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UM-20
User Manual

Low-cost Oven-controlled Crystal Oscillator (OCXO) Assembly

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CHANGELOG

Rev.	Date	Author	Comments
A	20170512	AEK	Initial version.
B	20170608	AEK	Added images of modules, included initial `V_TRIM` values, added more explanatory text.

Purpose

This manual describes the design and performance of a small and inexpensive oven-controlled crystal oscillator (OCXO).

Personnel

Andrew Kalman (AEK) purchased the frequency counters and replacement oscillators for Pumpkin, collected information on a new OCXO design, conferred on nuances of oscillator circuits, and tested and characterized the OCXO.

David Wright (DJW) reverse-engineered the XL Microwave OCXO module, created the schematics and PCB for the OCXO module

Introduction

Like many hardware developers, Pumpkin utilizes various laboratory instruments as part of hardware development and experimentation. Frequency counters, waveform generators, spectrum analyzers, time interval counters and other instruments need accurate and stable oscillators.

An external frequency reference – like a 10.000000MHz signal from a GPS-disciplined oscillator[1] – is a popular and relatively inexpensive, stable and accurate frequency reference to distribute within a laboratory, for use as an external frequency standard for compatible instruments.

Figure 1: GPS time and frequency reference receiver

[1] E.g. the HP Z3805A GPS time and frequency reference receiver. This unit was often used in cellular towers; these units were often sold on eBay once their stated performance had expired. Upon first power-up and without a connected GPS antenna, it was possible to identify the location of the cell tower where the unit was located; the ones Pumpkin purchased were all from Chinese cell towers.

Using an external frequency standard physically ties an instrument to that standard, and makes it less portable, etc. We wanted to have an inexpensive, desktop frequency counter with an input range of up to ca. 100MHz, with a relatively accurate and stable internal oscillator. Additionally, we wanted to become more knowledgeable on the matter of oscillators.

OCXO Replacement

The XL Microwave line of microwave frequency counters satisfied our frequency counter requirements, and provides a high-frequency power meter, to boot. These frequency counters have a 1/2/5/10MHz external reference oscillator input, and a 10MHz reference output. Via eBay and other sources, Pumpkin purchased the following models in good to excellent condition:

- Model 3030-6 Options: D S/N 950823357[2]
- Model 3120 Options: 115 S/N 981025390[3]
- Model 3080 Options: 115 S/N 120825142[4]

Figure 2: XL Microwave Model 3120 frequency counter

By comparing this particular Model 3080's reference output to a GPS-disciplined 10MHz, we discovered that its internal OCXO was wildly out-of-range at 9,887,XXXHz.

Option 115's OCXO (the second of four progressively better internal oscillator options for these frequency counters) has the following performance:

- Aging/second: E-11 root Allan variance
- Aging/day: 5E-10 after 72 hours

[2] Built in 1995, warrantied by XL Microwave for 2 years until 1997.
[3] Built in 1998, warrantied by XL Microwave for 5 years until 2003.
[4] Built in 2002, warrantied by XL Microwave for 5 years until 2007. Unknown why the S/N code is not consistent with the other two …

- Aging/year: 1.5E-7 after 7 days, 1E-7 after 30 days
- Warm-up @25C: 2E-8 in 30 minutes
- Temperature (0 to 50C): 1E-8
- ±10% MAINS change: 1E-9

S/N '357 has a 10MHz IsoTemp Research, Inc. Model OCXO36-44 10.000MHz large OCXO S/N 9051-61 DATE 9552 that can be tuned down to 1E-10 using the method that compares the drift of its output to the GPS-derived 10MHz signal. The two screws on the can – marked Coarse and Fine – are covers for the pots inside ... the OCXO must be unscrewed from the Model 3030's chassis in order to get access to these screws … very nice.

Figure 3: IsoTemp OCXO36-44, the "original" Option 115 OCXO for Model 3xxx frequency counters

S/N '390 has the same oscillator.

Opening up S/N '142 revealed that this unit's internal OCXO has an MTI 220-0102-A 5.0000 MHz OCXO module S/N 124463 on a small PCB, with a trimpot for frequency trimming. This MTI OCXO puts out a 3V (roughly) sine wave; the reference output could not be pulled to 10MHz with the trimpot when connected via `J4` to the Model 3080's frequency input; it was, however, tunable to 5MHz when there was no load on its output. Contacting MTI for a replacement revealed that each OCXO cost around $500 new, but there was a $1500 minimum order.

Table 1: MTI OCXO-based oscillator module from SN '142

It appears that at some point (after 1998?), XL Microwave switched from IsoTemp's (large) OCXO36-44s to MTI's smaller 220-0102 OCXOs; the IsoTemp units appear to be of higher long-term quality and may be double-ovenized, but probably also cost much more.

Various Internet searches and user forums (especially http://leapsecond.com/time-nuts.htm) revealed a large community of tinkerers and engineers with a shared interest in frequency standards and measurements. For example, Gerry Sweeney built a nice reference using an IsoTemp OCXO131: http://gerrysweeney.com/tag/ocxo131/ ... note that he is using an OCXO100-XXX .. that is a +5V unit. There is also an OCXO191 available (probably 12V). And this has even more detail: http://gerrysweeney.com/tag/ocxo131-191/.

Pumpkin purchased multiple IsoTemp OCXO131-40 (12V, sine-wave output) from an eBay seller for around $21 each and set out to create a drop-in replacement OCXO for S/N ‘142, and for other XL Microwave Model 3xxx units.

OCXO Design

S/N ‘142s MTI-based OCXO is mounted on a 2” x 2” 0.062” PCB using SAE dimensions and fasteners. Four 4-40 captive threaded standoffs on a 1.5” bolt square enable the module to be mounted to the Model 3xxx’s chassis via 4-40” flathead screws.

The assembly has a 0.100” pitch 4-position rectangular receptacle connector TE Connectivity / AMP P/N 3-640440-4 for a few inches of 22AWG wiring, as follows:

1.	O	Purple	10MHz output
2.	G	Black	Ground
3.	+	Red	+12V
4.	S	Yellow	Heater status[5]

Table 2: MTA100 connector pinout to mate to XL Microwave 3xxx

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Note Our 705-01667 PCB’s connector pinout is opposite from the above … the 22AWG wires are connected to the PCB based on the O/G/+/S labels.

Critical Components

We decided to create a replacement module with a few enhancements compared to the original:

- Compatibility with inexpensive (used) IsoTemp OCXO131-40 10.000MHz OCXOs
- An external +12V barrel jack for desktop calibration / testing
- An MMCX connector on the output, for desktop calibration / testing
- A high-quality multi-turn trimpot
- Precision resistors in the trimpot circuit

These components are expanded upon in detail below.

[5] Not present / not used on the fancier OCXO36-44 and units originally equipped with them.

OCXO131-40

This IsoTemp OCXO module is available at low cost from various eBay sellers. These units are probably pulled from working frequency standards, or from other equipment. It can be assumed that they are well aged. Measuring 36.3 x 27.2 x 19.1mm, they are a tight fit on the compatible PCB. They are SC-cut, sinewave output with a fast warmup, and have frequency stability specifications that are on par with the MTI 220-series OCXO that was originally in S/N ‘142. Hard to beat for $21 each … units purchased from eBay often have date codes in the early 2000’s …

Barrel Jack and MMCX Connector

By placing a 2.1mm/5.5mm barrel jack on the OCXO PCB, it’s trivial to power the OCXO separately from the Model 3xxx frequency counter. Similarly, by connecting an MMCX jack to the OCXO’s output, it’s trivial to connect the OCXO output to an oscilloscope or frequency counter, via an MCX-to-BNC adapter cable. These two features facilitate initial measurements and trimming of the 10.000MHz OCXO while on a lab bench. The barrel jack and MMCX upright jack are located on the PCB so that they are accessible even when the PCB is installed into the Model 3xxx.

High-quality Trimpot

We chose the Vishay Accutrim™ 1280G 26-turn trimpot with its 15ppm/ºC temperature coefficient (tempco). At $15, it is not inexpensive, but it is similar to what was on the MTI-based OCXO originally in the Model 3080.

Ultra-low Tempco Resistors

In an attempt to have the finest possible trim voltage adjustability, we chose to augment the trimpot with fixed resistors. We chose the Vishay VCFP series ultra-high-precision resistor with a 0.2ppm/ºC temperature coefficient. These are 0.01% resistors in a 1206-size package. At $10 each, they are also not inexpensive, and they are available only in a limited range of values.

It has been suggested that resistors grouped in single packages provide optimal tracking and stability, better than (separate) discrete resistors. One option would be a non-divider version of Vishay’s SOT-23 MPM-series divider networks.

Circuit Design

DJW reverse-engineered the original OCXO PCB to create a reference schematic and design a new PCB. The new schematic and PCB layers are attached to this manual.

12V LDO

A 12V TO-220 linear regulator accepts 12V power from the Model 3xxx and provides power to the OCXO and an op-amp. The choice of a 12V regulator is a little odd, as its input is only 12V, and it cannot therefore regulate its output to 12V. However, most OCXOs run at 12V or 5V, and we'd be dissipating over half a Watt if we used a 5V-supply oscillator, so we stuck with this topology, for use with the 12V IsoTemp OCXO131-40.

Based on our preference for 12V linear regulators, we chose the LM2940SX-12 low-dropout (LDO) regulator. This part has overvoltage (up to 26V) and reverse-voltage protection, and has a low dropout at low currents, in a surface-mount package.

Op-amp Circuit

The original circuit included an op-amp that detected when the OCXO was no longer in warm-up mode, and drove an output to +5V to indicate that warmup was complete. While warming up, the op-amp detected the increased current draw and drove a small FET to pull the **`–WARMING`** signal down to 0V.

We replicated this circuit, with a 180mA trip point, using an LT1716 precision rail-to-rail comparator.

OCXO

The original circuit included a filter on the OCXO's +VDC terminal, as well as a pi filter on the output. We verified that the trim voltage on the OCXO131-40 is effective over a range of 0V to 5V, centered at 2.5V.

We replicated the earlier circuit's filters, added an MMCX jack on the OCXO's output, and planned for a VCO trim voltage centered at 2.5V.

VCO Trim

Based on Gerry Sweeney's OCXO board's circuit design, we selected the high-precision Maxim MAX6350 5V regulator to generate a stable voltage for the trim voltage from 12V. Its tempco is 1ppm/ºC. This voltage passes through a trimpot that is flanked by two fixed resistors, to narrow the range of the trim voltage for greater precision when trimming the VCO.

The tempco of the trimpot **R7** is considerably higher than that of the fixed resistors **R6** and **R8**. By choosing resistor values for **R6** and **R8** that are much (>10x) larger than that of the trimpot **R7**, the poor tempco contribution of the trimpot is minimized.

We improved the trimpot of the original design via improved tempco components. Our initial choice for ***R6****,* ***R7*** *and* ***R8*** *was 15kΩ, 1kΩ and 15kΩ, respectively.*

PCB Design

DJW designed a new PCB that was drop-in compatible with the original PCB in S/N '140, and compatible with all Model 3xxx internal oscillators. We followed Connor Winfield's AN2093 *OCXO Layout Guidelines* and other web resources.

The PCB has two layers, with soldered-in 4-40 threaded standoffs in the corners. Because the OCXO131-40 is quite large relative to the available PCB real estate, ¼" long standoffs were used, to make room for some of the taller components in the design (**L2**, **U1** & **C1**) to be placed on the underside of the PCB.

The trimpot **R7** was placed in close proximity to OCXO **U4**'s metal can, and resistors **R6** and **R8** were placed close to the trimpot. These four components were placed in close proximity so that they can be thermally coupled via a thermal encapsulating epoxy.

Trimpot **R7** was placed in a position that makes it easy to adjust the OCXO when installed in a Model 3xxx. MMCX jack **J2** is also relatively accessible. Barrel jack **J3** is also on the edge of the PCB, and can be used to power the circuit.

Note It is not recommended to power the circuit when it's also connected to the Model 3xxx via **J1**. It can be used when the PCB is installed into the Model 3xxx, it's not connected via **J1**, and test equipment is measuring the circuit's output via **J2**.

A few test points are provided to measure the VCO trim voltage, the post-regulator 12V, etc.

Usage

Frequency Survey

The initial accuracies of the used OCXO131-40s are listed below.[6]

S/N	Date	Initial output (Hz) after 30 minutes — VCO not connected, i.e., untrimmed	Initial V_TRIM (Vdc) — VCO not connected, i.e., untrimmed	V_TRIM (V) required for 10.000000MHz, output into 50Ω	Current draw (mA) after 30 minutes, at 12.00Vdc
1946-88	0223	10,000,001.04	2.37	2.12	110
2140-395	0301	*neither assembled nor tested*			
2140-618	0310	9,999,999.82	2.38	2.49	113
2140-624	0310	9,999,999.19	2.42	2.76	85
2302-1000	0406	10,000,000.04	2.41	2.43	95
4231-0013	0902	9,999,999.55	2.39	2.61	112

Table 3: Frequency survey of OCXO131-40 units, installed on 705-01667A PCBs

Assembly

Five modules were assembled by hand, using the Pumpkin PCB and five of the six OCXO131-40s that we acquired. The module with its attached harness is shown in Figure 4 and Figure 5.

Figure 4: Top view of assembled module

Figure 5: Bottom view of assembled module

[6] An XL Microwave Model 3120 with a GPS DO 10MHz external reference was used for the frequency measurements; a Fluke 289 DMM was used for the **V_TRIM** measurements; an Agilent E3620A provided the **V_TRIM** voltage and 12Vdc power.

Module Applications at Pumpkin

Multiple Rev A PCBs were assembled with used OCXO131-40s; their applications are below.[7]

Pumpkin S/N	IsoTemp S/N	Application	Notes
101	1946-88	XL Microwave 3030 S/N 950823357	
n/a	2140-395		
102	2140-618	not installed	First unit to be assembled; trimpot and precision resistor remain unpotted.
103	2140-624	SRS DS345 S/N 32542	Wired for 7-pin connector to U1 (factory OCXO). Use cal byte 0 to tune – nominal value is 2980.
104	2302-1000	SRS DS345 S/N 30029	
105	4231-0013	not installed	

Table 4: Applications of Rev A OCXO Modules

Two applications of the OCXO Module are expanded upon below.

[7] An XL Microwave Model 3120 with a GPS DO 10MHz external reference was used for the frequency measurements; a Fluke 289 DMM was used for the **V_TRIM** measurements; an Agilent E3620A provided the **V_TRIM** voltage and 12Vdc power.

Use in XL Microwave Model 3xxx

Installation

As a test, we decided to install the assembled OCXO module with OCXO131-40 S/N 2140-624 into an XL Microwave Model 3030 frequency counter.

Both the upper and lower covers of a Model 3xxx must be removed in order to access the screws that hold the oscillator assembly in place. Four 4-40 x 3/16" flathead screws hold the OCXO assembly in place, and **J1** is connected to a single connector labeled 10 MHz BUFFER on a nearby PCB.

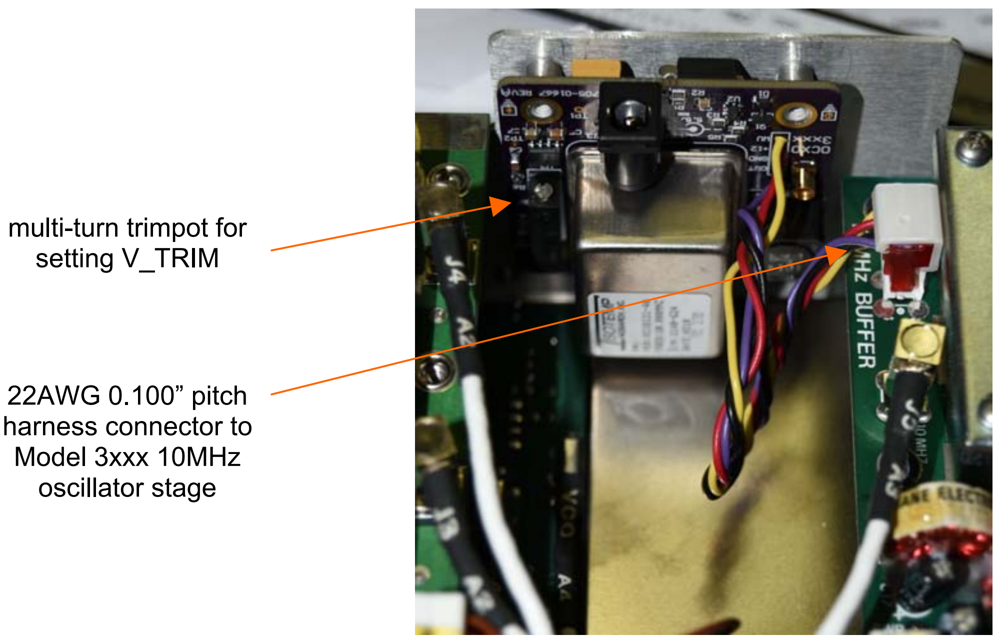


Figure 6: OCXO PCB assembly installed in Model 3xxx

Frequency Tuning

It turns out that the initial values of 15kΩ for **R6** and **R8** restricted the VCO trim range too much *on this particular unit* to be able to reach 10.000000MHz. Replacing **R6** and **R8** with zero-Ohm resistors yielded a **V_TRIM** (**TP3**) of 2.73Vdc to reach 10.000000MHz.

With zero-Ohm **R6** and **R8**, the trim range of the VCO (stated by IsoTemp to be up to 0.9ppm or 9Hz over the full range) required a full ±2.5V of **V_TRIM** at the VCO input with **R7** = 1kΩ. To reach a

V_TRIM of 2.76Vdc required **R6** and **R8** values of under 5kΩ; 1kΩ resistors were eventually fitted.

R6 & R8 Values	V_TRIM Range	Notes
0Ω	± 2.50V	*Entire range yields changes in output frequency of ± 6.27Hz, or around 0.6ppm (within specs). OCXO131-44 S/N 2140-618 output was 9,999,993.55Hz @ V_TRIM= 0.00Vdc, and 10,000,006.87Hz @ V_TRIM = 5.00Vdc.*
1kΩ	± 0.83V	*S/Ns* 1946-88, 2302-1000, 2140-624 & 4231-0013 were trimmed with these values.
2kΩ	± 0.50V	
5kΩ	± 0.23V	
10kΩ	± 0.12V	
15kΩ	± 0.08V	S/N 2140-618 was trimmed with these values.

Table 5: OCXO131-40 frequency tuning range as a function of R6 & R8

Realistically, the choice for **R6** & **R8** boils down to 0Ω (guaranteeing the greatest possible frequency tuning range) or 1kΩ (giving a tuning sensitivity that's 3x greater that that of the 0Ω configuration, but with less frequency tuning). Values greater than 2kΩ for **R6** and **R8** are likely to prevent trimming to 10.000000MHz, unless the initial **V_TRIM** is within roughly 100mV of 2.5V.

Note Different values for **R6** and **R8** could be used on a case-by-case basis to optimize the trim range for a given OCXO131-40.

In-place Tuning

The lower cover of the Model 3xxx must be removed in order to trim the installed OCXO assembly to 10.000000MHz. This requires that the Model 3xxx be upside-down when adjusting the OCXO frequency.[8]

[8] A carefully positioned hole could be drilled in the lower cover of the Model 3xxx, to gain access to the PCB assembly's trimpot without removing the lower cover.

Use in SRS DS345

Installation

We installed the assembled OCXO module with OCXO131-40 S/N 2302-1000 into a SRS DS345 synthesized function generator. This unit was configured at the factory without Option 02 (Internal OCXO).

Since the Pumpkin OCXO module was not designed for use in the DS345, we had to find a robust way to mount it. We found that in the DS345's rear corner where the various back-panel BNCs are located, there is enough room to locate one of our modules by mounting it to one of the sides of the aluminum sheet metal chassis. We machined two countersunk 82º holes sized for 4-40 flathead screws 1.500" apart, 0.325" from the top edge of the chassis.

Figure 7: OCXO PCB assembly installed in DS345

The DS345 maintains a chassis ground that is separate from (digital) ground; since the OCXO module Rev A PCBs connected the four 4-40-size standoffs to (electrical) ground, we had to isolate these modules when used in the DS345. The solution was to use nylon screws, along with nylon washers in the top two mounting holes.[9]

[9] The OCXO module's lower two captive standoffs simply had the nylon screws screwed into them until them bottomed out; the net effect is that they form a captive spacer that insulates the lower standoffs from the DS345's chassis.

Prior to installation, we replaced the four-wire harness that is for a Model 3xxx with a 5-wire, 7-pin harness suitable for use in the DS345. The pinout for the 7-pin connector is as follows:

1.	-	NC	+15V (not used)
2.	-	NC	-15V (not used)
3.	-	White	VCO trim from DS345[10]
4.	G	Black	Ground
5.	O	Purple	10MHz output to DS345
6.	S	Yellow	Monitor[11]
7.	+	Red	+15V

Table 6: OCXO module pinout to mate to SRS DS345

N.B. The DS345 supplies +15V (and –15V) to the factory-installed OCXO. Regulator **U1** on the OCXO module is compatible with +15V input. In contrast to the usage in the Model 3xxx, when used in the DS345, the OCXO module's 12V regulator **U1** is actually providing a regulated +12Vdc output to the OCXO131-40.

Frequency Tuning

The DS345 provides an OCXO tuning voltage called **OPT_VCO** to an installed OCXO on its connector **U203** (the factory OCXO). By connecting this signal to the VCO input on the Pumpkin OCXO module, DS345 users can fine-tune the OCXO's frequency using the DS345's internal calibration byte #0. Since **OPT_VCO** is driven by an op-amp, the effect of the OCXO module's trimpot on its VCO trim voltage **V_TRIM** are overridden. A cal byte value of 0 represents an **OPT_VCO** value of -5.5Vdc, and a value of 4095 represents an **OPT_VCO** value of +5.5Vdc. The factory default value is 2980, corresponding to 2.5Vdc.

In-place Tuning

Both the first and second position of the 4-position DIP switch **SW300** inside the DS345 must be set to ON; The first position selects the OCXO as the module's internal 10MHz source; the second position enables front-panel changes to calibration constants. See the DS345 manual for more information.

An cal word #0 initial value of 2977 (**OPT_VCO** = 2.476Vdc) tuned the OCXO to 10MHz.

[10] In Rev A modules, the wire was soldered to **TP3**. In the Rev B design, this signal is part of the **J1** header / connector.

[11] Not used by the DS345.

Usage

DC Voltages

TP1 (12V LDO output) typically measures 11.87Vdc for a +12Vdc input to the module. Note that this means that the LDO is not regulating its output.

TP2 (stable 5V for trimpot) will measure close to 4.9999Vdc.

TP3 (OCXO's VCO) varies for 10.00000000MHz. The trim voltage seems to be around 4-6mV/0.1Hz.

Note It was observed that the trim voltage for 10MHz when installed typically differs from the trim voltage when the PCB assembly is on a bench and not installed in an XL Microwave Model 3xxx.

-WARMING rises to 4.87V once the OCXO is out of its warm-up phase.

The total current (@12V) when warming is 250-300mA, post-warming is 85mA. The 180mA trip threshold of **U2** is therefore confirmed.

Loading vs. Frequency

The output of the OCXO changes slightly with loading, particularly capacitive loading. The output does not have an active buffer. The frequency difference between the OCXO assembly running on a bench, into a high-impedance oscilloscope, and the 10MHz output frequency from the Model 3xxx, is in the region of 0.5Hz, or 50ppb.

Frequency Stability

Once installed in the Model 3xxx, the frequency of the OCXO PCB assembly is measured at the Model 3xxx's output BNC on its back panel. These tests were performed without any thermally encapsulating epoxy on the PCB assembly.

Over the course of several days, when monitored by a Model 3020 using a GPS-disciplined 10MHz oscillator as its external frequency input, and with the OCXO131-40 tuned to 10,000,000.00Hz, a maximum change of -.01Hz / + 0.00Hz was observed. This is 1E-9 territory, which is within the IsoTemp OCXO131 specifications of ±0.5ppb over the course of one day.

An SRS SR620 time interval counter was setup with a 0.01s gate period and a sample size of 1,000 to measure Allen variance; the result was relatively stable around 27 to 33 mHz, or 2-3ppb over a τ of 10s. This number is in keeping with plots of typical OCXO frequency stability.

Warmup / Initial Behavior

It was observed that compared to the OCXO36-based (double-oven?) oscillator, the smaller OCXO131-based oscillator warms up very quickly, is closer to 10.000MHz at initial turn-on, and reaches the post-warmup stage sooner.

Oscillator Outputs

The output of the OCXO36-44 through the Model 3xxx's 10Mhz output terminated into 50Ω is shown Figure 8.

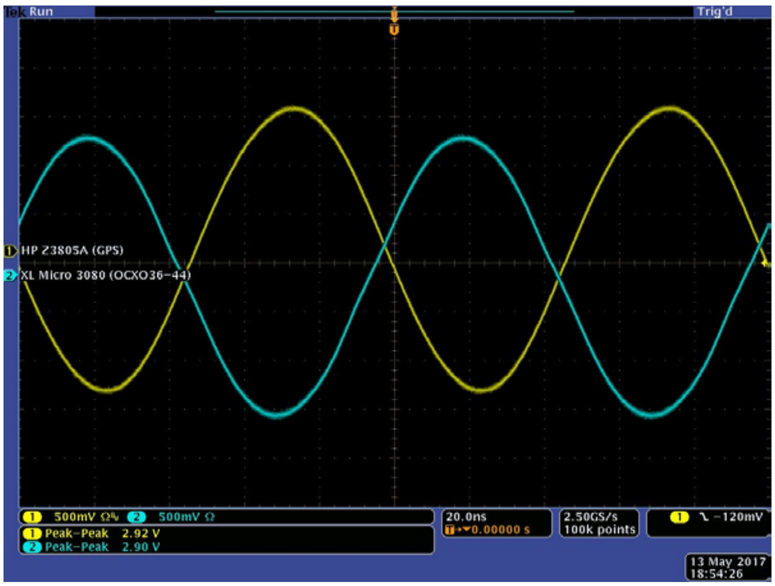


Figure 8: OCXO36-44 waveform (blue) compared to Z3805A GPS-disciplined waveform (yellow)

The output of the OCXO131-40 through the Model 3xxx's 10Mhz output terminated into 50Ω is shown Figure 9.

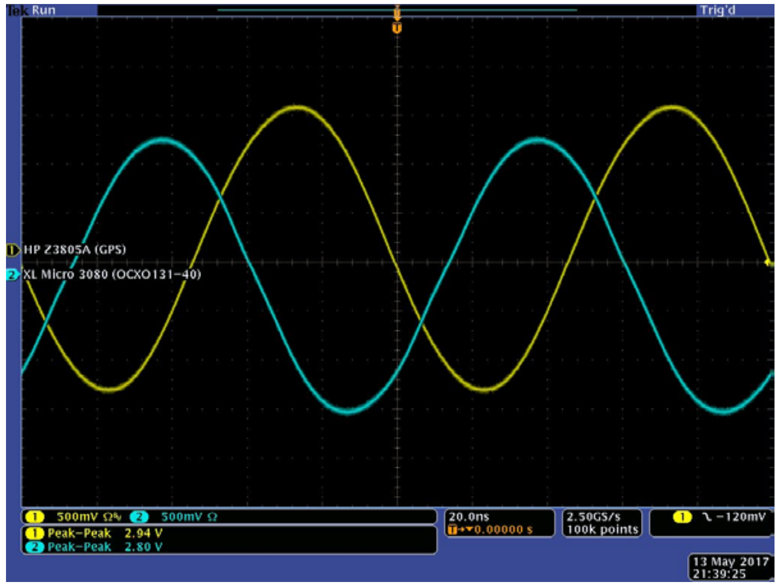


Figure 9: OCXO131-40 waveform (blue) compared to Z3805A GPS-disciplined waveform (yellow)

Summary

The low-cost OCXO PCB assembly achieves the stated performance of the IsoTemp OCXO131-40, and includes some user-friendly features that improve on the original, MTI-based unit[12] that became Option 115 in later XL Microwave 3xxx units. The tuning range is a function of the fixed resistors **R6** and **R8** in the design. The design can conceivably be used for other applications.

The frequency stability of the IsoTemp OCXO131-40 remains less than that of its larger sibling, the IsoTemp OCXO36-44, which was apparently used as Option 115 on earlier Model 3xxx frequency counters.

Future Work / Enhancements

A small microcontroller (MCU) that sensed temperature and could drive a digital / programmable divider or voltage source would be an even better way to set **V_TRIM**; with a terminal interface to the MCU and with non-volatile memory (NVM), the MCU could implement a control algorithm to maximize oscillator performance during warmup and over a wide temperature range, with the ability to store critical parameters in NVM. A command and telemetry interface would permit this to be automated.

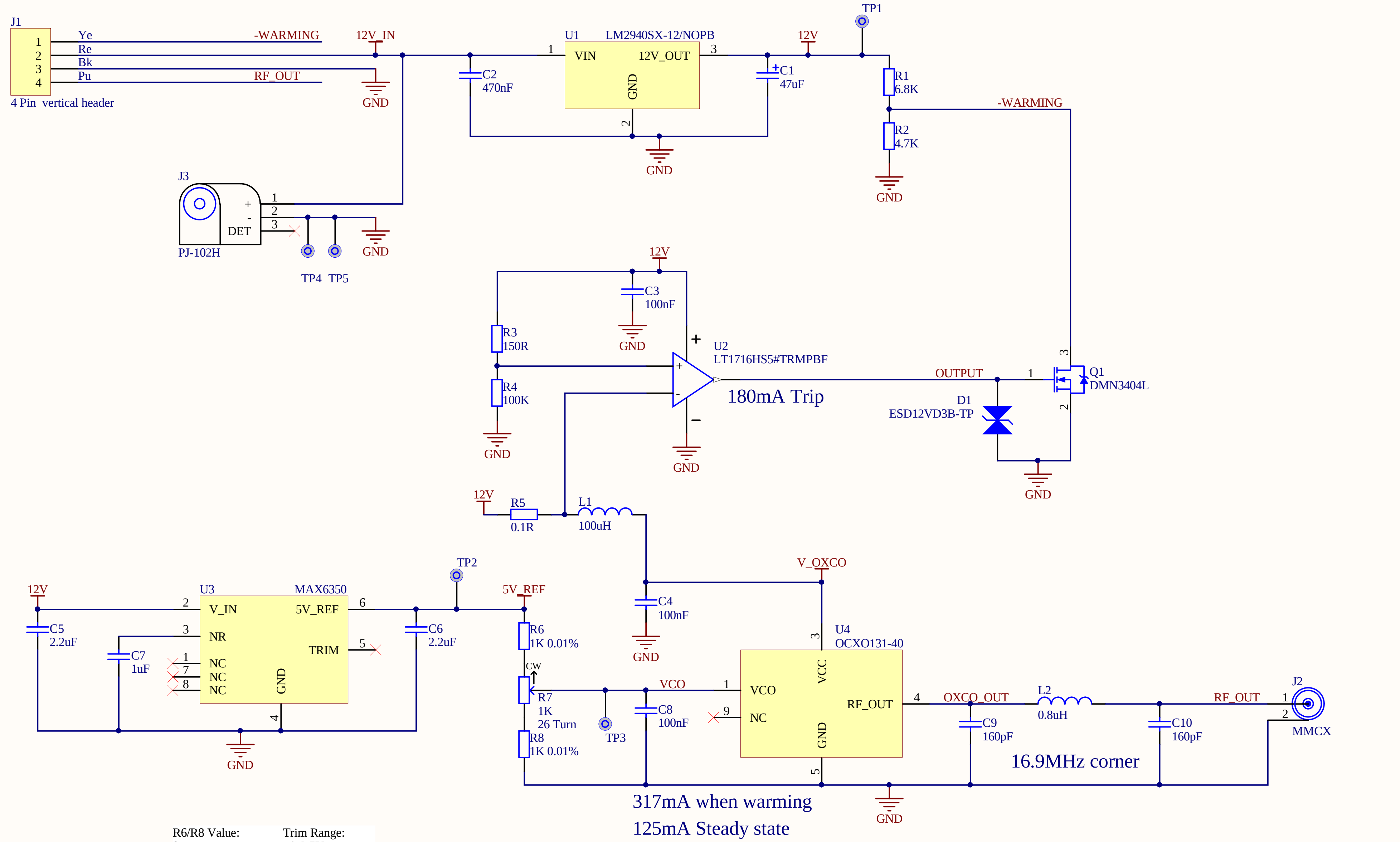
[12] Interestingly, MTI now offers the 220-series OCXO in standard, hi-rel and space versions.

Attachments

Schematics and PCB layers of the PCB (Pumpkin P/N 705-01667A) are attached, along with datasheets associated with the various critical components utilized in or associated with the PCB and its design.

Third-party datasheets are attached for reference only and do not imply any endorsements, etc.

Comment	Description	Designator	Quantity	Supplier 1	Supplier Part Number 1
47uF	7343 47uF Tantalum Cap	C1	1	Digi-Key	399-3905-1-ND
470nF	0805 470nF Chip Cap	C2	1	Digi-Key	399-11174-1-ND
100nF	0805 100nF Chip Cap	C3, C4, C8	3	Digi-Key	478-3352-1-ND
2.2uF	0805 2.2uF Chip Cap	C5, C6	2	Digi-Key	445-8787-1-ND
1uF	0805 1uF Chip Cap	C7	1	Digi-Key	445-5687-1-ND
220pF	0603 220pF Chip Cap	C9, C10	2	Digi-Key	490-12545-1-ND
ESD12VD3B-TP	12V TVS Diode	D1	1	Digi-Key	ESD12VD3B-TPMSCT-ND
4 Pin vertical header	4 Pin vertical header TH	J1	1	Digi-Key	S7037-ND
MMCX	MMCX Through-hole vertical	J2	1	Digi-Key	WM9481-ND
PJ-102H	PJ-102H DC Barrel Connector	J3	1	Digi-Key	CP-102AH-ND
100uH	Inductor 100uH	L1	1	Digi-Key	732-1248-1-ND
0.8uH	Inductor 0.8uH	L2	1	Digi-Key	308-2272-1-ND
DMN3404L	N Channel MOSFET	Q1	1	Digi-Key	DMN3404LDICT-ND
6.8K	0805 6K8 Chip Resistor	R1	1	Digi-Key	311-6.80KCRCT-ND
4.7K	0805 4K7 Chip Resistor	R2	1	Digi-Key	P16049CT-ND
150R	0805 150R Chip Resistor	R3	1	Digi-Key	P150CCT-ND
100K	0805 100K Chip Resistor	R4	1	Digi-Key	P16060CT-ND
0.1R	0805 0.1R Chip Resistor	R5	1	Digi-Key	1276-6170-1-ND
15K 0.01%	1206 15K Chip Resistor	R6, R8	2	Digi-Key	Y1630-15.0KBCT-ND
1K	Precision Multi Turn RA Potentiometer	R7	1	Digi-Key	Y0056-1.0KB-ND
Testpoint	Testpoint	TP1, TP2, TP3	3		
GND Testpoint	GND Testpoint	TP4, TP5	2		
LM2940SX-12/NOPB	12V Regulator	U1	1	Digi-Key	LM2940SX-12/NOPBCT-ND
LT1716HS5#TRMPBF	Comparator	U2	1	Digi-Key	LT1716HS5#TRMPBFCT-ND
MAX6350	5V Reference	U3	1	Digi-Key	MAX6350CSA+-ND
OCXO131-40	OCXO	U4	1	IsoTemp	OCXO131-40



R6/R8 Value:	Trim Range:
0	+/- 2.5V
1K	+/- 0.84V
2K	+/- 0.8V
5K	+/-0.23V
10K	+/-0.12V
15K	+/- 0.08V

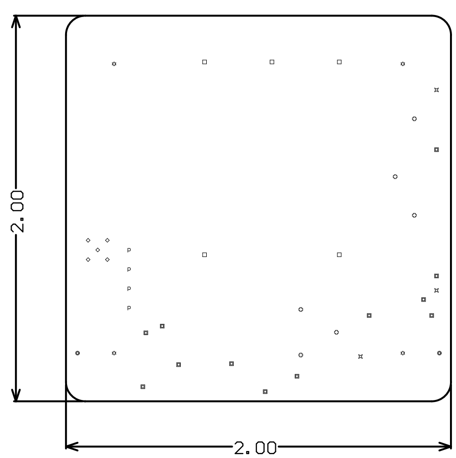
For use in XL Microwave 3030/3080/3120/3200/3260 Frequency Counters.

750 Naples Street
San Francisco, California 94112

Doc. Rev: 01

Title	OCXO 3xxx Module		
Size: Letter	Number: 705-01667		Revision: A
Date: 5/13/2017		Sheet of: 1 of 1	
File: C:\Users\..\OCXO.SchDoc		Drawn By: DJW	

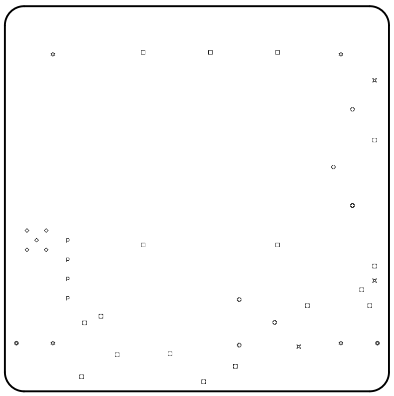
01667A Mechanical Drawing
Drill Drawing



1. ALL DIMENSIONS IN INCHES
2. SCALE IS 1:1
4. SMOBC BOTH SIDES. COLOR: GREEN
5. SOLDERMASK IS LPI, SEMI-GLOSS FINISH
6. SILKSCREEN LEGEND WHITE
7. SILKSCREEN TOP AND BOTTOM
8. FINAL BOARD THICKNESS = 0.062
9. FINAL COPPER THICKNESS = 1oz
10. 2 CIRCUIT LAYERS
11. MINIMUM SPACING 0.007
12. MINIMUM SMD PITCH IS 0.020
13. SURFACEMOUNT COMPONENTS TOP AND BOTTOM
14. DO NOT ADD TOOLING HOLES
16. NUMBER OF SMD PADS: 62
17. NUMBER OF HOLES: 41
18. SMALLEST HOLE IS 0.3mm

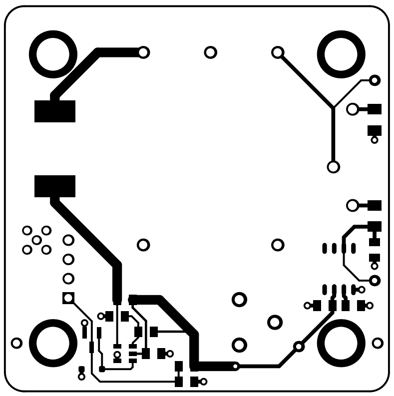
Symbol	Count	Hole Size	Plated	Hole Type
⊡	12	19.69mil (0.500mm)	PTH	Round
¤	3	27.56mil (0.700mm)	PTH	Round
◇	5	33.07mil (0.840mm)	PTH	Round
◎	2	37.00mil (0.940mm)	PTH	Round
P	4	40.16mil (1.020mm)	PTH	Round
□	5	43.31mil (1.100mm)	PTH	Round
✥	6	47.24mil (1.200mm)	PTH	Round
✡	4	170.00mil (4.318mm)	PTH	Round
	41 Total			

01667A
Drill Drawing

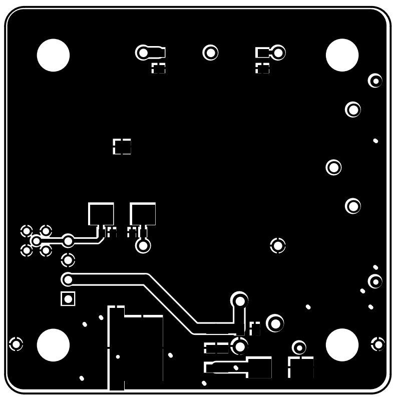


Symbol	Count	Hole Size	Plated	Hole Type
⧈	12	19.69mil (0.500mm)	PTH	Round
⌑	3	27.56mil (0.700mm)	PTH	Round
◇	5	33.07mil (0.840mm)	PTH	Round
◎	2	37.00mil (0.940mm)	PTH	Round
P	4	40.16mil (1.020mm)	PTH	Round
□	5	43.31mil (1.100mm)	PTH	Round
✥	6	47.24mil (1.200mm)	PTH	Round
✡	4	170.00mil (4.318mm)	PTH	Round
	41 Total			

01667A Layer 1 (TOP)

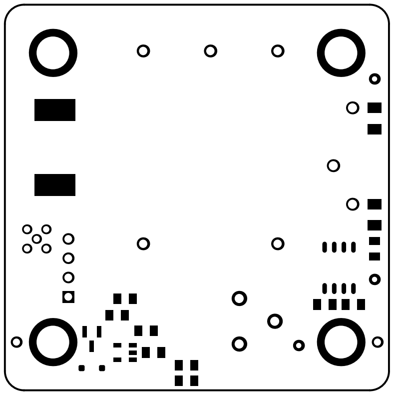


01667A Layer 4 (BOTTOM)



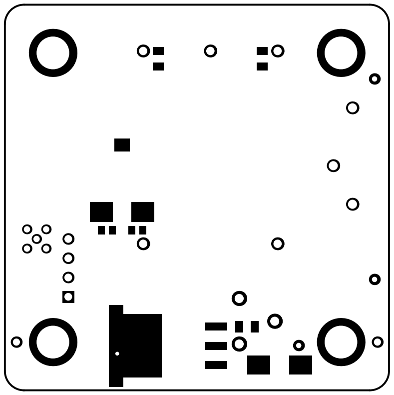
01667A

Top Soldermask

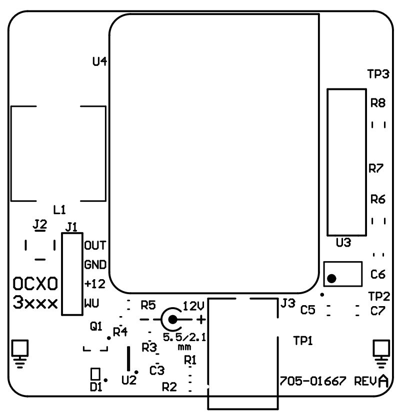


01667A

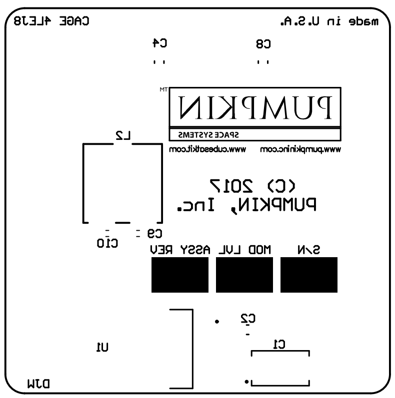
Bottom Soldermask



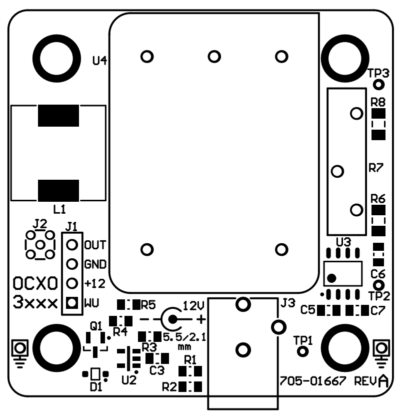
01667A Top Silkscreen



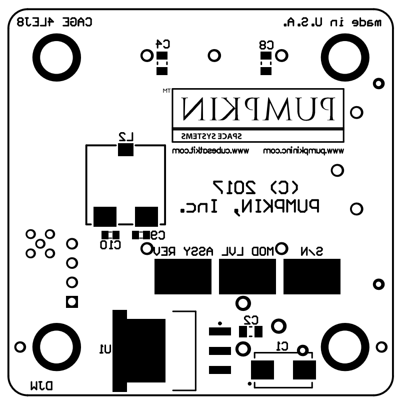
01667A Bottom Silkscreen



01667A Top Silkscreen
Top Soldermask



01667A Bottom Silkscreen
Bottom Soldermask



OCXO Layout Guidelines

CONNOR WINFIELD

Application Note: AN2093

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Section 1: About this document.

1.1 Introduction

The techniques included in this application note will help to ensure successful printed circuit board layout using an oven-controlled crystal oscillator (OCXO). Problems with layout can result in noisy and distorted frequency transmissions, error-prone digital communications, latch-up problems, significantly reduced frequency stability, thermal instability within the OCXO, and other undesirable system behavior.

1.2 This document includes the following

- Power and ground circuit design tips.
- Theory of operation / Characterization
- Techniques to achieve optimal thermal conditions using multilayer boards
- A design checklist

1.3 About this document

The methods presented in this application note should be taken as suggestions which provide a good starting point in the design and layout of a PCB. It should be noted that one design rule does not necessarily fit all designs. It is highly recommended that prototype PCBs be manufactured to test designs.

For further information please contact Connor-Winfield Engineering Department.

RoHS COMPLIANT

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Section 2: Power & Ground Considerations.

2.1 Power Supply and Grounds.

All system designs have a power supply and ground circuit that is shared by all of the components on the board. The operation of one component can affect the operation of other components that share the same power supply and ground circuit.

2.2 Power Supply.

The goal of a system's power supply is to maintain a stable voltage within a specified range while supplying sufficient current. While an ideal power supply would maintain the same voltage for any possible current draw, real world systems exhibit the following behaviors:

- A change in current and its associated noise caused by one device affects other devices attached to the same power supply net.
- A change in current draw affects the voltage of the power net.

2.3 Typical Power Supply System.

A typical power supply circuit consists of the following:

- Voltage regulators that maintain voltage stability within a required range while supplying sufficient current to all components served.
- Bulk, decoupling and bypass capacitors.
- Power and supply circuit runners or power supply planes for power distribution to components.
- Local decoupling and bypass capacitors at each supply sensitive component.

2.4 Power Supply Management.

Improper voltage regulation can result in instability of many system components or complete system failure.

Periods of insufficient power are often referred to as "Brown-Outs", where power supply voltage drops to an insufficient level, or "Black-Outs" where power supply voltages totally disappear for a period of time.

For the OCXO to power up and configure properly on initial power-up, Vcc must exceed the maximum power-on reset (VPOR) voltage in order for the device to proceed with configuration and initialization. The VCC voltage is internally monitored on power-up to properly trigger the device configuration circuitry.

On subsequent brown-out conditions where the device is not power-cycled (i.e., the supply voltages are not take down to 0v), the Vcc voltage must be taken down below the minimum VPOR voltage in order to clear out the device configuration content. Subsequently, the voltages must exceed the VPOR voltage once again in order for the device to be programmed with the new configuration.

A brown-out condition is defined by the Vcc rail dropping below its respective data retention voltage defined by the VRAM in the data sheet.

Please refer to the OCXO data sheet for the minimum and maximum VPOR voltages and Data Retention Voltages.

Prevent system malfunction during periods of insufficient power supply voltage by using external lower voltage detector logic and supply management circuitry.

2.5 POR/BOR Operation.

The power-on reset occurs when the device is started from a Vss level. The brown-out condition occurs when a previously powered device drops below a specified range.

The devices RAM retention voltage (VRAM) is lower than the VPOR/VBOR voltage trip point. When VPRO/VBOR < Vcc < 2.7V, the electrical performance of the OCXO will NOT meet the data sheet specifications.

2.6 Power-on Reset.

When the device powers up, the device Vcc will cross the VPOR/VBOR voltage. Once the Vcc voltage crosses the VPOR/VBOR voltage the following will occur:

- Volatile registers are loaded with values form the corresponding non-volatile registers.
- The TCONF register will load the factory programming.
- The device is capable of Digital / Analog operation.

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2.7 Brown-Out Reset.

When the device powers down, the device Vcc will cross the VPOR / VBOR voltage. Once the Vcc voltage decreases below the VPOR / VBOR voltage the following occurs:

- Factory serial programming interface is disabled.
- Non-Volatile register are no longer programmable.

If the VCC voltage decreases below the VRAM voltage the following occurs:

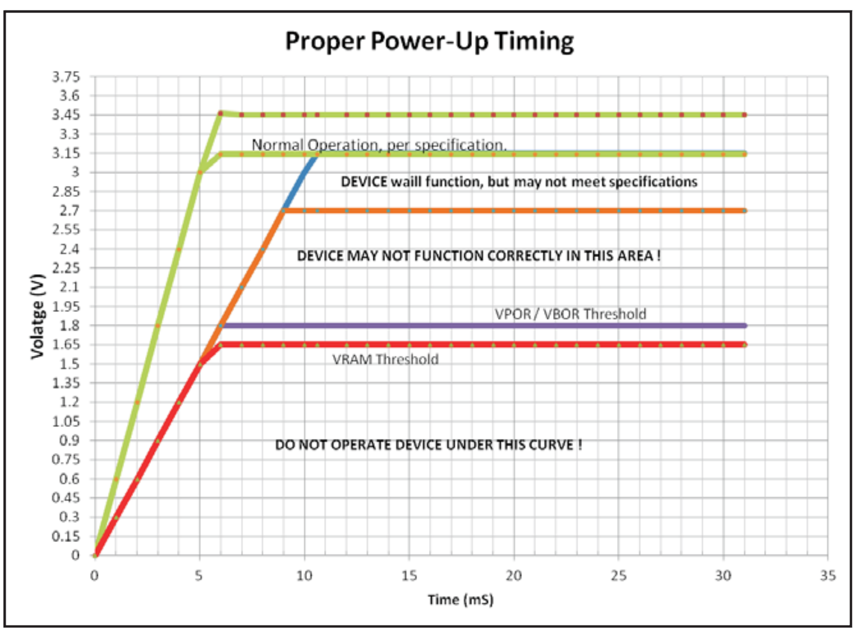
- Volatile registers may become corrupted.
- TCONF register may become corrupted.
- OCXO oven core may lose thermal equilibrium.
- OCXO frequency stability may not meet the data sheet specifications.

As the voltage recovers above the VPOR / VBOR voltage see section "Power-on Reset"
On subsequent brown-out conditions where the device is not power-cycled properly (i.e., the supply voltages are not taken down to 0V), the power supply voltage must be dropped below 1.6 volts in order to clear out the EEPROM device configuration content.

2 8 Voltage Regulators.

A voltage regulator takes an input voltage from an external source and steps it down to a suitable voltage level that can power components on the circuit board. Two common types of voltage regulators are dc-dc converters and low-dropout regulators (LDO). When deciding on a voltage regulator, always review the regulator data sheets to match component specifications with system requirements.

As digital logic gates of ICs switch from one state to another, the IC's current draw fluctuates at a frequency determined by the logic state transition rate or "rise-time". These current oscillations cause the power supply voltage to fluctuate as a small voltage develops across the net due to its intrinsic impedance. The circuit's impedance can be lowered by carefully selecting a capacitor that provides a low-impedance path to ground for high frequencies. As a capacitor charges or discharges current flows through it which itself is restricted by the internal resistance of the capacitor. This internal resistance is known as Capacitive Reactance and is given the symbol XC in ohms. Unlike resistance which has a fixed value, ie 100Ω, 1kΩ, etc. Capacitive Reactance varies with frequency so any variation in frequency will have an effect on the capacitor. The loop from the voltage supply pin to decoupling capacitor to ground should be kept as small as possible by placing the capacitor near the power supply pin and ground pin of the device.



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2.9 Low-Dropout Regulators.

Low-Dropout Regulators (LDOs) are less efficient than dc-dc converters, but they also introduce significantly less noise into the power circuits.

2.10 Power Supply Bulk Decoupling and Bypassing.

Noise can be introduced into the power circuit from the voltage regulator, from ICs connected to the net, and from electromagnetic noise that couples into the power supply trace and planes. Power supply "bulk" decoupling capacitors help to minimize the effects of noise and provide other benefits to the circuit as well. Large value bulk capacitors improve performance during low frequency fluctuations in supply current draw by providing a temporary source of charge. Many voltage regulators maintain their voltage by using a negative feedback loop topology that can become unstable at certain frequencies. A capacitor placed at the regulator's output can prevent the voltage supply from becoming unstable. Check the regulator's manufacturer data sheet for recommended capacitor specifications. Bulk decoupling capacitors should be placed as close as possible to the output pin of the voltage regulator.

2.11 Ground Circuits.

The ground circuit can introduce noise to an embedded system and affect components. An ideal ground circuit is "equipotential", meaning that the voltage of the circuit does not change regardless of the current. Real-world ground circuits have a characteristic impedance and experience changes in voltage with changes in current. Careful PCB design can minimize this non-ideal behavior to create a ground circuit that provides a low impedance return path for current.

2.12 Designing with a Ground Plane.

While some systems connect components to a ground circuit through wires or traces most designs use a ground plane in which the PCB's components connect their ground pins to a common conductive plane. Designing with a ground plane is highly recommended for two reasons:

- The return current noise of one device has less effect on other components when sharing ground in a parallel configuration.
- Short connections to ground minimize current return path inductance, which can induce large voltage swings in ground.

2.13 Ground Plane Fill.

A ground plane should cover as much of the board as possible, even in spaces between devices and traces.

"Islands" of copper formed between traces or devices should always be connected to ground and should never be left floating. Spreading the ground plane across the board also aids in noise dissipation and shields traces.

Caution! Care must be taken to thermally isolate the OCXO from the underlying power and ground planes to ensure the OCXO can reach thermal equilibrium. Separating the analog current return path from the noisier digital current return path can improve analog measurements. Ground isolation can also improve performance in boards connected to industrial or noisy systems. Separate ground planes should be connected in only one location, usually near the power supply.

"Caution! Care must be taken to thermally isolate the OCXO from the underlying power and ground planes to ensure the OCXO can reach thermal equilibrium."

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Section 3: Theory of Operation / Characterization.

3.1 OCXO Theory of operation.

The OCXO encloses a crystal in a temperature-controlled chamber called an oven. Frequency stability is achieved by maintaining tight temperature control of the crystal within the oscillator oven. Care must be taken not wick thermal energy away from the OCXO preventing the core from reaching thermal equilibrium.

When an OCXO is turned on, it goes through a ''warm-up'' period while the temperature of the crystal in the internal oven stabilizes at a temperature significantly warmer than ambient.

During "warm-up", the performance of the oscillator will not meet the specified frequency stability until normal operating temperature is reached. After the oven has "bridged" the temperature within the oven remains constant as ambient varies.

The oven controller operates such that if the internal temperature of the oven decreases due to an ambient temperature drop, the oven controller will provide more power to compensate for thermal losses. Similarly, an increase in ambient temperature causes a reduction in applied power into the oven and the compensation temperature decreases.

In most modern designs additional heat is considered a problem and will cause most devices to degrade in performance or eventually fail. The heat generated within the OCXO oven core is used to maintain a constant temperature at the crystal.

"During "warm-up", the performance of the oscillator is degraded until normal operating temperature is reached."

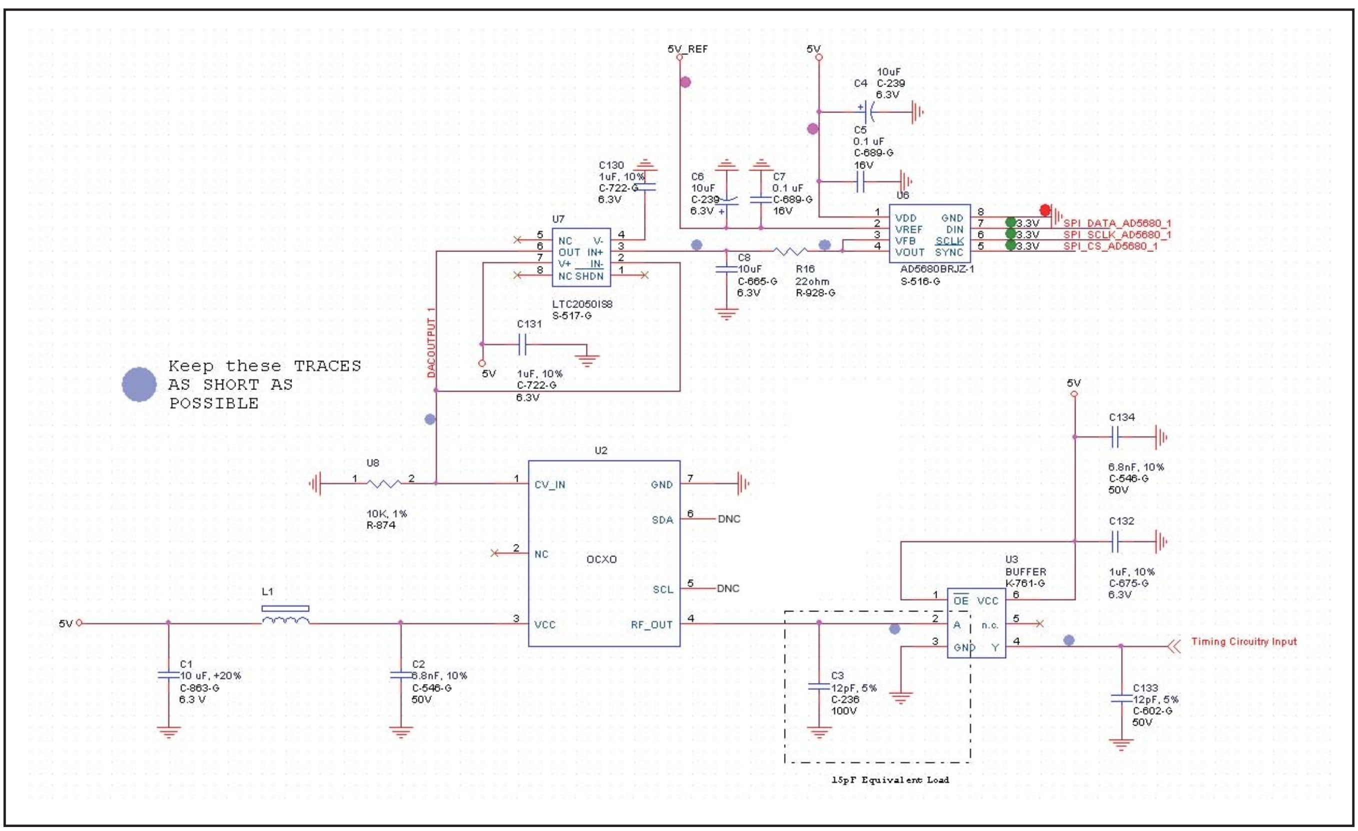

Figure: 5-01

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Typical Thermal Performance Characteristics.

Test Conditions: OCXO mounted in socket, VCC=3.3V, Temperature = @25°C unless otherwise noted.
The following graphs represent the typical characteristics of a DOC052F-010.0MHz OCXO.
Consult with Connor-Winfield Engineering Department for characterization data on any of our existing models.

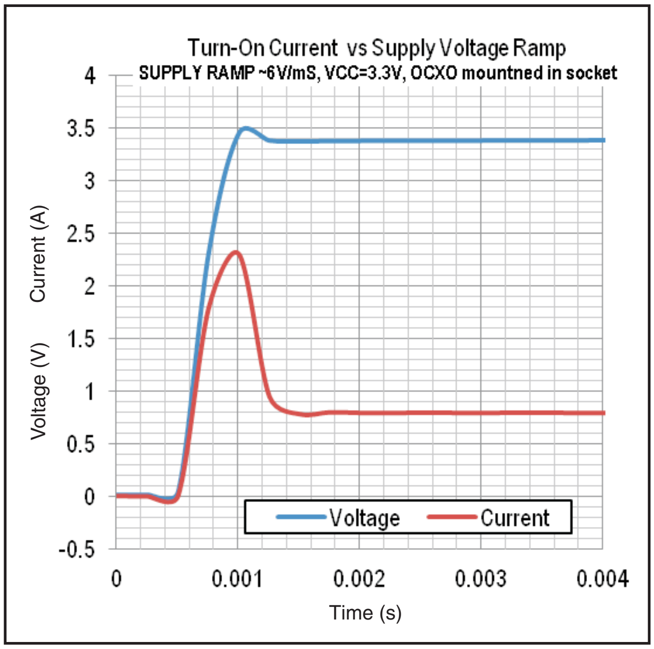

Figure: 6-01

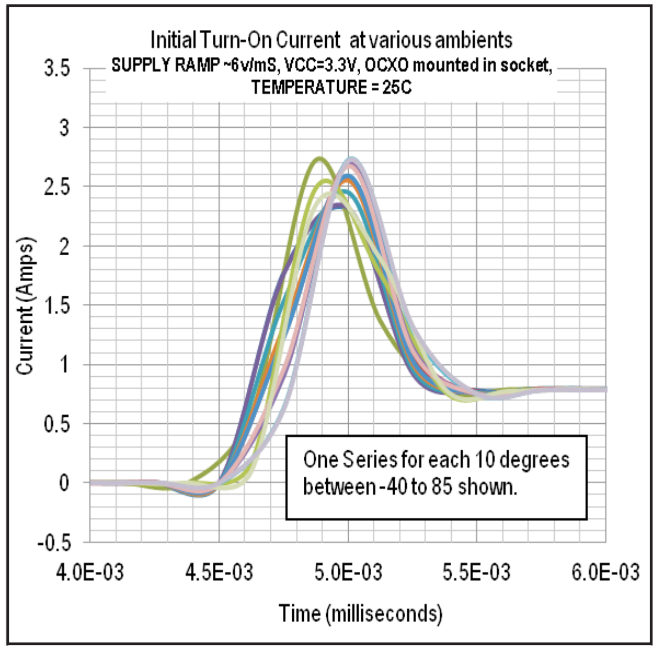

Figure: 6-02

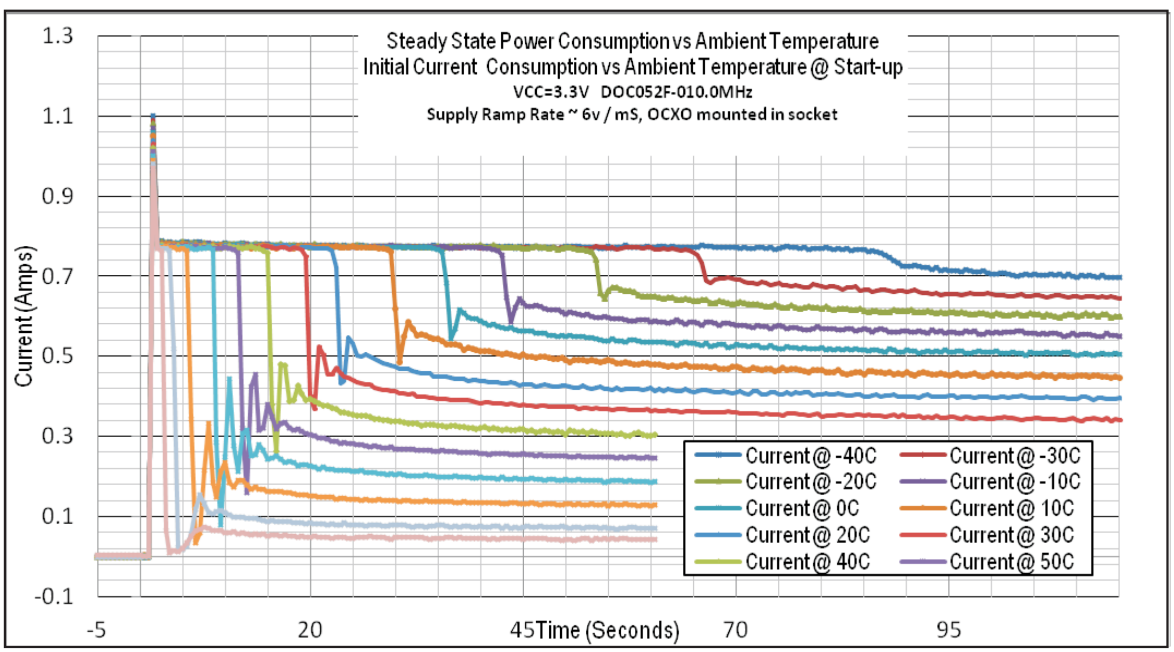

Figure: 6-03

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Typical Thermal Performance Characteristics.

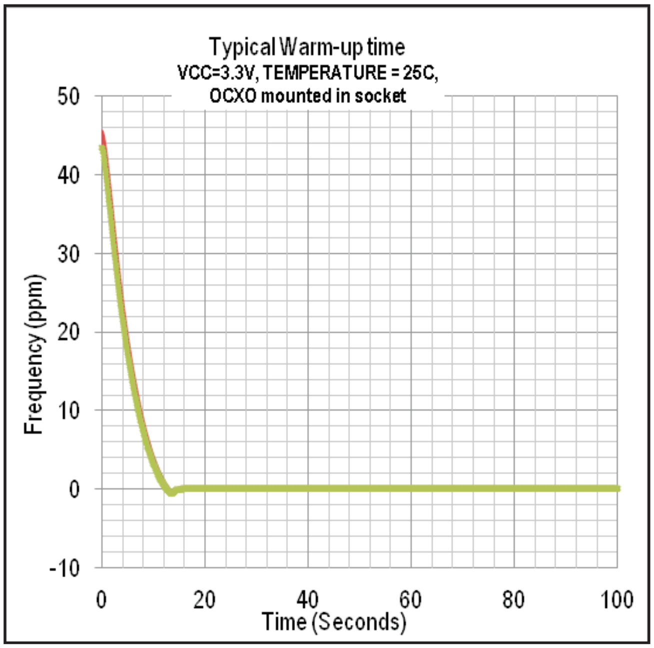

Figure: 7-01 Typical Warm-up Time (seconds)

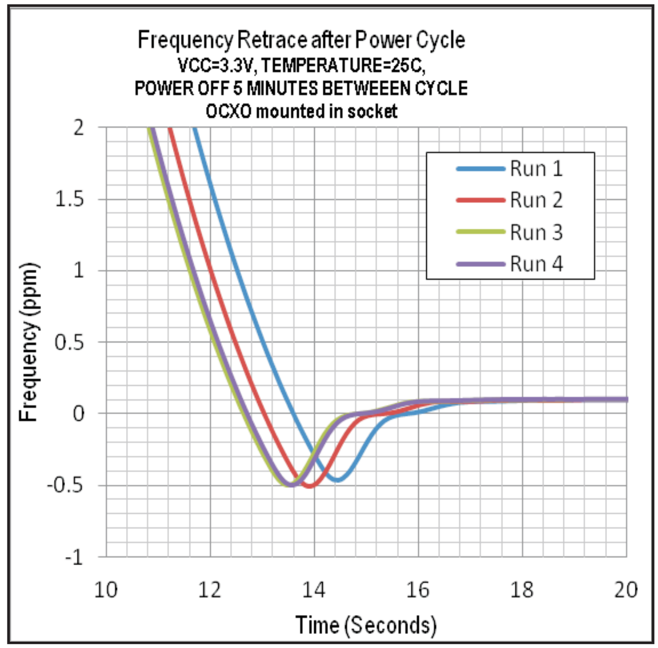

Figure: 7-02 Retrace after power cycle.

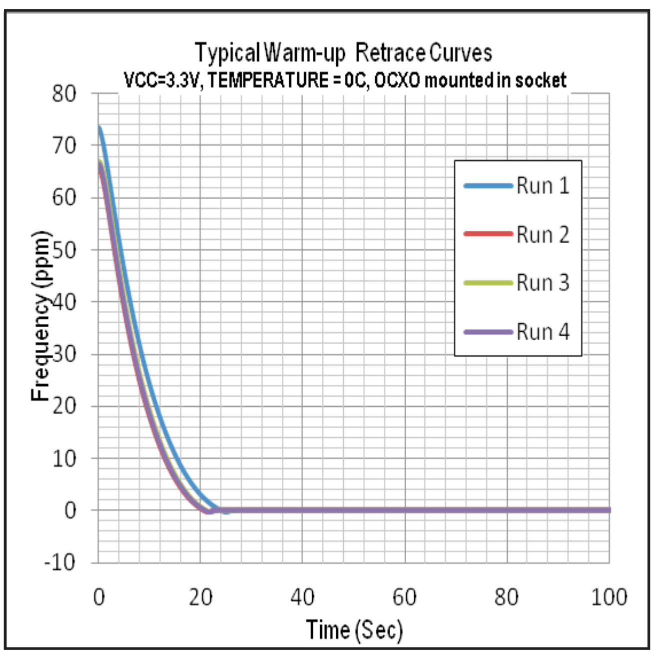

Figure: 7-03 Typical Warm-up Time (seconds)

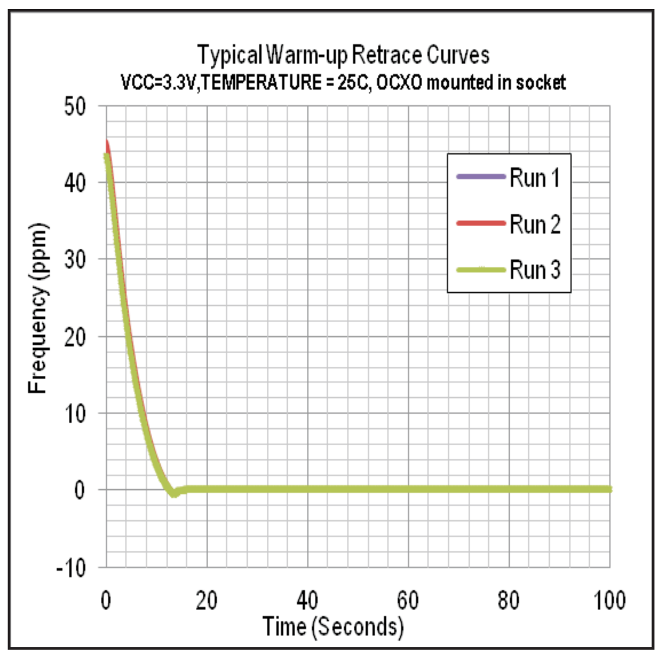

Figure: 7-04 Typical Warm-up Retrace Curves

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Typical Thermal Performance Characteristics.

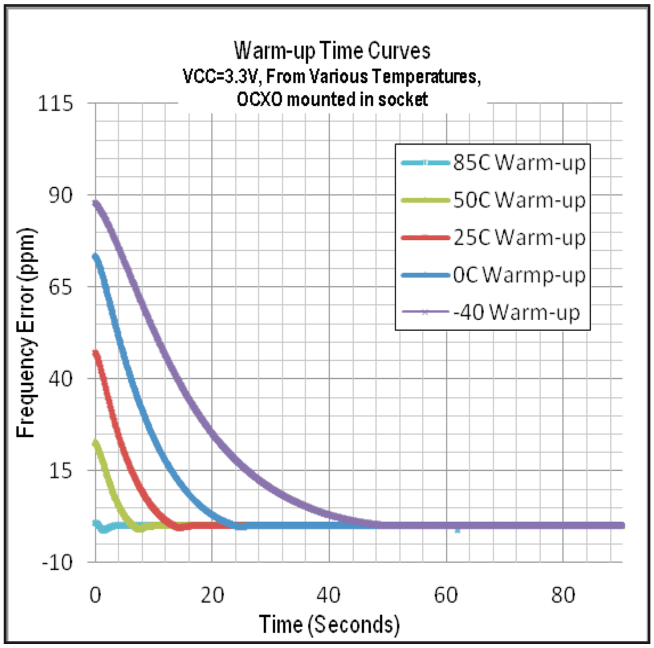

Figure: 8-01 Typical Warm-up Retrace Curves

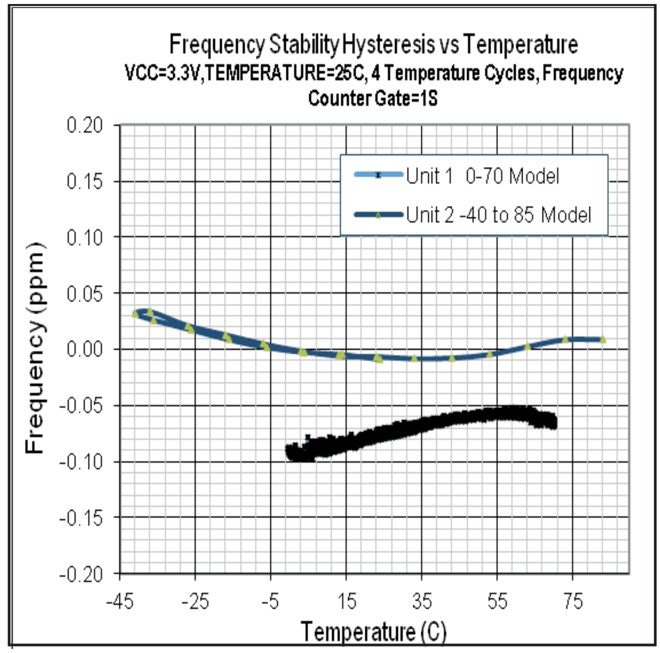

Figure: 8-02 Typical Oscillator Output Start Time

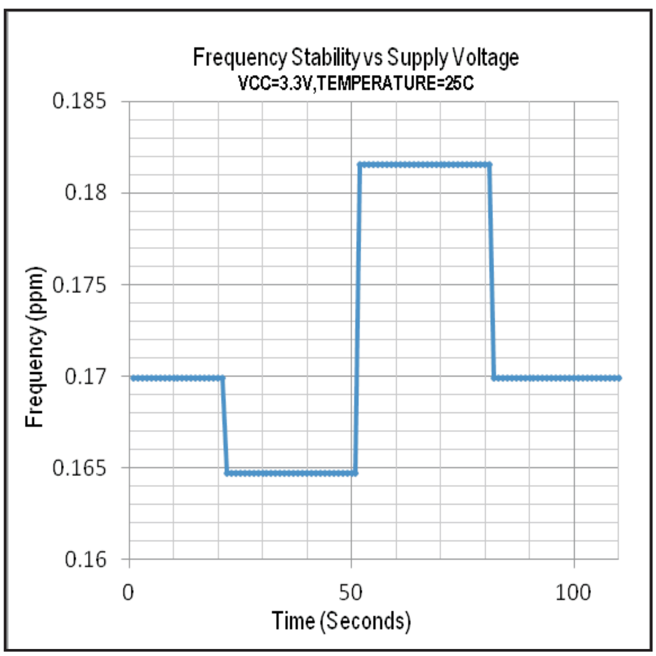

Figure: 8-03 Frequency Error vs Supply Voltage drift (nom, +5,-5,nom)

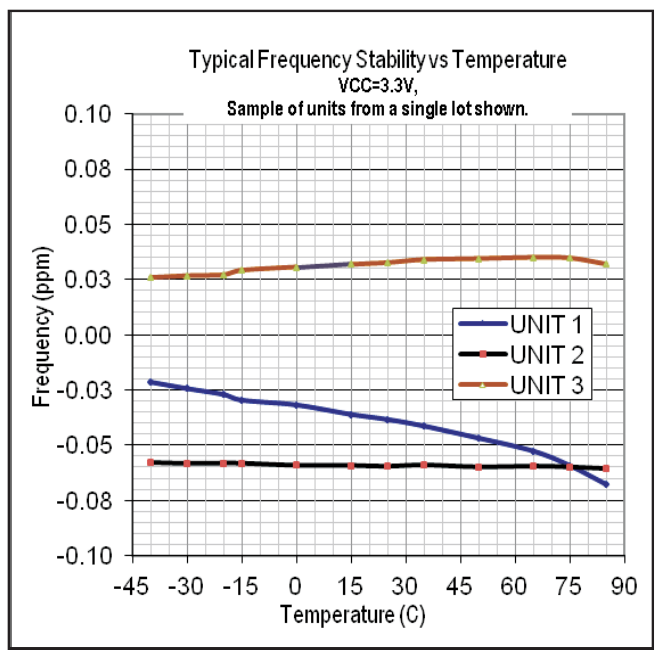

Figure: 8-04 Typical Frequency Stability vs Temperature

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Typical Thermal Performance Characteristics.

Test Conditions: OCXO mounted on 0.062" 6 layer board, VCC=3.3V, Temperature = @25°C unless otherwise noted.
The following graphs represent the typical characteristics of a DOC052F-010.0MHz OCXO.
Consult with Connor-Winfield Engineering Department for characterization data on any of our existing models.

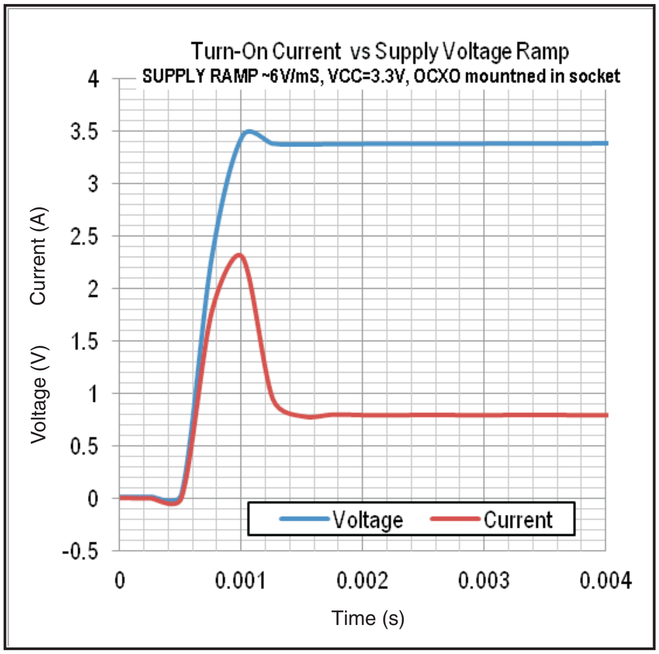

Figure: 9-01

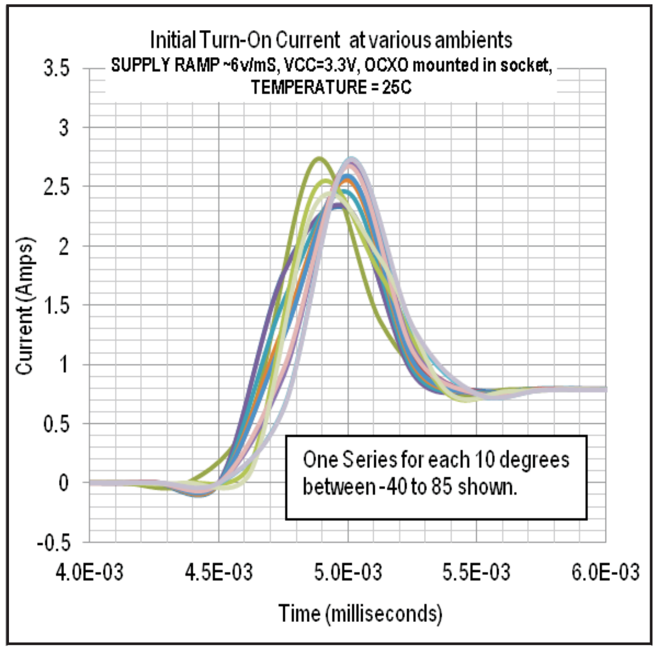

Figure: 9-02

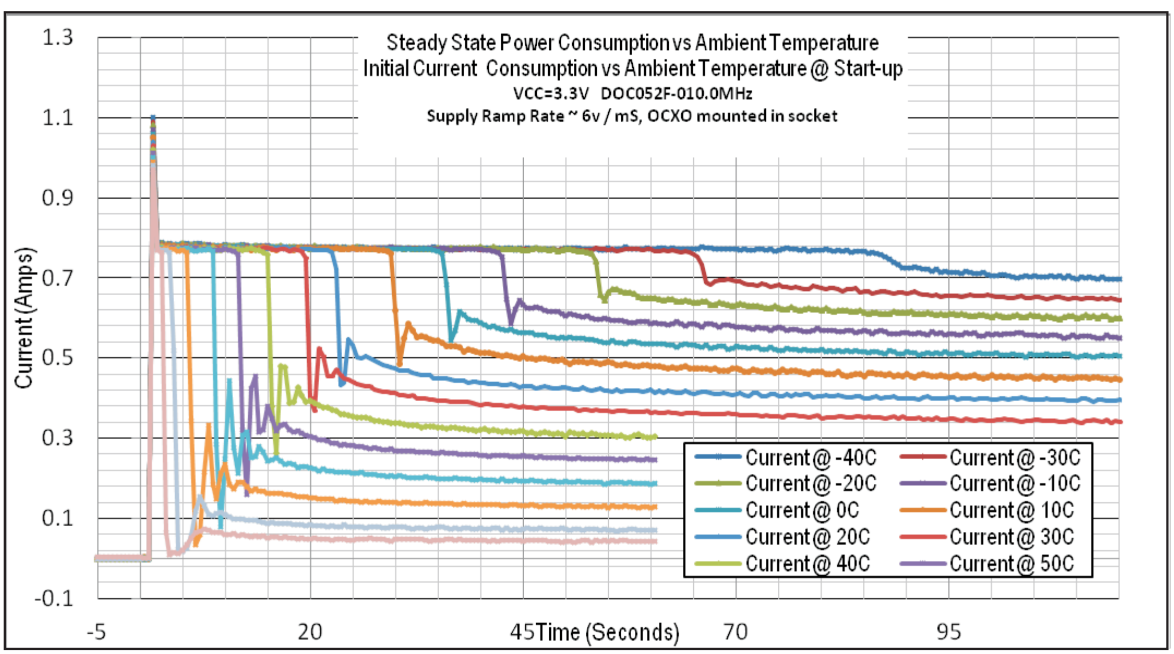

Figure: 9-03

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Typical Thermal Performance Characteristics.

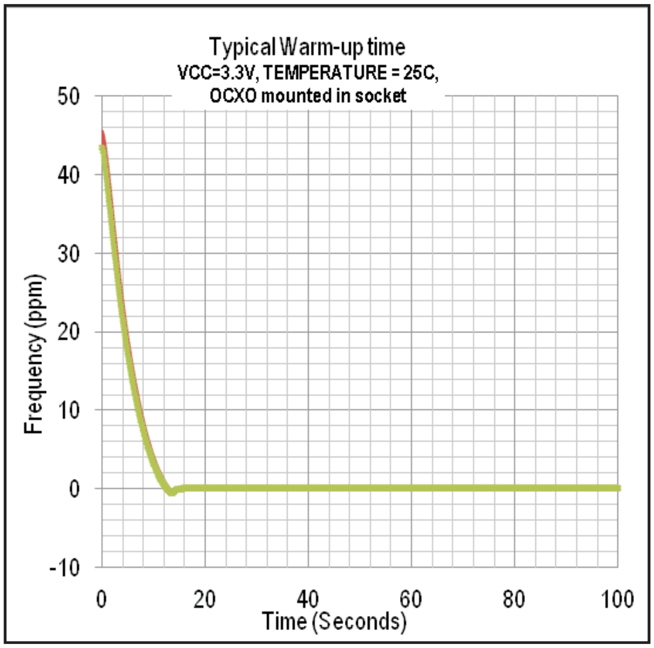

Figure: 10-01 Typical Warm-up Time (seconds)

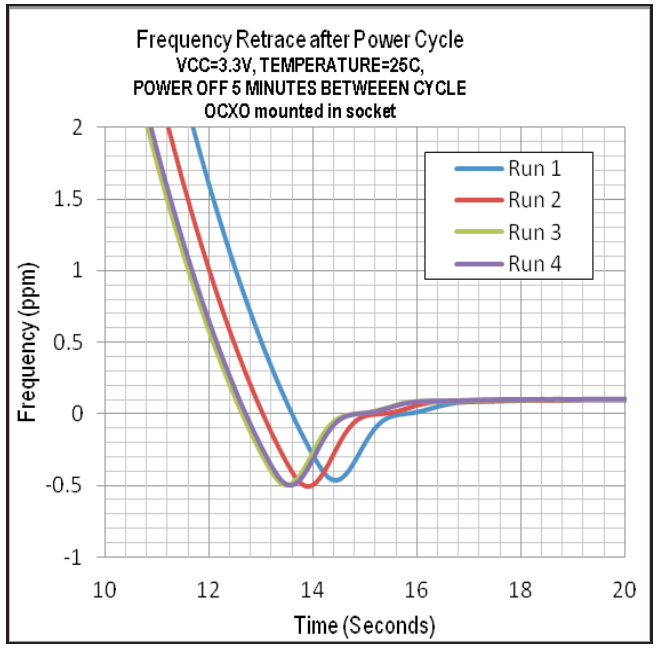

Figure: 10-02 Retrace after power cycle.

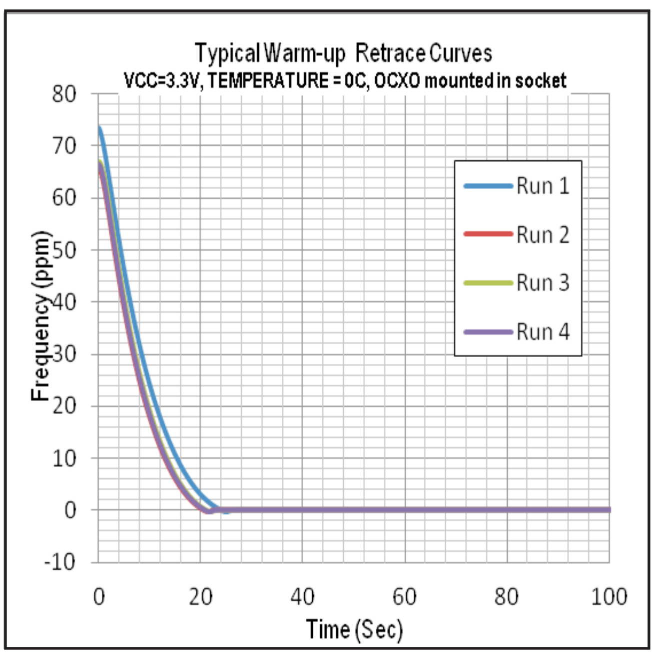

Figure: 10-03 Typical Warm-up Time (seconds)

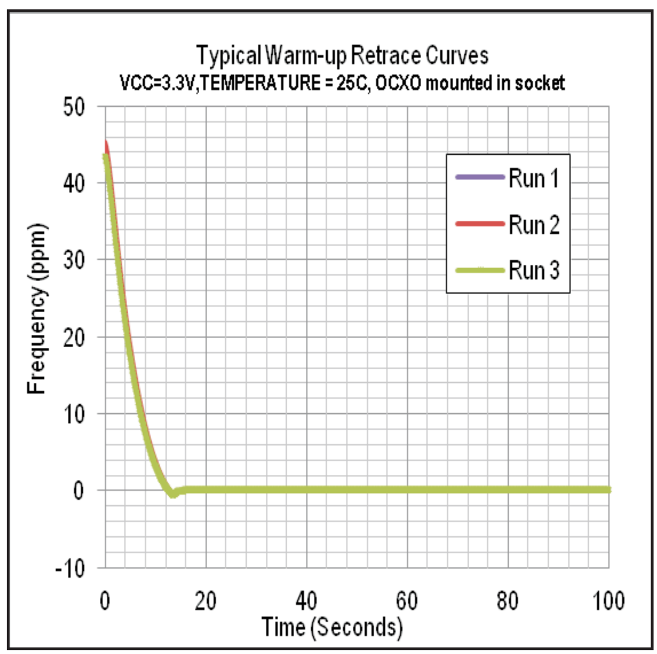

Figure: 10-04 Typical Warm-up Retrace Curves

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Typical Thermal Performance Characteristics.

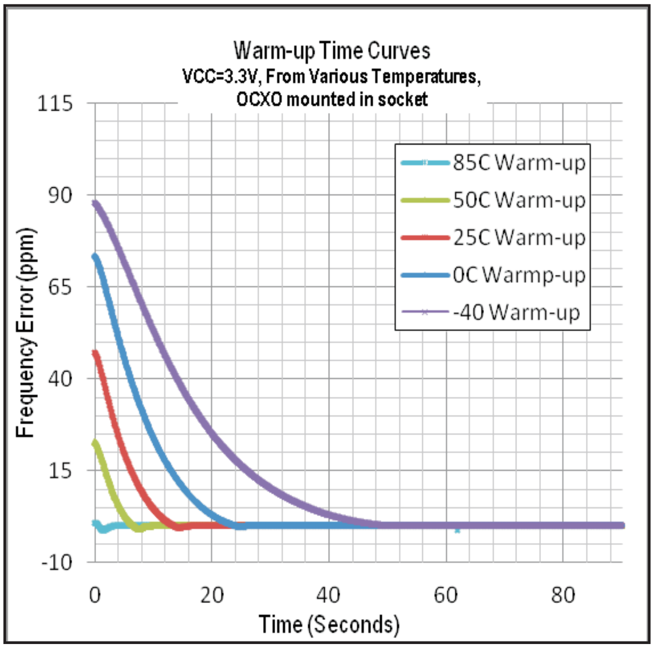

Figure: 11-01 Typical Warm-up Retrace Curves

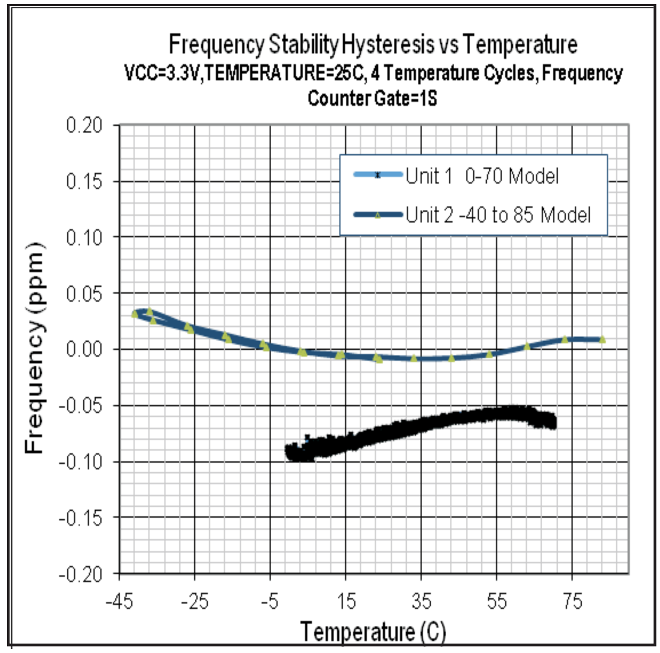

Figure: 11-02 Typical Oscillator Output Start Time

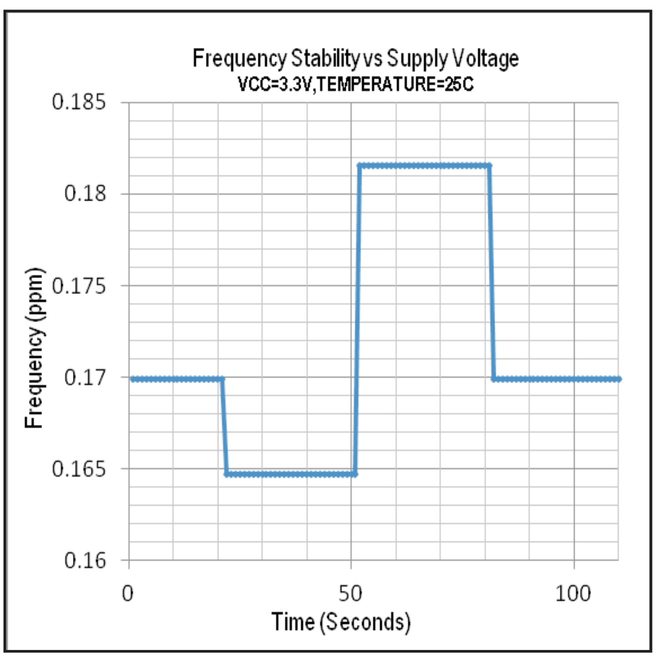

Figure: 11-03 Frequency Error vs Supply Voltage drift (nom, +5,-5,nom)

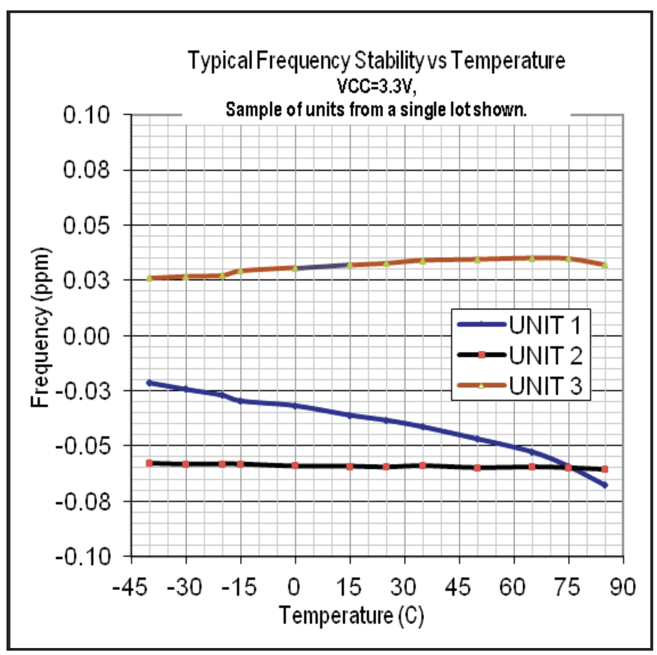

Figure: 11-04 Typical Frequency Stability vs Temperature

Application Note	**AN2093**
Page	**11**
Revision	**P01**
Date	**10 May 2013**

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Typical Electrical Characteristics

Test Conditions: OCXO mounted on 0.062" 6 layer board, VCC=3.3V, Temperature = @25°C unless otherwise noted.
The following graphs represent the typical characteristics of a DOC052F-010.0MHz OCXO.
Consult with Connor-Winfield Engineering Department for characterization data on any of our existing models.

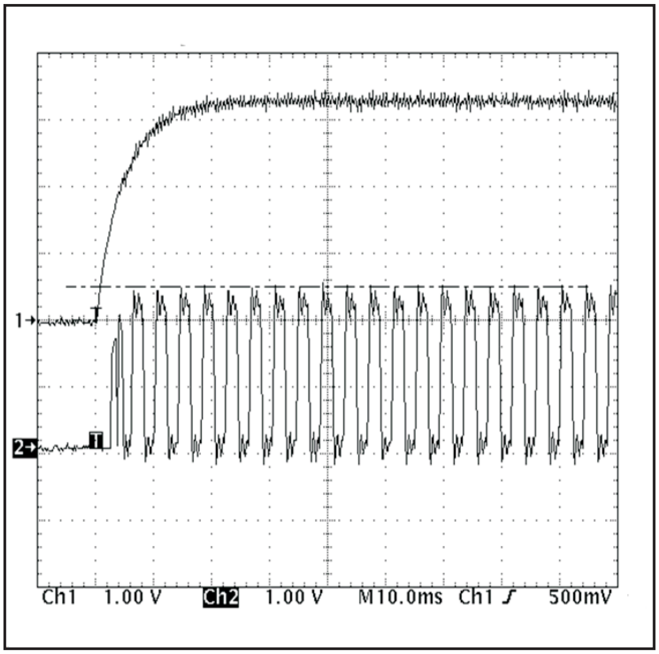

Figure: 12-01 Typical Oscillator Output Start Time

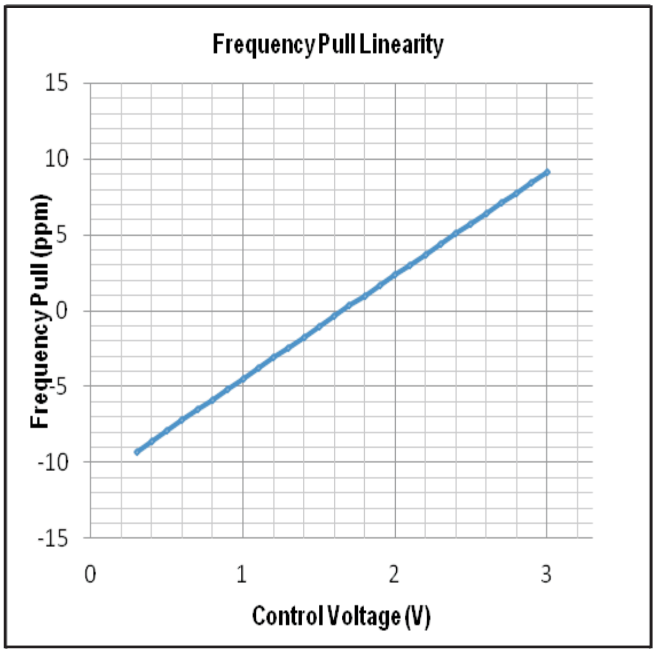

Figure: 12-02 Control Voltage Tuning Linearity

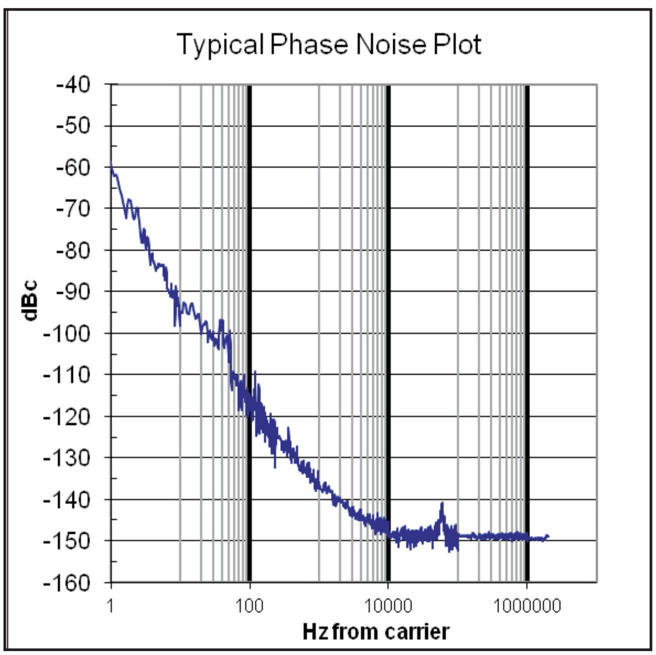

Figure: 12-03 Typical Phase Noise Plot

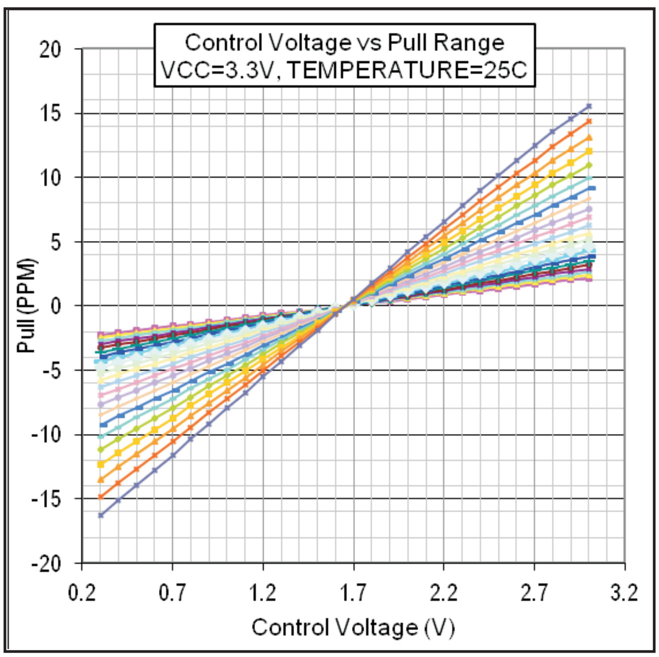

Figure: 12-04 Available Tuning Slopes

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Typical Electrical Characteristics

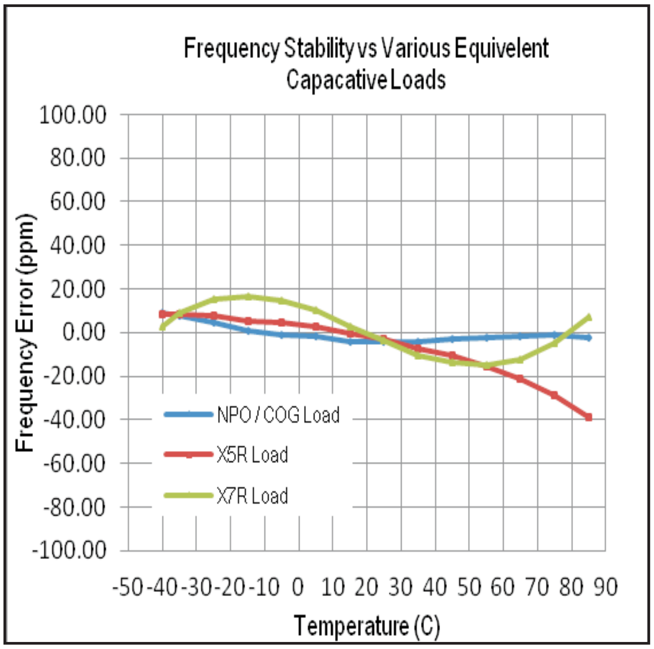

Figure: 13-01

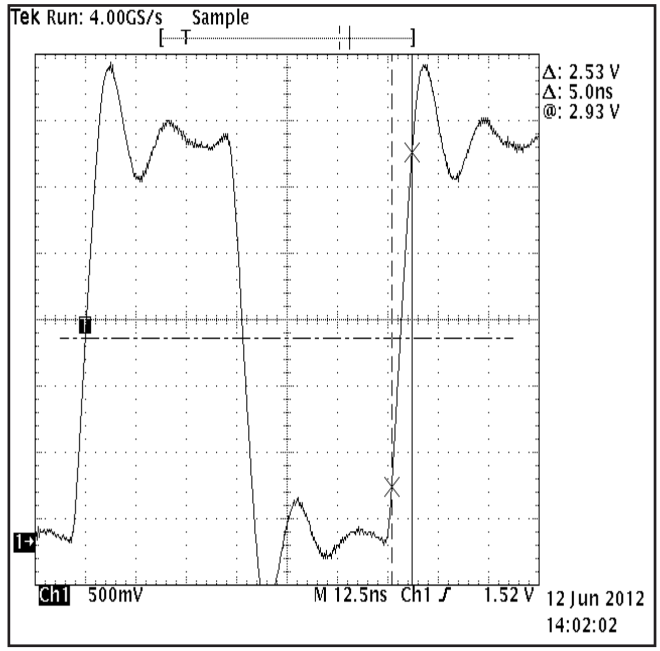

Figure: 13-02

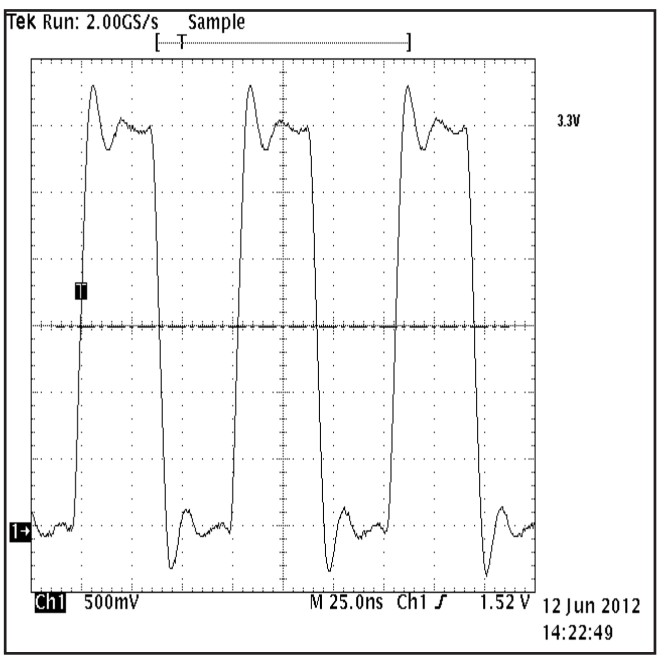

Figure: 13-03

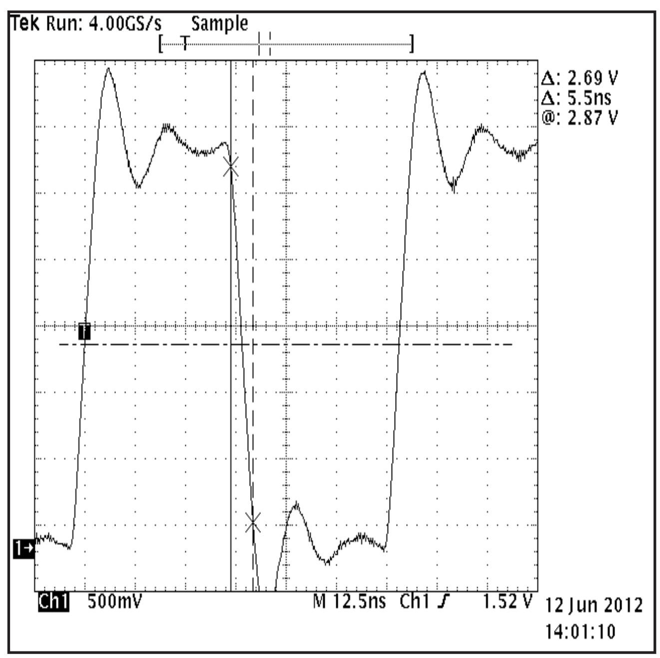

Figure: 13-04

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Section 4: Multi-Layer Board Design / Thermal Considerations

4.1 Layout Considerations

To achieve the stated frequency stability specifications the OCXO must be able to reach and sustain thermal equilibrium over ALL operating conditions. Observation of the ambient operating temperature range, controlled air flow, thermal ramp rates and minimizing thermal energy gains/losses are critical for a successful layout.

"Any attempt to cool, or disperse this heat will cause oven core temperature to drift and OCXO will not meet the specified frequency stability. Improper board layout could also allow heat transfer from nearby components to overheat the oven core resulting in loss of specified frequency stability."

Several thermal design parameters must be carefully considered.

- Board Layout Considerations
- Controlling Thermal Transfer/Transients
- Controlling Air Flow

4.2 Board Layout Considerations

Careful selection of layer stack-ups, ground fills, and trace routing is highly recommended for a successful layout.

"To achieve the stated frequency stability the OCXO must be able to reach and sustain thermal equilibrium over ALL operating conditions"

Consider the following layout concerns.

1. Always place the OCXO near the timing circuitry, and keep all Power / Ground and RF traces as small as possible.
2. Always adhere to stated loading specifications} for OCXO RF output. OCXOs are load sensitive and require an equivalent load capacitor with a flat capacitance vs. temperature curve to achieve stated frequency stability specifications. Consider NPO/COG capacitors when practical for optimal temperature characteristics. See FIGURE 13-01 Frequency Response to various equivalent capacitive loads.
3. Use secondary buffers to fan the OCXO RF signal to multiple inputs or timing circuits. Avoid designs that would "switch in" additional capacitive loads. Avoid designs that would "switch between" multiple capacitive loads. OCXOs are load sensitive devices. See FIGURE XXX
4. Always use speed rated level translators or buffers in applications requiring communication between digital devices operating from multiple supply voltages. Never use resistor divider networks on RF signals.
5. It is recommended to place a 10uF to 47uF bulk capacitor as close to as possible to the VCC pin of the device.
6. Place a small ceramic decoupling capacitor typically NPO/COG/X7R with a 2 to 3 ohm reactance at the output frequency of the OCXO to shunt any noise on the supply rail to ground. Additional decoupling capacitors can be used to filter out other unwanted supply noise generated from other devices.
7. Avoid using series current sense resistors in OCXO monitoring applications. Improper selection of resistor values could create significant voltage drops when combined with the thermal coefficients of the supply, and large current draw from the OCXO.
8. Careful evaluation of via size should be considered with all high power devices to guarantee sufficient current. Maximum current through a via calculations should be made using highest expected board temperature instead of maximum ambient temperature as heat generating components will typically heat the board well beyond the ambient temperature range of the OCXO. Improper via size selection could cause current starvation issues which would result in current oscillations as the oven core is starved of power and unable to reach thermal equilibrium. Via to pad stringers or runners should also be evaluated for sufficient current carrying capacity at maximum expected board temperatures. Via in pad work best, but adds additional board cost.

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Free via size calculations tools are available online. Saturn PCB Design Inc. offers this free tool available at the following URL.

http://saturnpcb.com/pcb_toolkit.htm

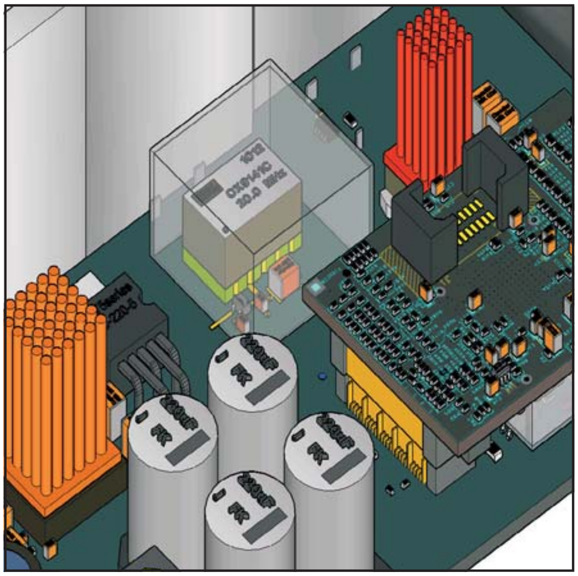

Figure: 15-01

9. Low impedance power and ground planes should be used instead of stringer traces or star based power distribution methods to reduce induced voltages caused by high current devices such as OCXOs.
10. For control voltage equipped models it is important to connect the ground of the control voltage source as close as possible to the OCXO ground to minimize trace impedance and therefore minimize any generated voltages which could cause large frequency errors. It is highly recommended to use the supplied OCXO VREF source to derive the control voltage when equipped. For models that do not offer the OCXO VREF source it is also recommended that the control voltage source run off the same rail as the OCXO to eliminate the supply voltage thermal drift errors that could exist between multiple rails. This will prevent large unwanted frequency shift errors as the relative voltage drift between the supplies will be eliminated.
Scenario: Assume a control voltage equipped OCXO with a tuning sensitivity of 7ppm / volt is powered from a 3.3V supply (3V3_OCXOSupply) with a temperature coefficient of 2.6mV / °C.

The DAC which drives the OCXO CV pin is powered from a secondary 3.3V rail (3v3_DacSupply) with a thermal coefficient of 0.2mV / °C (See Figure 15-02 Example schematic Figure 15-03 Thermal Coefficient vs. Temperature) In this example the OCXO was initially tuned to 0 ppm at 0°C with a calibration error of ± 0.025 ppm. As the ambient temperature in the system changes to 70℃ over the next hour, the voltage error between the two rails would have drifted from 0 volts between the two rails, to 0.1834 volts resulting in a 1.2838 ppm frequency error.

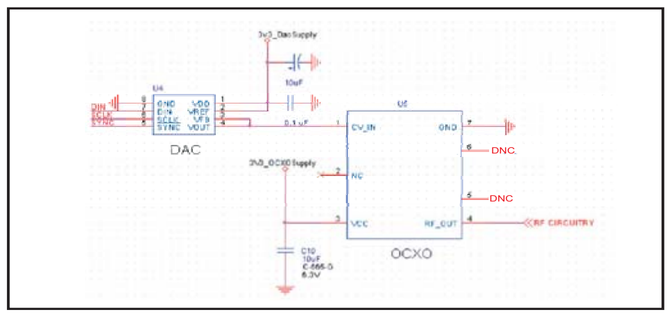

Figure: 15-02 Example Circuit

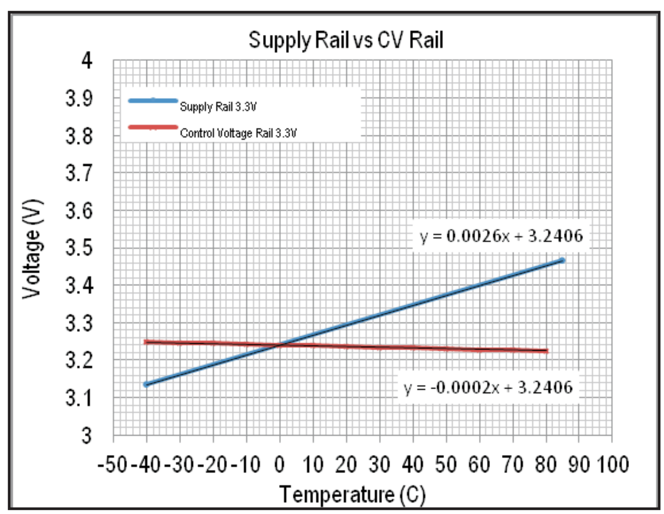

Figure: 15-03 Thermal Drift between Supply Rails

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Multi-Layer Board Design / Thermal Considerations

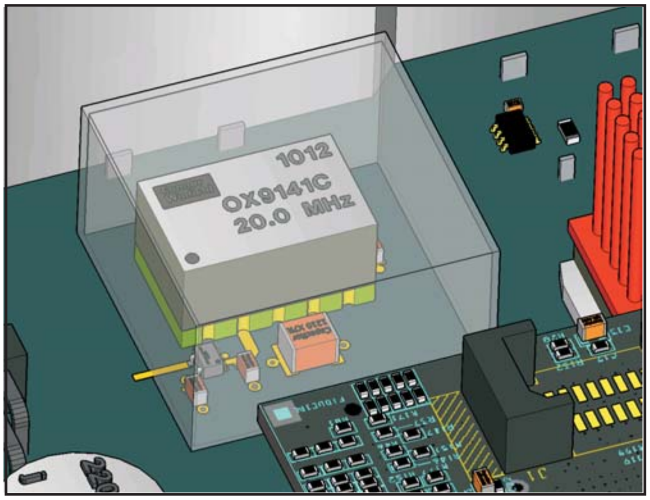

Figure: 16-01

A small air gap should exist between the OCXO and all the walls of the cover.

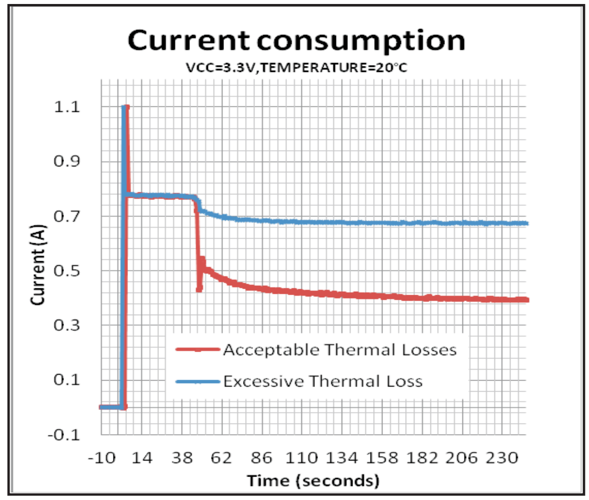

Figure: 16-03

11. To reduce unwanted thermal gains/losses, open a window in any top level copper pours under the device. Excessive thermal losses may result in higher than normal current consumption or complete device failure. See Figure 16-03. Excessive thermal gains will overheat the oven core causing frequency instability. FIGURE 16-02 illustrates a how to properly flood a top layer while creating a "window" under the OCXO.

12. Optionally a thermal "moat" can be created to prevent thermal energy transfers between the OCXO and board as seen in Figure 17-01. A thermal moat is a routed area around the OCXO and is very effective means to prevent losses from the oscillator while still allowing a top layer pour on the board to heat sink cool other electrical components.
13. Plastic and metal covers can be used to further reduce small temperature fluctuations in the system by reducing variable air flow across the device. An effective cover will should still allow a small air gap between the OCXO and any wall of the cover. SEE FIGURE 16-01
14. DO NOT CONNECT ANY ELECTRICAL SIGNALS TO PINS MARKED DNC. These pins are reserved for factory use only, and connecting or monitoring these signals could permanently damage the device.

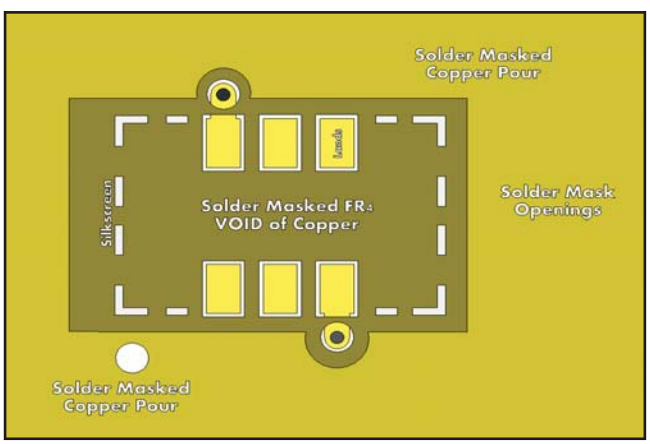

Figure: 16-02
OCXO Pad Layout w/ Top Level Copper pour.

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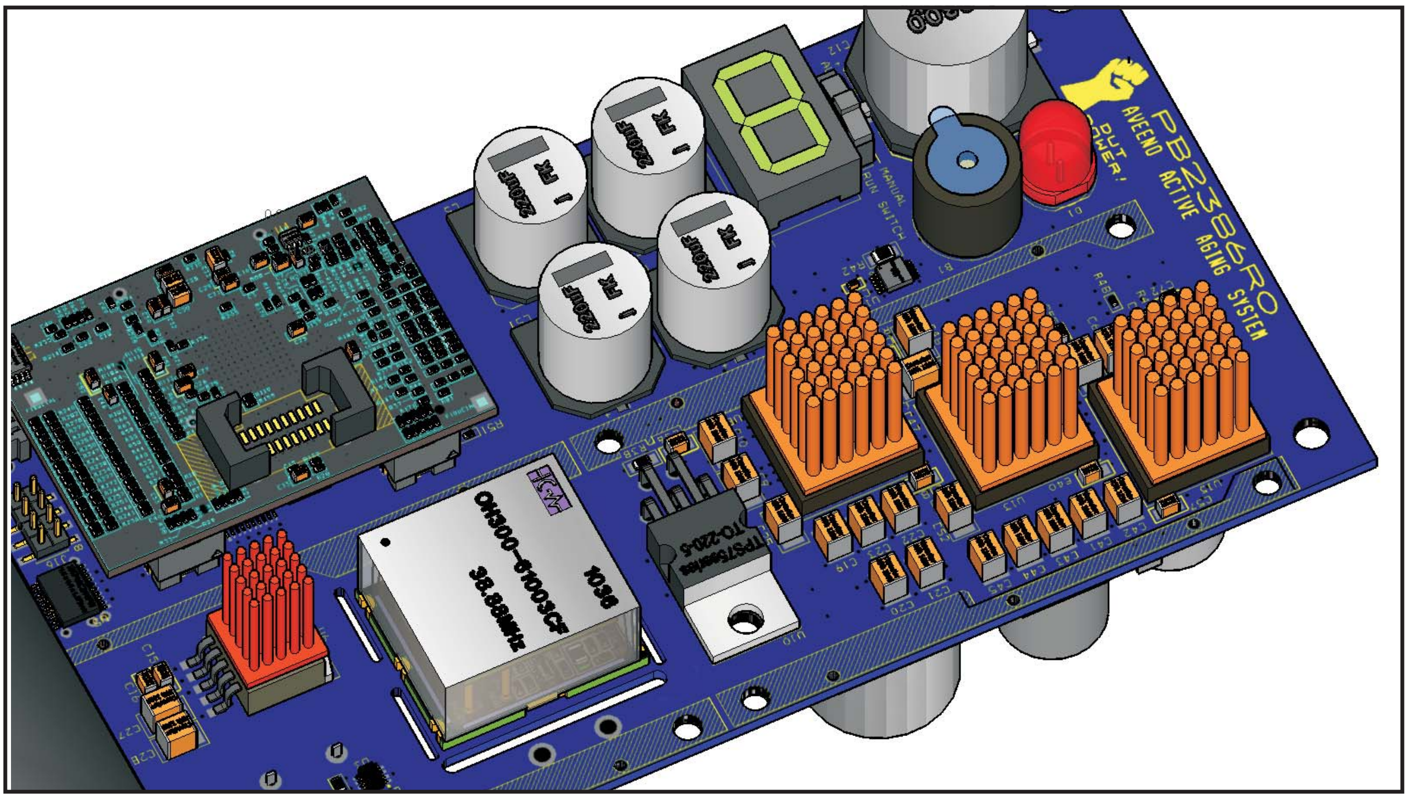

Figure: 17-01

Optionally a thermal "moat" can be created to prevent thermal energy transfers between the OCXO and the surrounding heat generating components.

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Multi-Layer Board Design / Thermal Considerations

4.3 Controlling Thermal Transfer / Transients

Controlling thermal transients is critical for proper operation of all OCXOs. Any sudden changes in air-flow, or temperature will drastically effect short term frequency stability. Ambient system, cabinet, or enclosure temperature must always transition under the maximum stated rate identified on the product data sheet. Typical $\Delta t^{o}C$ / t (minutes) rates for OCXO range from 0.5 to 1°C/minute. Any additional heat generated by nearby integrated circuits, or mechanical parts could cause the internal oven temperature to fall out of equilibrium and no longer maintain frequency stability. The OCXO controller can only self-regulate oven core temperature if thermal energy conducted through the printed circuit board is kept to a minimum.

Avoid the following, as they will cause the oven core to overheat or drop out of thermal regulation.

- Placing the OCXO near heat generating components (electrical or mechanical that could bleed thermal energy into the OCXO causing the oven core to overheat, even when the ambient air is within the operating limits)
- Placing the OCXO into intermittent air flow paths (ie switched or variable speed fans) as this will cause the oven core to fall out of thermal regulation
- On multi-layer boards avoid top level copper floods, pours and fills under the OCXO land pattern that would contribute to excessive heat gains/losses through the printed circuit board resulting in an inability for the oven core to maintain thermal equilibrium.

Avoid layouts as seen in FIGURE 18-02

4.4 Controlling Airflow

Shielding the OCXO from intermittent or variable speed airflow paths will minimize small temperature fluctuations and substantially improve short / medium term stability. This can best be accomplished by shielding the OCXO behind taller non-heat generating components or mechanical parts to create a physical barrier, or with the use of a metal or plastic cover.

See figures 18-01 and 18-02

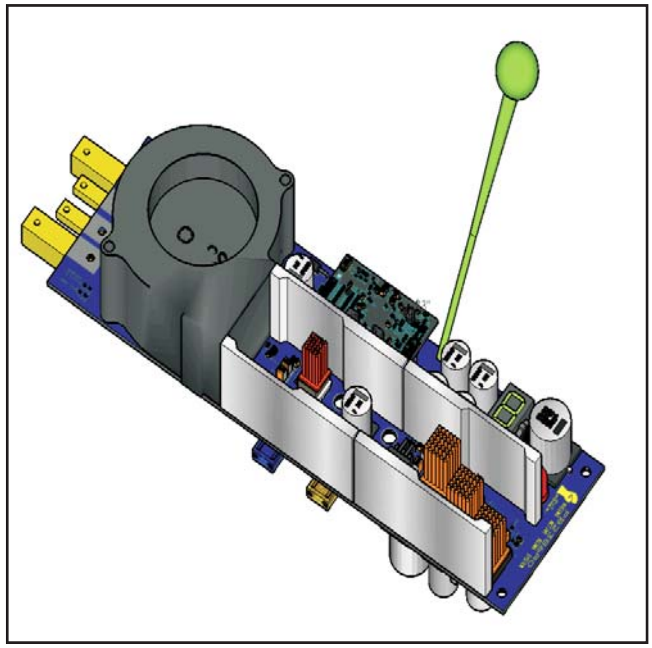

Figure: 18-01

Good Choice for OCXO placement. OCXO is outside of air tunnel, not near any heat generating components

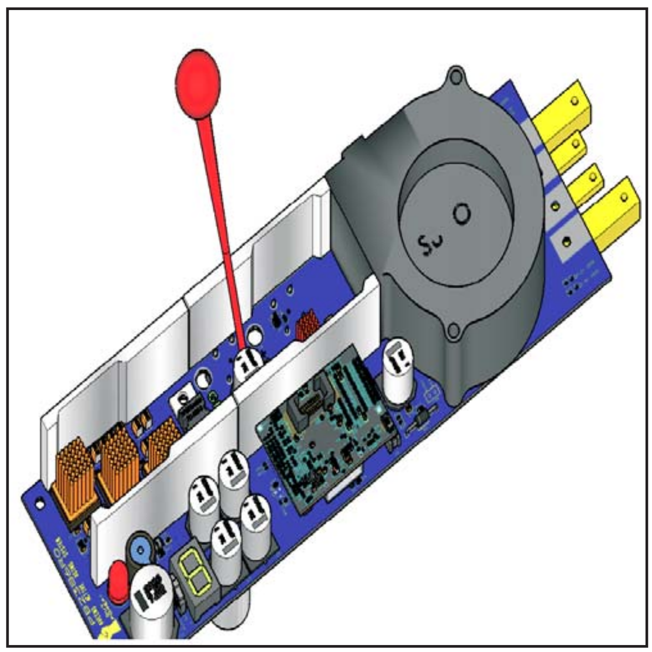

Figure: 18-02

Poor location for OCXO. Variable speed or switched fans create large temperature fluctuations

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Section 5: Design Checklist

5.1 Power Supply Checklist

- Select a LOW noise power circuit / source
- Add a large bulk capacitor at the voltage regulator's output that can provide current for local capacitors and ensure regulator stability.
- Place bulk capacitors as close to the voltage regulator output as possible.
- The large bulk capacitor's capacitance should be 10 to 100 times as large as local IC decoupling capacitors.
- Add a second capacitor an order of magnitude or two smaller in capacitance relative to the large bulk capacitor to help filter high-frequency noise.
- Place a local capacitance as close as possible to the power supply pin of each IC.
- The side of the local capacitor that connects to ground should be placed as close to the IC's ground pin as possible in order to minimize the loop area between the cap and the power and ground pins.
- Add a filter, such as an L-C filter or an R-C filter, to the power supply circuit.

5.2 Ground

- Design using a ground plane instead of traces when connecting components to ground.
- If a top level copper pour is used, it should cover as much of the board as possible, including the spaces between devices and traces. EXCLUDE THE AREA UNDER THE OCXO.
- Separating the analog ground plane from the digital ground plane improves analog performance.
- Separate ground planes should be connected in only one location, usually close to the power supply.

5.3 General

- Keep analog and digital signals as far apart from each other as possible.
- Avoid routing analog and digital traces perpendicular to each other.
- Avoid routing analog or digital signals under oscillators.
- Trace width should remain constant throughout the length of the trace.
- Turns in traces should be routed using two 45 degree turns instead of one 90 degree turn.
- Trace length should always be minimized.
- Use vias only when absolutely necessary.
- Avoid the use of vias when routing high-frequency signals.
- Keep traces as small as possible.
- Place the OCXO as close as possible to the timing circuitry.
- Never leave the control voltage signal floating.
- Design using a power plane instead of traces routed from the power supply.

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5.4 OCXO Layout Considerations

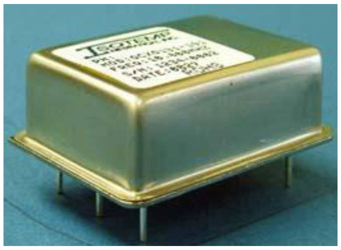
- Always place OCXO as close to timing circuitry as possible..
- Always adhere to stated loading specifications for RF output of OCXO and consider using NPO / COG capacitors to create equivalent loading capacitance for optimal capacitance vs. temperature characteristics.
- It is recommended to place a 10uF to 47uF bulk capacitor as close to as possible to the VCC pin of the OCXO.
- Place a small ceramic decoupling capacitor typically X7R with a 2 to 3 ohm reactance at the output frequency of the OCXO to shunt any noise on the supply rail to ground.
- Calculate via size to ensure sufficient current is available to the OCXO at the anticipated maximum board temperature which may be SIGNIFICANTLY higher than ambient air temperature.
- Connect the ground of the control voltage source as close as possible to the OCXO ground to minimize trace impedance.
- Open a window in all ground and power planes under the device. Excessive thermal losses may result in higher than normal current consumption or complete device failure.
- Do not place OCXO in path or turbulent airflow which could cause quickly changing temperature fluctuations that could compromise the oven core temperature.
- [Optional] Route a thermal “moat” to prevent thermal energy transfers between the OCXO and board.
- [Optional] Use plastic and metal covers can be used to further reduce small temperature fluctuations in the system by reducing variable air flow across the device.
- DO NOT connect any signals to “Do Not Connect” (D.N.C.) pins. These are FACTORY use only. DNC pads may be soldered down to electrically isolated pads for structural support only.

Section 6: References

Chester Simpson "Linear and Switching Voltage Regulator Fundamentals"
National Semiconductor http://www.national.com/assets/en/appnotes/f4.pdf

Habeeb Ur Rahman Mohammed, Ph.D " Supply Noise Effect on Oscillator Phase Noise,"
Texas Instruments, Application Report SLWA066–November 2011 http://www.ti.com/lit/an/slwa066/slwa066.pdf

OCXO 131 Series



The OCXO 131 series oscillators feature small European style packages designed for applications where space is at a premium and good frequency stability is required. The oscillators can be used in phased locked loops or as stand alone references in many communications applications such as Stratum 3 switching apparatus or cellular telephone base stations. An internal voltage reference is provided to make frequency corrections via a simple potentiometer or may be used as a voltage source for a digital to analog converter. The package is a hermetically sealed through hole printed circuit board mount. A choice of quartz resonators offers a variety of performance versus cost options to fit most applications.

Features:

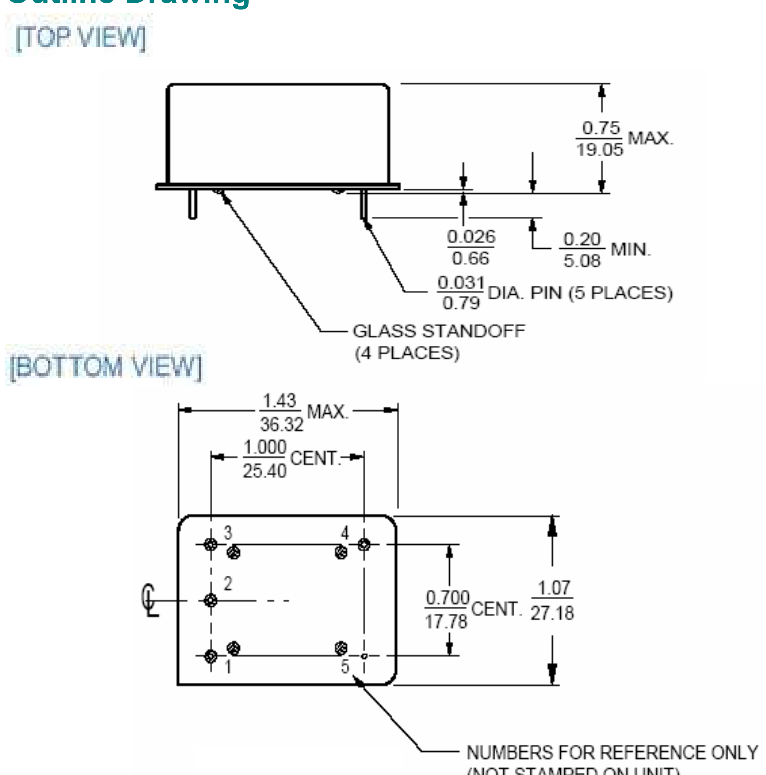
- Typical 36.3 x 27.2 x 19.1 mm.
- SC-Cut Crystal
- High Stability; Low Phase Noise
- CMOS//Sine Wave output; Fast Warm-up

Ordering Information

OCXO	Package (mm)	Supply Voltage (V)	Pulling Range (ppm)	Freq. Stability (ppb)	Temp. Range (ºC)	Output Logic and Symmetry		Oscillator Mode	Pin Out	Lead Free	Freq. (MHz)
131 Series	L: 36.3 W: 27.2 H: 19.1	12.0 5.0	±0.4	± 5 ± 10 ± 20 ± 30 ± 50	0~+50 0~+70 -30~+70	Output CMOS15pF Sine Wave	Symmetry 50±10%	* Not selectable by customer	Normal Please refer to "OUTLINE DRAWING"	RoHS Compliant Not RoHS Compliant	XX.XXXXXX

Ordering Example: OCXO131 Series; V_{DD}: 12V; Pulling Range: ±0.4ppm; Freq. Stability: ± 20 ppb; Temp. Range: -30ºC to 70ºC; Sine Wave; Pin Out: Normal; RoHS Compliant; Freq. 10.000000 MHz.

Outline Drawing



INCH
mm (Reference only)

Freq. Stability vs. TEMP. Range

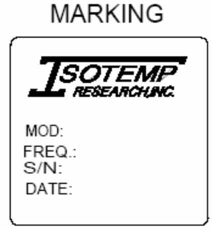
ppb / Temp. (ºC)	±5	±10	: ±20
0 to +50	○	○	○
0 to +70	△	○	○
-30 to +70	△	△	○

○ = Standard △ = Available (case by case) X = Not available

PIN CONNECTIONS	
PIN	FUNCTION
1 (See Note 1)	VCO INPUT or NOT CONNECTED
2 (See Note 1)	REFERENCE VOLTAGE or NOT CONNECTED
3	+ VDC
4	R.F. OUTPUT
5	0 VOLTS & CASE

Note1: If the specification does not specify parameters for either PIN1 or PIN2 then that respective PIN is not internally CONNECTED.

MARKING



OCXO 131 Series

Electrical Specification

	Min.	Nominal	Max.	Note	Unit
Output					
Frequency		10.00			MHz
Wave Form		Sine Wave			
Level	6.0	8.0	10.0		dBm
Load		50			Ω
Harmonics		-30			dBc
Spurious		-60			
Frequency Stability					
Ambient			±20	Referenced to +25ºC	ppb
Operating Temperature	-30		+70		ºC
Aging *					
At time of shipment			±0.5		ppb
After indefinite storage					
Daily			±0.5	After 30 days	
Yearly			±100		
10 Years			±300		ppb
Voltage			±5	VDC ±5% change	
Warm-up			±20	In 5 minutes @+25ºC (Reference to 4 hours)	
Phase Noise @ 10 MHz					
@ 10 Hz			-120		
@ 100 Hz			-135		
@ 1 kHz			-150		dBc
@ 10 kHz			-150		
@ 100 kHz			-150		
Electrical Frequency Adjustment					
Range	0.4		0.9		±ppm
Control	0.0		8.0		V
Slope		Positive			
Center	3.2	4.0	4.8	Control Voltage at which nominal frequency occurs at time of shipment	V
Input Impedance	100				KΩ
Input Power					
Voltage	11.4	12.0	12.6		V
@ turn on			3.8		W
Steady state @25ºC			1.5		
Reference Voltage					
Voltage	7.6	8.0	8.4	Optional 4.0V (Note1) 5.0V (Note2)	V
Load	9.0		∞		KΩ
Temperature Stability			±0.015		VDC

Note 1: For all +5V input power Units
Note 2: For +12V CMOS Units

* All aging stabilities are after storage of up to one year and apply after 30 days of continuous operation.
The daily aging rate also applies at the time of shipment from factory.

** The electronic frequency adjustment rage is sufficient for the life of the oscillator specification subject to change with frequency.

Available Frequency Range: 5 MHz to 40 MHz Including 5.0, 10.0, 16.384, 19.44, 24.576, and 32.768 MHz

MAX6325/MAX6341/MAX6350

1ppm/°C, Low-Noise, +2.5V/+4.096V/+5V Voltage References

General Description

The MAX6325/MAX6341/MAX6350 are low-noise, precision voltage references with extremely low, 0.5ppm/°C typical temperature coefficients and excellent, ±0.02% initial accuracy. These devices feature buried-zener technology for lowest noise performance. Load-regulation specifications are guaranteed for source and sink currents up to 15mA. Excellent line and load regulation and low output impedance at high frequencies make them ideal for high-resolution data-conversion systems up to 16 bits.

The MAX6325 is set for a 2.5V output, the MAX6341 is set for a 4.096V output, and the MAX6350 is set for a 5V output. All three provide for the option of external trimming and noise reduction.

19-1203; Rev 1; 1/01

Features

- ♦ **Ultra Low, 1ppm/°C Max Tempco**
- ♦ **Very Low, 1.5µVp-p Noise (0.1Hz to 10Hz) (MAX6325)**
- ♦ **±0.02% Initial Accuracy (MAX6350)**
- ♦ **±15mA Output Source and Sink Current**
- ♦ **Low, 18mW Power Consumption (MAX6325)**
- ♦ **Industry-Standard Pinout**
- ♦ **Optional Noise Reduction and Voltage Trim**
- ♦ **Excellent Transient Response**
- ♦ **8-Pin SO Package Available**
- ♦ **Low, 30ppm/1000hr Long-Term Stability**
- ♦ **Stable for All Capacitive Loads**

Applications

High-Resolution Analog-to-Digital and Digital-to-Analog Converters

High-Accuracy Reference Standard

High-Accuracy Industrial and Process Control

Digital Voltmeters

ATE Equipment

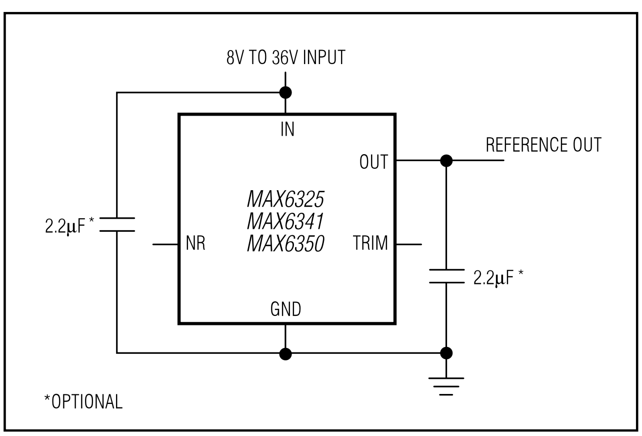
Precision Current Sources

Ordering Information

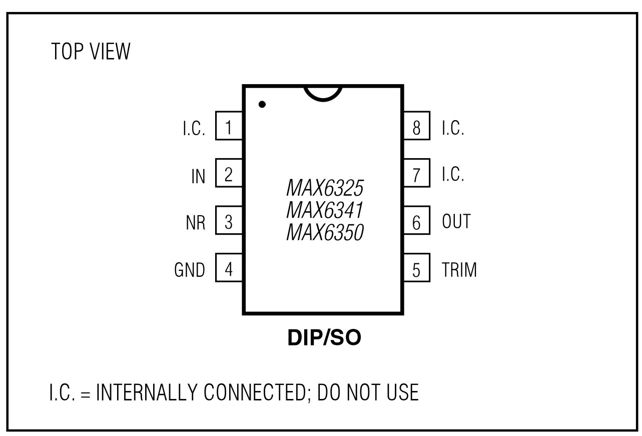
PART	TEMP. RANGE	PIN-PACKAGE	MAX TEMPCO (ppm/°C)
MAX6325CPA	0°C to +70°C	8 Plastic DIP	1.0
MAX6325CSA	0°C to +70°C	8 SO	1.0
MAX6325EPA	-40°C to +85°C	8 Plastic DIP	1.5
MAX6325ESA	-40°C to +85°C	8 SO	1.5
MAX6325MJA	-55°C to +125°C	8 CERDIP	2.5

Ordering Information continued at end of data sheet.

Typical Operating Circuit



Pin Configuration



ABSOLUTE MAXIMUM RATINGS

(Voltages Referenced to GND)
IN ....-0.3V to 40V
OUT, TRIM ....-0.3V to 12V
NR ....-0.3V to 6V
OUT Short-Circuit to GND Duration (V_{IN} ≤ 12V)..........Continuous
OUT Short-Circuit to GND Duration (V_{IN} ≤ 40V) 5s
OUT Short-Circuit to IN Duration (V_{IN} ≤ 12V) ....Continuous
Continuous Power Dissipation (T_A = +70°C)
8-Pin Plastic DIP (derate 9.09mW/°C above +70°C) 727mW
8-Pin SO (derate 5.88mW/°C above +70°C)...................471mW
8-Pin CERDIP (derate 8.00mW/°C above +70°C)...........640mW
Operating Temperature Ranges
MAX63_ _ C_ A...0°C to +70°C
MAX63_ _ E_ A.......................................-40°C to +85°C
MAX63_ _ MJA ....-55°C to +125°C
Storage Temperature Range ....-65°C to +150°C
Lead Temperature (soldering, 10s)..................................+300°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS—MAX6325

(V_{IN} = +10V, I_{OUT} = 0mA, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	T_A	MIN	TYP	MAX	UNITS
Input Voltage Range	V_{IN}		C, E, M	8		36	V
Output Voltage	V_{OUT}	MAX6325	+25°C	2.499	2.500	2.501	V
Output Voltage Temperature Coefficient (Note 1)	TCV_{OUT}	MAX6325C_A	C		0.5	1.0	ppm/°C
		MAX6325E_A	E		0.75	1.5	
		MAX6325MJA	M		1.0	2.5	
Line Regulation (Note 2)	$\Delta V_{OUT}/\Delta V_{IN}$	8V ≤ V_{IN} ≤ 10V	+25°C		10	18	ppm/V
			C			30	
			E			35	
			M			45	
		10V ≤ V_{IN} ≤ 36V	+25°C		2	5	
			C			7	
			E			8	
			M			10	
Load Regulation (Note 2)	$\Delta V_{OUT}/\Delta I_{OUT}$	Sourcing: 0mA ≤ I_{OUT} ≤ 15mA	C		1	6	ppm/mA
			E		1	7	
			M		3	15	
		Sinking: -15mA ≤ I_{OUT} ≤ 0mA	C		1	6	
			E		1	7	
			M		10	30	
Supply Current	I_{IN}		+25°C		1.8	2.7	mA
			C, E, M			3.0	
Trim-Adjustment Range	ΔV_{OUT}	(Figure 1)	C, E, M	±15	±25		mV
Turn-On Settling Time	t_{ON}	To ±0.01% of final value	+25°C		5		µs
Output Noise Voltage (Note 3)	e_n	0.1Hz ≤ f ≤ 10Hz	+25°C		1.5		µVp-p
		10Hz ≤ f ≤ 1kHz	+25°C		1.3	2.8	μV_{RMS}
Temperature Hysteresis		(Note 4)	+25°C		20		ppm
Long-Term Stability	$\Delta V_{OUT}/t$		+25°C		30		ppm/1000hr

ELECTRICAL CHARACTERISTICS—MAX6341

(V_{IN} = +10V, I_{OUT} = 0mA, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	T_A	MIN	TYP	MAX	UNITS
Input Voltage Range	V_{IN}		C, E, M	8		36	V
Output Voltage	V_{OUT}	MAX6341	+25°C	4.095	4.096	4.097	V
Output Voltage Temperature Coefficient (Note 1)	TCV_{OUT}	MAX6341C_A	C		0.5	1.0	ppm/°C
		MAX6341E_A	E		0.75	1.5	
		MAX6341MJA	M		1.0	2.5	
Line Regulation (Note 2)	$\Delta V_{OUT}/\Delta V_{IN}$	8V ≤ V_{IN} ≤ 10V	+25°C		10	18	ppm/V
			C			30	
			E			35	
			M			45	
		10V ≤ V_{IN} ≤ 36V	+25°C		2	5	
			C			7	
			E			8	
			M			10	
Load Regulation (Note 2)	$\Delta V_{OUT}/\Delta I_{OUT}$	Sourcing: 0mA ≤ I_{OUT} ≤ 15mA	C		1	6	ppm/mA
			E		1	7	
			M		3	9	
		Sinking: -15mA ≤ I_{OUT} ≤ 0mA	C		1	6	
			E		1	7	
			M		7	18	
Supply Current	I_{IN}		+25°C		1.9	2.9	mA
			C, E, M			3.2	
Trim-Adjustment Range	ΔV_{OUT}	(Figure 1)	C, E, M	±24	±40		mV
Turn-On Settling Time	t_{ON}	To ±0.01% of final value	+25°C		8		µs
Output Noise Voltage (Note 3)	e_n	0.1Hz ≤ f ≤ 10Hz	+25°C		2.4		µVp-p
		10Hz ≤ f ≤ 1kHz	+25°C		2.0	4.0	$µV_{RMS}$
Temperature Hysteresis		(Note 4)	+25°C		20		ppm
Long-Term Stability	$\Delta V_{OUT}/t$		+25°C		30		ppm/ 1000hr

ELECTRICAL CHARACTERISTICS—MAX6350

(V_{IN} = +10V, I_{OUT} = 0mA, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	T_A	MIN	TYP	MAX	UNITS
Input Voltage Range	V_{IN}		C, E, M	8		36	V
Output Voltage	V_{OUT}	MAX6350	+25°C	4.999	5.000	5.001	V
Output Voltage Temperature Coefficient (Note 1)	TCV_{OUT}	MAX6350C_A	C		0.5	1.0	ppm/°C
		MAX6350E_A	E		0.75	1.5	
		MAX6350MJA	M		1.0	2.5	
Line Regulation (Note 2)	$\Delta V_{OUT}/\Delta V_{IN}$	8V ≤ V_{IN} ≤ 10V	+25°C		10	18	ppm/V
			C			30	
			E			35	
			M			45	
		10V ≤ V_{IN} ≤ 36V	+25°C		2	5	
			C			7	
			E			8	
			M			10	
Load Regulation (Note 2)	$\Delta V_{OUT}/\Delta I_{OUT}$	Sourcing: 0mA ≤ I_{OUT} ≤ 15mA	C		1	6	ppm/mA
			E		1	7	
			M		2	9	
		Sinking: -15mA ≤ I_{OUT} ≤ 0mA	C		1	6	
			E		1	7	
			M		6	15	
Supply Current	I_{IN}		+25°C		2.0	3.0	mA
			C, E, M			3.3	
Trim-Adjustment Range	ΔV_{OUT}	(Figure 1)	C, E, M	±30	±50		mV
Turn-On Settling Time	t_{ON}	To ±0.01% of final value	+25°C		10		µs
Output Noise Voltage (Note 3)	e_n	0.1Hz ≤ f ≤ 10Hz	+25°C		3.0		µVp-p
		10Hz ≤ f ≤ 1kHz	+25°C		2.5	5.0	$µV_{RMS}$
Temperature Hysteresis		(Note 4)	+25°C		20		ppm
Long-Term Stability	$\Delta V_{OUT}/t$		+25°C		30		ppm/ 1000hr

Note 1: Temperature coefficient is measured by the box method; i.e., the maximum ΔV_{OUT} is divided by ΔT x V_{OUT}.

Note 2: Line regulation (ΔV_{OUT} / (V_{OUT} x ΔV_{IN})) and load regulation (ΔV_{OUT} / (V_{OUT} x ΔI_{OUT})) are measured with pulses and do not include output voltage changes due to die-temperature changes.

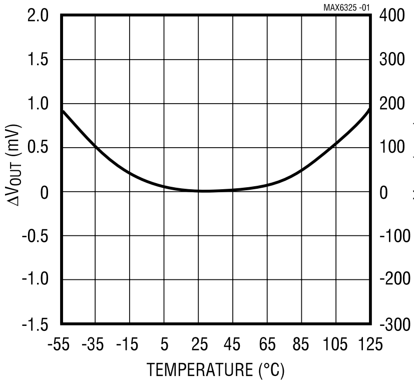
Note 3: Noise specifications are guaranteed by design.

Note 4: Temperature hysteresis is specified at T_A = +25°C by measuring V_{OUT} before and after changing temperature by +25°C, using the plastic DIP package.

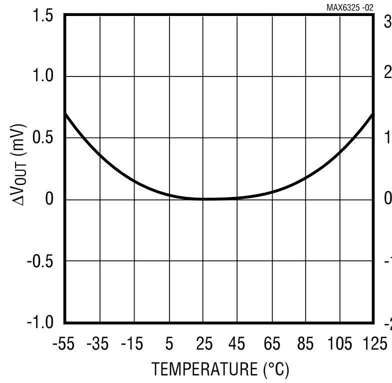
Typical Operating Characteristics

(V_{IN} = +10V, I_{OUT} = 0mA, T_A = +25°C, unless otherwise noted.)

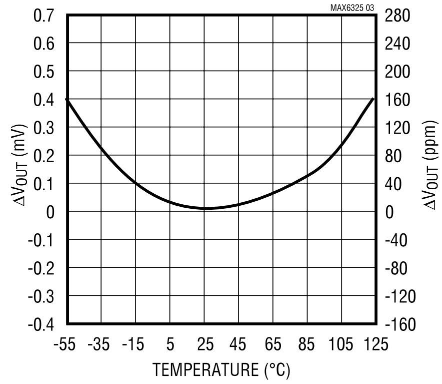
MAX6350 NORMALIZED OUTPUT VOLTAGE vs. TEMPERATURE



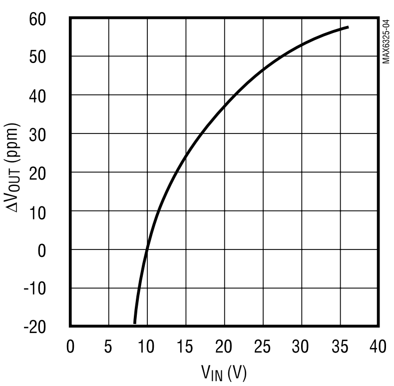
MAX6341 NORMALIZED OUTPUT VOLTAGE vs. TEMPERATURE



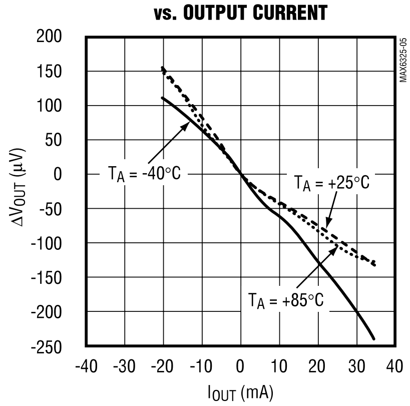
MAX6325 NORMALIZED OUTPUT VOLTAGE vs. TEMPERATURE



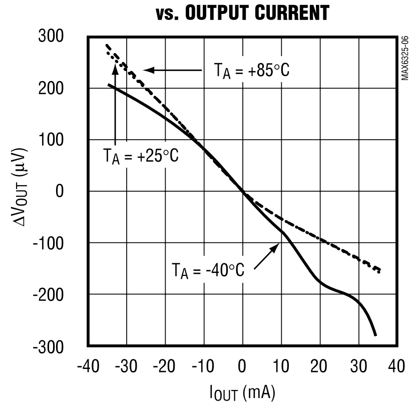
CHANGE IN OUTPUT VOLTAGE vs. INPUT VOLTAGE



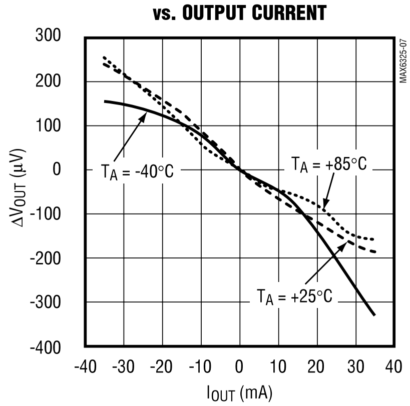
MAX6325 CHANGE IN OUTPUT VOLTAGE vs. OUTPUT CURRENT



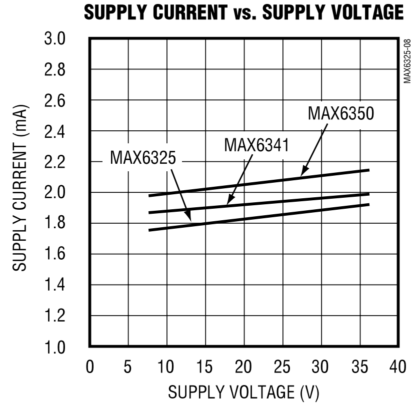
MAX6341 CHANGE IN OUTPUT VOLTAGE vs. OUTPUT CURRENT



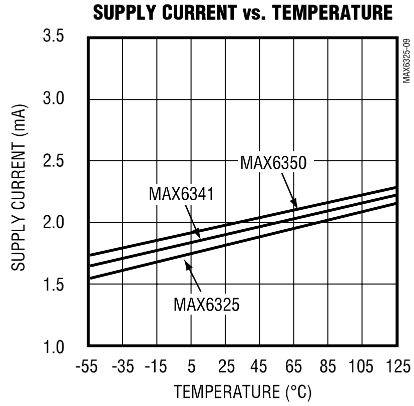
MAX6350 CHANGE IN OUTPUT VOLTAGE vs. OUTPUT CURRENT



SUPPLY CURRENT vs. SUPPLY VOLTAGE



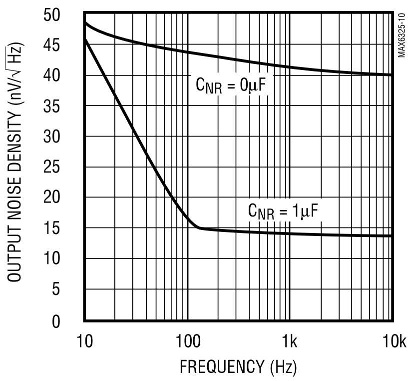
SUPPLY CURRENT vs. TEMPERATURE



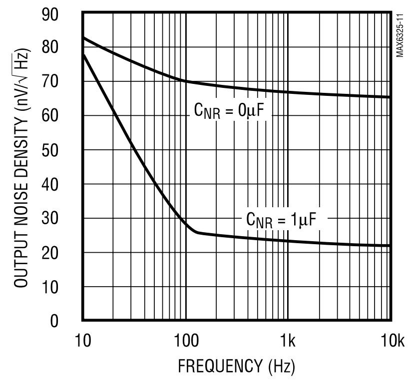
Typical Operating Characteristics (continued)

(V_{IN} = +10V, I_{OUT} = 0mA, T_A = +25°C, unless otherwise noted.)

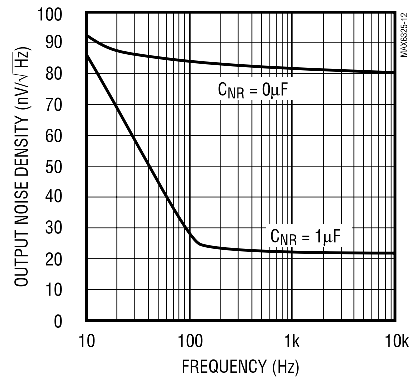
MAX6325 OUTPUT NOISE-VOLTAGE DENSITY vs. FREQUENCY



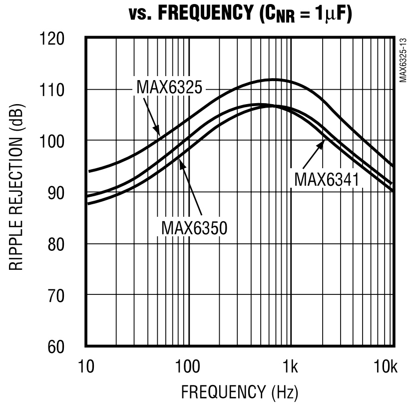
MAX6341 OUTPUT NOISE-VOLTAGE DENSITY vs. FREQUENCY



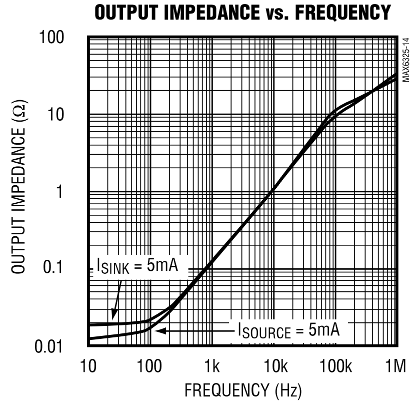
MAX6350 OUTPUT NOISE-VOLTAGE DENSITY vs. FREQUENCY



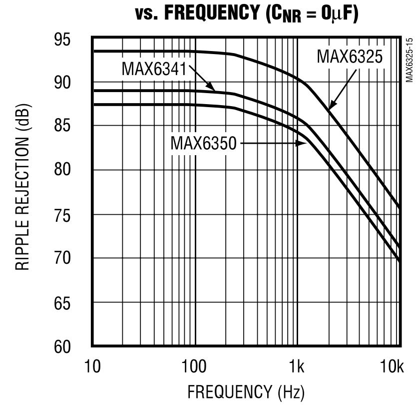
RIPPLE REJECTION vs. FREQUENCY (C_{NR} = 1μF)



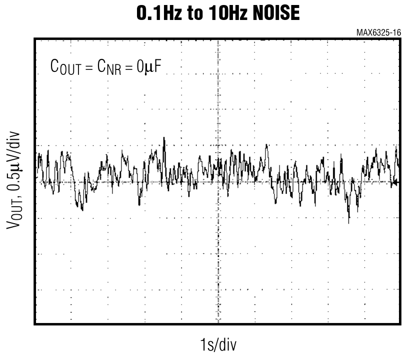
OUTPUT IMPEDANCE vs. FREQUENCY



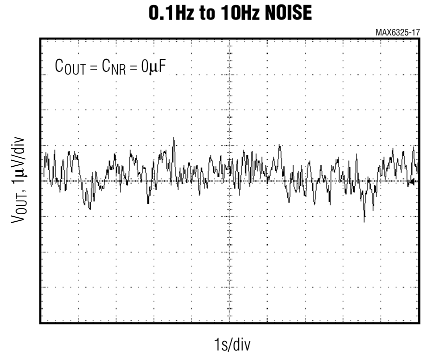
RIPPLE REJECTION vs. FREQUENCY (C_{NR} = 0μF)



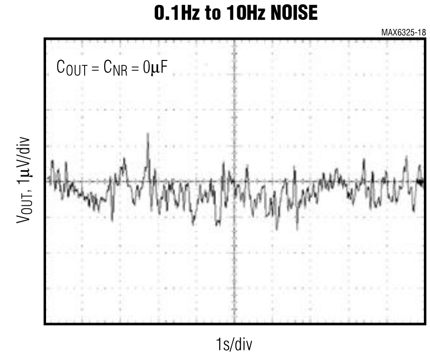
MAX6325 0.1Hz to 10Hz NOISE



MAX6341 0.1Hz to 10Hz NOISE



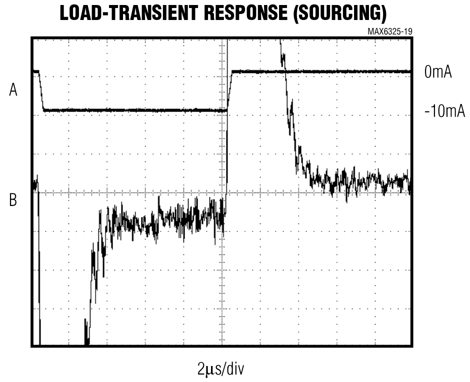
MAX6350 0.1Hz to 10Hz NOISE



Typical Operating Characteristics (continued)

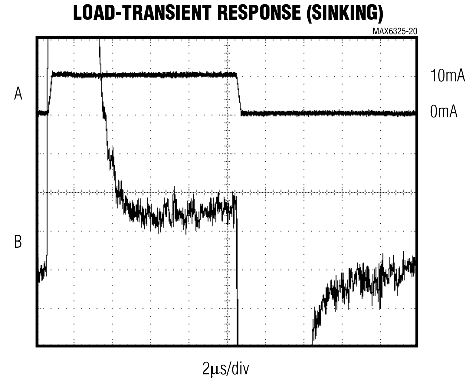
(V_{IN} = +10V, I_{OUT} = 0mA, T_A = +25°C, unless otherwise noted.)

LOAD-TRANSIENT RESPONSE (SOURCING)



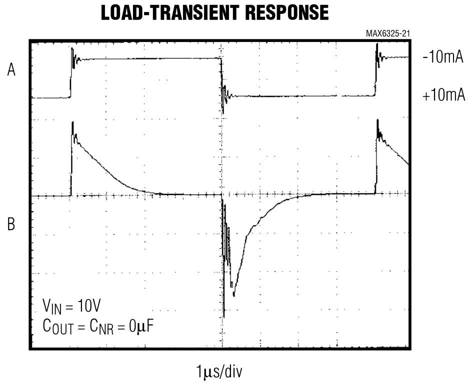
A: I_{OUT}, 10mA/div (SOURCING)
B: V_{OUT}, 500µV/div

LOAD-TRANSIENT RESPONSE (SINKING)



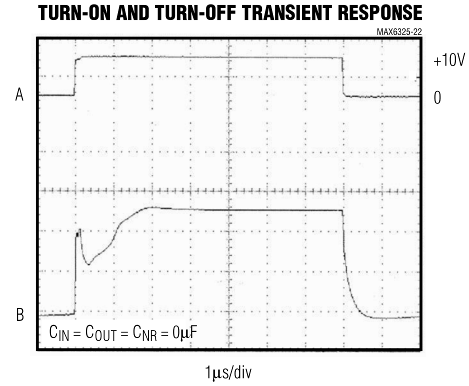
A: I_{OUT}, 10mA/div (SINKING)
B: V_{OUT}, 500µV/div

LOAD-TRANSIENT RESPONSE



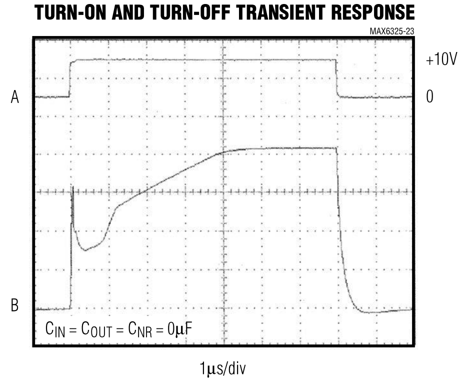
A: I_{OUT} (±10mA SOURCE AND SINK), 20mA/div, AC COUPLED
B: V_{OUT}, 20mV/div, AC COUPLED

MAX6325
TURN-ON AND TURN-OFF TRANSIENT RESPONSE



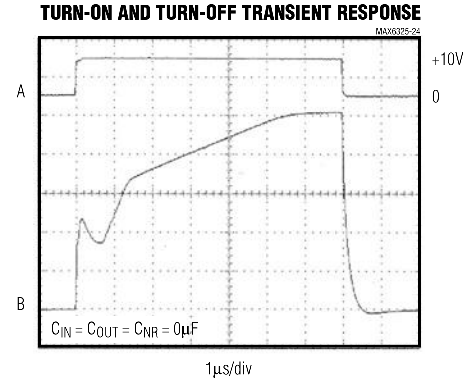
A: V_{IN}, 10V/div
B: V_{OUT}, 1V/div

MAX6341
TURN-ON AND TURN-OFF TRANSIENT RESPONSE



A: V_{IN}, 10V/div
B: V_{OUT}, 1V/div

MAX6350
TURN-ON AND TURN-OFF TRANSIENT RESPONSE



A: V_{IN}, 10V/div
B: V_{OUT}, 1V/div

Pin Description

PIN	NAME	FUNCTION
1, 7, 8	I.C.	Internally Connected. **Do not use**.
2	IN	Positive Power-Supply Input
3	NR	Noise Reduction. Optional capacitor connection for wideband noise reduction. Leave open if not used (Figure 2).
4	GND	Ground
5	TRIM	External Trim Input. Allows ±1% output adjustment (Figure 1). Leave open if not used.
6	OUT	Voltage Reference Output

Detailed Description

Temperature Stability

The MAX6325/MAX6341/MAX6350 are highly stable, low-noise voltage references that use a low-power temperature-compensation scheme to achieve laboratory-standard temperature stability. This produces a nearly flat temperature curve, yet does not require the power associated with heated references.

The output voltage can be trimmed a minimum of 0.6% by connecting a 10kΩ potentiometer between OUT and GND, and connecting its tap to the TRIM pin, as shown in Figure 1. The external trimming does not affect temperature stability.

Noise Reduction

To augment wideband noise reduction, add a 1µF capacitor to the NR pin (Figure 2). Larger values do not improve noise appreciably (see *Typical Operating Characteristics*).

Noise in the power-supply input can affect output noise, but can be reduced by adding an optional bypass capacitor to the IN pin and GND.

Bypassing

The MAX6325/MAX6341/MAX6350 are stable with capacitive load values from 0µF to 100µF, for all values of load current. Adding an output bypass capacitor can help reduce noise and output glitching caused by load transients.

Applications Information

Negative Regulator

Figure 3 shows how both a +5V and -5V precision reference can be obtained from a single, unregulated +5V supply. A MAX865 generates approximately ±9V to operate the MAX6350 reference and MAX400 inverting amplifier. The +5V is inverted by the ultra-low offset MAX400 op amp. Resistor R1 is optional, and may be used to trim the ±5V references. R2 and R4 should be matched, both in absolute resistance and temperature coefficient. R3 is optional, and is adjusted to set the -5V reference.

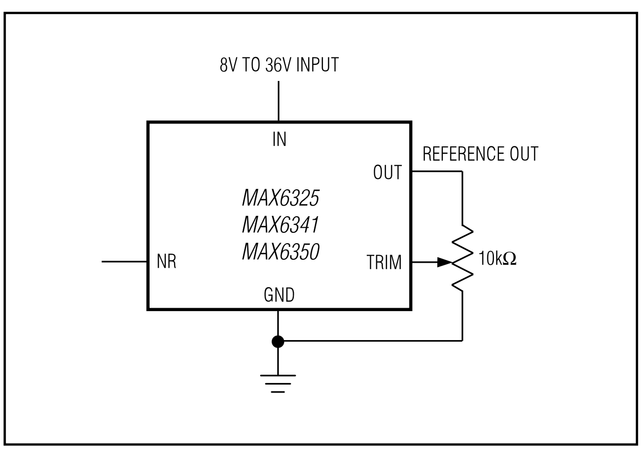


Figure 1. Output Voltage Adjustment

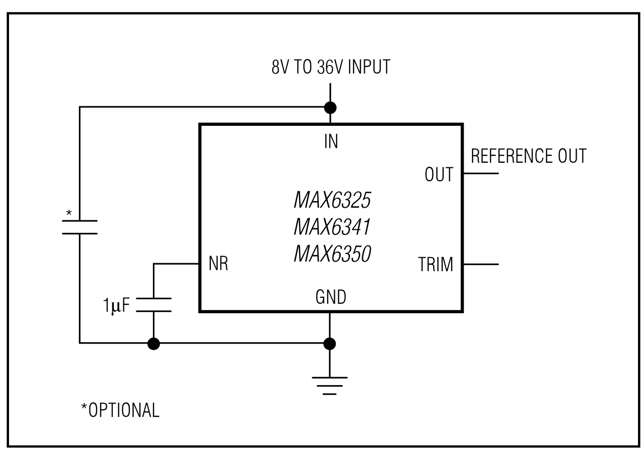


Figure 2. Noise-Reduction Capacitor

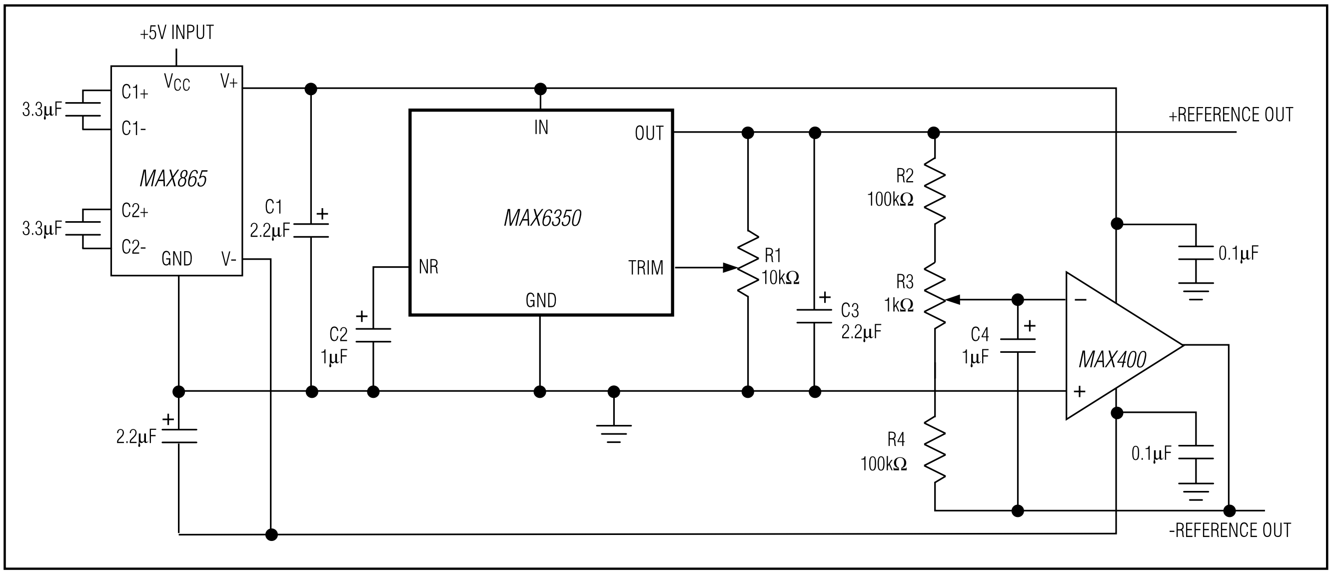


Figure 3. +5V and -5V References from a Single +5V Supply

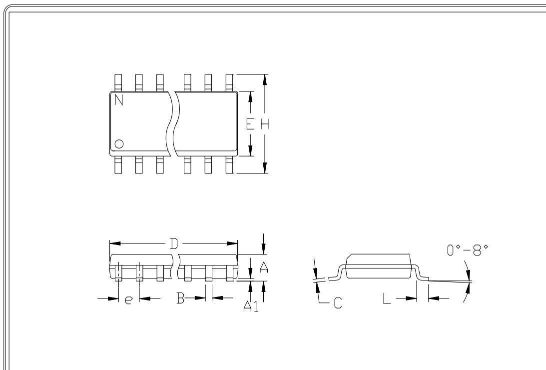
Ordering Information (continued)

PART	TEMP. RANGE	PIN-PACKAGE	MAX. TEMPCO (ppm/°C)
MAX6341CPA	0°C to +70°C	8 Plastic DIP	1.0
MAX6341CSA	0°C to +70°C	8 SO	1.0
MAX6341EPA	-40°C to +85°C	8 Plastic DIP	1.5
MAX6341ESA	-40°C to +85°C	8 SO	1.5
MAX6341MJA	-55°C to +125°C	8 CERDIP	2.5
MAX6350CPA	0°C to +70°C	8 Plastic DIP	1.0
MAX6350CSA	0°C to +70°C	8 SO	1.0
MAX6350EPA	-40°C to +85°C	8 Plastic DIP	1.5
MAX6350ESA	-40°C to +85°C	8 SO	1.5
MAX6350MJA	-55°C to +125°C	8 CERDIP	2.5

Chip Information

TRANSISTOR COUNT: 435

Package Information

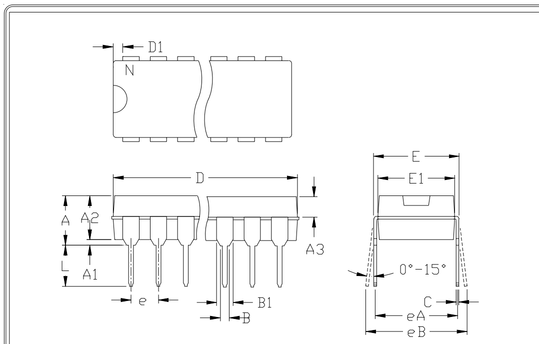


	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.053	0.069	1.35	1.75
A1	0.004	0.010	0.10	0.25
B	0.014	0.019	0.35	0.49
C	0.007	0.010	0.19	0.25
e	0.050		1.27	
E	0.150	0.157	3.80	4.00
H	0.228	0.244	5.80	6.20
h	0.010	0.020	0.25	0.50
L	0.016	0.050	0.40	1.27

	INCHES		MILLIMETERS			
	MIN	MAX	MIN	MAX	N	MS012
D	0.189	0.197	4.80	5.00	8	A
D	0.337	0.344	8.55	8.75	14	B
D	0.386	0.394	9.80	10.00	16	C

NOTES:
1. D&E DO NOT INCLUDE MOLD FLASH
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED .15mm (.006")
3. LEADS TO BE COPLANAR WITHIN .102mm (.004")
4. CONTROLLING DIMENSION: MILLIMETER
5. MEETS JEDEC MS012-XX AS SHOWN IN ABOVE TABLE
6. N = NUMBER OF PINS

PROPRIETARY INFORMATION | PACKAGE FAMILY OUTLINE: SOIC .150" | 1/1 | 21-0041 A | DOCUMENT CONTR



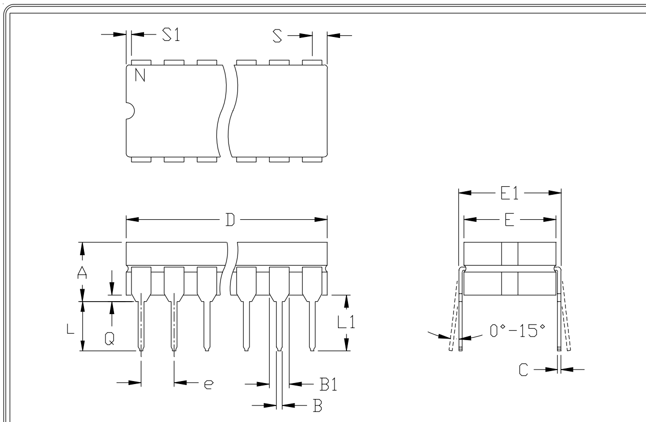
	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	---	0.200	---	5.08
A1	0.015	---	0.38	---
A2	0.125	0.175	3.18	4.45
A3	0.055	0.080	1.40	2.03
B	0.016	0.022	0.41	0.56
B1	0.045	0.065	1.14	1.65
C	0.008	0.012	0.20	0.30
D1	0.005	0.080	0.13	2.03
E	0.300	0.325	7.62	8.26
E1	0.240	0.310	6.10	7.87
e	0.100	---	2.54	---
eA	0.300	---	7.62	---
eB	---	0.400	---	10.16
L	0.115	0.150	2.92	3.81

	INCHES		MILLIMETERS			
	MIN	MAX	MIN	MAX	N	MS001
D	0.348	0.390	8.84	9.91	8	AB
D	0.735	0.765	18.67	19.43	14	AC
D	0.745	0.765	18.92	19.43	16	AA
D	0.885	0.915	22.48	23.24	18	AD
D	1.015	1.045	25.78	26.54	20	AE
D	1.14	1.265	28.96	32.13	24	AF
D	1.360	1.380	34.54	35.05	28	*5

NOTES:
1. D&E DO NOT INCLUDE MOLD FLASH
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED .15mm (.006")
3. CONTROLLING DIMENSION: MILLIMETER
4. MEETS JEDEC MS001-XX AS SHOWN IN ABOVE TABLE
5. SIMILIAR TO JEDEC MO-058AB
6. N = NUMBER OF PINS

PROPRIETARY INFORMATION | TITLE: PACKAGE FAMILY OUTLINE: PDIP .300" | 1/1 | DOCUMENT CONTROL NUMBER: 21-0043 | REV: A

Package Information (continued)



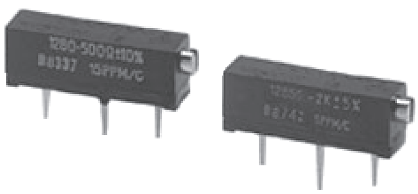
	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	---	0.200	---	5.08
B	0.014	0.023	0.36	0.58
B1	0.038	0.065	0.97	1.65
C	0.008	0.015	0.20	0.38
E	0.220	0.310	5.59	7.87
E1	0.290	0.320	7.37	8.13
e	0.100		2.54	
L	0.125	0.200	3.18	5.08
L1	0.150	---	0.00	---
Q	0.015	0.070	0.38	1.78
S	---	0.098	---	2.49
S1	0.005	---	0.13	---

	INCHES		MILLIMETERS			
	MIN	MAX	MIN	MAX	N	CASE
D	---	0.405	---	10.29	8	P:D4
D	---	0.785	---	19.94	14	C:D1
D	---	0.840	---	21.34	16	E:D2
D	---	0.960	---	24.38	18	V:D6
D	---	1.060	---	26.92	20	R:D8
D	---	1.280	---	32.51	24	L:D9

NOTES:
1. CONTROLLING DIMENSION: INCH
2. MEETS 1835 CASE OUTLINE CONFIGURATION #1 AS SHOWN IN ABOVE TABLE
3. N = NUMBER OF PINS

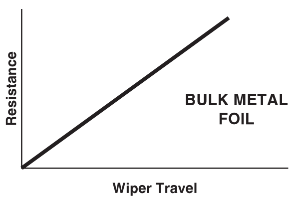
PROPRIETARY INFORMATION | TITLE: PACKAGE FAMILY OUTLINE: CDIP .300" | 1/1 | DOCUMENT CONTROL NUMBER: 21-0045 | REV: A

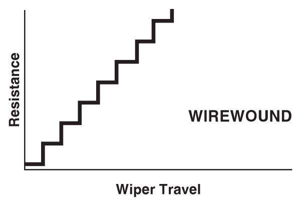
Bulk Metal® Foil Technology Ultra High Precision Trimming Potentiometers 3/4" Rectilinear, ± 5 ppm/°C and ± 15 ppm/°C TCR with a Smooth and Unidirectional Output

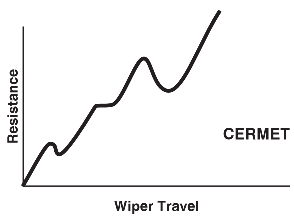


INTRODUCTION

Vishay Foil precision trimmers have the Bulk Metal® Foil resistive element which possesses a unique inherent temperature and load life stability. Plus, their advanced virtually back lash-free adjustment mechanism makes them easy to set quickly and accurately and keeps the setting exactly on target.







FEATURES

Pb-free

RoHS COMPLIANT

- Temperature coefficient of resistance (TCR): (- 55 °C to + 125 °C ref. at + 25 °C)
  - ± 15 ppm/°C (model 1280G);
  - ± 5 ppm/°C (model 1285G)[3];
  - through the wiper ± 50 ppm/°C
- A smooth and unidirectional resistance with leadscrew adjustment
- Load life stability: 0.5 % maximum ΔR under full rated power at + 25 °C for 2000 h
- Electrostatic discharge (ESD) up to 25 000 V
- Settability: 0.05 % typical; 0.1 % maximum
- Setting stability: 0.1 % typical; 0.5 % maximum, ΔSS
- Power rating: 0.75 W at + 25 °C
- Resistance range: 10 Ω to 20 kΩ
- Resistance tolerance: ± 10 %, ± 5 %
- Backlash: < 0.05 %
- Tap test: 0.05 % typical; 0.1 % maximum
- "O"-ring prevents ingress of fluids during any board cleaning operation
- Terminal finish: gold plated (tin/lead finish available on request)

TABLE 1 - 1280G AND 1285G SERIES ELECTRICAL SPECIFICATIONS	
Resistance Tolerance	Model 1280G 10 % (1), Model 1285G 5 %
Resistance Range	10 Ω to 20 kΩ
TCR Model 1280G	± 15 ppm/°C (- 55 °C to + 125 °C, ref. + 25 °C)
TCR Model 1285G (3)	± 5 ppm/°C (- 55 °C to + 125 °C, ref. + 25 °C)
Power	0.75 W at + 25 °C derated linearly to 0 W at + 125 °C (see Fig. 2)
Settability	0.05 % typical; 0.1 % maximum
Setting Stability	0.1 % typical; 0.5 % maximum
Roll-on, Roll-off	0.25 % typical; 1.0 % maximum
Load Life Stability	0.5 % ΔR after 2000 h under full rated power at + 25 °C
End Resistance	2 Ω maximum
C.R.V. (noise) (2)	3 Ω typical; 10 Ω maximum
Frequency Characteristics	10 ns rise time at 1 kΩ to 100 MHz

Notes

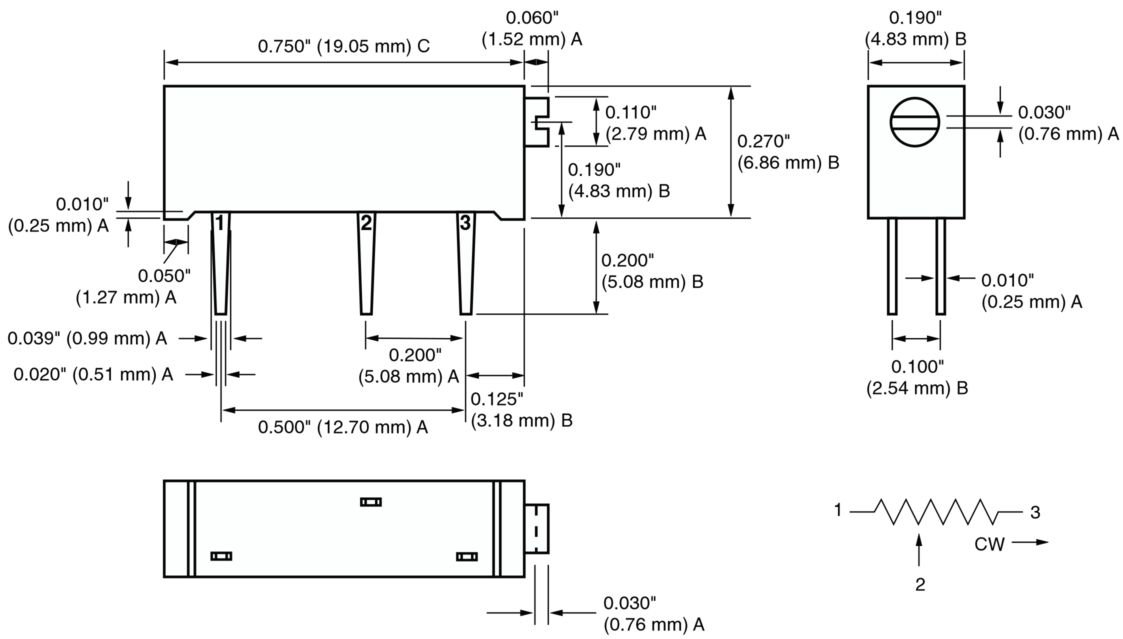
(1) 5 % available on special order
(2) The 1280G can be screened for low noise, if required
(3) For model 1285G 10 Ω and 20 Ω TCR is ± 10 ppm/°C
(4) Panel mount available on special order

TABLE 2 - STANDARD VALUE
10 Ω, 20 Ω, 50 Ω, 100 Ω, 200 Ω, 500 Ω, 1 kΩ, 2 kΩ, 5 kΩ, 10 kΩ, 20 kΩ

TABLE 3 - 1280G AND 1285G SERIES MECHANICAL SPECIFICATIONS

Adjustment Turns	26 ± 2 turns
Backlash	< 0.05 %
Stops	clutch, wiper idles
Sealed	+ 85 °C water immersion
Torque	5 oz. in. maximum
Weight	1.5 grams maximum
Construction Case Material Lead Screw Wiper Rider Block Element Lead Material	 Valox® Brass Precious metal brush Nylon Bulk Metal® Foil Gold plated phosphor bronze

FIGURE 1 - 1280G/1285G SCHEMATIC AND DIMENSIONS in Inches (Millimeters)



TOLERANCES:
A = ± 0.005" (0.13 mm)
B = ± 0.010" (0.25 mm)
C = ± 0.015" (0.38 mm)

FIGURE 2 - POWER DERATING CURVE

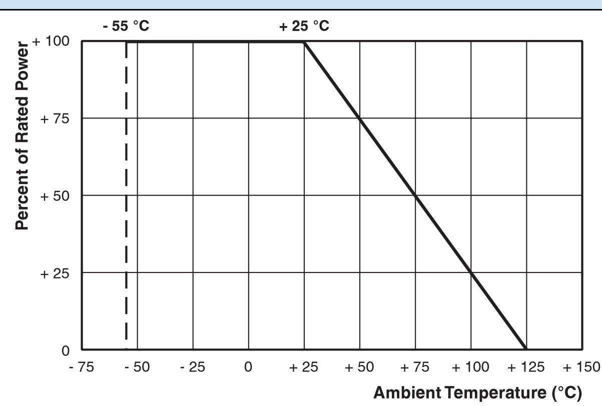


TABLE 4 - GLOBAL PART NUMBER INFORMATION

NEW GLOBAL PART NUMBER: Y0056100R000K0L (preferred part number format)

Y	0	0	5	6	1	0	0	R	0	0	0	K	0	L

DENOTES PRECISION	VALUE	CHARACTERISTICS (1)
Y	**R** = Ω **K** = kΩ	**0** = gold plated termination (lead (Pb)-free) **1 to 999** = custom

PRODUCT CODE	RESISTANCE TOLERANCE	PACKAGING
0056 = 1280G **0059** = 1285G	**J** = ± 5.0 % **K** = ± 10.0 %	**L** = foam/box pack

FOR EXAMPLE: ABOVE GLOBAL ORDER Y0056 100R000 K 0 L:

TYPE: 1280G
VALUES: 100.0 Ω
ABSOLUTE TOLERANCE: ± 10 %
TERMINATION: gold plated (lead (Pb)-free)
PACKAGING: foam/box pack

HISTORICAL PART NUMBER: 1280G 100R K (will continue to be used)

1280G	100R	K
MODEL	VALUE	TOLERANCE
1280G **1285G**	**100R** = 100 Ω	**J** = ± 5.0 % **K** = ± 10.0 %

Note

(1) For non-standard requests or additional values, please contact application engineering.

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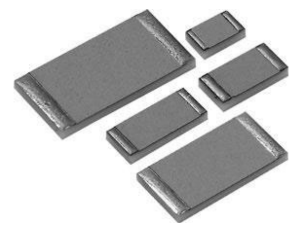
Ultra High-Precision Z-Foil Flip Chip Resistor

with TCR of ±0.2 ppm/°C, 35% Space Saving vs. Wraparound Design and PCR of 5 ppm at Rated Power



Pb-free Available
RoHS* COMPLIANT

FEATURES

- Temperature coefficient of resistance (TCR): ± 0.2 ppm/°C typical (–55°C to +125°C, +25°C ref.)
- Tolerance: to ±0.01% (100 ppm)
- Power coefficient “ΔR due to self heating” 5 ppm at rated power
- Load-life stability (70°C for 2000 h): ±0.005% (50 ppm)
- Power rating to: 600 mW at +70°C
- Electrostatic discharge (ESD): at least to 25 kV
- Resistance range: 5 Ω to 125 kΩ (for lower and higher values, please contact us)
- Bulk Metal® Foil resistors are not restricted to standard values; specific “as required” values can be supplied at no extra cost or delivery (e.g., 1K2345 vs. 1K)
- Non-inductive, non-capacitive design
- Thermal stabilization time: <1 s (within 10 ppm of steady state value)
- Short time overload: ≤0.005% (50 ppm)
- Non hot spot design
- Rise time: 1 ns effectively no ringing
- Current noise: <0.010 μV_{rms} / V of applied voltage (<–40 dB)
- Voltage coefficient: <0.1 ppm/V
- Non-inductive: <0.08 μH
- Terminal finishes available: lead (Pb)-free, tin/lead alloy
- Compliant to RoHS directive 2002/95/EC*
- Matched sets are available per request
- Rapid prototype sample quantities are available. For more information, please contact us at foil@vpgsensors.com

INTRODUCTION

Based on VFR’s Bulk Metal Z-Foil technology, the VFCP Series (foil resistor flip-chip) excels over all previous stability standards for precision resistors with an order of magnitude improvement in high-temperature stability, load-life stability, and moisture resistance. These new benchmark levels of performance provide design engineers with the tools to build circuits not previously achievable while reducing costs and space in the most critical applications by eliminating the need for corrective circuitry and reducing the large land patterns needed for a wrap-around configuration. The device’s flip-chip configuration saves up to 35% PCB space compared with a surface-mount chip with wraparound terminations while also providing better strain relief to eliminate cracked substrates and board delamination.

In addition to its remarkably improved load-life stability, the VFCP Series is noise-free and provides ESD protection of 25 kV or more for increased reliability. The device’s solid element alloy is matched to the substrate, forming a single entity with balanced resistance versus temperature characteristics for an unusually low and predictable TCR over a wide temperature range from –55°C to more than +125°C. The adhesive that holds the foil to the flat substrate withstands high temperatures, pulsing power, moisture incursions, shock and vibration, and low-temperature exposure while still holding securely to the foil element. Resistance patterns are photo-etched into the element to permit the trimming of resistance values to very tight tolerances as low as 0.01%.

The Flip Chips devices are qualified as anti-sulfurated resistors for use in environments with high levels of contamination. Such environments include alternative energy applications, industrial control systems, sensors, RTDs, electric instrumentation, weather and communication base stations, and any electronic appliance used in high concentrations of sulfur. The combination of flip-chip terminations and Z-Foil construction and materials results in the most stable resistors available, requiring the lowest error allowance. This means that more error allowance can be transferred to active devices—resulting in lower costs—or applied to the foil resistors themselves, allowing for looser initial tolerances than would be required for other resistor technologies.

RELATED VIDEO

Refer to Bulk Metal® Foil Resistor TCR Performance (Product Demo).

* This datasheet provides information about parts that are RoHS-compliant and/or parts that are non-RoHS-compliant. For example, parts with lead (Pb) terminations are not RoHS compliant. Please see the information/tables in this datasheet for details.

TABLE 1 — TOLERANCE AND TCR VS. RESISTANCE VALUE

Resistance Value (Ω)	Tolerance (%)	Typical TCR and Max. Spread (–55 °C to +125 °C, +25 °C Ref.) (ppm/°C)
250 to 125k	±0.01%	±0.2 ±1.6
100 to <250	±0.02%	±0.2 ±1.6
50 to <100	±0.05%	±0.2 ±1.8
25 to <50	±0.1%	±0.2 ±2.8
10 to <25	±0.25%	±0.2 ±2.8
5 to <10	±0.5%	±0.2 ±7.8

FIGURE 1 — POWER DERATING CURVE

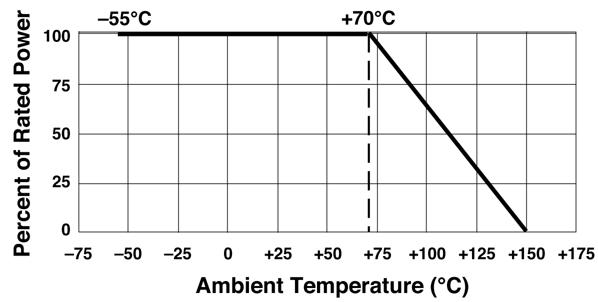
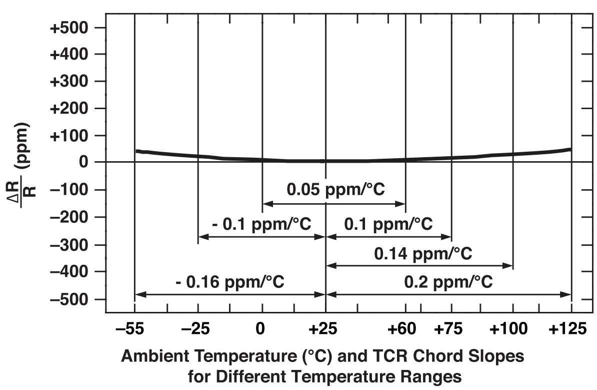


FIGURE 2 — NOMINAL RESISTANCE/TEMPERATURE CURVE

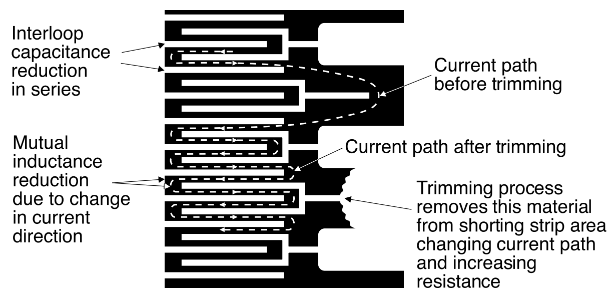


Note

The TCR values for <100 Ω are influenced by the termination composition and result in deviation from this curve.

FIGURE 3 — TRIMMING TO VALUES

(conceptual illustration)



Foil shown in black, etched spaces in white

Note

To acquire a precision resistance value, the Bulk Metal Foil chip is trimmed by selectively removing built-in "shorting bars." To increase the resistance in known increments, marked areas are cut, producing progressively smaller increases in resistance. This method reduces the effect of "hot spots" and improves the long-term stability of VFR resistors.

TABLE 2 — MODEL SELECTION

Chip Size	Rated Power at +70 °C (mW)	Maximum Voltage Rating ($\leq\sqrt{P \times R}$)	Resistance Range (Ω)	Max. Weight (mg)
0805	100 mW	28 V	5 to 8k	5.2
1206	250 mW	79 V	5 to 25k	10.3
1506	300 mW	95 V	5 to 30k	12
2010	400 mW	167 V	5 to 70k	25
2512	600 mW	220 V	5 to 125k	35

TABLE 3 — LOAD-LIFE STABILITY

(+70 °C for 2000 h)

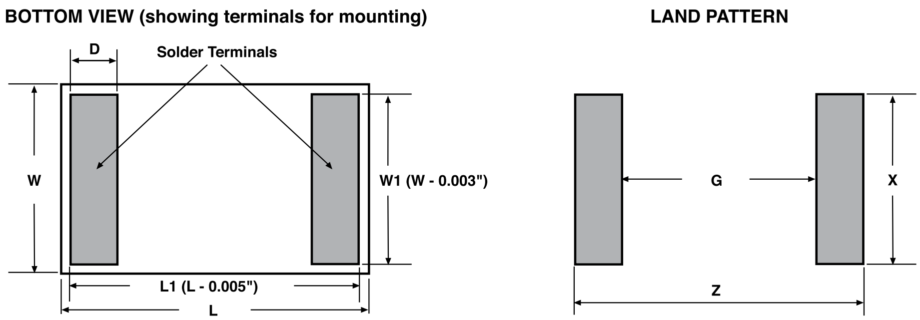
Chip Size	MAXIMUM ΔR LIMITS
0805	±0.005% at 50 mW ±0.01% at 100 mW
1206	±0.005% at 150 mW ±0.01% at 250 mW
1506	±0.005% at 150 mW ±0.01% at 300 mW
2010	±0.005% at 200 mW ±0.01% at 400 mW
2512	±0.005% at 500 mW ±0.01% at 600 mW

TABLE 4—PERFORMANCE SPECIFICATIONS

Test or Condition	MIL-PRF-55342 Characteristic E ΔR Limits	Typical ΔR Limits	Maximum ΔR Limits(1)
Thermal Shock	±0.1%	±0.005% (50 ppm)	± 0.01% (100 ppm)
Low Temperature Operation	±0.1%	±0.005% (50 ppm)	± 0.01% (100 ppm)
Short Time Overload	±0.1%	±0.005% (50 ppm)	± 0.01% (100 ppm)
High Temperature Exposure	±0.1%	±0.01% (100 ppm)	±0.02% (200 ppm)
Resistance to Soldering Heat	±0.2%	±0.005% (50 ppm)	±0.015% (150 ppm)
Moisture Resistance	±0.2%	±0.005% (50 ppm)	±0.03% (300 ppm)
Load Life Stability +70°C for 2000 hours at Rated Power	±0.5%	±0.005% (50 ppm)	±0.01% (100 ppm)

Note
(1) As shown +0.01 ohms (Ω) to allow for measurement errors at low values.

TABLE 5—DIMENSIONS AND LAND PATTERN in inches (millimeters)



Chip Size	L ±0.005 (0.13)	W ±0.005 (0.13)	Thickness Maximum	D ±0.005 (0.13)	Z	G	X
0805	0.079 (2.01)	0.049 (1.24)	0.025 (0.64)	0.010 (0.25)	0.078 (1.98)	0.053 (1.35)	0.049 (1.24)
1206	0.126 (3.20)	0.062 (1.57)	0.025 (0.64)	0.015 (0.38)	0.125 (3.18)	0.090 (2.29)	0.062 (1.57)
1506	0.150 (3.81)	0.062 (1.57)	0.025 (0.64)	0.012 (0.30)	0.150 (3.81)	0.120 (3.05)	0.062 (1.57)
2010	0.200 (5.08)	0.100 (2.54)	0.025 (0.64)	0.020 (0.51)	0.199 (5.05)	0.153 (3.89)	0.100 (2.54)
2512	0.250 (6.35)	0.126 (3.20)	0.025 (0.64)	0.024 (0.61)	0.250 (6.35)	0.196 (4.98)	0.126 (3.20)

Notes
Avoid the use of those cleaning agents that could attack epoxy resins, which form part of the resistor construction.
Vacuum pick-up is recommended for handling.
Soldering iron not recommended.

RELATED PRODUCT TRAINING MODULE

Refer to Precision Resistors—There is more to resistor precision than meets the eye.

RELATED VIDEO

Refer to Bulk Metal® Foil Resistor Accelerated Life Test (Product Demo).

HARMONIC DISTORTION

Harmonic distortion is an important consideration in the choice of precision resistors for sensitive applications. A significant signal voltage across the resistor may change the resistance value depending on the construction, material, and size. Under these conditions Bulk Metal Foil resistors behave more linearly than other resistor types.

FLOWER OF SULFUR

ASTM B 809, also known as flower of sulfur, is a test to determine the porosity of metallic coating using humid sulfur vapor. This vapor can penetrate conformal coatings and cause damage to the device when it reacts with lower layers of silver. Surface-mount Bulk Metal Foil chip resistors avoid this problem with a special coating that is proven to be reliable in extreme environments and even against sulfur. The flower of sulfur test is especially relevant to designers of circuits used in alternative energy and industrial applications, where environmental pollution is a constant concern. Analog circuitry in these applications almost always operates under severe environmental, thermal, and mechanical conditions, and must withstand frequent and extended service by professionals and novices alike. The picture is further complicated by tough regulatory restrictions and high consumer expectations. VFR received a steady stream of customer inquiries, which led to more focus on anti-sulfurated resistor research and development. As a result we have qualified our surface-mount foil chip resistors as "antisulfurated resistors." These resistors are capable of exposure to sulfurous environments without damage. Beyond alternative energy, applications include industrial control systems, sensors, RTDs, electric instrumentation, weather and communication base stations. These resistors are also suited for electronic appliances used in high concentrations of sulfur.

POWER COEFFICIENT OF RESISTANCE (PCR)

The TCR of a resistor for a given temperature range is established by measuring the resistance at two different ambient temperatures: at room temperature and in a cooling chamber or oven. The ratio of relative resistance change and temperature difference gives the slope of DR/R = f (T) curve. This slope is usually expressed in parts per million per degree Centigrade (ppm/°C). In these conditions, a uniform temperature is achieved in the measured resistance. In practice, however, the temperature rise of the resistor is also partially due to self-heating as a result of the power it is dissipating. As stipulated by the Joule effect, when current flows through a resistance, there will be an associated generation of of a heat flow and of a temperature gradient. Therefore, the TCR alone does not provide the actual resistance change for precision resistor. Hence, another metric is introduced to incorporate this inherent characteristic—the Power Coefficient of Resistance (PCR). PCR is expressed in parts per million per Watt or in ppm at rated power. In the case of Z-based Bulk Metal® Foil, the PCR is 5 ppm typical at rated power or 4 ppm per Watt typical for power resistors.

TABLE 6—GLOBAL PART NUMBER INFORMATION[(1)]

NEW GLOBAL PART NUMBER: Y163010K0000T9W (preferred part number format)

Y	1	6	3	0	1	0	K	0	0	0	0	T	9	W

DENOTES PRECISION
- **Y**

VALUE
- **R** = Ω
- **K** = kΩ

CHARACTERISTICS
- **0** = tin/lead
- **9** = lead (Pb)-free
- **1 to 999** = custom

PRODUCT CODE
- **1629** = VFCP0805
- **1630** = VFCP1206
- **1631** = VFCP1506
- **1632** = VFCP2010
- **1633** = VFCP2512

RESISTANCE TOLERANCE
- **T** = ±0.01%
- **Q** = ±0.02%
- **A** = ±0.05%
- **B** = ±0.10%
- **C** = ±0.25%
- **D** = ±0.50%
- **F** = ±1.00%

PACKAGING
- **R** = tape and reel
- **W** = waffle pack

FOR EXAMPLE: ABOVE GLOBAL ORDER Y1630 10K0000 T 9 W:

TYPE: VFCP1206
VALUE: 10.0 kΩ
ABSOLUTE TOLERANCE: ±0.01%
TERMINATION: lead (Pb)-free
PACKAGING: waffle pack

HISTORICAL PART NUMBER: VFCP1206 10K000 TCR0.2 T S W (will continue to be used)

VFCP1206	10K000	TCR0.2	T	S	W
MODEL	OHMIC VALUE	TCR	RESISTANCE TOLERANCE	TERMINATION	PACKAGING
VFCP0805 **VFCP1206** **VFCP1506** **VFCP2010** **VFCP2512**	10.0 kΩ	Characteristic	**T** = ±0.01% **Q** = ±0.02% **A** = ±0.05% **B** = ±0.10% **C** = ±0.25% **D** = ±0.50% **F** = ±1.00%	**S** = lead (Pb)-free **B** = tin/lead	**T** = tape and reel **W** = waffle pack

Note
(1) For non-standard requests, please contact Application Engineering

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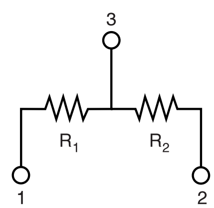
Molded, SOT-23 Thin Film Resistor, Surface Mount Divider Network

Vishay Dale Thin Film MPM Series Dividers provide ± 2 ppm/°C tracking and a ratio tolerance as tight as 0.01 %, small size, and exceptional stability for all surface mount applications. The standard SOT-23 package format with unity and common standard resistance divider ratios provide easy selection for most applications requiring matched pair resistor elements. The ratios listed are available for off the shelf delivery. If you require a non-standard ratio, consult the applications engineering group as we may be able to meet your requirements.

SCHEMATIC



FEATURES

- Excellent long term ratio stability (ΔR ± 0.015 %, 2000 h, + 70 °C)
- Ratio tolerances to ± 0.01 %
- Low TCR tracking ± 2 ppm
- Standard JEDEC TO-236 package variation AB
- Material categorization: For definitions of compliance please see www.vishay.com/doc?99912

Pb-free
RoHS*
Available
HALOGEN FREE

Note

* This datasheet provides information about parts that are RoHS-compliant and/or parts that are non-RoHS-compliant. For example, parts with lead (Pb) terminations are not RoHS-compliant. Please see the information/tables in this datasheet for details.

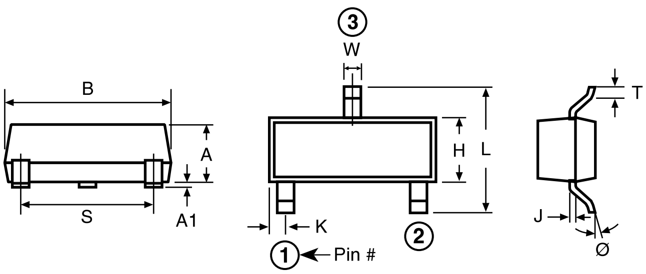
TYPICAL PERFORMANCE

●	ABSOLUTE	TRACKING
TCR	25	2
	ABSOLUTE	RATIO
TOL.	0.1	0.05

STANDARD DIVIDER RATIO (R_2/R_1)		
RATIO	R_2 (Ω)	R_1 (Ω)
100:1	100K	1K
50:1	50K	1K
25:1	25K	1K
20:1	20K	1K
10:1	10K	1K
9:1	9K	1K
6:1	6K	1K
5:1	10K	2K
5:1	5K	1K
4:1	8K	2K
4:1	4K	1K
2:1	10K	5K
2:1	2K	1K
1:1	50K	50K
1:1	25K	25K
1:1	10K	10K
1:1	5K	5K
1:1	2.5K	2.5K
1:1	1K	1K
1:1	500	500
1:1	250	250

STANDARD ELECTRICAL SPECIFICATIONS		
TEST	**SPECIFICATIONS**	**CONDITIONS**
Material	Passivated nichrome	-
Pin/Lead Number	3	-
Resistance Range	250 Ω to 100 kΩ per resistor	-
TCR: Absolute	± 25 ppm/°C	- 55 °C to + 125 °C
TCR: Tracking	± 2 ppm/°C (typical)	- 55 °C to + 125 °C
Tolerance: Absolute	± 0.05 % to ± 1.0 %	+ 25 °C
Tolerance: Ratio	± 0.01 % to 0.5 %	+ 25 °C
Power Rating: Resistor	100 mW	Maximum at + 70 °C
Power Rating: Package	200 mW	Maximum at + 70 °C
Stability: Absolute	ΔR ± 0.05 %	2000 h at + 70 °C
Stability: Ratio	ΔR ± 0.015 %	2000 h at + 70 °C
Voltage Coefficient	0.1 ppm/V	-
Working Voltage	100 V max. not to exceed $\sqrt{P \times R}$	-
Operating Temperature Range	- 55 °C to + 125 °C	-
Storage Temperature Range	- 55 °C to + 150 °C	-
Noise	< - 30 dB	-
Thermal EMF	0.2 μV/°C	-
Shelf Life Stability: Absolute	ΔR ± 0.01 %	1 year at + 25 °C
Shelf Life Stability: Ratio	ΔR ± 0.002 %	1 year at + 25 °C

DIMENSIONS AND IMPRINTING in inches and millimeters

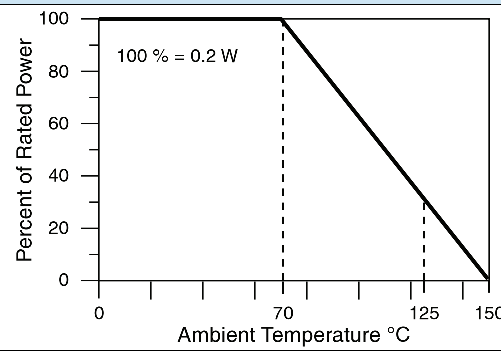


DIMENSION	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
A	0.031	0.040	0.79	1.02
A1	0.001	0.004	0.02	0.10
B	0.105	0.120	2.67	3.05
S	0.071	0.079	1.80	2.00
W	0.015	0.021	0.38	0.54
L	0.083	0.098	2.10	2.50
H	0.047	0.055	1.20	1.40
T	0.005	0.010	0.13	0.25
J	0.0035	0.0059	0.089	0.15
K	0.017	0.022	0.44	0.55
Ø	0	8°	0	8°

MECHANICAL SPECIFICATIONS

Resistive Element	Passivated nichrome
Substrate Material	Silicon
Body	Molded epoxy
Terminals	Copper alloy
Lead (Pb)-free Option	100 % matte tin
Tin Lead Option	Sn85
Tin Lead and Lead (Pb)-free Finish	Plated

DERATING CURVE



GLOBAL PART NUMBER INFORMATION

New Global Part Numbering: MPM1003AWS

	M	P	M			1	0	0	3			A	W	S
M	P	M	T	1	0	0	1	5	0	0	1	A	T	1

GLOBAL MODEL (3 or 4 digits)

MPM (Tin lead)

MPMT (Lead (Pb)-free) (e3)

RESISTANCE (4 or 8 digits)

First 3 digits are significant figures and the last digit specifies the number of zeros to follow. When like values are required use total resistance. When dual values are required list both values.

Example:
(List R_1 first in part number with dual values)
1002 = 10K (5K/5K)
1003 = 100K (50K/50K)
10011002 = 1K/10K divider

TOLERANCE AND RATIO TOLERANCE

Abs. Tol.	Ratio
A = 0.1 %	0.05 %
B = 0.1 %	0.1 %
C = 0.25 %	0.1 %
D = 0.5 %	0.1 %
F = 1 %	0.5 %
Z = 0.1 % (1)	0.025 %
Q = 0.05 % (1)	0.01 %

PACKAGING

BS = BULK 100 min., 1 mult
WS = WAFFLE 100 min., 1 mult

TAPE AND REEL
T0 = 100 min., 100 mult
T1 = 1000 min., 1000 mult (2)
T3 = 300 min., 300 mult
T5 = 500 min., 500 mult
TF = Full reel 4000
TS = 100 min., 1 mult

Historical Part Number example: MPM1002BW (for reference purposes only)

MPM	1002	B	W
SERIES	RESISTANCE	TOLERANCE AND RATIO TOLERANCE	PACKAGING

Notes
(1) Tol. available 1K and up equal values only
(2) Preferred packaging code

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220 SERIES OCXO

AS9100 / ISO9001 Certified

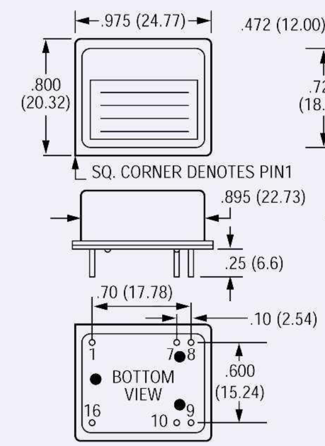
High Frequency

The 220 Series Oven Controlled Crystal Oscillator (OCXO) is an ideal solution for a variety of applications. The standard 220 model is a great fit for most of your commercial applications. The 220 is also available in both rugged as well as low-g versions that are perfect for your military applications. In addition, MTI has an extensive heritage with the 220 series OCXO utilizing swept quartz for space flight applications. The 220 Series is now available up to 500 MHz.

Key Features

- Wide frequency range (up to 500MHz)
- Fast Warm-up
- Low Phase Noise
- Hermetically Sealed Package
- AT and SC Crystal Cuts Available
- Surface Mount Package Available
- Available in Space Flight Version
- Meets Stratum III, IIIe Requirements

Interface Control Drawing



PIN ASSIGNMENTS	
NUM	FUNCTION
1	ELEC TUNING IN
7	REF VOLTAGE O/P
8	OVEN GROUND
9	RF RET, GND
10	RF OUTPUT
16	SUPPLY VOLTAGE

Applications

- Base Stations
- Instrumentation
- GPS Receivers
- Stratum IIIe Performance
- Rack Mounted App
- Test Equipment
- V-SAT Terminals

Typical Performance

Parameter	10 MHz	100MHz	500MHz
Thermal Stability	2.0E-08	5.00E-07	5.0E-07
Phase Noise @ 1Hz	-85dBc/Hz	-50dBc/Hz	-45dBc/Hz
Phase Noise @ 100kHz	-155dBc/Hz	-150dBc/Hz	-150dBc/Hz
Short Term Stability (1s)	1.0E-11	1.0E-08	1.0E-08
Short Term Stability (10s)	5.0E-11	5.0E-08	5.0E-08
Output Level	+9dBm	+9dBm	+11.5dBm

Performance Range

Parameter	Available Range
Frequency	5MHz to 500MHz
Thermal Stability	2.0E-08 to 5.0E-08
Operating Temperature	-40°C to +85°C
Aging (per year)	1.0E-07 to 1.0E-06
Supply Voltage	3.3V to 15.0V(DC)
Supply Voltage Sensitivity	5.0E-09 to 1.0E-07
Output	Sine, HCMOS
Harmonics	-20dBc
Spurious	-80dBc
Warm-up Time	5.0E-09 in 3 minutes
Warm-up Power	3.0W to 5.3W
Continuous Power	0.8W to 2.4W
Tuning Range	1.2E-06 to 5.0E-06
Tuning Voltage	0.0V to 10.0V

*Parameters can be modified to meet specific application requirements

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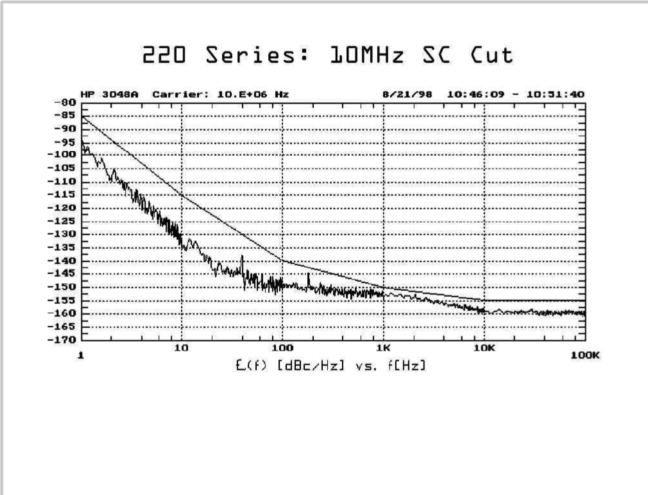
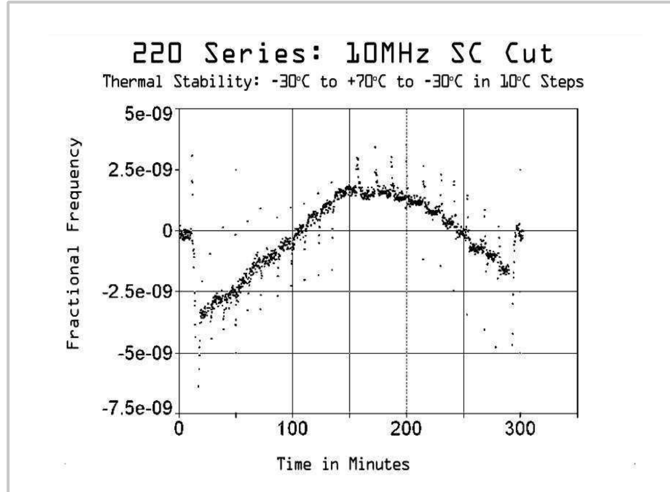
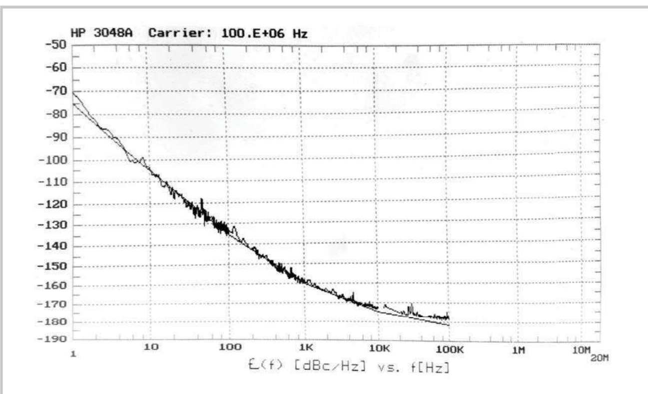
Phase Noise



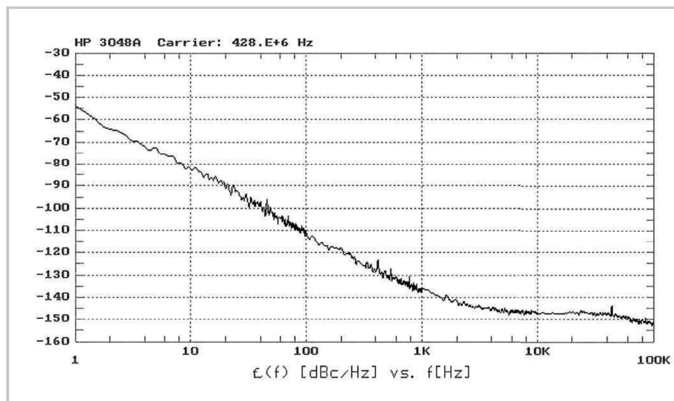
Thermal Stability



100MHz Ultra Low Phase Noise



428MHz High Frequency / Low Phase Noise



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220 SERIES OCXO

AS9100 / ISO9001 Certified

Hi-Rel

MTI-Milliren Technologies, Inc. offers a high relialibility Oven Controlled Crystal Oscillator (OCXO) to defense and aerospace OEM's with the 220 Series now available with integrated pyro-shock isolation in a 1/3 cubic inch hermetically sealed package. Designed to withstand the most demanding flight environments, the 220 Series has been tested and has survived multiple 1000g shocks as well as random acceleration of 24g rms up to 2kHz without degradation in performance (Post Launch).

The 220 Series is available nuclear hardened to tactical levels for Prompt Dose Gamma, Neutron and space flight levels for Total Dose Gamma exposures as well as Heavy Ion with no latch-up behavior. The 220 Series maintains a lengthy heritage from MTI's proven space flight technology and is available in a frequency range of 5MHz to 200MHz with thermal stability performance of ±1.0E-08 from –54°C to +85°C at 10MHz. This rugged precision OCXO is ideal for Space and Airborne environments.

Key Features

Output Frequency: 10.000MHz
Thermal Stability: ±1.0E-08
Temperature Range: -54°C to +85°C
Frequency Tolerance: ±1.0E-07 @ +25°C
Daily Aging: 1.0E-09/day after 24 Hours Continuous Operation
Mechanical Tuning: ±1.2E-06
Warm Up: 1.0E-08 after 3 Minutes referenced to 30 Minutes @ -40°C
Oven Supply Voltage and Power: 20VDC +/-5%; 7.5W Warm-up, 1.8W continuous at -40°C
Oscillator Supply Voltage and Power: 10 to 16VDC; 0.2W Max.
Output Power: +1dBm ±2dB
Short Term Stability: 5.0E-12 at 1 Second

Spurious: -80dBc
Harmonics: -25dBc
Phase Noise:

Offset	Level
10Hz	-125dBc/Hz
100Hz	-145dBc/Hz
1000Hz	-150dBc/Hz
10000Hz	-155dBc/Hz

Environmental

Shock: MIL-STD-202 Method 213 Test Condition I (1000g, 3 Milliseconds, 1/2 Sine).
Vibration: MIL-STD-202, Method 204, Test Condition G, Sine, (0.06 Inch Double Amplitude From 10-100Hz, 30g from 100-2000Hz.) MIL-STD-202 Method 214, Random, 10 – 2000Hz up to 24g rms any axis 120min/axis.
Salt Spray: MIL-STD-202, Method 101, Test Condition B.
Hermetic Seal: MIL-STD-202 Method 112, Test Condition D (Fine Leak)
Altitude: Space environment, <1E-6 Torr, Airborne to 80kft
Radiation Hardened: Gamma, X-Ray, Neutron, Prompt and Total Dose (Consult Sales, TD (STD)=50KRadSi)
Package: Dimensions 0.975" (24.8mm)X 0.800" (20.3mm)X 0.500" (12.7mm) Max
Weight: 13gm Max.
Case Material: Passivated Stainless Steel Cover, Electroless Nickel Plated CRS Steel Base , Glass Seals, Kovar Pins, Electroless Nickel Plated Base
Screening Level: MIL-PRF-55310 Class B, Class S, Per Customer SCD, as required.

*RoHS compliant available

*Parameters can be modified to meet specific requirements

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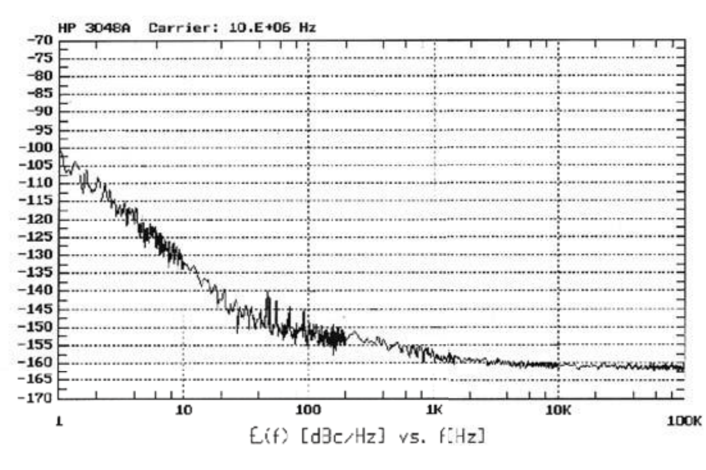
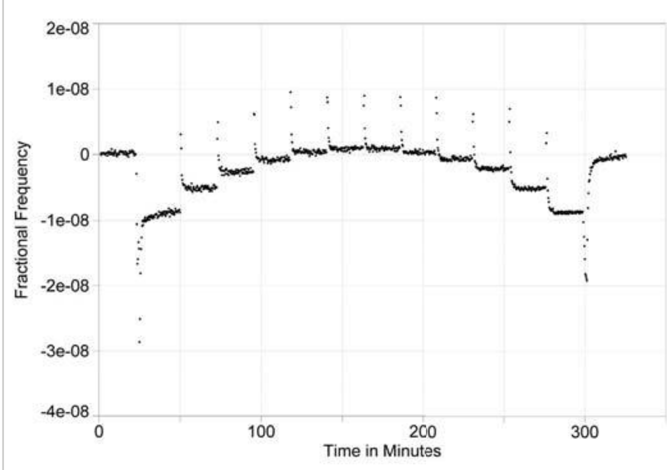
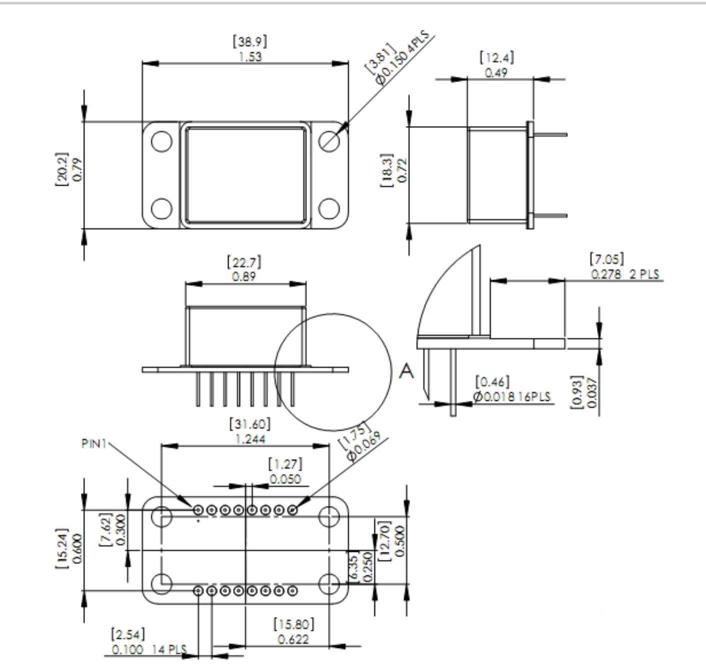
Phase Noise



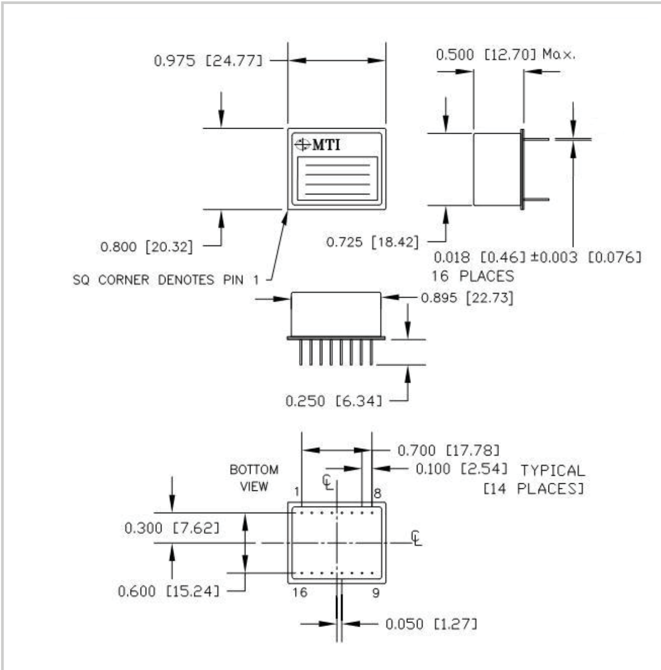
Frequency vs. Temperature (-40 ° C to 80 ° C)



220 Series Flange Mount Interface Drawing



220 Series PCB Pin Mount Interface Drawing



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220 SERIES OCXO

AS9100 / ISO9001 Certified

Space

MTI-Milliren Technologies, Inc. offers the ultra compact 220 series Oven Controlled Crystal Oscillator for aerospace applications. The 220 series maintains a lengthy heritage from MTI's proven space flight technology and is available in a frequency range from 5MHz to 200MHz. The 220 Series is available nuclear hardened to tactical levels for Prompt Dose Gamma, Neutron and to space flight levels for Total Dose Gamma exposures as well as Heavy Ion with no latch up behavior. This hermetically sealed, precision OCXO is ideal for Space flight applications. This part is fully assembled and tested in the USA.

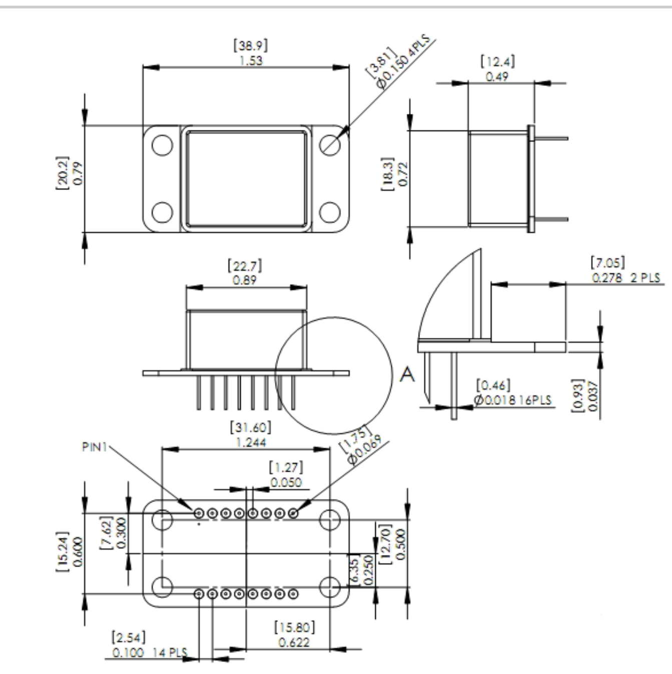
Typical Performance (@10MHz)

- **Thermal Stability:** ±1.0E-08 over -40°C to +75°C
- **Daily Aging:** 1.0E-09/day after 24 Hours Continuous Operation
- **Short Term Stability:** 5.0E-12 at 1 Second
- **Phase Noise:** -85dBc/Hz @1 Hz Offset, -155dBc/Hz @ 100kHz Offset
- **Warm Up:** 1.0E-08 after 3 Minutes referenced to 30 Minutes @ -40°C
- **Continuous Power:** 2.0W Max
- **Output:** Sinewave +7dBm, ±2dB

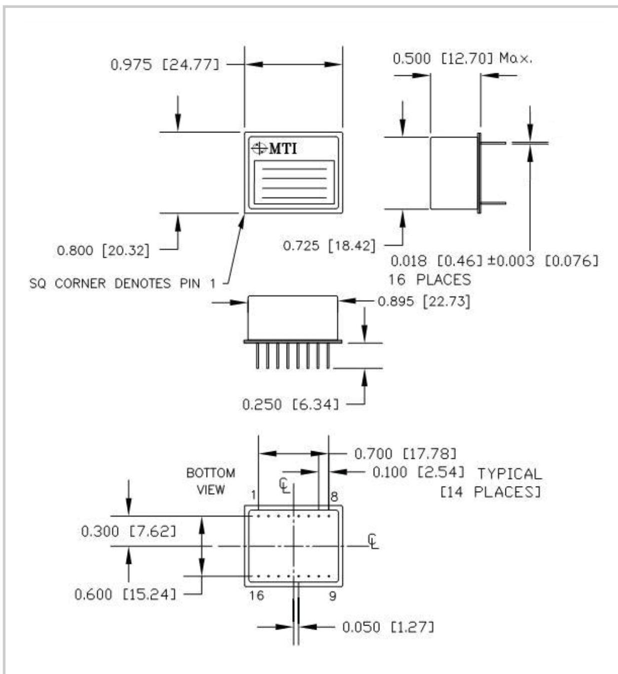
Key Features

- **Low Component Count**
- **Ultra Compact**
- **Light Weight**
- **Radiation Hardened**
- **Wide Frequency Range**
- **Significant Heritage**

220 Series Flange Mount Interface Drawing



220 Series PCB Pin Mount Interface Drawing



*RoHS compliant available

*Parameters can be modified to meet specific requirements

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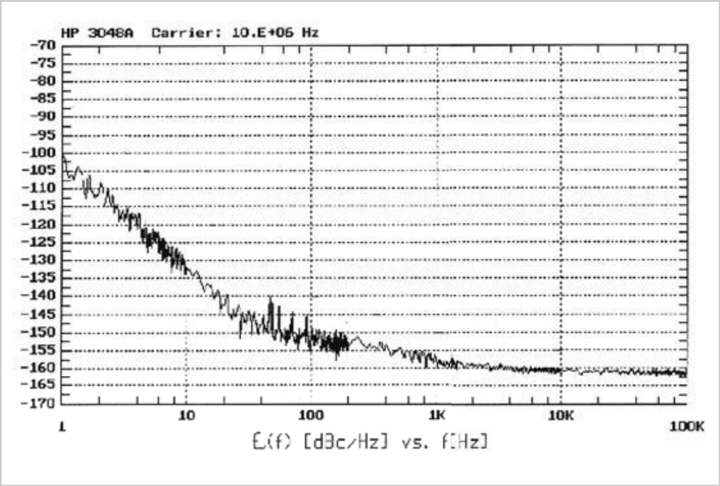
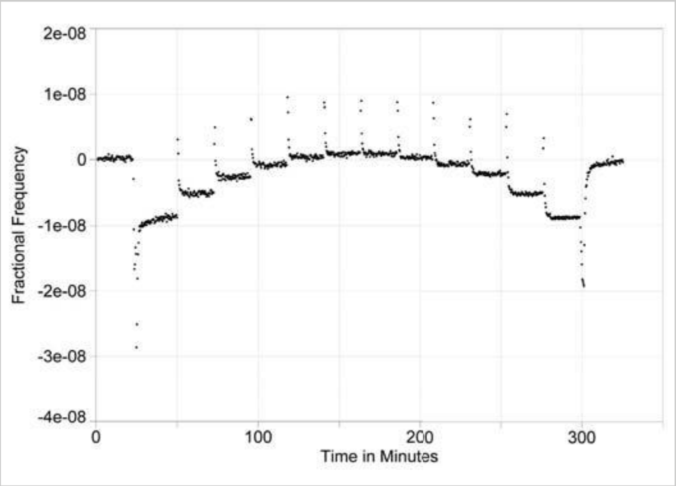
Phase Noise



Frequency vs. Temperature (-40 ° C to 75 ° C)



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