



# YIG Product Introduction

## History

Ferretec was incorporated in the State of California in October 1981. Since its first shipments in early 1983, Ferretec YIG products, part of Teledyne Family serves the microwave community with state-of-the-art tunable YIG filters, oscillators, harmonic generators, and subsystems.

In January 2004, Ferretec YIG Product line was acquired by Teledyne Technologies and became part of Teledyne Microwave. In March 2004 Ferretec moved to the newly renovated 100,000 square-foot facility in Mountain View, California. The facility layout was designed to optimize manufacturing flow and to allow for future capacity and new product development. An automated microwave integrated circuit laboratory containing special environmental controls and chip handling equipment produces MIC circuits for the Ferretec YIG-tuned oscillator product line.



Customized test stations and detailed test procedures have been developed to test microwave components as well as driver and control circuits for standard and special design assemblies.

*“A major goal of Teledyne YIG Products is to reduce manufacturing labor input while maintaining stringent quality standards”*

## Facilities

Customized test stations and detailed test procedures have been developed to test microwave components as well as driver and control circuits for standard and special design assemblies. Select-at-test resistors are specified by computer, and a custom test data sheet is generated that includes the complete Bill of Materials and the specific test parameters for the individual board. Microprocessor-controlled temperature test chambers are available for testing, burn-in and temperature cycling. Vibration equipment aids in stress-screening of both commercial and military products.

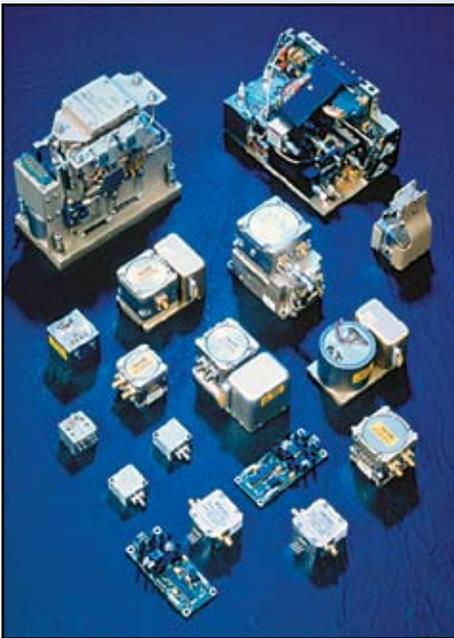
## Philosophy

A major goal of Ferretec YIG Products is to reduce manufacturing labor input while maintaining stringent quality standards. Teledyne Microwave is certified to ISO-9001 and ISO-14001.

The first product line introduced by Ferretec Products was closed-loop YIG filters, which are trademarked Ferretrac®. This product, described in detail in this catalog, is based upon Ferretec patents. Customers include many key U.S. defense contractors such as BAE, LOCKHEED-SANDERS, ITT AVIONICS, RAYTHEON, NORTHROP

GRUMAN, and many international defense contractors. This technology is also being used by a variety of U.S. Government facilities and international-based companies. In 1984, Ferretec was awarded a contract by ITT Avionics to develop an integrated closed-loop receiver front-end for an update of the ALQ172 EW equipment on the B-52. Ferretec has shipped over 1800 of these fully militarized subsystems which employ Ferretrac® filter technology.

Teledyne's YIG Products supplies both closed- and open-loop YIG filters, YIG



All of Teledyne's YIG products combine advanced technology and state-of-the-art performance with sophisticated manufacturing techniques to ensure consistently high quality.

Oscillators, YIG-tuned harmonic generators, and YIG-based integrated receiver front-ends/tuners. Analog and digital drivers are available for all Ferretec YIG products.

## Experience

All of Teledyne's YIG products combine advanced technology and state-of-the-art performance with sophisticated manufacturing techniques to ensure consistently high quality.

Teledyne products has extensive experience in the design, manufacture, and management of large military and commercial programs. Engineering expertise in the integration of microwave components with analog and digital control circuits, combined with a highly productive manufacturing organization, has resulted in the selection of Ferretec Products by major defense systems companies both domestically and internationally for high-volume production programs.

## Quality

Teledyne products are organized to support government programs from the program management office through to the quality organization. **QUALITY** is not just a word or procedure, but rather the planned result of a Ferretec Products team committed to excellence and customer satisfaction. This results in commitment to our customers, at every level. From sales and engineering through manufacturing, quality is the responsibility of everyone within the Teledyne Microwave organization.

## Why Choose Teledyne?

Teledyne Microwave has approached the YIG component market with innovative design and manufacturing technology aimed at providing a family of products suited to the level of integration the customer desires for an optimum systems solution.

## Filters

The RF Circuit and electromagnet. The customer provides the necessary current drive to tune the filter. These filters include either bandpass or band-reject types.

## Oscillators

Ultra low phase noise broadband Oscillators. Can be provide with and without driver.

## Filters with Analog Drivers

An accurate and stable voltage-to-current converter (drive) is integrated with the filter so that a linear voltage ramp tunes the filter.

## Filters with Digital Drivers

Allows tuning directly from your system controller or computer. A digital-to-analog converter (DAC), either serial or parallel, is added to the driver.

## Closed-Loop Filters

A discriminator and loop circuit provide the capability to lock the filter to an RF reference such as a receiver local oscillator. All tuning errors are removed as a result. These include Ferretac® closed-loop filters.

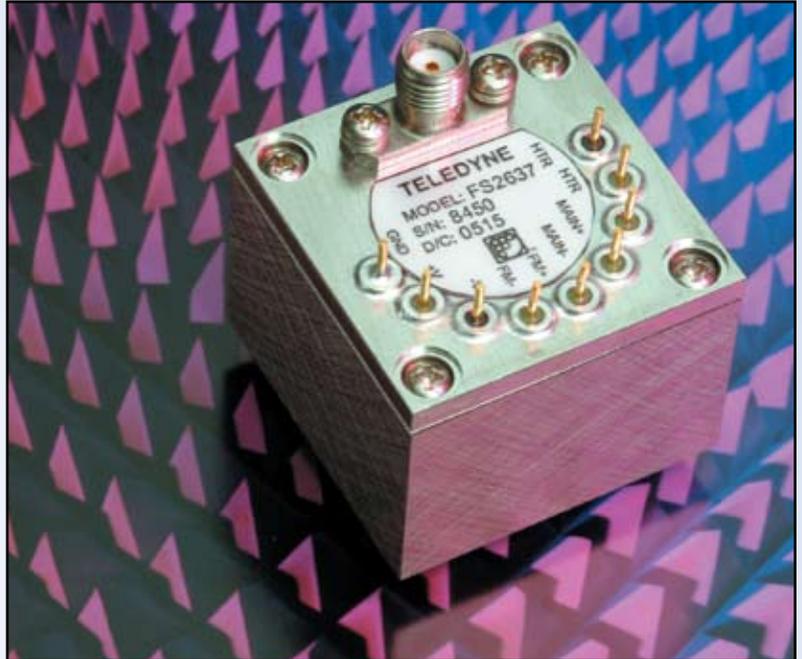
# YIG Oscillators

## Introduction

“YIG-Tuned Oscillator” is the generic name applied to solid-state oscillators whose tunable element is a sphere of Yttrium-Iron-Garnet (YIG). Gallium is often added to “dope” the sphere to extend the frequency range. These materials have extremely high unloaded Q's whose resonant frequency is varied (tuned) by an externally applied magnetic field. A single sphere, properly coupled to a microwave circuit, can be used over very broad frequency ranges, 0.5 to 26.5 GHz for example. The tuning range in oscillators realized with YIG tuning elements is limited mainly by the other circuit elements and the active devices.

Teledyne YIG-tuned oscillators are designed for very broad tuning range applications such as multi-octave sweep oscillators, receiver local oscillators, and electronic defense equipment.

These oscillators are offered in multiple package styles, from a 2” cylindrical, down to surface mount versions. They demonstrate tuning linearities typically better than 0.1% with output power flat over the tuning range to typically better than  $\pm 2$  dB. All Teledyne oscillators contain integral RF buffer amplifiers which insure both increased power output and isolation of the oscillator circuit from the load. Frequency pulling is typically less than 0.2 MHz with a 1.5:1 VSWR load at any phase. As an option, Teledyne can supply an integral driver (voltage-to-current converter) enabling tuning via a linear voltage ramp, typically 0 to 10 volts, or a digital tuning word of up to 12 bits.



Teledyne Microwave offer a wide range of YIG Oscillators with exceptional Phase noise over multi octave bandwidths

### Features

- ◆ Multi-Octave Tuning
- ◆ Excellent Linearity
- ◆ Flat Power Output vs Frequency
- ◆ Low Phase Noise
- ◆ Temperature Stable
- ◆ Phase Lock & Modulation Capability
- ◆ Analog & Digital Drivers Available

### Applications

- ◆ Sweep Oscillators
- ◆ Low Noise Synthesizers
- ◆ Receiver Local Oscillators
- ◆ Jammer Exciters
- ◆ ATE Modules

## Low Noise

The high unloaded  $Q$  of the tuning element insures the low phase noise essential in today's state-of-the-art systems. Teledyne employs a bipolar device in oscillators for low noise applications. These low noise devices produce oscillators with phase noise typically  $-125$  dBc/Hz at 100 KHz from the carrier. Units designed for operation above 10 GHz use a GaAs FET device for very broad-band operation (4 to 18 GHz for example) with typical phase noise of  $-100$  dBc/Hz at a 100 KHz offset. All Teledyne oscillators can be optionally equipped with an internal (FM) coil which can be used to modulate the signal or enable the oscillator to be phase locked to an ultra-stable reference for even lower phase noise close to the carrier. Deviations as high as 40 MHz at a 400 KHz rate are possible using the FM coil. Teledyne drivers for YIG-tuned oscillators are also designed with low noise applications in mind without sacrificing tuning speed. Driver contributed incidental FM is typically better than 50 KHz peak to peak. Special low noise drivers to further decrease driver contributed noise are available.

## MIL Environments

A hermetically sealed structure and specially temperature-compensated magnet make Teledyne YIG-tuned oscillators ideal for use in harsh MIL environments with temperature ranges of  $-55^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ . The use of microwave hybrid circuits, superior heat sinking, and special screening meeting the intent of MIL-STD-883 insures high MTBF. Drivers use all MIL parts and are designed to minimize aging which degrades tuning accuracy over time. This lowers maintenance and calibration requirements with the obvious benefits to lifecycle cost.

## Teledyne Support

This catalog serves to provide examples of Teledyne YIG capability. Teledyne provides applications support to aid customers to formulate specifications for devices unique to their applications. Our engineers, equipped with computer-aided design tools, are available to become a part of your design team. Contact Teledyne or the Teledyne representative in your area.

## Specification Definitions

### Power Output

The RF fundamental power output into a 50 ohm load over the specified tuning range under all other specified conditions.

### Power Output Variation

The variation or flatness of output power into a 50 ohm load over the specified tuning range under all specified environmental conditions.

### Harmonics

The output level, with respect to the fundamental output (carrier), of signals which are integer multiples of the fundamental, under all specified environmental conditions.

### Non-Harmonic Spurious

The level, with respect to the fundamental output (carrier), of signals not harmonically related to the fundamental, under all specified environmental conditions.

### Tuning Linearity

The deviation from a straight line fitted to the curve of output frequency, measured into a 50 ohm load ( $<1.2:1$  VSWR), vs. main tuning coil current as the oscillator is tuned upward from the low to high end of the specified tuning range. When expressed as a percentage, the worst case deviation is a percentage of the highest frequency in the specified tuning range.

### Temperature Drift

The change in RF output frequency using constant coil currents (or constant tuning voltage or digital word in the case of oscillators with drivers) as the oscillator baseplate temperature is varied over the specified temperature range. Measurements are taken after the oscillator has stabilized at a selected temperature, and temperature induced hysteresis effects have been removed.

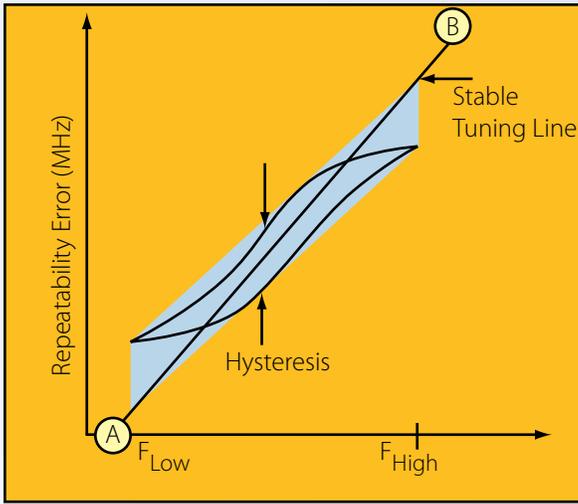


Figure 1 — Magnetic Relaxation Uncertainty — Maximum frequency repeatability error at any fixed coil current due to unknown hysteresis bias of the magnet as a result of tuning speed, magnitude of step and/or direction, vibration, and mechanical and/or thermal shock. Maximum error is equal to hysteresis.

## Hysteresis

The maximum difference in tuned frequency, measured at the same coil current (or same tuning voltage or digital word in the case of oscillators with drivers), when the oscillator is tuned slowly through the specified tuning range both upward (low end to high end) and downward (high end to low end).

Since hysteresis is caused by an unstable magnetization, it represents a tuning uncertainty as shown in Figure 1. For a given coil current, the tuned frequency will fall within the shadowed area depending on tuning step size, tuning speed, and environmental factors. The line A–B represents a stable magnetic condition. This can be best realized by step tuning each frequency from the low end of the tuning range.

## Frequency Pushing

The change in output frequency produced by an incremental change in the power supply voltage.

### Frequency Pulling

The change in output frequency as the phase of the impedance of a specified load mismatch is varied over a 360 degree range.

## Phase Noise

The level of phase/frequency instability of the oscillator. Characterized in the frequency domain, phase noise is measured with respect to the fundamental output level in a 1 Hz bandwidth at a specified offset from the fundamental output (carrier). This parameter does not include noise effects of power supplies or drivers.

## Coil

The average slope of the tuning curve of output frequency vs. coil current. The approximate current needed by the main tuning coil or FM coil to achieve a specific frequency can be calculated by dividing the highest tuned frequency by the sensitivity.

## Heater Current

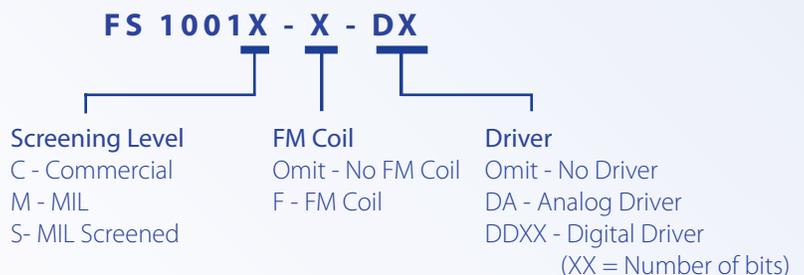
As a means of preventing temperature drift of the YIG sphere, it is maintained at a constant temperature (near 80 °C) by a small internal, self-regulating, heater element. This element requires a voltage of  $28 \pm 4$  volts. Since the heater is isolated from other circuits, the regulation requirements are not as stringent as for other supplies (bias and tuning). The current drawn by the heater element varies with temperature and is typically specified for a steady-state condition at 25 °C. When initially powered on, there is a current surge which diminishes to near the steady-state value in a few seconds.

## Tuning Speed

There are several factors affecting tuning speed, including tuning coil and magnet design, method of tuning, driver design, power supply voltage, etc. Tradeoffs may be required to achieve both adequate tuning speed, low phase noise, and low incidental FM. For data on tuning speed for your particular application, contact Teledyne directly

# Model Numbers

Several options are available which can be specified in the Model Number chosen:



# Specifications 1.25" Cube & 2" Cylindrical Package

	FS2707	FS2637	FS2678	FS1014	FS1012	FS1013	FS2745
<b>Tuning Range (GHz)</b>	2-10	8-18	12-20	4-18	6-18	8-18	2-10
Power Output (dBm)							
Minimum (0 to 60°C)	12	13	10	13	16	16	10
(-55 to +85°C)	11	11	10	10	13	13	8
Variation (dB, max)							
(0 to 60°C)	±2	±2.5	±2.5	±2.5	±2.5	±2.5	±6
(-55 to +85°C)	±3	±3.5	±3.5	±3.5	±3	±3	±8
Harmonics (dBc, max)	-12	-12	-12	-12	-12	-12	-10
Non-Harmonic Spurious (dBc, max)	-60	-60	-60	-60	-60	-60	-60
Temperature Drift (MHz, max)							
(0 to 60°C)	15	15	30	20	20	20	25
(-55 to +85°C)	20	20	40	30	30	30	30
Tuning Linearity (% , max)	±0.15	±0.10	±0.15	±0.075	±0.075	±0.075	±0.1
Hysteresis (MHz, max)	8	12	12	15	12	10	20
Frequency Pushing (MHz/V, max)	1.5	0.5	0.5	0.2	0.2	0.2	1.0
Frequency Pulling (1.5:1 VSWR, max)	0.2	0.5	0.5	0.2	0.2	0.2	1.0
<b>Tuning Coil</b>							
Sensitivity (MHz/mA) ±10%	20	20	20	20	20	20	18
Resistance (Ω, max)	6	6	6	6	6	6	6
Inductance (μH, max)	90	90	90	90	90	90	43
<b>Optional FM Coil</b>							
Sensitivity (KHz/mA, typ)	400	400	400	400	400	400	400
3 dB Bandwidth (KHz, typ)	400	2000	2000	400	400	400	400
Resistance (Ω, typ)	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Inductance (μH, typ)	1.0	1.5	1.5	1.0	1.0	1.0	1.0
<b>Bias Current</b>							
@ +15 Volts (mA, max)	150	180	180	250	250	250	150
@ -5 Volts (mA, max)	N/A	30	30	N/A	N/A	N/A	25
<b>Heater Current</b>							
28 ± 4 Volts (mA, max) 25°C Steady State	50	70	70	40	40	40	100
Surge at Turn-On (mA, max)	500	500	500	500	500	500	500
<b>Outline</b>	OUTLINE 1			OUTLINE 2			OUTLINE 1
Weight (max)	20 oz/570 grams						

# Specifications 1.25", 1.4", 1.0" Cube and Low Profile Package

	FS1021	FS1022	FS1023	FS1033	FS1034	FS1035	FS1042	FS1043	FS2692
<b>Tuning Range (GHz)</b>	2-10	2-8	2-6	5-18	6-18	8-18	2-8	2-6	6-13
Power Output (dBm)									
Minimum (0 to 60°C)	12	13	13	12	13	13	14	15	13
(-55 to +85°C)	10	11	11	10	11	11	13	13	11
Variation (dB, max)									
(0 to 60°C)	±2	±2	±2	±2.5	±2.5	±2.5	±2	±2	±3
(-55 to +85°C)	±3	±3	±2	±3	±3	±3	±3	±3	±3
Harmonics (dBc, max)	-12	-12	-12	-12	-12	-12	-12	-12	-12
Non-Harmonic Spurious (dBc, max)	-60	-60	-60	-60	-60	-60	-60	-60	-60
Temperature Drift (MHz, max)									
(0 to 60°C)	15	15	15	20	20	20	15	15	20
(-55 to +85°C)	20	20	20	30	30	30	20	20	30
Tuning Linearity (% , max)	±0.15	±0.10	±0.08	±0.10	±0.085	±0.05	±0.10	±0.08	±0.25
Hysteresis (MHz, max)	10	8	6	15	12	10	8	6	10
Frequency Pushing (MHz/V, max)	1.5	1.5	1.5	0.2	0.2	0.2	1.5	1.5	1.5
Frequency Pulling (1.5:1 VSWR, max)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
<b>Tuning Coil</b>									
Sensitivity (MHz/mA) ±10%	20	20	20	20	20	20	20	20	20
Resistance (Ω, max)	6	6	6	6	6	6	6	6	10
Inductance (μH, max)	75	75	75	75	75	75	22	22	30
<b>Optional FM Coil</b>									
Sensitivity (KHz/mA, typ),	400	400	400	400	400	400	400	400	310
3 dB Bandwidth (KHz, typ)	400	400	400	400	400	400	400	400	2000
Resistance (Ω, typ)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Inductance (μH, typ)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0
<b>BIAS CURRENT</b>									
@ +15 Volts (mA, max)"	200	200	200	250	250	250	200	200	175
@ -5 Volts (mA, max)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	30
<b>Heater Current</b>									
@ 28 ± 4 Volts (mA, max)	40	40	40	40	40	40	40	40	50
@ 25°C Steady State									
Surge at Turn-On (mA, max)	500	500	500	500	500	500	600	600	300
<b>Outline</b>	OUTLINE 1, 3 OR 4				OUTLINE 1 OR 4			OUTLINE 3 OR 5	
Weight (max)	11 oz/312 grams							3.5 oz/98 grams	

# Oscillators with Drivers

The addition of a stable voltage-to-current converter, or driver, allows the system designer to achieve linear tuning via an analog voltage ramp or digital tuning word. All components in Teledyne drivers are chosen for maximum stability in both short- and long-term operation. The driver is matched to the oscillator by computer selection of trim resistors. This procedure avoids the use of large potentiometer ranges which increase aging errors.

Most YIG oscillator applications require fast tuning speeds while at the same time they must produce clean, stable output frequency when held at a single frequency (CW). This represents a conflict in requirements for the bandwidth of the driver circuit. Large band-width would insure fast tuning response, while narrower bandwidth would reduce the effects

of power supply ripple, ripple on the tuning voltage, and driver added noise which cause incidental FM. Teledyne oscillator drivers were designed after a careful analysis of the contributed noise factors of each component. The resulting design offers the lowest incidental FM compatible with fast tuning speed.

Teledyne MIL drivers contain all MIL-specified parts (see Screening Level Definitions) and are temperature compensated for operation over the -55 to +85°C range. The resulting static frequency drift with temperature of the oscillator/ driver combination is minimized. Conformal coating of the printed circuit boards and a moisture-sealed housing insure survival in the MIL-E-5400 Class 2 airborne environment.

## Typical Driver Specifications

Tuning Input	Analog 0 to 10V Digital (TTL) 5 to 12 bits
Tuning Impedance	>10 KΩ for Analog Tuning. One TTL load for digital tuning
Power Supply ±15 V <sup>(1)</sup> ±5	(in addition to oscillator coil and bias requirements) @30mA for Analog Tuning @50mA for Digital Tuning @30mA for Digital Tuning

(1) The current for the oscillator main tuning coil is drawn from the +15 Volt supply in Teledyne standard drivers

# Screening Levels

The following defines the component quality, inspection, and screening levels available with Teledyne oscillators or oscillators with drivers.

### Commercial ("C")

1. Internal Visual Inspection.
  2. 100% Electrical Test at 25°C: Tuning Range, Harmonics, Linearity, Hysteresis, Power Output, Bias Current Power Variation
  3. External Visual Inspection.
- Commercial drivers use best commercial quality components which are identical in function to those used in "M" and "S" level units.

### Military ("M")

1. Internal Visual per MIL-STD-883C, Method 2017.3.
2. 24-Hour Stabilization Bake at 125°C per MIL-STD-883C, Method 1008.2, Condition B.
3. Laser Weld Seal in inert nitrogen gas environment.

4. Fine Leak Test per MIL-STD-883C, Method 1014.5, Condition A1 or A2.
5. Gross Leak Test per MIL-STD-883C, Method 1014.5, Condition C1 or C2.
6. Burn-in, 96 Hours at 85°C per MIL-STD-883C, Method 1015.4, Condition B.
7. 100% Electrical Test: Tuning Range, Power Variation, Linearity Harmonics, Temperature Drift, Hysteresis, Power Output Bias Current
8. External Visual per MIL-STD-883C, Method 2009.4.

Military drivers use components selected as follows: Resistors and Capacitors: Established Reliability (ER). Transistors and Diodes: JANTX Integrated Circuits: Screened to MIL-STD-883, Level B. Printed wiring boards are conformally coated with a material in conformance with MIL-C-46058. The integrated oscillator and driver is subjected to screening steps 6, 7, and 8.

### Military, Screened ("S")

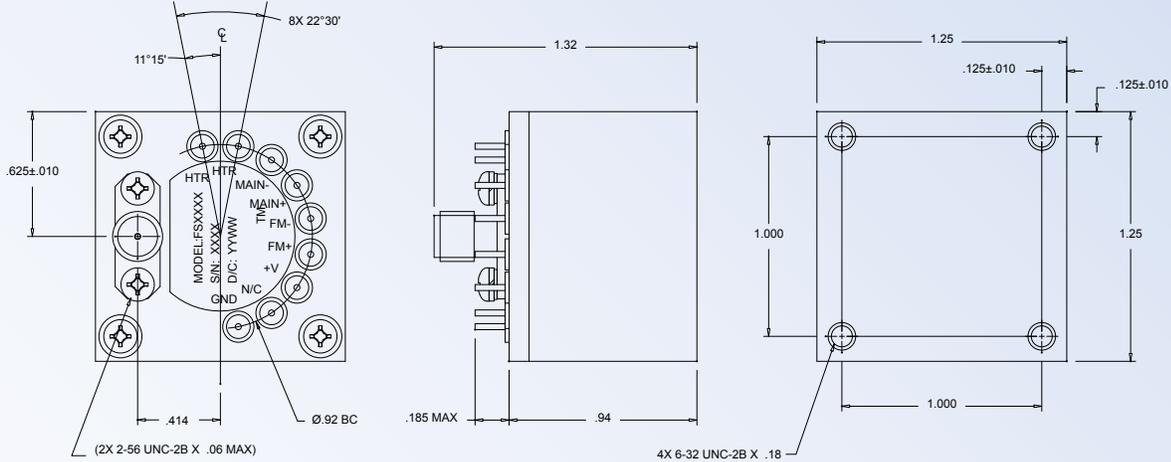
1. Internal Visual per MIL-STD-883C, Method 2017.3.
2. 24-Hour Stabilization Bake at 125°C per MIL-STD-883C, Method 1008.2, Condition B.

3. Laser Weld Seal in inert nitrogen gas environment.
4. Fine Leak Test per MIL-STD-883C, Method 1014.5, Condition A1 or A2.
5. Gross Leak Test per MIL-STD-883C, Method 1014.5, Condition C1 or C2.
6. Temperature Cycle, -55°C to +125°C, 10 cycles per MIL-STD-883C, Method 1010.5, Condition B.
7. Mechanical Shock, 500g's at 1 msec, Y1 axis, per MIL-STD-883C, Method 2002.3, Condition A, or Constant Acceleration, 5000g's, per MIL-STD-883C, Method 2001.2, Condition A.
8. Burn-in, 96 Hours at 85°C per MIL-STD-883C, Method 1015.4, Condition B.
9. Fine Leak Test per MIL-STD-883C, Method 1014.5, Condition A1 or A2.
10. Gross Leak Test per MIL-STD-883C, Method 1014.5, Condition C1 or C2.
11. 100% Electrical Test: Tuning Range, Power Variation, Linearity, Harmonics, Temperature Drift Hysteresis, Power Output, Bias Current
12. External Visual per MIL-STD-883C, Method 2009.4.

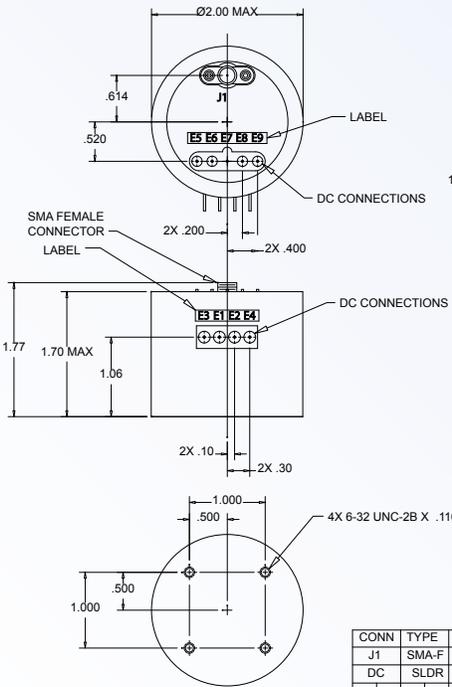
Military, screened drivers are similar to "M" level described except that MIL-M-38510 integrated circuits are used if available. The integrated oscillator and driver is subjected to screening steps 6, 8, 11 and 12

# Outline Drawings

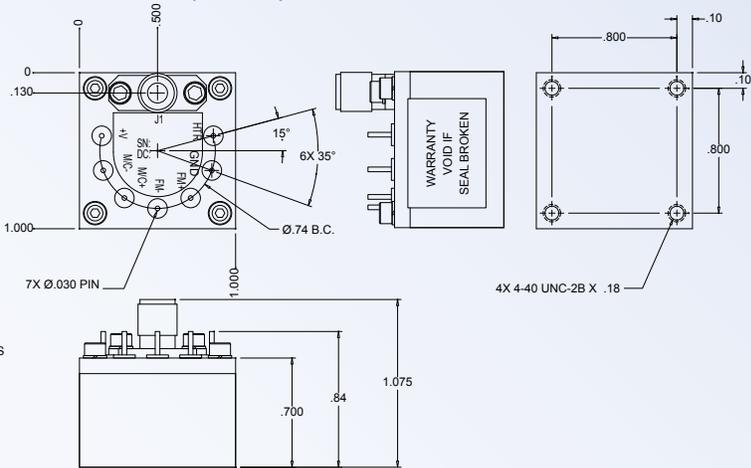
**OUTLINE 1. (1304893)**



**OUTLINE 2. (2000048)**



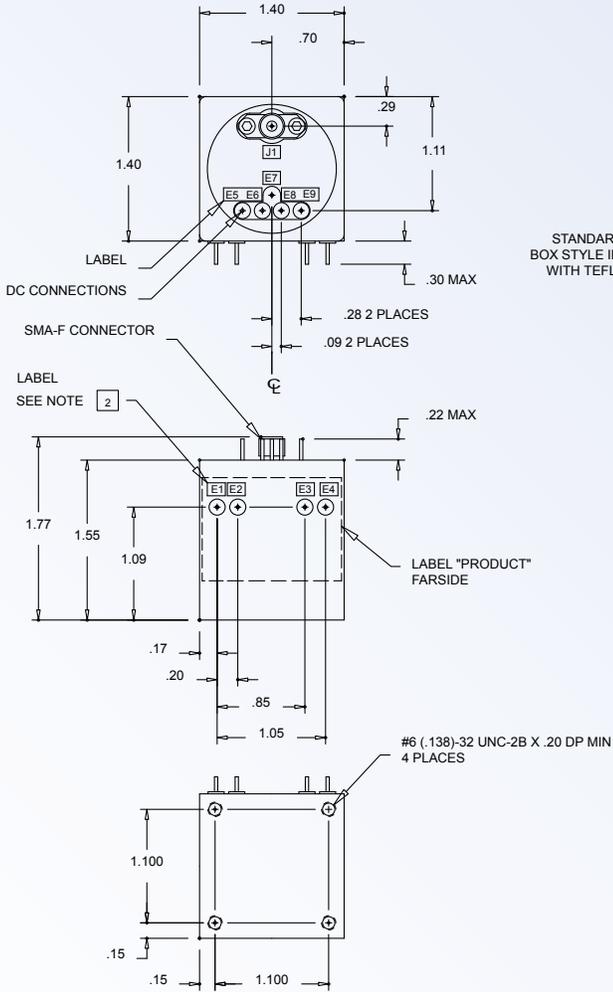
**OUTLINE 3. (1303584)**



CONN	TYPE	PIN NO.	FUNCTION
J1	SMA-F	THD	RF OUT
DC	SLDR	E1	MAIN COIL (+)
		E2	MAIN COIL (-)
		E3	FM COIL (+)
		E4	FM COIL (-)
		E5	N/C
		E6	+15 OSC BIAS VOLT
		E7	GROUND
		E8	HEATER VOLT
		E9	HEATER VOLT

# Outline Drawings

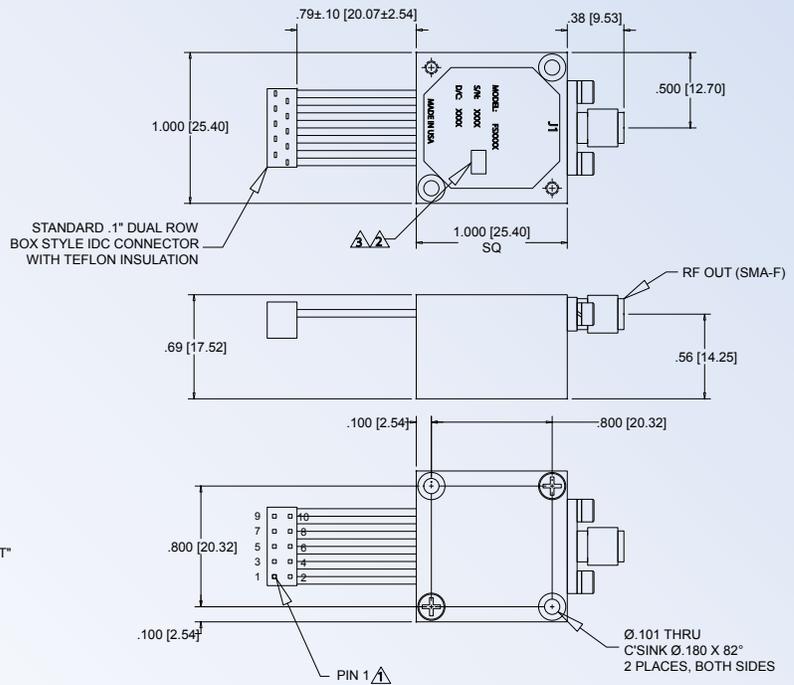
**OUTLINE 4. (0200106)**



CONN.	TYPE	PIN NO.	FUNCTION
J1	SMA-F	THD	RF OUT
DC	SLDR	E1	MAIN COIL (+)
		E2	FM COIL (+)
		E3	FM COIL (-)
		E4	MAIN COIL (-)
		E5	N/C
		E6	+15 OSC BIAS VOLT
		E7	GROUND
		E8	HEATER VOLT 1
DC	SLDR	E9	HEATER VOLT 1

TOLERANCE	
XX	±.02 [.51]
XXX	±.005 [.127]

**OUTLINE 5. (1305318)**



PIN NO.	TYPE	FUNCTION
J1	SMA-F	RF OUTPUT
1	CONN	MAIN COIL +
2		MAIN COIL -
3		GND
4		FM COIL +
5		FM COIL -
6		GND / -5V (AS REQUIRED)
7		+V
8		GND
9		HEATER RTN
10	CONN	HEATER