OCXO AND CLOCK DISTRIBUTION SYSTEM

As used with VE2ZAZ Controller

Jacques Audet VE2AZX
June 2011
Rev. Jan 2013
Circuit added to provide 1 e-11 tuning resolution with +/- 5 V tuning on VE2ZAZ Controller. It also attenuates and offsets the +/- 5V control voltage to the 0 to +5V range required by the MV89A. The 10K pot allows centering the OCXO at exactly 10 MHz with 0V at the V1 input. This decreases the control voltage dependence on supply variations in the GPS controller.
**MV89A MEASUREMENTS**

<table>
<thead>
<tr>
<th>Vc</th>
<th>Freq * 200</th>
<th>Freq (Hz) ref. @ 10 MHz</th>
<th>SLOPE Hz / V</th>
<th>mV into 1K</th>
<th>Zin at Vc in</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-1769.3</td>
<td>-3.8465</td>
<td>1.471</td>
<td>42.70</td>
<td>57173</td>
</tr>
<tr>
<td>2.484</td>
<td>-1021.2</td>
<td>-0.106</td>
<td></td>
<td>4.04</td>
<td>57433</td>
</tr>
<tr>
<td>5.02</td>
<td>-292.4</td>
<td>3.538</td>
<td></td>
<td>43.40</td>
<td></td>
</tr>
</tbody>
</table>

**OCXO Average Zin** 57303

**Circuit added to provide 1 e -11 tuning resolution with +/- 5 V tuning on VE2ZAZ Controller**

With V1 = 0 The 10K pot gives:
Vc min / max = 2.115 / 3.021 V
Delta V = 0.906V or 1.333 Hz frequency adjustment range.

With 10K pot at middle and with V1 min / max = -4.5 / +4.5 V, we get:
Vc min / max = 2.054 / 3.074 V
Delta V = 1.02 V or 1.5 Hz frequency adjustment range.

VE2ZAZ's controller has 14 bits resolution or 16384 levels. Then the corresponding freq resolution = 1.5 Hz / 16384 = 91.5 uHz. At 10 MHz, this is 9.15 e -12 resolution, or approx. 1e-11 resolution.
ZFSC- 8-1

QB-188

MATCHING CKT

+16 V IN

GND

IN

OUT

+12 V REG

MV89A

OCXO

Vctrl

10 MHz

Adj

Cabinet: Hammond 1455T1601

X 2.529
POWER OCXO & CLOCK DISTRIBUTION

OUTPUTS
10 MHz
+ 12 dBm
ISOLATION OUT 1 TO OUT 2
ISOLATION OUT 1 TO OUT 4

START 1.000 000 MHz

STOP 100.000 000 MHz
ISOLATION OUT 1 TO OUT 8
S11 AT HI-PASS MATCHING OUTPUT

MARKER 1

10 MHz

START 9.000 000 MHz
STDP 11.000 000 MHz
S11 AT HI-PASS MATCHING OUTPUT
Scaling and Frequency Adjust Circuit
MV89A Homemade PCB
Completed System

MV89A

8 to 1 Splitter

Supply Filter

Matching

Amplifier

Completed System
Rear View

Without Controller, Vc IN is shorted
OUTDOOR GPS ANTENNA

- PVC Pipe 1¼ in.
- PVC Adapter 3 in. to 1½ in.
- PVC Adapter 1½ in to 1¼ in.
- 3 in Pipe CAP
  Note added short length of pipe inside
- Galvanized Steel Plate
  To hold the GPS Antenna
- Bulkhead Feedthru
  SMA to N
Bulkhead Feedthru
SMA to N Mounted on PVC Adapter
1 ½ in to 1 ¾ in.

PVC Adapter 3 in. to 1 ½ in.
and SMA to N
Bulkhead Feedthru
GPS Antenna with a short length of RG-174 mounts on top of PVC adapter 3 in. to 1 1/2 in.

Completed Antenna attached to the Roof Side
A NEW HIGH STABILITY DOCXO.
STATISTICS OF THE RESULTS OF FREQUENCY STABILITY MEASUREMENTS.

By S.V.Anastasiev, A.A.Volkov, Y.L.Vorokhovsky, Morion, Inc, Phone: 7-812-350-9565; Fax: 7-812-350-7290; St.Petersburg, Russia

SUMMARY

Recently the significant increase of demand for Ultra Stable Quartz Oscillators has been evidenced. Such oscillators are used for many applications including CDMA, GPS/GLONASS, etc. The following major requirements are usually applied for these oscillators: frequency stability vs. Temperature changes of +/- (1..2)*10^-10; long term stability of +/- (1..2)*10^-8/year; short term stability of <5*10^-12 for time intervals of 1 through 100 seconds. As the world experience shows, very tight combinations of requirements can be met in Double Oven crystal oscillator (DOCXO). However, development, production and measurement of such DOCXOs is a quite technically complicated task.

In the R&D laboratory of the Morion, Inc. the design of DOCXO was made with parameters satisfying the above mentioned requirements. Also the process of serial production of such DOCXOs has been worked out.

The major parameters of MV89 type DOCXO:
Nominal frequency: 4.096; 5.0; 8.192; 10.0 MHz
Frequency stability in operating temperature range of -20..+70 °C: ±1.0*10^-10; ±1.5*10^-10; ±2.0*10^-10;
Aging per day: ±1.0*10^-10;
Short-term stability for 1..100 s: <5*10^-12;
Output level: >0 dBm into 50 Ohms load;
Power consumption: <3.5 W (steady state @ 25°C);
Dimensions: 2”*2”*1.5” (50.8*50.8*38mm).

The design of DOCXO is based on previous designs of Morion's precision oscillators and takes into account the modernizing of existing technology.

A new DOCXO has two modifications: MV89A with standard frequencies 8.192, 10 MHz and MV89B – 4.096 and 5.0 MHz. MV89A differs from MV89B by presence of frequency doubler. High quality SC-cut crystals in cold weld package HC40 are used in both modifications. Long term stability of
most of these crystals is enough to meet the specification requirements in serial production.

DOCXO consists of three main parts:
- inner oven with a crystal, oscillator circuitry and VCO;
- outer oven with a thermocontroller of inner oven and reference voltage regulator;
- base plate with a thermocontroller of outer oven and buffer amplifier.

This structure is mounted in hermetically sealed metal case with standard pin-out.

MAIN CHARACTERISTICS OF FREQUENCY STABILITY

Temperature stability.

Frequency stability in ambient temperature range depends on stability of an average temperature of crystal and stability of temperature gradients in the crystal blank. In double oven structure it is possible to achieve the stability of crystal temperature approximately $0.01^\circ\text{C}$. Calculated temperature gradients are about $0.1^\circ\text{C}$. It is important to maintain the temperature of oscillator circuit constant to avoid frequency deviation caused by changing of components characteristics. Achieved frequency stability in ambient temperature range $-40^\circ\text{C} \div 75^\circ\text{C}$ for MV89 is shown in Fig.1.
Statistical data shows that 70% of total quantity produced meet $\pm2\times10^{-10}$ in temperature range $-40^\circ C \div +75^\circ C$ 90% meet $\pm2\times10^{-10}$ in temperature range $-10^\circ C \div +70^\circ C$. And about 85% meet $\pm1\times10^{-10}$ vs. temperature $-10 \div +70^\circ C$. 

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**Fig.1.**

<table>
<thead>
<tr>
<th>T. °C</th>
<th>Frequency, MHz</th>
<th>Dev. ppb</th>
<th>I mA</th>
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<tr>
<td>-40</td>
<td>9 999 999 992 278</td>
<td>-0.008 900</td>
<td>712.30</td>
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<tr>
<td>-20</td>
<td>9 999 999 992 207</td>
<td>-0.016 800</td>
<td>587.90</td>
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<td>0</td>
<td>9 999 999 992 136</td>
<td>-0.024 700</td>
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<td>10</td>
<td>9 999 999 992 065</td>
<td>-0.031 600</td>
<td>461.30</td>
</tr>
<tr>
<td>20</td>
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<td>0.000 000</td>
<td>318.90</td>
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<tr>
<td>30</td>
<td>9 999 999 992 286</td>
<td>0.008 100</td>
<td>204.85</td>
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<tr>
<td>40</td>
<td>9 999 999 992 200</td>
<td>-0.016 700</td>
<td>120.85</td>
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<tr>
<td>50</td>
<td>9 999 999 992 174</td>
<td>-0.002 000</td>
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<tr>
<td>60</td>
<td>9 999 999 992 521</td>
<td>0.015 400</td>
<td>46.14</td>
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<table>
<thead>
<tr>
<th>Checkpoint type</th>
<th>Value</th>
<th>Limit</th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Input 20.601</td>
<td>0.031 200</td>
<td>&lt; Tpb</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Input 40.753</td>
<td>0.046 600</td>
<td>&lt; Tpb</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Input 20.703</td>
<td>0.033 200</td>
<td>&lt; Tpb</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Input 11.700</td>
<td>0.031 200</td>
<td>&lt; Tpb</td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

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635
Long term stability.

Fig. 2 shows typical frequency vs. time characteristic of MV89.

Long term stability mainly defined by the quality of crystal. More than 80% of crystals used in MV89 meet $\pm 2 \times 10^{-10}$/day and 70% meet $\pm 1 \times 10^{-10}$/day. Those DOCXO reliably have according long term stability in 1st year $\leq \pm 2 \times 10^{-8}$ and $\leq \pm 1 \times 10^{-8}$. They may be reliably delivered for very tight requirements like $\leq \pm 5 \times 10^{-8}$ for 10 years of operation.
Short term stability.

Fig. 3 shows typical Allan variance characteristic of MV89.

Allan Deviation $\sigma_y(\tau)$

![Allan Deviation graph]

- Ch A: 10.0 MHz 1.1 Vpp
- Ch B: 10.0 MHz 0.8 Vpp
- Instantaneous Phase
- B/A=Single DDS

Statistical data shows that 90% of total quantity meet Allan variance for average time interval
- 1s – $2 \times 10^{-12}$
- 10s – $3.5 \times 10^{-12}$
- 100s – $5.5 \times 10^{-12}$
Phase noise.

Fig. 4 shows the typical phase noise plot of MV89A 10 MHz.

Statistical data: more than 98% of total quantity of MV89A units meet phase noise:
- at offset 1 Hz: -100 dBc
- 10 Hz: -130 dBc
- 100 Hz: -145 dBc
- 1000 Hz: -150 dBc

CONCLUSION

The introduced DOCXO is being produced at Morion, Inc. Now our R&D department is working out a new DOCXO with a reduced height and low power consumption.
DOUBLE OVEN ULTRA PRECISION OCXO MV89

Features:
- Frequency range 4.096 - 10.0 MHz
- Very high stability vs. temperature - up to ±5x10⁻¹¹
- Very low aging - up to ±5x10⁻⁹/year
- Not sensitive for rapid changes of ambient temperature
- Ideal for GPS, CDMA, 3G applications

ORDERING GUIDE: MV89 – B 01 E – 10.0 MHz

<table>
<thead>
<tr>
<th>Availability of certain stability vs. operating temperature range</th>
<th>±3x10⁻¹⁰</th>
<th>±2x10⁻¹⁰</th>
<th>±1x10⁻¹⁰</th>
<th>±5x10⁻¹¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>A 0…+55 °C</td>
<td>03</td>
<td>02</td>
<td>01</td>
<td>005</td>
</tr>
<tr>
<td>B -10…+60 °C</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>C</td>
</tr>
<tr>
<td>C -20…+70 °C</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>C</td>
</tr>
<tr>
<td>D -40…+70 °C</td>
<td>A</td>
<td>A</td>
<td>C</td>
<td>NA</td>
</tr>
</tbody>
</table>

A – available, NA – not available, C – consult factory
For other temperature ranges see designation at the end of Data Sheet

Package drawing:

Mechanical characteristics:

- Vibrations:
  - Frequency range: 1-200 Hz
  - Acceleration: 5g
- Shock:
  - Acceleration: 150 g
  - Duration: 3±1 ms
- Storage temperature range: -55…+80 °C

ADDITIONAL NOTES:
- Showed values of frequency stability vs. temperature usually are tested in Still Air test conditions. Please inform factory about different conditions in operation to provide appropriate tests.
- Please consult factory for daily aging values. Normally typical correspondence of daily aging per day to aging per year is as following: ±5x10⁻⁸/year - ±5x10⁻¹⁰/day; ±3x10⁻⁸/year - ±3x10⁻¹⁰/day; ±2x10⁻⁸/year - ±2x10⁻¹⁰/day; ±1x10⁻⁸/year - ±1x10⁻¹⁰/day.
- For non standard operating temperature ranges please use the following two letters designations (first letter for the lower limit, second letter for the upper limit), °C:

| A | B | C | D | E | F | G | H | J | K | L | M | N | P | Q | R | S | T | U | W | X |
| -60 | -55 | -50 | -45 | -40 | -30 | -20 | -10 | 0 | +10 | +30 | +40 | +45 | +50 | +55 | +60 | +65 | +70 | +75 | +80 | +85 |

Due to continuous development and improvement Morion, Inc. reserves the right to modify design or specifications of its products without prior notice

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