DROs, Part 4

DESIGN A WIDE RANGE OF QUIET DRO CIRCUITS

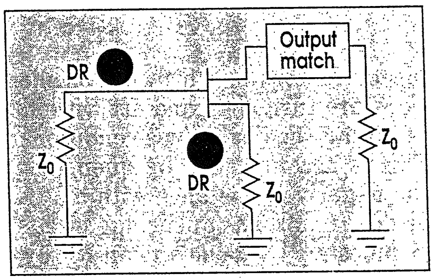
Different system requirements can be met with one of the following single- and multiple-frequency DRO sources.

MODERN dielectric resonator oscillators (DROs) are more than just simple, single-frequency circuits. Oscillators can be built around low-cost discrete devices and MMIC amplifiers for a variety of different applications.

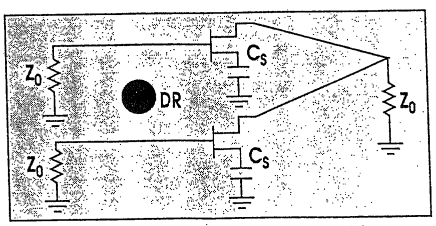
A dual-resonator oscillator (Fig. 1) presents a highly-stable DRO circuit using identical resonators in a series feedback configuration in both the source and gate circuit of a field-effect transistor (FET).[1] This oscillator has three output ports, and its microstrip circuitry is wideband due to the simple, minimally-tuned 50-Ω lines on all three ports of the transistor. This oscillator is not particularly susceptible to spurious oscillations and can provide good temperature stability by selecting appropriate dielectric mixes for the resonators.

A push-push DRO (Fig. 2) uses a common dielectric resonator with two transistors. In this approach, the fundamental frequency is canceled and the second harmonics are added at the output plane of the oscillator. This circuit helps to generate low-noise oscillations at frequencies much higher than otherwise possible. For example, using a 17-GHz resonator, a 34-GHz GaAs FET DRO was reported to have a phase noise of –100 dBc/Hz offset 100 kHz from the carrier.[2] In comparison (Fig. 3), an 18-GHz push-push bipolar DRO offers lower phase noise than a fundamental-frequency GaAs FET oscillator covering a similar frequency range.

A.P.S. (PAUL) KHANNA, Engineering Manager, Avantek, Inc., a subsidiary of Hewlett-Packard Co., 481 Cottonwood Dr., Milpitas, CA 95035; (408) 943-4226.



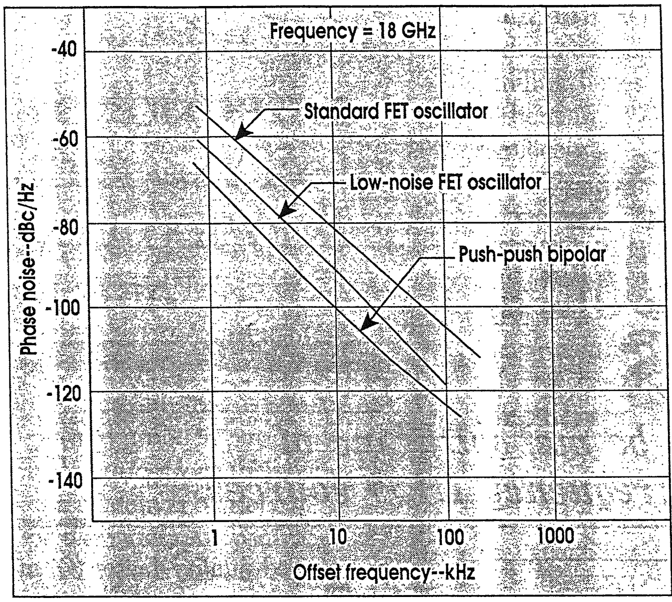
1. In a dual-resonator DRO, two identical resonators are linked to an active device in a series feedback circuit.



2. In a push-push DRO, a common dielectric resonator serves two transistors.

The reduced quality factor (Q) of dielectric resonators, as well as dive limitations, make it virtually impossible to achieve low phase noise with fundamental-output DROs at higher millimeter-wave frequencies. An effective alternative is the use of a low-phase-noise DRO followed by a transistor doubler. A 45-GHz source with –112-dBc/Hz phase noise offset 100 kHz from the carrier has been constructed with a low-noise GaAs FET DRO followed by a pseudomorphic high-electron-mobility-transistor (PHEMT) frequency multiplier.[3]

A selectable multi-frequency oscillator (Fig. 4) can produce three selectable output frequencies with fast settling time. A single GaAs FET is used in conjunction with a simple single-pole, three-throw (SP3T) switch to select the dielectric resonator corresponding to the desired output frequency. Compared to the traditional approach of using several continuously-operating DROs and a high-isolation, impedance-matched SP3T switch, this approach is free of the spurious signals at the unselected frequencies. This approach is also less expensive, uses fewer components, and is more reliable compared to the old approach. Fast switching between the output frequencies is obtained by keeping the active device always biased "on" and using the switchable high-Q resonators to control the frequencies. Using this approach the

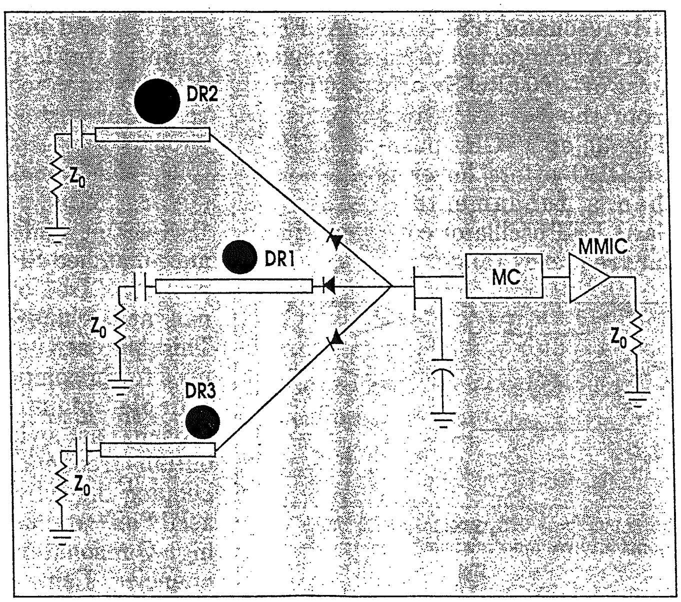


3. Push-push bipolar DRO sources achieve slightly lower phase noise than fundamental-frequency GaAs FET oscillators.

output frequency settles within ±100 PPM in less than 2 μs.[4] Special precautions need to be taken to keep the RF output power and DC/RF efficiencies as close as possible at each frequency to minimize the settling time. The number and range of frequencies selectable using single-device and multiple switchable resonators are limited due to the PIN-switch parasitics and the negative-resistance bandwidth capability of the active device.

QUENCHABLE DROs

Microwave quenchable oscillators represent a new class of fast-switching oscillators in which the oscillations are turned on and off without affecting the device bias conditions. This is accomplished by quenching the negative resistance with a PIN diode (Fig. 5). The quenching circuit includes a PIN diode and an RF bypass capacitor, is coupled to the transistor at the same port as the reactive feedback, and is the means for applying the bias voltage to the diode. The quenching circuit selectively diverts a small fraction of the current flowing through the oscillator transistor to control the PIN-diode resistance. For a PIN-diode resistance value of 50 Ω or less, the oscillations are switched off completely. Using this quenching technique, the DRO settles to within 10 PPM in less than 2 μs.[5]



4. Different resonators provide different frequencies in a multi-frequency DRO design.

Quenchable DROs can be effectively used in the selectable-frequency oscillator assemblies by joining them with ring combiners. Unlike the selectable multi-frequency oscillator based on a single device, there is no limit to the number or range of the output frequencies. Additionally, each oscillator can be optimally biased for fast switching at its frequency.

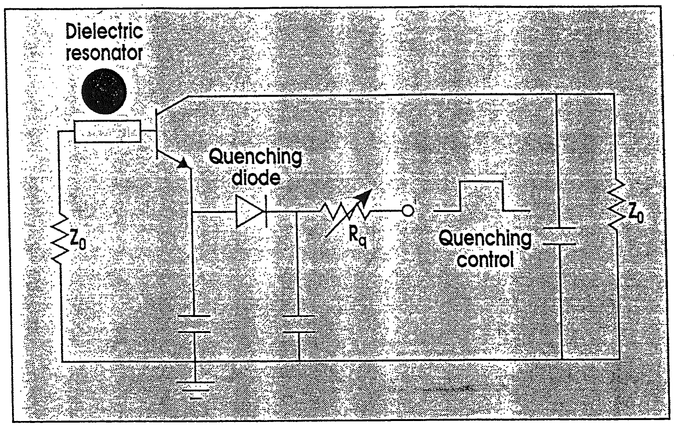
The quenching current through the PIN diode can also be controlled to vary the degree of nonlinearity and, hence, the operating point of the oscillator. The partial quenching thus achieved can be used to control the power output, harmonics, and amplitude modulation.

A silicon, monolithic, self-oscillating mixer is shown in Fig. 6. The dielectric resonator is used in parallel feedback between the input and output of the device, a silicon bipolar Darlington-pair MMIC. The RF input signal is mixed with the local oscillator (LO) in the first transistor (Q1), while the second transistor (Q2) offers gain at the intermediate frequency (IF). The particular MMIC used in this design features a cutoff frequency (f_T) of 10 GHz and maximum frequency of oscillation (f_{MAX}) of 20 GHz. The device is housed in a standard 70-mil microstrip ceramic package. The MMIC features interdigitated 0.75-μm-wide arsenic-doped emitters, 4-μm emitter-to-emitter pitch, ion implantation, thin-film polysilicon resistors, and gold metalization.

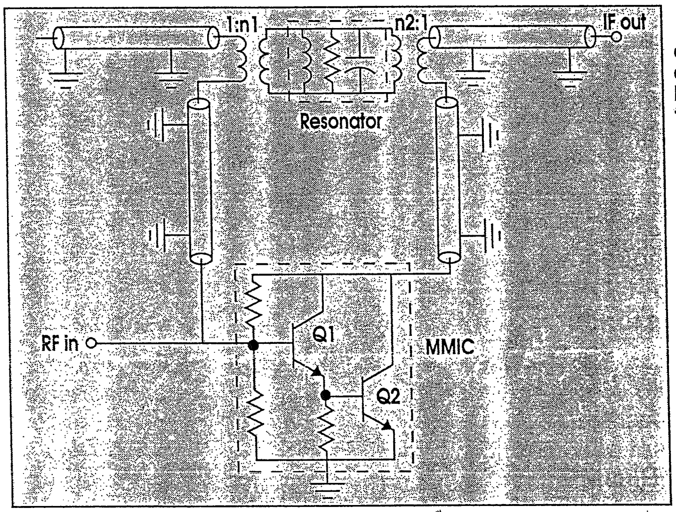
A prototype source based on this technique was fabricated using a 31-mil-thick epoxy-glass (FR4) board. The dielectric resonator achieved a resonant frequency of 5.15 GHz, dielectric constant of 37, and unloaded Q of 7000. With this prototype, an RF signal from 3.7 to 4.2 GHz was downconverted to L-band with 9 ±1-dB conversion gain. The self-oscillating mixer's output compression point was measured at +7 dBm.[6]

At present, free-running DROs do not have the low phase noise and

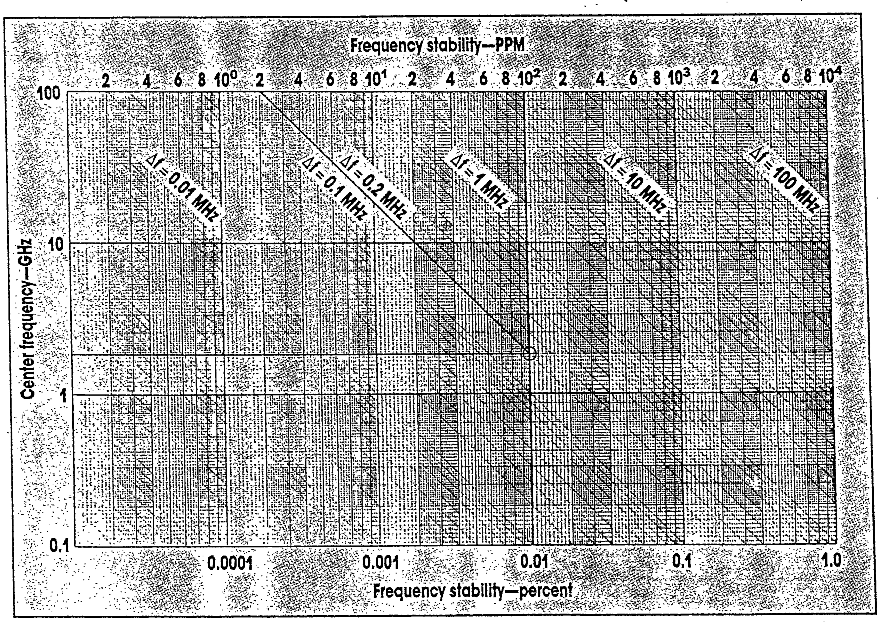
DESIGNING DROs



5. A quenchable DRO can provide multiple-frequency operation, along with fast switching speed.



6. A self-oscillator mixer can be constructed with low-cost silicon MMIC technology.



7. Changes in frequency (Δf) can be converted to frequency stability by locating the stability numbers at the intersection of a given center frequency and Δf.

temperature stabilities required for certain high-performance applications (Fig. 7). This limitation necessitates the use of phase locking, injection locking, ovenizing, or analog or digital compensation circuits when necessary. Another important limitation of the DRO is the phase-noise degradation under vibration due to the variation of the distance between the resonator and the outer shield. Significant deterioration of the phase noise at offsets up to the highest frequency of vibration can be expected under vibration. Ruggedization of the oscillator, injection locking, or phase locking are typically used to minimize these effects.

As DRO technology continues to advance, some of the features and improvements to watch for include lower phase noise and higher temperature stability, reduction in cost and size, wider mechanical and electrical tuning bandwidths, and improved performance under vibration. These achievements may come about as a result of new materials for dielectric resonators for linear temperature coefficient and higher Q's, and use of higher-order modes in DROs. ••

References

1. A.P.S. Khanna *et al.*, "Efficient, Low-Noise, Three-Port X-Band FET Oscillator Using Two Dielectric Resonators," *IEEE MTT-S International Microwave Symposium Digest*, Dallas, 1982, pp. 277-279.
2. A.M. Pavio and M.A. Smith, "Push-Push Dielectric Resonator Oscillator," *IEEE MTT-S International Microwave Symposium Digest*, St. Louis, 1985, pp. 266-269.
3. A.P.S. Khanna, Carl Creamer, Ed Topacio, and Edmer Camargo, "A 45-GHz, Highly-Stable, +15-dBm Low-Noise GaAs MESFET Source Using a GaAs PHEMT as a Frequency Doubler," *Microwave Journal*, November 1991, pp. 117-127.
4. A.P.S. Khanna and R. Soohoo, "Fast-Switching, X- and Ku-Band Multi-Frequency Dielectric Resonator Oscillator Using a Single GaAs FET," *IEEE MTT-S International Microwave Symposium Digest*, Las Vegas, 1987, pp. 189-191.
5. A.P.S. Khanna, R.T. Oyafuso, R. Soohoo, and J. Huynh, "Microwave Quenchable Oscillators—A New Class," *IEEE MTT-S International Microwave Symposium Digest*, Long Beach, 1989, pp. 515-518.
6. I. Kipnis and A.P.S. Khanna, "Large-Signal Computer-Aided Analysis and Design of Silicon Bipolar MMIC Oscillators and Self-Oscillating Mixers," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 37, No. 3, pp. 558-564.