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COVERstory

Novel Approach Yields Fast, Clean Synthesizers

This line of frequency synthesizers rides a patent-pending phase-refining technology to meet market demands for low phase noise, fast switching speed, small size, and low cost.

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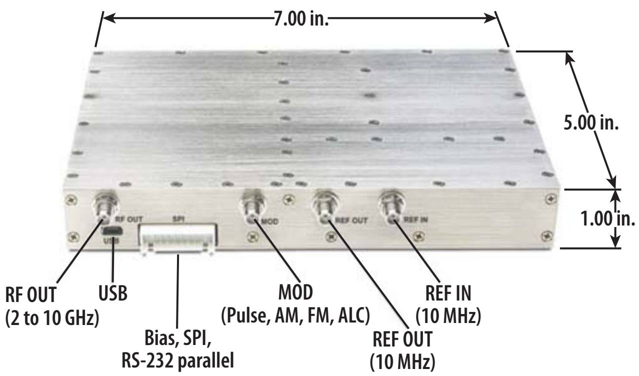
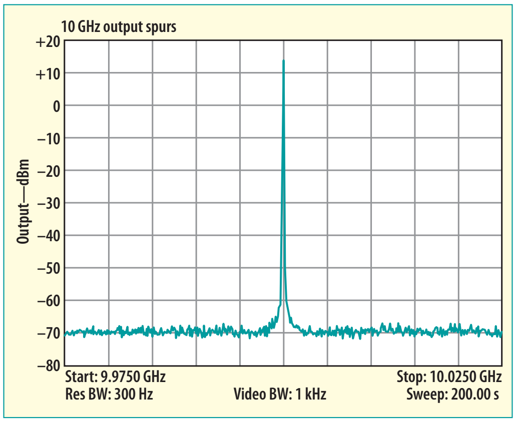
Frequency synthesizers are invaluable components in many systems, from commercial communications networks to test and measurement instruments.[1] Because of their wide application, the RF/microwave industry constantly feels the pressure to deliver higher-performance, higher-functionality, smaller-size, and lower-cost synthesizer designs. In addition, as dictated by the ever-increasing data rates of modern communications systems, a major challenge in synthesizer design is to achieve fast switching speeds without sacrificing performance, size, or cost. In a data communications system, for example, the time spent by the synthesizer transitioning between the frequencies becomes increasingly valuable since it cannot be used for data processing. While many systems still work adequately based on frequency synthesizers with millisecond switching speed, newer systems require microsecond operation together with comparable spectrum purity (i.e., phase noise and spurious) of the lower-speed designs.[2,3]

Direct-analog frequency synthesizers offer excellent switching speed and spectral purity characteristics. Unfortunately, today's direct-analog frequency synthesizer designs are hardware extensive and limited to applications that can tolerate fairly high costs. In contrast, indirect phase-lock-loop (PLL) frequency-synthesis architectures bring smaller-size and lower-cost benefits but suffer from serious design tradeoffs. Historically, high-performance microwave PLL frequency synthesizers have relied on YIG-tuned oscillators for broadband operation with excellent phase noise characteristics. However, the high power consumption, relatively large size, high cost, and slow tuning speed inherent to the YIG oscillators encourage the use of frequency synthesizer architectures based on voltage-controlled oscillators (VCOs), which primarily rely on the low-noise characteristics of a low-frequency reference oscillator. Today's commercial oven-controlled crystal oscillators (OCXOs) are capable of outstanding phase-noise performance of -160 to -176 dBc/Hz at a 10 kHz offset from a 100-MHz carrier frequency. Such phase-noise performance can be potentially translated to -120 to -136 dBc/Hz at a 10 kHz offset from a 10-GHz carrier. This theoretical performance corresponds to—or even exceeds—the performance of the best YIG oscillators



1. The QuickSyn™ frequency synthesizer offers high performance and versatile functionality in a compact housing.



2. A very clean, perturbation-free signal is available in the 2-to-10-GHz frequency range with step size of 0.001 Hz.

at the same frequency settings. Nevertheless, it is very difficult to provide such an ideal frequency translation since some noise degradation always occurs. Thus, achieving YIG-like noise characteristics for a VCO-based design is not a trivial task and calls for advanced frequency-synthesizer solutions.

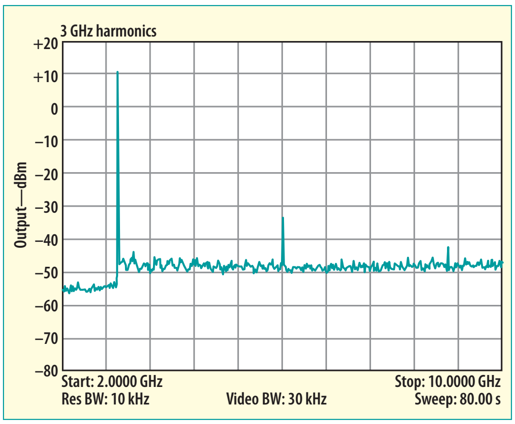
To address today's market requirements, Phase Matrix has developed the QuickSyn™ series of frequency synthesizers, a new generation of microwave frequency synthesizers based on a revolutionary (patent-pending) phase-refining technology that provides a unique combination of fast-switching speed, very low phase noise, low spurious content, and low cost characteristics.[4] In contrast to traditional approaches (which tend to minimize the PLL loop division ratio), this new technology makes a radical step by completely removing the divider from the PLL feedback path. Moreover, it inverts the PLL division ratio by applying a multiplication within the PLL that drastically improves both phase noise and spurious characteristics. The loop filter bandwidth is significantly extended in comparison to conventional designs (targeting the VCO noise floor region where it becomes competitive with its YIG counterparts), which results in faster switching speed and reduced microphonic effects. This technique combined with the use of a high-frequency, ultra low-noise reference and a custom-built, low-noise locking engine allows us to achieve simultaneously fast-switching speed and instrument-grade spectral purity without the use of expensive and bulky parts. This results in a compact, elegant design, which demonstrates excellent performance and extended functionality (***Fig. 1***).

The core design of the QuickSyn™ covers the 2-to-10-GHz frequency range, utilizing a fundamental-frequency, solid-state, voltage-controlled oscillator (VCO) to achieve the desired output frequency. In contrast to widely used frequency multiplication schemes, this approach eliminates possible spectrum contamination by subharmonic products. The use of an advanced direct-digital-synthesis (DDS) approach enables a very fine frequency resolution of 0.001 Hz without the common penalty of slower tuning speed. Since DDS-based designs are normally prone to increased spurious content, both hardware and software techniques[5] are used extensively to suppress DDS spurious content to negligible levels, which are managed down to less than -70 dBc (***Fig. 2***). A distributed output-power amplification scheme results in reduced harmonics, which typically do not exceed -40 dBc (***Fig. 3***).

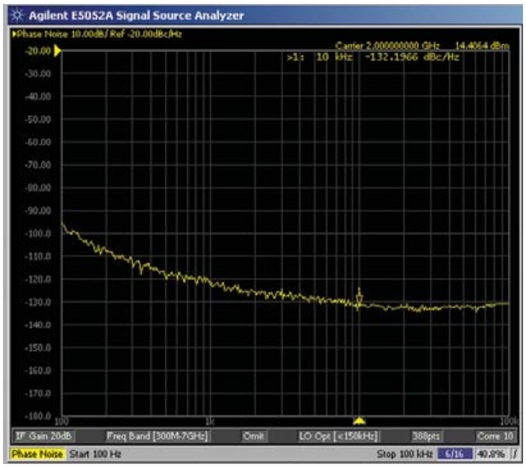
The VCO phase noise is controlled by utilizing an ultra-low-noise reference OCXO as well as very wide (a few MHz) loop bandwidth. Thus, the synthesizer phase noise within its PLL filter bandwidth mainly depends on the multiplied reference noise as well as residual noise characteristics of the locking mechanism. Typical phase noise measured at a 10 GHz output and a 10 kHz offset is -120 dBc/Hz. The phase noise drops down to -131 dBc/Hz at a 10 kHz offset from a 2-GHz output signal (***Fig. 4***), which exceeds the performance of traditional YIG-based synthesizers at the same frequency settings. Phase noise remains flat to a few MHz offset and then rolls down sharply showing a noise floor of about -155 dBc/Hz. Phase hits usually inherent to YIG-based designs are also greatly reduced due to the use of a low-mass VCO and very wide loop filter bandwidth.

The switching speed of the QuickSyn™ frequency synthesizer is also significantly faster in comparison to traditional YIG-based synthesizers. The PLL hardware itself needs just a few microseconds (subject to frequency accuracy definition) to bring the output frequency to a desired value, while the output is completely locked and refined within less than a hundred microseconds. The digital signal processing adds extra delays required to receive a tuning command, perform all necessary calculations, and program individual devices. Most of these delays, however, can be reduced or completely eliminated in the list mode, which is the precalculation and memorization of all necessary parameters required to control the individual components of the synthesizer for a preset list of frequencies. The actual throughput numbers heavily depend on a particular operating scenario and are normally specified between a few tens and few hundreds of microseconds.

The synthesizer provides +15 dBm maximum RF output power, which can be leveled and digitally controlled with a built-in attenuator and digital-to-analog converter (DAC). The synthesizer also includes a temperature sensor to



3. A distributed output power amplification scheme results in low harmonics.



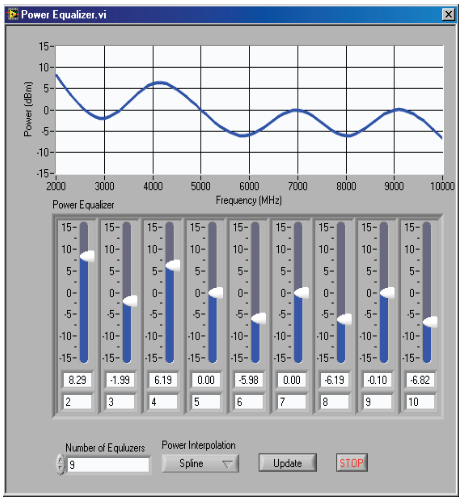
4. The QuickSyn™ frequency synthesizer exhibits better than -130 dBc/Hz phase noise at a 10 kHz offset from a 2-GHz carrier.

provide all necessary information for output power calibration and further correction if required. Employing a sophisticated frequency and temperature interpolation routine, the QuickSyn™ frequency synthesizer provides the flat and repeatable output power characteristics across operating frequency and temperature ranges. In addition to the factory preset flat response, a user can easily set a desirable power-to-frequency slope to compensate connecting cables as well as other devices external to the synthesizer. Virtually any power-to-frequency response can be created with a built-in programmable equalizer (***Fig. 5***). An additional analog power control input provides a closed-loop automatic-level-control (ALC) capability. By adding an external coupler and RF detector, the signal from the detector can be fed back to the analog power control input to close the loop. This configuration ensures precise, instrument-grade output power characteristics regardless of the signal match.

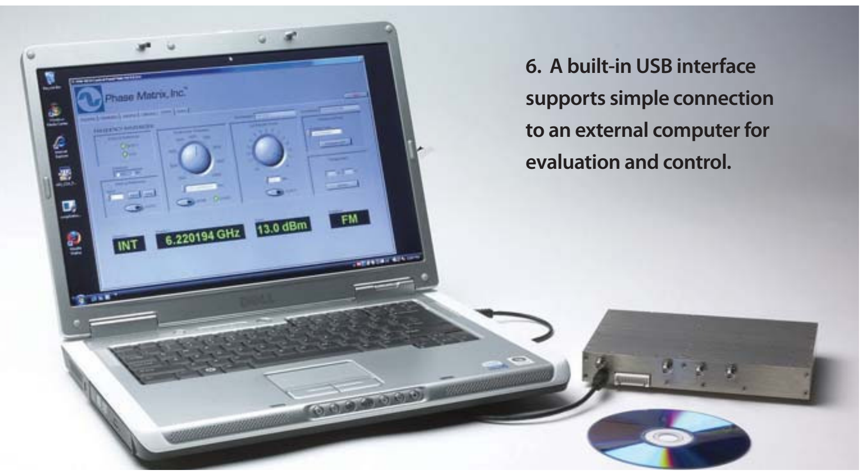
A built-in 32-b, 200-MHz reduced-instruction-set-computing (RISC) central processing unit (CPU) brings the required horsepower to support all necessary frequency tuning calculations as well as a number of features such as output power calibration and control, independent frequency and power sweep, and list mode. Furthermore, the QuickSyn™ frequency synthesizer has built-in amplitude modulation (AM), frequency modulation (FM), phase modulation (PM), and pulse modulation capabilities, making it one of the more versatile frequency synthesizers currently available. It supports a variety of interfaces including SPI, which offers full-duplex communication with high throughput and flexibility. The complimentary Universal Serial Bus (USB) connection and customer-friendly interface enable instant deployment or just evaluation of the synthesizer using a personal computer (***Fig. 6***).

QuickSyn™ frequency synthesizer's circuits are shielded in a metal box measuring only 5 x 7 x 1 in. The microwave synthesizer is biased from a single +12-VDC supply and includes custom-built active filters to prevent possible signal contamination. The power consumption for a basic configuration does not exceed 20 W. It is also worth mentioning that the QuickSyn™ synthesizer architecture is extremely flexible and can be easily reconfigured for specific customer requirements.

In short, the high-performance QuickSyn™ microwave frequency synthesizers leverage radically new phase-refining technology to support current market demands for high performance in smaller, low-cost frequency sources. The technology offers faster tuning speed and lower phase noise characteristics in comparison with traditional PLL techniques. The improved performance, extended functionality, and small footprint make QuickSyn™ frequency synthesizers ideal building blocks for a wide range of commercial, industrial systems and measurement instruments.



5. The synthesizer's programmable output-power equalizer can easily set any desired power-to-frequency response across the operating bandwidth.



6. A built-in USB interface supports simple connection to an external computer for evaluation and control.

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