622.08MHz SMD-VCXO with filter

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Abstract

This paper describes the 622.08MHz SMD-VCXO, developed for optical transmission applications.

By applying the WDM (Wavelength Division Multiplexing) technology, it is possible to transmit large volume data. The CDR (Clock Data Recovery) must be connected with each wavelength signal is required to be smaller and lower height by system case size restriction. To transmit the data in high speed, high clock frequency is required. And the jitter that causes the transmission error must be reducing.

In the oscillator, fundamental mode 155.52MHz is oscillated, and 622.08MHz, which is the 4^{th} harmonics, is selected through the band pass filter instead of the conventional resonant circuit. This SMD-VCXO miniaturized by such a circuit construction. We confirmed that all the target specifications were achieved and jitter was achieved 0.01UI (Unit Interval) max.

Introduction

Today the Internet has become essential global communication system and the Internet users are glowing dynamically in the world. In the business world and in the private life at any time they like they access, search and utilize the information with large volume data including the moving pictures. Thus to sustain such large information exchange through the Internet, it is required to the infrastructure to have large volume transmission capability and high transmission speed. Also they should be transmission error free.

It is possible to transmit large volume data explosively by applying the WDM technology. This technology is to send many different wavelength optical signals in one optical fiber cable, taking advantage of the fact that different wavelength optical signals do not interfere with one another.

Although one CDR device is connected to each fiber-optic signal, many signals on multiple wavelengths are sent along a single fiber-optic cable, which increases the number of CDRs in comparison with previous devices. If we further combine multiple fiber-optic cables, then the number of CDR devices increases over ten times.

Because the cabinet for installing CDR has restriction of space, the subject is how to install the CDR that increased. As for CDR, it is required to a miniaturization, in order to narrow the interval of PCB and to perform high-density mounting. And the VCXO, as the clock source, must of course also be smaller and thinner.

The clock frequency needs to be raised in order to raise the speed of transmission. Since, however, a VCXO whose frequency is set directly by the clock, as opposed to the actual transmission speed, has not been made, it is necessary to use a lower frequency and step it up. Increasing the step-up, however, deteriorates the jitter, which in turn causes transmission errors, ultimately leading to a reduction in transmission quality. A high frequency is therefore required for the VCXO.

For all of these reasons, we launched on the development of low jitter and small SMD-VCXO with the equivalent electrical characteristics as conventional oscillators for the optical transmission applications.

Specifications

Table 1 shows the target specifications. We made that this oscillator to perform equivalent level of the conventional oscillators for the optical transmission applications.

Nominal frequency, 622.08MHz, was decided by design of optical transmission applications. The supply voltage is +3.3V, which demands for a low supply voltage. The jitter is 16ps rms max, because of the 0.01UI (Unit Interval) required by SONET/SDH (Synchronous Optical Network / Synchronous Digital Hierarchy). The dimension was made to be same as one of our company's standard oscillator for the optical transmission applications (155.52MHz, Model 7311C).

Table.1 Target Specifications

Item	Spec.
Nominal Frequency	622.08MHz
Supply Voltage	+3.3V
Control Voltage	+1.65±1.5V
Load	50ohm
Operating. Temp. Range	-10 to +70deg.C
Freq. Stability	±50ppm max.
Freq. Trim Range	±100ppm min.
Output Level	1mW min.
(Sub-) Harmonics	-20dB
Dimension	11.4x9.6x4.5mm
Jitter	16ps rms max.

Design of the SMD-VCXO

In order to realize low jitter, a small size, and high frequency, the two most important points were to oscillate high frequency and to simplifying the circuit construction.

Design of frequency

As we mentioned above, the oscillator was required to have a high frequency of 622.08MHz, but since there is no crystal that can be directly oscillated, we had to step up the low frequency oscillation. This oscillator used a 155.52MHz fundamental mode crystal stepped up four times, which meant that it was possible to reduce the amount stepped up while maintaining the same variable amount as previously. The ideal would be to use a 622.08MHz fundamental mode crystal, as it would then be possible to achieve 622.08MHz without having to step up, making it possible not only to prevent jitter deterioration, but also to achieve a wider variable. This would also contribute to a simplification of the circuit by making a resonant circuit for selecting overtone oscillation unnecessary in the oscillator circuit.

In the conventional circuit, for example, it used 51.84MHz fundamental mode crystal or 155.52MHz third overtone mode crystal, and 622.08MHz is achieved multiplication.

Although a wide variable amount is achieved in fundamental mode at, for example, 51.84MHz, an oscillation frequency this low requires much stepping up. The low frequency created by stepping up causes fluctuation in the waveform, which in turn causes deterioration of the jitter. It is therefore effective to raise the oscillation frequency and reduce the amount stepped up. On the other hand, with the third overtone of frequencies such as 155.52MHz, there is less stepping up, which improves the jitter characteristic, but renders a broad variable amount unachievable.

Design of circuit

With conventional high-frequency oscillators, high overtone oscillation and/or stepping up are employed, requiring the use of many moving parts. This puts limits on how small the oscillator could be made, with 20x20x10 being the smallest possible package size (one of our company's existing products). We therefore used a band pass filter instead of a step-up circuit. While a step-up circuit made up of a band pass filter and one made up of a transistor would both have a function to select the fourth high cycle, the one with the band pass filter would take up less surface area on the board. Furthermore, it is possible to easily dampen frequency components outside the pass band (here, low cycles other than 622.08MHz).

On the other hand, a step-up circuit with a transistor would have a low Q value for the resonant circuit, making it that much more problematic to dampen neighboring low frequencies. We achieve an equal amount of dampening as when using a band pass filter by setting up two amplifier stages that have resonant circuits.

Used crystal unit

In this oscillator, 155.52MHz fundamental mode crystal unit is used. [1] The thickness of the blank in this range of high frequency is approximately 10 micro meter in general, it was used concave blank by chemical etching. However, it is difficult for the concave blank to control spurious. Our crystal blank is a flat blank because it has less spurious resonance.

Figure 1 shows the inside of the 155.52MHz fundamental mode crystal unit used in this oscillator.

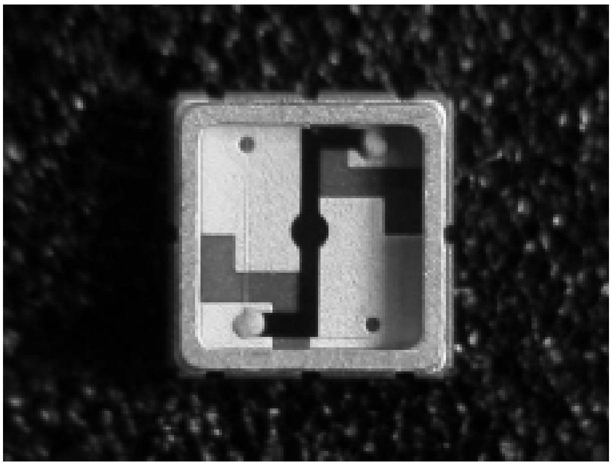

Figure.1 155.52MHz fundamental mode crystal unit internal

Circuit construction

Block diagram

Figure 2 shows the construction and function block diagram for this oscillator. This oscillation circuit is made up 3 stages, at the 1st stage (oscillation stage), 155.52MHz fundamental mode crystal. At the 2nd stage (filter stage) the 4th harmonics (i.e. 622.08MHz) is selected through the band pass filter. At the 3rd stage (amplifier stage) the output from the band pass filter in amplified.

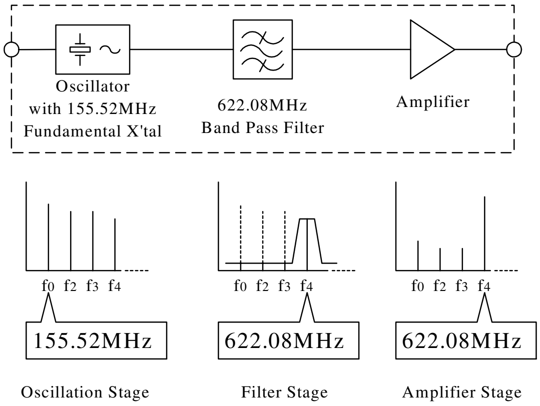

Figure 2 Constructions and function block diagram of this new oscillator

Circuit of this VCXO

This section describes the circuit construction in detail. The oscillator has a Colpitz circuit and oscillates a 155.52MHz fundamental mode crystal. The band pass filter is selected the 4th harmonics, which is 622.08MHz among the harmonics is made at oscillation circuit. By use of the band pass filter, it was possible to easily attenuate unwanted signals. We were thus able to attenuate approximately 40dB. Finally the output of the band pass filter is amplified the one chip amplifier.

Since this circuit does not have a resonant circuit, it is not necessary to tune the resonant circuit. Frequency tolerance is adjusted by capacitor.

Conventional Circuit

This section describes in detail the circuit in a conventional oscillator. Figure 3 shows the construction of a conventional circuit. The oscillator has a Colpitz circuit and oscillates a 155.52MHz third overtone mode crystal. This oscillation circuit has the resonant circuit to select overtone vibration on the emitter side of the transistor.

The multiplication circuit was made up of a transistor circuit, which included a resonant circuit with remove the coil and a trimmer capacitor. Here is where it selected the fourth high frequency (stepped up four times) in the oscillated frequency.

After that, we connected the amplifier configured like a step-up circuit in two stages and achieved the output level by amplifying it with a 1-chip amplifier.

With this circuit, we had to adjust it to get the tuning for the tuning circuit, the step-up circuit, and the amplifier circuit in order to select the overtone. Of course, we also aligned the frequency.

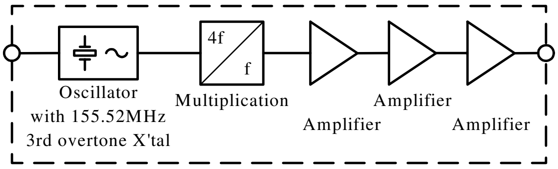

Figure 2 Construction and Function Block diagram of the conventional oscillator

Results

Frequency Stability

Figure 4 shows the frequency temperature characteristics. In the total ±50ppm, we allocated ±20ppm for the temperature characteristics and no frequency jumps were observed.

Frequency control characteristics

Figure 5 shows the frequency control characteristics. The frequency control range was a typical ±150ppm, and based on the frequency stability of ±50ppm, about 100ppm of Absolute Pulling Range was obtained.

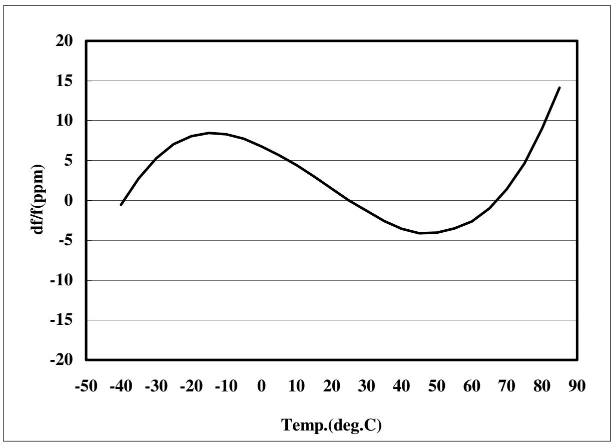

Figure.4 Typical frequency-temperature characteristics

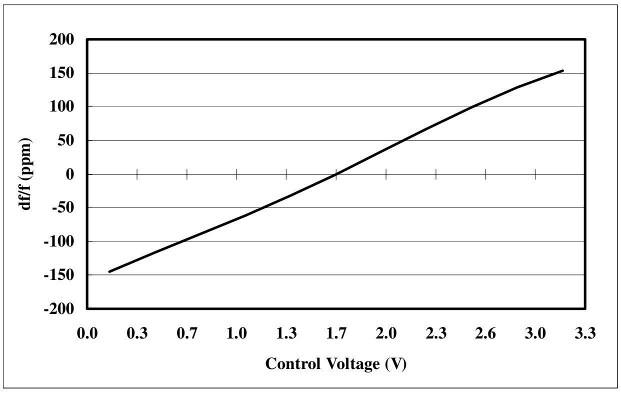

Figure.5 Typical frequency-control voltage characteristics

Jitter

Jitter is an important factor in high-speed transmission devices. The amount of jitter required by SONET/SDH is 0.01UI (Unit Interval). Therefore, for 622.08MHz, this would be:

$$
\begin{aligned}
0.01\text{UI} &= 0.01 \times (1/622.08 \times 10^{-6}) \\
&= 0.01 \times 1607 \\
&= 16 \text{ (ps rms)}
\end{aligned}
$$

Figure 6 shows the measurement results of the jitter characteristics for this oscillator. The measurements were conducted using a Wave Crest “DTS 2079.” The jitter was 2.3ps rms.

At the same time, from the phase noise we were able to calculate the jitter if we limited the frequency range. [2] (See Appendix)

Table 2 shows the jitter values calculated from the phase noise data.

Figure 7 shows phase noise for this oscillator.

Table 2 Jitter values calculated from the phase noise data

f min	f max	D[dB]	J[ps]
10kHz	1MHz	-78.1	0.032
12kHz	20MHz	-80.1	0.025
50kHz	80MHz	-74.9	0.046

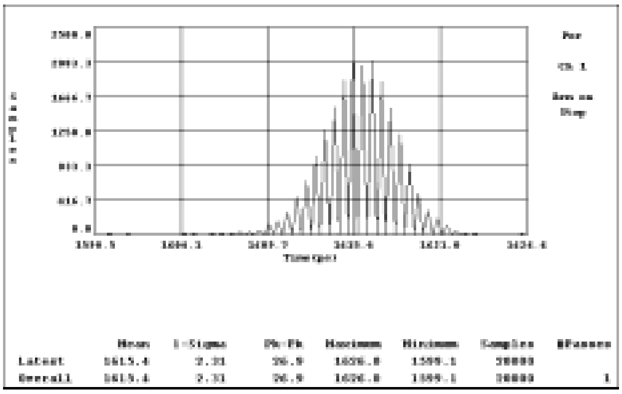

Figure.6 Typical jitter characteristics

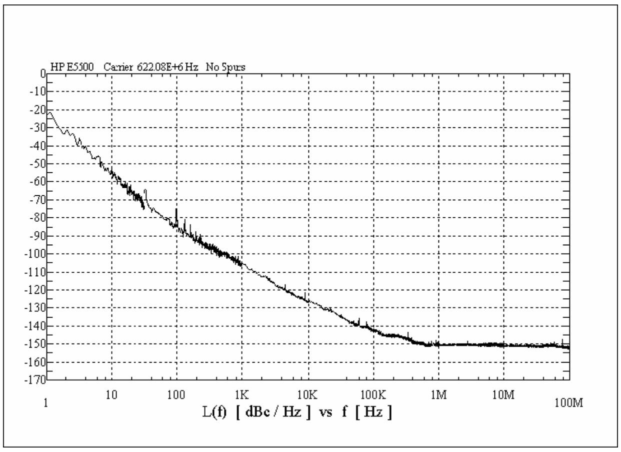

Figure. 7 Typical phase noise characteristics

Dimension Appearance

Figure 8 shows the SMD-VCXO and conventional lead type VCXO. By volume comparison, the SMD-VCXO was realized miniaturization approximately 1/8th of the conventional VCXO.

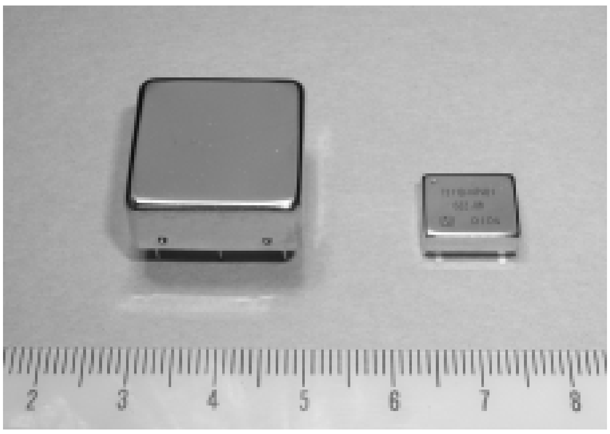

Figure.3 The comparison of SMD-VCXO and conventional VCXO

Conclusion

We approached the development of this device with the goal of making the VCXO used inside CDRs smaller, thinner, and higher in frequency, which was necessary in order to make smaller CDRs, as they are required in increasingly large numbers thanks to WDM technology. Smaller CDRs are necessary to meet the demands of higher speed and larger transmission capacities in networks. Because of the conventional high frequency VCXO has miniaturization limit, the circuit of this SMD-VCXO is construction to use the band pass filter instead of the conventional multiplication circuit.

The results of the trial production showed that we satisfied the target specifications.

In the future, we plan to expand the lineup of the 660MHz band FEC (Forward Error Correction) rate and the 700MHz band FEC rate, based on the results of this experiment.

It is forecasted for optical transmission application to be required the smaller package for more multiplex and the more high clock frequency for more high transmission speed by D-WDM (Dense-WDM) technology. We will study the smaller package and the more high frequency for VCXO in order to meet these demands.

Appendix

The RMS jitter can be derived from the phase noise data as follows [3]. The phase noise data *d(f)* is observed in unit *dBc/Hz*, where *f* is the offset frequency. In unit watt, the phase noise data is given by

$$p(f) = 10^{d(f)/10} \times 10^{-3}, \qquad (1)$$

where *0 dB* oscillator output level is assumed 1 milli-watt.

The RMS jitter is related to the integration of the phase noise over frequency. The integrated phase noise is given by

$$P = \int_{f\,\min}^{f\,\max} p(f)df \qquad (2)$$

where $f_{\min}$ and $f_{\max}$ are the lower and upper limit of the bandwidth considered, and we get

$$D = 10\log(P \times 10^{3}) \qquad (3)$$

in unit *dB*.

The RMS jitter in radian is given by

$$J = 10^{D/20} = \sqrt{P \times 10^{3}}\ . \qquad (4)$$

The RMS jitters in unit intervals and seconds are respectively given by

$$J = \frac{1}{2\pi}10^{D/20} \quad \text{in unit intervals} \qquad (5)$$

$$= \frac{1}{f_0}\frac{1}{2\pi}10^{D/20} \quad \text{in seconds,} \qquad (6)$$

where f_0 is the oscillator frequency.

The phase noise *d(f)* is measured by using HP E5500, Phase Noise Measurement System. This system can calculate the integrated phase noise *D* over any frequency region.

References

[1] M.Koyama, A.Chiba, K.Koizumi, Y.Sato, *"Fundamental mode 155MHz with flat blank in the crystal unit using VCXO"*, Proc.1999, IEEE IFCS, pp338-342.

[2] Kimiaki Nishida, NDK Technical Information, Apr. 2001

[3] D.B.Lesson, *"A simple model of feedback oscillator noise spectrum" Proceedings* of the IEEE, vol. 54, pp.329-330, 1966