Microwaves & RF

**JACK BROWNE** / TECHNICAL DIRECTOR

# DTO Steps Quickly Across 9 To 15 GHz

**This fast-tuning oscillator incorporates multiple VCOs and a unique quenching circuit based on a silicon bipolar transistor to cover a broad bandwidth with extremely low spurious content.**

Fast tuning oscillators are vital to many systems, including radar simulators and electronic-warfare (EW) platforms. In modern applications, such sources must settle on a new frequency quickly, without generating unwanted spurious signal products that can not only compromise performance as well as mission success, in the case of an EW system. The DTO-12000-50M digitally tuned oscillator (DTO) from Phase Matrix (*www.phasematrix.com*) provides fast-settling frequency tuning from 9 to 15 GHz by combining multiple fundamental-frequency voltage-controlled oscillators (VCOs) with reliable digital circuitry and innovative analog circuit techniques.

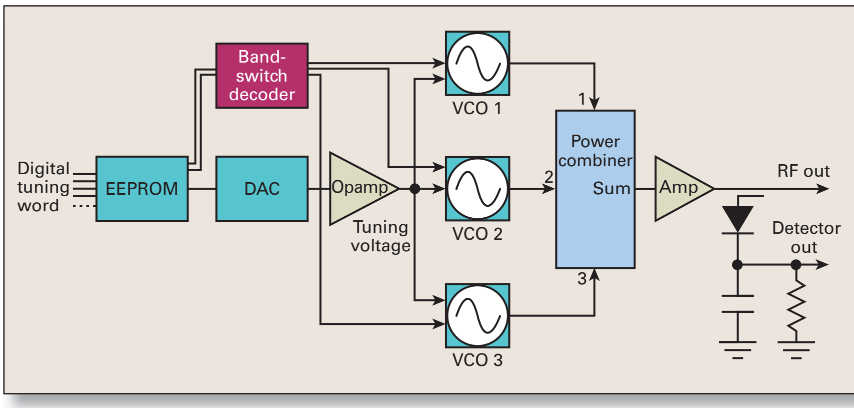
The DTO-12000-50M DTO (*Fig. 1*) packs three separate voltage-controlled oscillators (VCOs) into its compact housing to cover its wide tuning range. The signals from each oscillator are sent to a common output port by means of a Wilkinson power combiner, with a low-noise GaAs field-effect transistor (FET) buffer amplifier boosting oscillator output levels to a minimum of +15 dBm and a maximum of +19 dBm across the full tuning range. The buffer amplifier also ensures high isolation between the oscillator output port and the attached load.

The DTO's three VCOs are tuned by means of a 12-b parallel digital tuning word (*Fig. 2*). Tuning voltages to the VCOs are linearized by means of stored calibration factors in an electronically erasable programmable read-only memory (EEPROM) device, feeding a high-performance digital-to-analog converter (DAC). An example of the linearity of one of the digitally linearized bands is shown in Fig. 3. A band-switch decoder assists in selecting the proper VCO according to desired tuned frequency, while a detector diode in the buffer amplifier's output signal path is used to provide status indication.

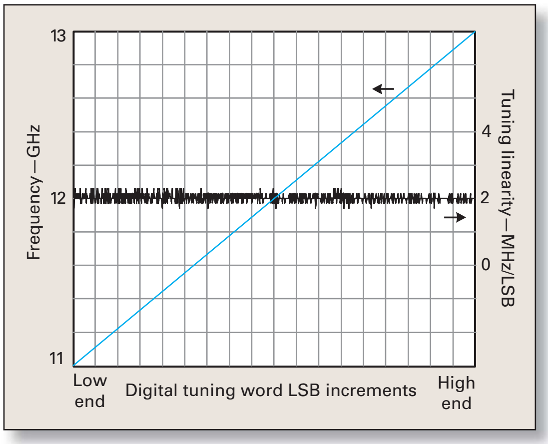
**1. The DTO-12000-50M digitally tuned oscillator (DTO) spans 9 to 15 GHz with three fundamental-frequency VCOs housed in a package measuring just 4.0 x 3.0 x 0.5 in.**

Although the switching arrangement appears complex, it results in a reliable design with fast switching speed that is well suited for radar simulators, EW platforms, and other military and aerospace applications. The switching speed, which is only 4 microseconds to tune within ±2 MHz of a new frequency, owes a great deal to a unique quenching technique for selecting among the VCOs. Developed in part by Phase Matrix's Paul Khanna while the oscillator designer was at legendary microwave technology company Avantek in the late 1980s, the quenching circuit (*Fig. 4, bottom*) combines a switching diode with a high-frequency silicon bipolar transistor to effect high-speed switching among the three VCOs. The use of the silicon bipolar transistor helps provide low phase noise with fast settling time.

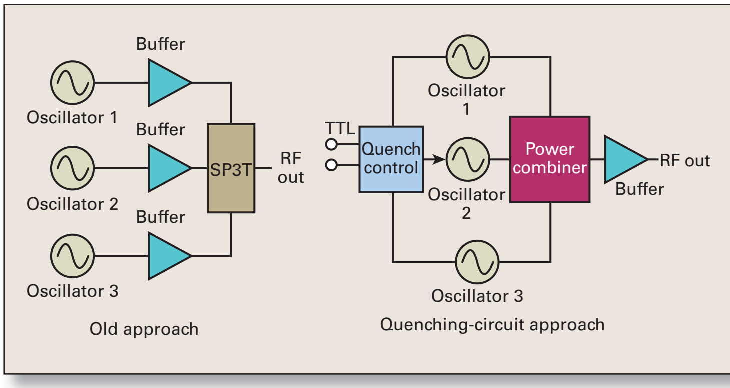
The oscillator circuit employs capacitive feedback at the bipolar




**2. The broadband oscillator employs 12-b digital tuning and linearization courtesy of an EEPROM to provide stable, fast switching among three different VCOs.**




**3. The DTO-12000-50M DTO uses 12-b tuning and stored correction factors to achieve excellent tuning linearity.**




**4. Multiple-oscillator designs conventionally use a multithrow switch (top) to select an oscillator's output, compared to the elegance of the quenching circuit approach to use a silicon bipolar and pair of diodes (bottom) for fast switching.**

transistor's emitter, with the RF output taken from the transistor's collector (*Fig. 5*). A silicon varactor diode is connected to the transistor's base. The quenching circuit includes a PIN diode coupled to the transistor at the same port as the reactive feedback. It provides the means for selectively applying a bias voltage to the quenching diode. The quenching circuit selectively diverts a fraction of the current flowing through the oscillator transistor to control the PIN diode resistance (and the output of the oscillator). This resistance is responsible for quenching the negative resistance of the oscillator circuit and hence the signal output. The quenching diode is kept reverse biased when the oscillator is on.

In addition to switching among different VCOs in a multiple-oscillator design, this type of quenching circuit can be used to control the operating point of an oscillating device, such as a VCO or a dielectric resonator oscillator (DRO), to control the output power of the oscillator. This partial quenching approach can also be used to reduce an oscillator's harmonic levels. For a penalty of less than 2-dB variation in the oscillator's output power, the harmonic level can be reduced by as much as 10 dB. By using a modulation signal to control the quenching current, this same circuitry can also generate oscillator amplitude modulation (AM).

The quenching circuit represents a practical alternative to the use of a multithrow switch to select the output of a multiple-oscillator design. Traditionally, a single-pole, three-throw (SP3T) switch might be used to select from a trio of VCOs with different tuning ranges (*Fig. 4, top*). But such a switch brings frequency-dependent insertion loss to the design, along with added cost. It is also limited in port-to-port isolation, lacking the 100-dB or more isolation typically required to suppress the outputs of the unwanted oscillators. The microwave quenching circuit makes it possible to turn the different oscillators on and off at fast switching speeds and without generating spurious signals as the oscillators are switched.

As evidence of this, the DTO-12000-50M DTO maintains harmonic levels to -20 dBc or less, with spurious levels at -90 dBc or less. The phase noise is -80 dBc/Hz offset 100 kHz from the carrier. The DTO's quenching circuit achieves fast tuning without unwanted instability, holding post-tuning drift to 2 MHz from 1 to 50 ms following a switch in frequency and less than 2 MHz from 50 ms to 1 s following a change in frequency. The DTO tunes with sensitivity of 2 MHz/b and is quite tolerant of difficult load conditions, with output return loss of better than 12 dB and typically only 14 dB. The DTO-12000-50M features 10 MHz maximum pulling into a 12-dB return loss load and 10 MHz maximum pushing with ±0.2-V supply variations. The oscillator is designed for use at operating temperatures from -50 to +95°C and suffers maximum frequency drift over temperature of 100 MHz. It is specified for maximum positive supply of +14 VDC and maximum negative supply of -14 VDC, with 500 mA maximum supply current and typically 400 mA positive supply current. The maximum negative current draw is 50 mA. The broadband DTO measures only 4.0 x 3.0 x 0.5 in. The small size and wide bandwidth of the rugged oscillator, along with its fast frequency settling time, make it a good fit for a wide range of military systems. **DE**

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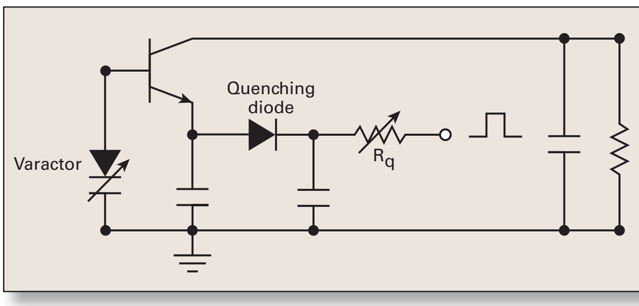


**5. This microwave quenching circuit is based on a silicon bipolar transistor and beam-lead PIN quenching diode with low reverse bias capacitance.**