DRO Application Note D-104

Phase-Locked DRO Characteristics
The REMEC line of Phase-locked Dielectric Resonator Oscillators consists of the following series:

- MDR 5100 Series - Phase-locked DRO, Internal Crystal Reference.
- MDR 6100 Series - Phase-locked DRO, External Crystal Reference.

These low-cost microwave oscillators exhibit excellent frequency stability and phase noise characteristics. The most common application for these microwave sources is as local oscillators in microwave radios. Other applications include frequency synthesizers, satellite converters, BITE oscillators, and frequency multipliers. The following paragraphs review the general characteristics of these oscillators. For detailed specifications or specific requirements, please contact REMEC.

General
REMEC’s line of phase-locked DROs cover 3.0-26 GHz with output power of +13 dBm at 26 GHz. They consist of an electronically tuned DRO phase-locked to a reference crystal oscillator via a sampling phase detector and loop amplifier/filter. This technique maintains the excellent frequency stability of the crystal oscillator and low phase noise characteristics of the crystal oscillator/DRO combination. The MDR 5100 Series contains an internal crystal oscillator reference, whereas the MDR 6100 Series, requires an external reference. The output frequency is an exact integral multiple of the reference frequency.

Description
Figure 1 shows a simplified block diagram of a phase-locked DRO. The sampling phase detector creates an error signal corresponding to any attempted phase difference between the DRO and the nth harmonic of the reference. This error signal is fed through the loop amplifier/filter to the DRO voltage tuning port, where it corrects for the attempted phase error. This feedback process allows the DRO to maintain the phase (and frequency) stability of the reference to the limits of the phase lock loop gain/bandwidth.
The correction voltage applied to the DRO tuning port is referred to as the Phase Voltage (ΦV) and is generally accessible for monitoring. Under ambient conditions, the DC level of the phase voltage is set to a specified voltage, nominally the center of the DRO tuning voltage range (Lock Range). As the DRO frequency attempts to drift due to temperature or aging, the phase voltage DC level will change as the phase lock loop corrects for the attempted drift. The phase voltage DC level will also change (and is initially set) by mechanically tuning the DRO Frequency Adjust. It should be noted that as the DRO is mechanically tuned over its specified mechanical tuning range, it will phase lock to each harmonic of the reference as they appear within the lock range.

The phase lock loop circuitry contains a search function to help in achieving phase lock when DC power is first applied to the unit. The search function will voltage tune the DRO over the full lock range until phase-lock is achieved. If the DRO is mechanically tuned off frequency, or the reference input is removed, the DRO will continue to sweep (search) over the full voltage tuning range. The Lock Range of a phase-locked DRO is typically 10 VDC, corresponding to a nominal frequency change of 1000 ppm.

**Crystal Oscillator Reference**
The MDR 5100 Series uses an internal crystal oscillator reference. The crystal used is a 5th overtone, AT-cut crystal at 100 MHz nominal frequency. Standard frequency stability is ±10 ppm over the -20 to +65°C operating temperature range. Higher stabilities of ±5 ppm are consistently achieved over -10 to +65°C using temperature compensation on the crystal oscillator. Further improvement is possible by ovenizing the crystal. A screwdriver adjustment (Xtal tune) is available for resetting the frequency to correct for crystal aging.

**Phase Lock Alarm**
The phase lock alarm is a lock limit alarm which indicates when the phase lock loop has lost, or is about to lose phase lock. The phase-locked DROs typically provide an open transistor collector to the alarm output. Loss of lock (or impending loss of lock) is indicated by the transistor collector being saturated to ground. This alarm circuit, when used with an appropriate pull-up resistor, is compatible with TTL and CMOS, or can be used directly with an LED or other types of panel indicators.
Phase Noise
The phase noise of a phase-locked DRO is determined by a combination of the reference phase noise, the DRO phase noise, and the phase lock loop bandwidth. Within the loop bandwidth, the phase noise will generally track the multiplied reference phase noise, i.e. reference oscillator phase noise equals $+20 \log N + 3 \, \text{dB}$ where $N = (\text{output freq}/\text{reference freq.})$. Outside the loop bandwidth, the phase noise will generally be that of the DRO. The phase noise near the region of the loop bandwidth will be affected by the loop gain/bandwidth. The phase lock loop bandwidth (typically 200 kHz) is generally set to optimize the overall phase noise as shown in Figure 2.

![Figure 2 Phase Noise (10 GHz)](image)

Environment
REMEC phase-locked DROs are generally built to meet the stringent microphonic and phase stability requirements of a microwave digital radios. Operating temperature range is normally -20 to +65 °C. Designs have been built to meet military requirements (MIL-E-5400) and operating temperature range of (-54 to +84°C).
Reliability

Product reliability is an important distinction for spaceflight level products, where mission life requirements are often in excess of 10 years in orbit. The reliability of a RF component is improved by a number of different measures including analysis, product design, product assembly, material selection and evaluation, hybrid screening, and qualification. Reliability analysis demonstrates the integrity of the design under certain environmental conditions and provides a prediction of the expected life of the device based on pre-established failure rates for element parts. Product design for high reliability usually involves analysis and verification that the electrical stresses of all element parts are well below their design limits. The derated flight design limits for elements are typically 50% of rated power and 75% of rated voltage. Moreover, design layouts that correctly size the attachment areas and reduce the number of components and interconnections (bond wires) result in significant improvement in the product's integrity and ease of assembly. Reliability from a product assembly perspective derives from the manufacturing of the device under controlled conditions by trained assemblers with documented processes and procedures. High reliability parts are built to higher-level visual inspection criteria and have greater restrictions on the amount of rework that is allowed. There are usually a number of additional manufacturing process steps required for a flight level product. For example, process control monitors are evaluated during VCO flight builds to assure that critical processes yield satisfactory results. Mixer diode leads are pre-tinned and wicked to remove excess gold from the solder joint to mitigate solder joint fatigue resulting from gold-enriched solder embrittlement. Material selection and evaluation underscores the premise that good element parts are required to make reliable hybrids. In addition to basic electrical performance, materials are selected for their compatibility with attachment and bonding processes, for their heat dissipation and thermal match characteristics, and for their production history. Element evaluation comprises a series of tests to confirm that specific lots of element parts are suitable for flight use. These tests include both sample testing and 100% screening of the elements, and are typically performed in part by both the element supplier and the hybrid manufacturer. Hybrid screening is a series of 100% tests and inspections that insure flight lot integrity while eliminating marginal products from the lot. Qualification testing validates the component design to stress levels representative of the mission life and assists in determining flight worthiness of new products and designs. Qualification by similarity is often used for designs in the same part family with similar construction technology.

Program Management

REMEC offers experienced program management for space products to ensure that all contractual commitments are satisfied. This dedicated function provides customer support for design and status reviews, contract administration, documentation generation and submittals, screened parts management, technical definition, problem resolution, and external liaison.