional spurs across the band and a cleaner overall spectral output. The HMC830LP6GE provides consistent over temperature performance at the band edges, to ensure no "dropouts" are experienced.

The ADF5355 PLL with integrated VCO covers a 55 MHz to 13.6 GHz frequency spectrum, the widest in its class, while the ADF4355-2 features a 55 MHz to 4.4 GHz frequency span. Both parts integrate ultralow phase noise VCOs delivering phase noise of -138 dBc/Hz @ 1 MHz offset, at 3.4 GHz for the ADF4344-2 and ADF5355 delivers phase noise of -132 dBc/Hz @ 1 MHz offset at 6.8 GHz.

The superior VCO phase-noise performance of the ADF5355 and ADF4355-2 is achieved through novel VCO topologies and architectures which were developed in conjunction with ADI's new proprietary advanced SiGe-B*i*CMOS processes. In ultrawideband RF and microwave communications applications, this ultralow phase noise has the benefit of improving overall system bit error rates and increasing data throughput while enabling better noise immunity and wider dynamic range.

ADI's new, cost-effective, ultrawideband PLL synthesizer ICs also feature up to 125 MHz phase comparator frequency and 38-bit resolution, which lowers jitter and allows for very fine step sizes, while the integrated PLL and VCO on an advanced B*i*CMOS process significantly reduces package size and power consumption compared to discrete GaAs implementations. And because a single PLL synthesizer can be configured to operate from 55 MHz to 13.6 GHz, designers can more quickly reconfigure their system designs and reduce their parts inventory while still supporting multiple frequency bands.

PLLs with Integrated VCOs for Microwave Market Applications

The HMC764LP6CE PLL with integrated VCO is optimized for narrow-band but high performance microwave communication applications. Analog Devices was the first in the industry to offer integrated PLL and VCOs at frequencies above 6 GHz. These products offer the same exceptional microwave VCO performance which Analog Devices is recognized for, with the added functionality of an advanced, integrated fractional synthesizer. 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 5, the HMC764LP6CE exhibits consistent tuning sensitivity and high output power of up to 16 dBm across its bandwidth, making it ideal for directly driving the L0 port of many of Analog Devices high linearity, double balanced and I/Q mixer and up- and downconversion products.



Figure 6. SSB phase noise vs. offset frequency for the HMC764LP6CE PLL with integrated VCO.

The outstanding single sideband (SSB) phase noise performance vs. offset frequency for the low, mid, and high frequency range of the HMC764LP6CE is shown in Figure 6. This data was measured with a reference frequency of 50 MHz, a loop bandwidth of 100 kHz, and in the presence of 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 FSK mode allows the device to be used as a simple, low cost direct FM transmitter source.



Figure 7. PLL with integrated VCO evaluation PCB, which is included in each designer's kit.

Even with such advanced capabilities and a high level of integration, developing a high performance programmable local oscillator can still require considerable design time. For this reason, Analog Devices has developed the PLL with Integrated VCO Reference Designer's Kit, which enables immediate measurement of the design at hand.

The typical evaluation PCB shown in Figure 7 is part of an easy to use, universal evaluation kit which can minimize design time and facilitate rapid prototyping. The Reference Designer's 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 the 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 Reference Designer's Kit contains the Analog Devices proprietary ADIsimPLL design tool to allow users to tailor the standard evaluation PCB loop filter to their specific application. Comprehensive PC-based PLL control software is provided, with PC-compatible register files to program the PLL via the USB interface. Within a very short time, the user can evaluate the fully locked local oscillator with only a PC, a signal analyzer, and dc power supplies. ADI's skilled group of applications engineers is also available to help customers quickly become familiar with this unique product.

Analog Devices PLL with integrated VCO products uniquely combine the attributes of low phase noise, advanced features, and ultrasmall size, making them 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 typically 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, Analog Devices integrated frequency generation solutions allow designers to achieve their goals for consistent performance, high reliability, and small size. Analog Devices PLLs with integrated VCOs also have much smaller resonators and hence offer superior microphonic performance compared to large hybrid designs. These PLL with integrated VCO products are housed in RoHS compliant QFN leadless packages, and are ideal for high speed, high volume SMT assembly lines.

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Analog Devices, Inc. Worldwide Headquarters Analog Devices, Inc. One Technology Way P.O. Box 9106 Norwood, MA 02062-9106 U.S.A. Tel: 781.329.4700 (800.262.5643, U.S.A. only) Fax: 781.461.3113

Analog Devices, Inc.

Europe Headquarters Analog Devices, Inc. Wilhelm-Wagenfeld-Str. 6 80807 Munich Germany Tel: 49.89.76903.0 Fax: 49.89.76903.157

Analog Devices, Inc.

Japan Headquarters Analog Devices, KK New Pier Takeshiba South Tower Building 1-16-1 Kaigan, Minato-ku, Tokyo, 105-6891 Japan Tel: 813.5402.8200 Fax: 813.5402.1064

Analog Devices, Inc. Asia Pacific Headquarters

Analog Devices 5F, Sandhill Plaza 2290 Zuchongzhi Road Zhangjiang Hi-Tech Park Pudong New District Shanghai, China 201203 Tel: 86.21.2320.8000 Fax: 86.21.2320.8222

