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2.48832GHz SMD-VCXO FOR OC-768

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Abstract - **This paper describes 2.48832GHz SMD-VCXO used for the SONET OC-768 (40Gbps) system. The telecommunications provider is advancing in the direction where the OC-768 transmission technology is adopted for the next generation type system like Metropolitan Area Network (MAN) to meet demand for the increasing Internet and the multimedia data.**

The input of 16 signals of 2.5Gbps is multiplexed in the OC-768 system, and it is assumed one serial 40Gbps output data stream. The voltage control type oscillator for the reference signal source of PLL circuit for the OC-768 system requires the low sub-harmonics and the phase noise.

In this oscillator, 155.52MHz fundamental mode AT-cut crystal unit is used. The 16th higher harmonic signal of 155.52MHz is selected with 2.48832GHz SAW filter and amplified. Two stages of this filtering circuit are used to suppress the sub-harmonics effectively. It performs the maximum sub-harmonic level -68dB, the phase noise -130.34dBc/Hz@30kHz. The package size is 40x12.5x3.6mm^3.

Keywords - **VCXO, OC-768**

I. INTRODUCTION

In the case of VCSO, the frequency control performance is greater than +/-370ppm, depended on the frequency temperature stability +/-70ppm from -10 to +85deg.C, calibration tolerance +/-200ppm and Absolute Pulling Range (APR) +/-100ppm.

2.48832GHz SMD-VCSO that uses SAW is commercialized now and its APR is +/-50ppm in normal.

On the other hand, in VCXO that uses the AT-cut crystal, the frequency control range is greater than +/-127ppm, depended on the frequency temperature stability +/-12ppm from -10 to +85deg.C, calibration tolerance +/-15ppm, and APR +/-100ppm. To compare with the frequency temperature behaviors above two types of oscillator is shown in Fig.1.

One of the reasons of the voltage-controlled oscillator's phase noise is the noise added in voltage control port.

Since the VCSO, a wide frequency control range is more necessary than that of VCXO; the frequency sensitivity of VCSO becomes higher than its VCXO at the same control voltage range. Thus the phase noise is worse about 9dB in the calculation.

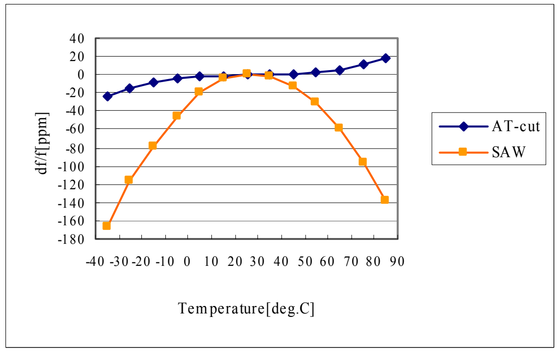

Fig.1 Frequency temperature behaviors

II. SPECIFICATIONS

The target specification is shown in Table I.

Table I Target Specification

Item	Spec.
Nominal Frequency	2.48832GHz
Output Impedance	50ohm
Operating Temp. Range	-10 to +85deg.C
Supply Voltage	+3.3V±5%
Current Consumption	+150mA max.
Frequency Stability	+/-50ppm max.
Control Voltage	+1.65V+/-1.5V
Freq. Trim Range	+/-100ppm min.
Output Level	0 to 4.5mW (0 to +6.5dBm)
Phase Noise (@30kHz)	-120dBc/Hz max.
Sub-Harmonics	-50dB max.
Harmonics	-20dB max.

III. DESIGN OF SMD-VCXO

A. Circuit description

Because the fundamental mode crystal of 622.08MHz had not reached at the mass production level, we have chosen the Colpitts oscillator circuit with a 155.52MHz fundamental crystal.

The package size for the crystal unit is $3.8x3.8x0.95mm^3$.

The output port of the oscillator circuit was consisted of the resonance type to get the strong harmonic of 622.08MHz (the fourth higher harmonics). The wideband amplifier follows for the next stage. Input condition of this wideband amplifier, the input signal level is large enough to saturate the output.

As a result, a lot of even number harmonics can be generated in the output. Additionally, the output drift is decreased by the temperature change in such an operation condition.

Next stage is the x4 multiplier (4x622.08MHz). In this stage the bias voltage is set lower to get the 2.48832GHz harmonics effectively with the impedance matching at 2.4GHz of the output port of this stage. 2.48832GHz signal is selected by the SAW filter at the same center frequency, and is amplified. This stage was doubled. As a result, excellent lower sub-harmonics suppressed VCXO was enabled. At the final stage of the low-pass filter it enables to suppress the higher harmonics.

The function block diagram is shown in Fig.2.

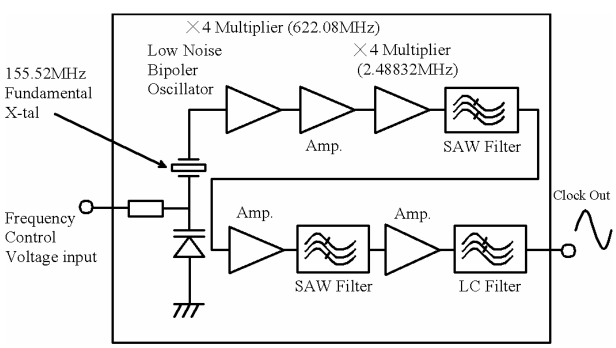

Fig.2 Functional block diagram of this new VCXO

B. Design of printed circuit board

To reduce the leakage between each pattern, the 0.2mm in thickness of the dielectric substance of the printed circuit board was chosen.

Each functional stage is set in straight line to isolate input/output signal effectively. The dielectric constant is 3.5, and the dielectric loss is 0.003.

C. Simulation of oscillation circuit

The crystal oscillator is a high-Q circuit. I simulated the frequency control range by using harmonic balance method in Agilent Advanced Design System. I made the equivalent circuit by using symbolically-defined-device (SDD), because there was no standard model for the capacity of the variable-capacitance diode. The modeling of the component is possible by the expression of the characteristic of a nonlinear device by using SDD. The modeling procedure of the variable-capacitance diode is as follows.

1) C-V characteristic measurement

A reverse-voltage is connected with the variable-capacitance diode. Next, the equivalent series capacitance measurement and the equivalent series resistance measurement are done.

2) Deriving of Fitting function

If the Fitting function of the C-V characteristic is requested, it becomes like (1).

$$c = -30.1702 + \frac{93.1778}{(0.7+v)^{0.5}} - \frac{7.05455}{(1+v)^{1.5}} - \frac{46.0992}{1+v} \quad (1)$$

The result is shown in Fig.3. Here, the dot is measurements and the line is fitting function.

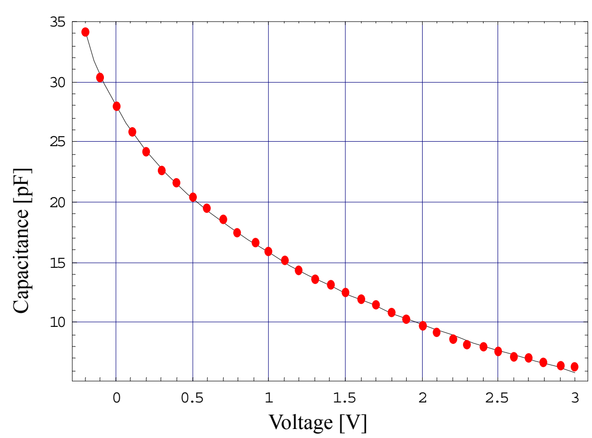

Fig.3 C-V Characteristics

3) The expression of charge Q is derived.

It becomes like (2) when converting it into the expression of charge Q by integrating (1).

$$Q=\int cdv$$
$$=-30.1702v+186.3556(0.7+v)^{0.5}-14.1091(1+v)^{-0.5}-46.0992\ln(1+v) \quad (2)$$

4) Modeling of variable-capacitance diode

The model of the variable-capacitance diode is shown in Fig.4. The expression of charge Q was substituted by using SDD of two ports to do capacity in modeling. Here, resistance was connected with SDD and it was assumed the equivalent series resistance. The SPICE parameter CJO of the connected diode model is small as it was possible to disregard it. As a result, the rectification characteristic function was provided.

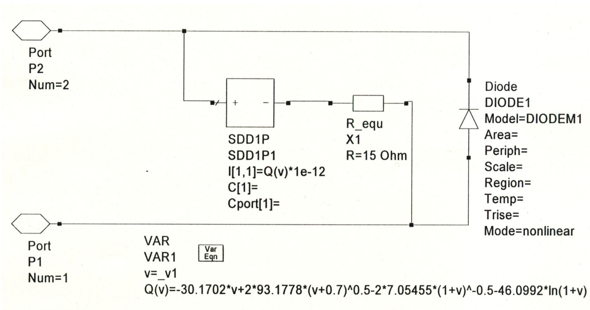

Fig.4 Variable capacitor diode model

The oscillation circuit that uses this variable-capacitance diode model is shown in Fig.5.

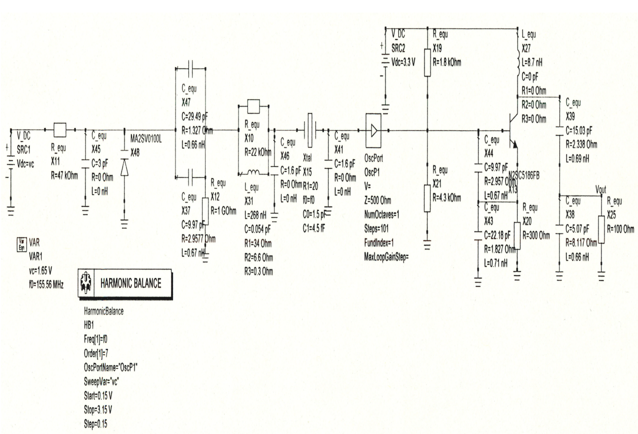

Fig.5 Oscillator circuit for simulation

The simulation and the measurement results of the frequency control characteristics are shown in Fig.6.

The simulation and measurements are almost corresponding. The frequency changes between -172 and +188ppm in the range of the control voltage from +0.15 to +3.15V.

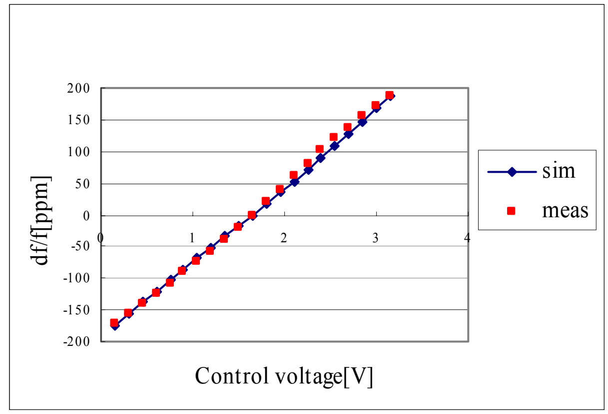

Fig.6 Typical frequency control voltage characteristics simulation and measurement result

IV. MEASUREMENT RESULTS

A. Frequency spectrum of VCXO

The measurement results are shown in Fig.7. The sub-harmonics level is -68dB, and the 2^{nd} harmonics level is -55.5dB from the carrier level.

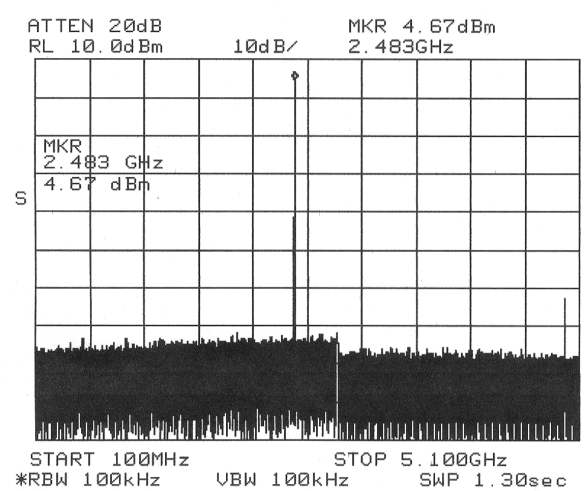

Fig.7 Frequency spectrum of VCXO

B. Phase noise characteristic

The phase noise characteristic is shown in Fig.8. It is -130.34dBc/Hz at the offset frequency 30 kHz.

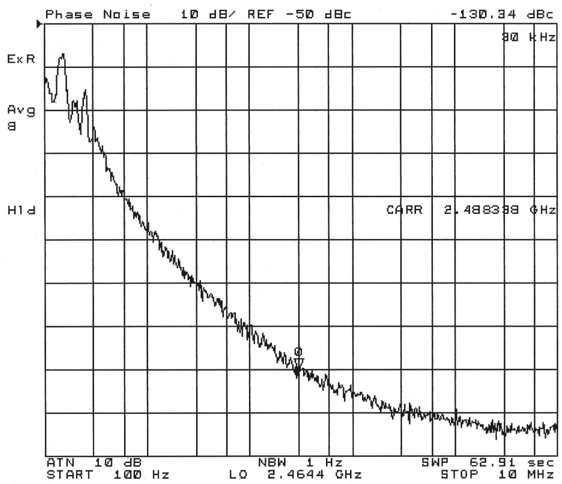

Fig.8 Typical phase noise Characteristics

C. Output power level characteristics

Typical output power characteristics are shown in Fig. 9. Output power is between +4.0 and +4.45dBm in temperature range from -10 to +85deg.C at power-supply voltage +3.3V.

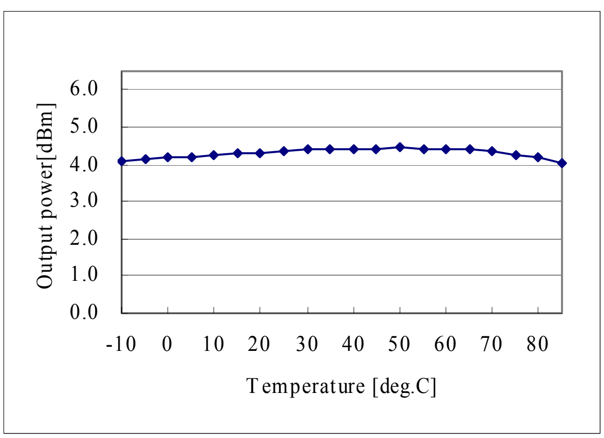

Fig.9 Typical output power characteristics

D. Frequency temperature characteristic

The frequency temperature characteristic is shown in Fig.10. The frequency change is from -6.1 to +10.3ppm in range from -10 to +85deg.C.

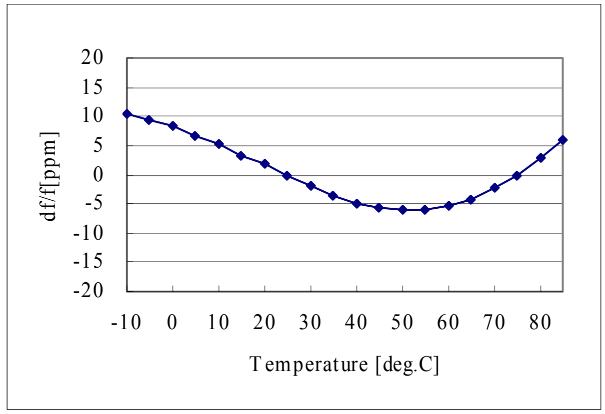

Fig.10 Typical frequency-temperature characteristics

E. New VCXO "7311R" photograph

New VCXO "7311R" photograph is shown in Fig.11.

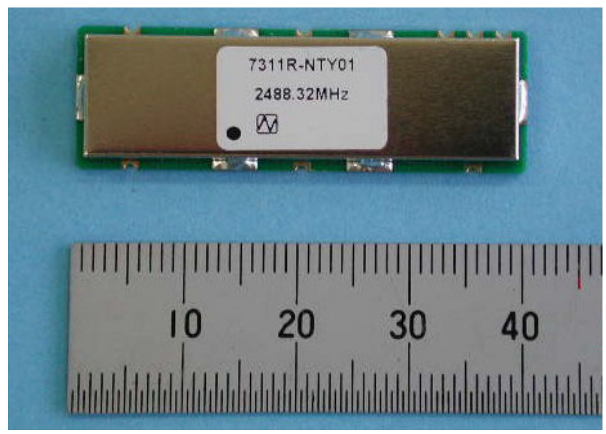

Fig.11 New VCXO "7311R"

V. CONCLUSION

Excellent VCXO in the sub-harmonics could be achieved. It performs excellent low phase noise because of the low voltage sensitivity of the frequency control compared with VCSO. It is suitable for the OC-768 system such a high data transmission. This VCXO has been already commercialized as **"NDK Model Name 7311R"**.

REFERENCE

Yuichi Sato, Mitsuaki Koyama, "622.08MHz SMD-VCXO with filter", *Proc.2001, IEEE IFCS*, pp734-739.