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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

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[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.

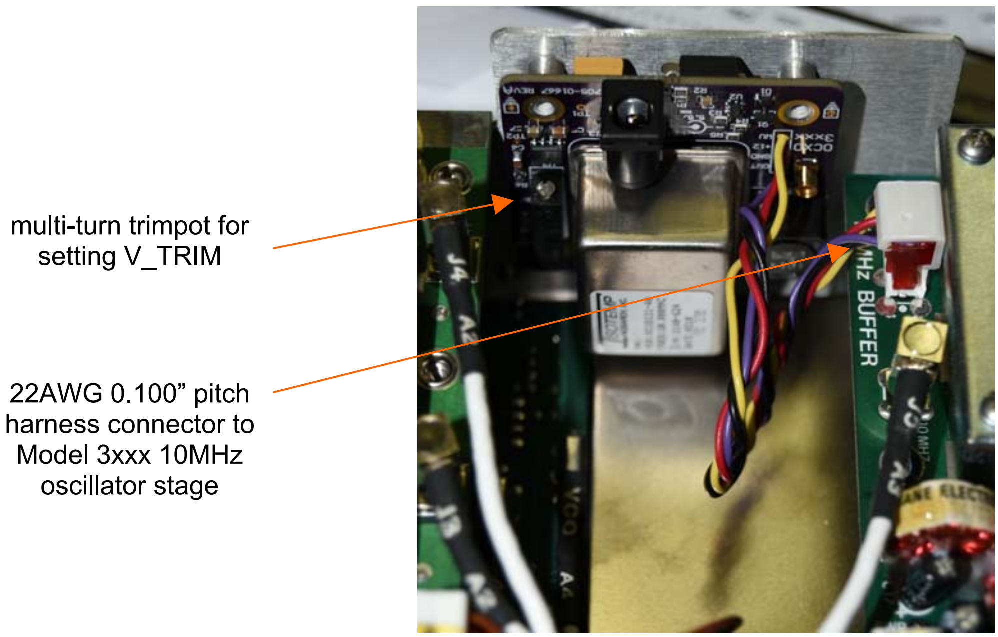

Figure 6: OCXO PCB assembly installed in Model 3xxx

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.

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[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.

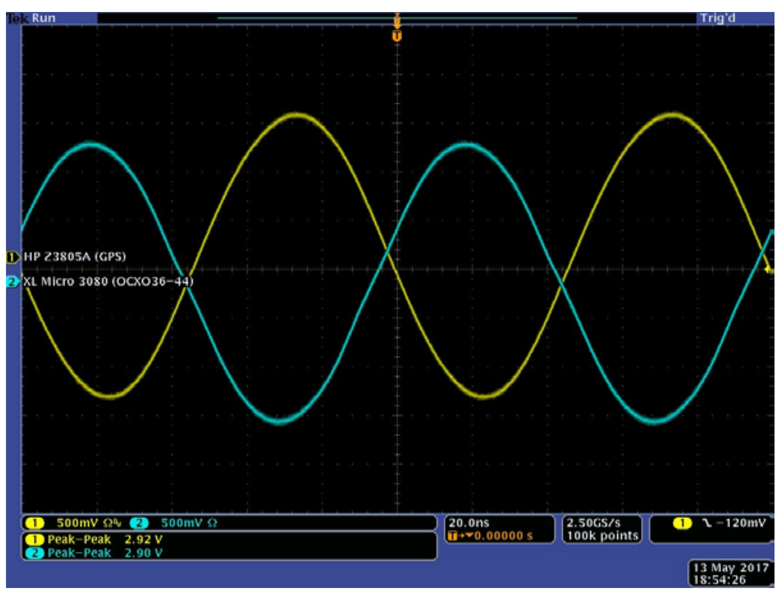


Figure 8: OCXO36-44 waveform (blue) compared to Z3805A GPS-disciplined waveform (yellow)

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

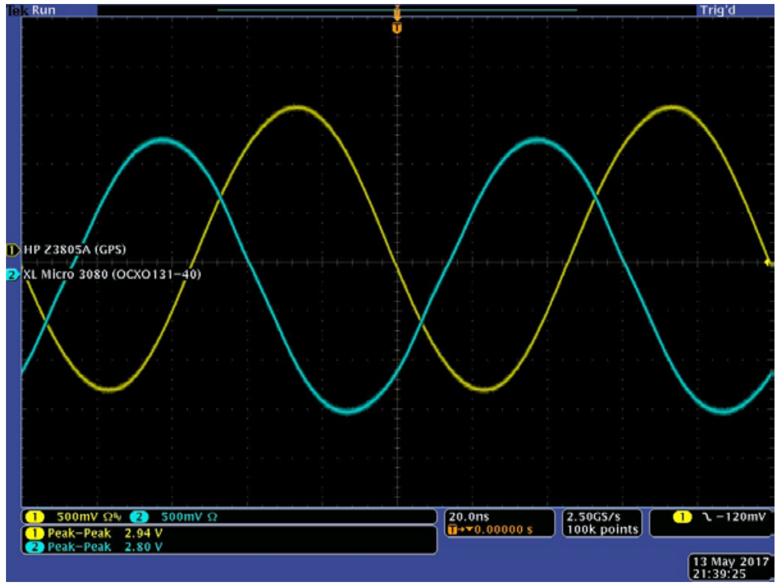


Figure 9: OCXO131-40 waveform (blue) compared to Z3805A GPS-disciplined waveform (yellow)

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.

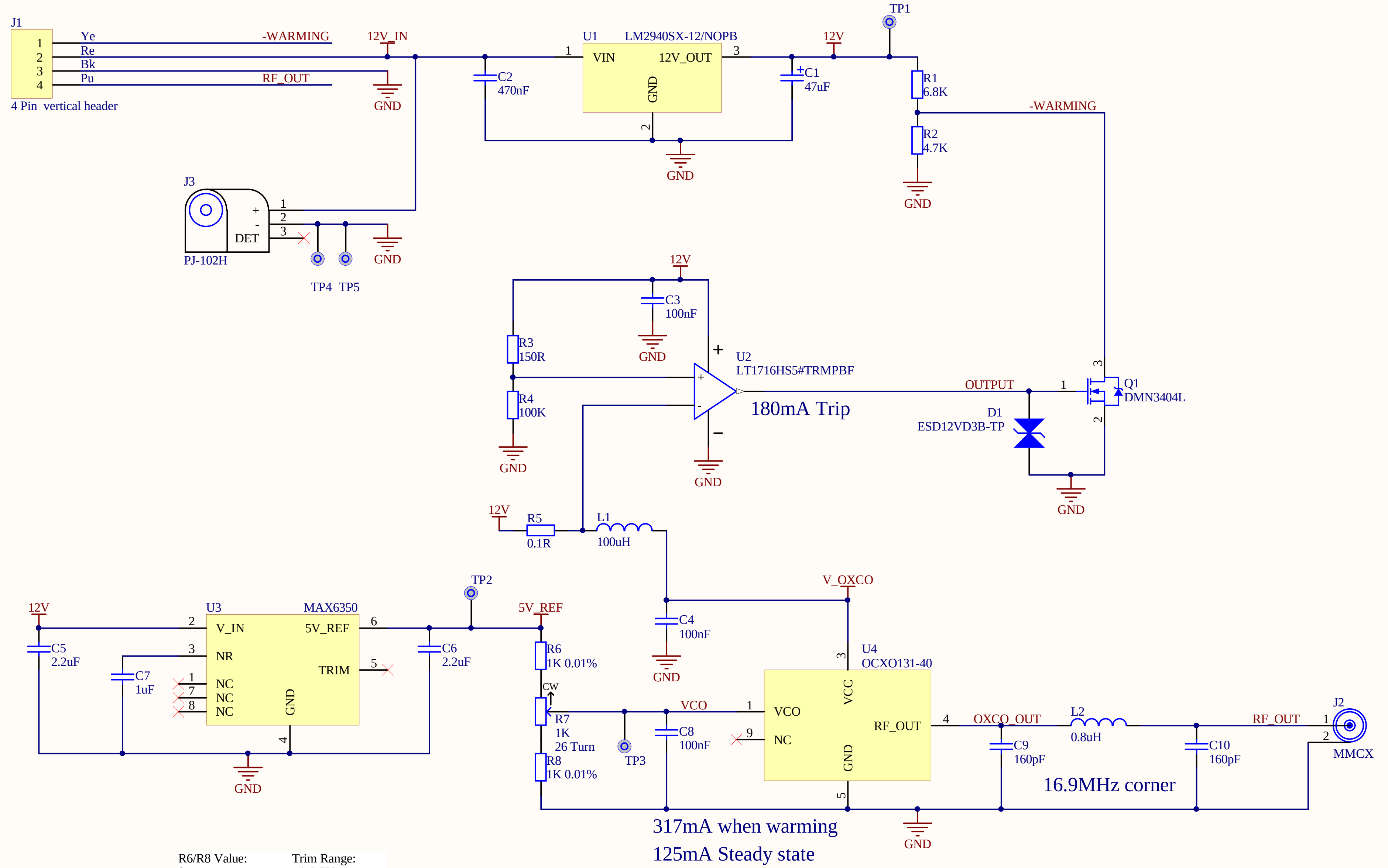
[12] Interestingly, MTI now offers the 220-series OCXO in standard, hi-rel and space versions.

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

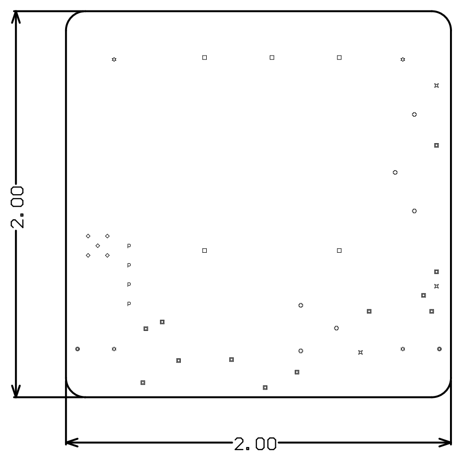
PUMPKIN INCORPORATED
750 Naples Street
San Francisco, California 94112

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	

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

Doc. Rev: 01

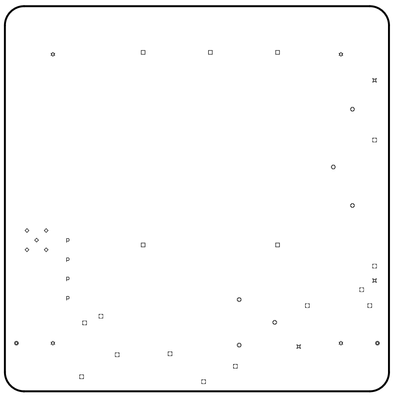
01667A Mechanical Drawing
Drill Drawing



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

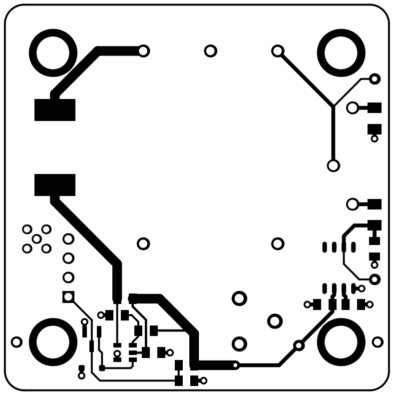
Symbol	Count	Hole Size	Plated	Hole Type
⧈	12	19.69mil (0.500mm)	PTH	Round
⌑	3	27.56mil (0.700mm)	PTH	Round
◇	5	33.07mil (0.840mm)	PTH	Round
◎	2	37.00mil (0.940mm)	PTH	Round
P	4	40.16mil (1.020mm)	PTH	Round
□	5	43.31mil (1.100mm)	PTH	Round
✤	6	47.24mil (1.200mm)	PTH	Round
✡	4	170.00mil (4.318mm)	PTH	Round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

01667A
Drill Drawing

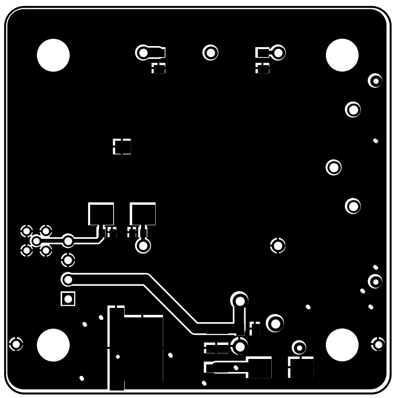


Symbol	Count	Hole Size	Plated	Hole Type
◘	12	19.69mil (0.500mm)	PTH	Round
⌑	3	27.56mil (0.700mm)	PTH	Round
◇	5	33.07mil (0.840mm)	PTH	Round
◎	2	37.00mil (0.940mm)	PTH	Round
P	4	40.16mil (1.020mm)	PTH	Round
□	5	43.31mil (1.100mm)	PTH	Round
✣	6	47.24mil (1.200mm)	PTH	Round
✡	4	170.00mil (4.318mm)	PTH	Round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

01667A Layer 1 (TOP)

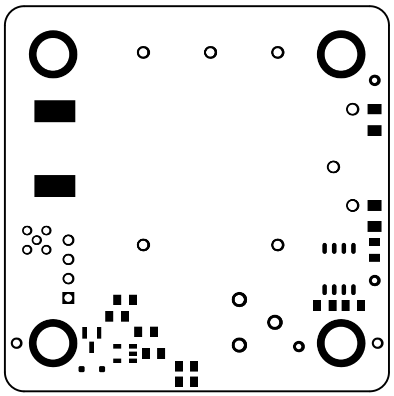


01667A Layer 4 (BOTTOM)



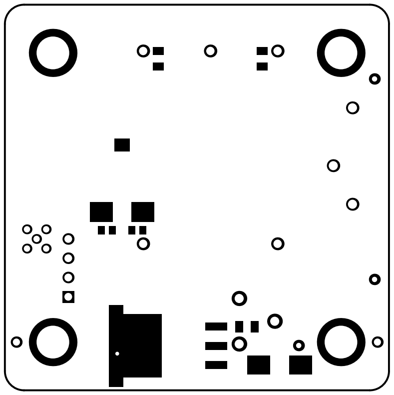
01667A

Top Soldermask

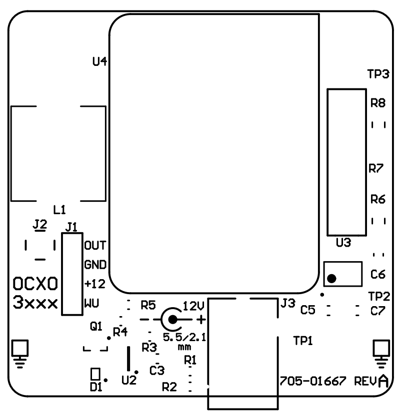


01667A

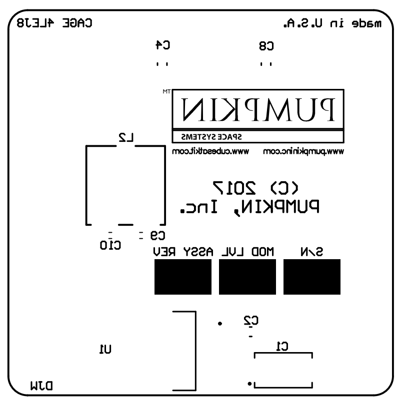
Bottom Soldermask



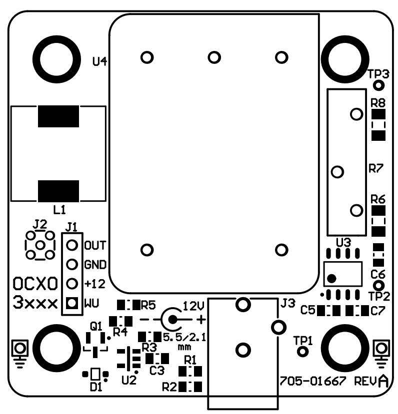
01667A Top Silkscreen



01667A Bottom Silkscreen



01667A Top Silkscreen
Top Soldermask



01667A Bottom Silkscreen
Bottom Soldermask